DRAFT Massachusetts Stormwater Management Handbook

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Because stormwater management is rapidly evolving, MassDEP intends to revise the Stormwater Handbook from time to time to ensure the Handbook reflects the most current science and regulatory requirements. As part of future updates, MassDEP will publish a list of revisions.

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
AUL	Activity and Use Limitation
BLSF	Bordering Land Subject to Flooding
BMP	Best Management Practice
BVW	Bordering Vegetated Wetland
CGP	Construction General Permit
CPPP	Construction Period Erosion Control Sedimentation and Pollution Prevention Plan
CSO	Combined Sewer Overflow
DGP	Dewatering General Permit
EIC	Effective Impervious Cover
EPA	Environmental Protection Agency
EPA-PRC	EPA Performance Removal Curve
ESSD	Environmentally Sensitive Site Design
FIB	Fecal Indicator Bacteria
HSG	Hydrologic Soil Group
HUC	Hydrologic Unit Code
IVW	Isolated Vegetated Wetland
IWPA	Interim Wellhead Protection Area
LID	Low Impact Development
LSCSF	Land Subject to Coastal Storm Flowage
LTPPP	Long Term Pollution Prevention Plan
LUHPPL	Land Use with Higher Potential Pollutant Load
LUHWW	Land Under Water Bodies and Waterways
MassDEP	Massachusetts Department of Environmental Protection
MASTEP	Massachusetts Stormwater Technology Evaluation Project
MCP	Massachusetts Contingency Plan
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
MSGP	Multi-Sector General Permit
NJCAT	New Jersey Corporation for Advanced Technology
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	U.S. Natural Resources and Conservation Service

ORAD	Order of Resource Area Delineation
ORW	Outstanding Resource Water
PAH	Polycyclic Aromatic Hydrocarbon
PAM	Polyacrylamides
PDS	Partial Duration Series
PVS	Photovoltaic Systems
QPA	Qualifying Pervious Area
RA	Riverfront Area
RCN	Runoff Curve Number
RGP	Remediation General Permit
RPE	Registered Professional Engineer
SCM	Stormwater Control Measure
SHGW	Seasonally High Groundwater
SRMBC	State Reclamation and Mosquito Control Board
STEP	Strategic Envirotechnology Partnership
SWMI	Sustainable Water Management Initiative
SWPPP	Stormwater Pollution Prevention Plan
TARP	Technology and Acceptance Reciprocity Partnership
TIA	Total Impervious Area
TIC	Total Impervious Cover
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UIC	Underground Injection Control
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
USLE	Universal Soil Loss Equation
WPA	Wetlands Protection Act
WQC	Water Quality Certification
WRA	Wetland Resource Area

Definitions

This section defines commonly used terms in the Massachusetts Stormwater Handbook that are not defined in the Wetlands Protection Act Regulations. For regulatory definitions, refer to 310 CMR 10.04, *Wetlands Protection*. Definitions included in 310 CMR 10.04 are capitalized throughout the Massachusetts Stormwater Handbook (*e.g.,* Redevelopment, Stormwater Management System, etc.).

- Competent Soils Professional. An individual with demonstrated expertise in soil science, limited to the following: a Massachusetts Registered Professional Engineer in civil or environmental engineering; or an Engineer in Training (EIT certificate) with a concentration in civil or environmental engineering, or who has a Bachelor of Arts or Sciences degree or more advanced degree in soil science, geology, or groundwater hydrology from an accredited college or university, that for purposes of stormwater management, assesses the Seasonal High Groundwater Elevation, soil texture, Saturated Hydraulic Conductivity Test, and hydrologic soil group. A soil evaluator pursuant to 310 CMR 15.017 and 15.018 is not a Competent Soils Professional.
- First Flush. Stormwater runoff in the beginning of a storm. Pollutants in this initial runoff are typically at concentrations that are higher than at the middle or end of a storm. The first flush in Massachusetts is the first 1.2-inches of runoff.
- Gray Stormwater Infrastructure. Stormwater Management Systems that are designed to move stormwater away from structures and the built environment. They include but are not limited to curbs, gutters, drains, piping, detention basins, subsurface infiltration structures and wet basins.
- Green Stormwater Infrastructure. Stormwater Management Systems that mimic nature and treat stormwater at its source by allowing stormwater to infiltrate, by reducing storm flows to sewer systems or Resource Areas, and by harvesting stormwater for reuse. Green Stormwater Infrastructure includes Stormwater Control Measures such as bioretention that use plant or soil systems for treatment, porous pavement or other permeable surfaces or substrates, cisterns, and landscaping.
- Infeasible. For purposes of stormwater management, not technologically possible, or not economically practicable and achievable in light of best industry practices.
- New Roadway. For purposes of stormwater management, creation of a roadway or activities undertaken to an existing roadway that increase the total impervious area by greater than or equal to a single lane width. This includes activities such as widening an existing roadway for vehicular travel and adding new on/off ramps.
- Small Scale Controls. For purposes of stormwater management, Environmentally Sensitive Site Design, Low Impact Development, Stormwater Control Measures, and Best Management Practices, that treat or store 1-inch or less of runoff and, in aggregate, account for the total pollutant removal required on-site. Small Scale Controls are designed to reduce, treat, and infiltrate stormwater at its source and provide stormwater management options within rights-of-ways or on sites that have limited space for traditional sized Stormwater Control Measures. They include, but are not limited to, plant and soil-based systems such as filtering bioretention, rain gardens, dry wells, and porous pavement that are designed as specified in Appendix A of the *Massachusetts Stormwater Handbook* [2021 edition], to achieve pollutant removal credits using the U.S. Environmental Protection Agency Pollutant Reduction Curves (EPA-PRC) prepared by the University of New Hampshire Stormwater Center, dated May 2019, the Department's EPA-PRC crosswalk published in the *Massachusetts Stormwater Handbook* [2021 edition], or Table TSS / TP in Section 2 of the *Massachusetts Stormwater Handbook* [2021 edition].
- Surface Waters means all waters other than ground water within the jurisdiction of the Commonwealth including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, and coastal waters.
- Total Impervious Area (TIA) means the total impervious area on a Project Site.

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1 Introduction

1.1 Background

Stormwater runoff results from rainfall and snow melt and represents the single largest source responsible for water quality impairments in the Commonwealth's rivers, lakes, ponds, and marine waters. New and existing development typically increase Impervious Surfaces and, if not properly managed, may alter natural drainage features, increase peak discharge rates and volumes, reduce recharge to wetlands and streams, and increase the load of pollutants to wetlands and water bodies.

The Stormwater Management Standards were established to address water quality (pollutants), water quantity (flooding, low base flow, recharge, and channel scour), and other related issues by requiring the implementation of a wide variety of stormwater management strategies. These strategies include the use of Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques to minimize impervious surface and land disturbance, source control and pollution prevention, structural Stormwater Control Measures (SCMs), construction period erosion and sedimentation control, and the long-term operation and maintenance of Stormwater Management Systems.[1]

1.2 Handbook Purpose

The Massachusetts Department of Environmental Protection (MassDEP) is responsible for implementing the Stormwater Management Standards under the Massachusetts Clean Waters Act, M.G.L. c. 21, §§ 26-53, and the Wetlands Protection Act, M.G.L. c. 131, § 40. The purpose of the Massachusetts Stormwater Handbook is threefold:

1. Explain how to implement the Stormwater Management Standards under the Wetlands and Water Quality Certification Regulations.
2. Provide technical specifications and guidance for designing Stormwater Control Measures that comply with the Stormwater Management Standards.
3. Provide an explanation of the field analysis that must be conducted and the engineering computations and plans that must be included in the Stormwater Report Checklist required to be filed with the Wetlands Notice of Intent (NOI) and/or Water Quality Certification (WQC) application.

Examples of plans to be included in the Stormwater Report Checklist required to be filed with the NOI and/or WQC application are the Long Term Pollution Prevention Plan (LTPPP), Operation and Maintenance Plan, and the Construction Period Erosion Control Sedimentation and Pollution Prevention Plan (CPPP).

1.3 Handbook Organization

The Massachusetts Stormwater Handbook is organized into six Chapters and four Appendices as summarized below.

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[1] The term **Stormwater Control Measure (SCM)** largely replaces the term **Best Management Practice (BMP)** that was used in the 1996/1997 MassDEP Stormwater Policy, and 2008 Wetlands Protection Act regulations, and associated 1997 and 2008 Massachusetts Stormwater Handbooks. MassDEP has endeavored to make sure that this terminology has been appropriately updated throughout the Massachusetts Stormwater handbook. If there is a discrepancy between terminology, the regulatory definitions of BMPs and SCMs as defined in 310 CMR 10.04 or 314 CMR 9.02 must be applied. For example, construction period erosion and sediment control practices should be identified as BMPs and not SCMs.

1.3.1 Chapter Summary

- **Chapter 1** provides background on the Massachusetts Stormwater Handbook.
- **Chapter 2** explains the eleven Stormwater Policy Standards.
- **Chapter 3** describes the legal basis under which the Stormwater Standards are implemented.
- **Chapter 4** provides an overview of site planning and design practices with a focus on Environmentally Sensitive Site Design (ESSD) and Low Impactive Development (LID) techniques, Nonstructural SCMs and source controls, and Structural SCMs.
- **Chapter 5** provides details on miscellaneous stormwater topics, including: explanation of retrofit projects; special considerations for Redevelopment projects; a description of the review process that must be followed when proprietary SCMs are proposed as part of new development and Redevelopment; mosquito control in stormwater management, a description of the specific requirements for Photovoltaic System Solar Array Projects; and State Highway specific considerations.
- **Chapter 6** describes the information and calculations that must be submitted in a Stormwater Report to document compliance with the Stormwater Standards.

1.3.2 Appendix Summary

- **Appendix A** provides design specifications for each SCM type described by Chapter 4. The Appendix also includes a suite of ESSD Credits to encourage implementation of ESSD and LID techniques while reducing or eliminating the Structural SCMs needed to meet the Stormwater Standard.
- **Appendix B** provides tabular and graphical versions of the EPA Performance Removal Curves for use in calculating pollutant removal credits for structural SCMs.
- **Appendix C** provides erosion and sediment control guidelines for use in implementation of Stormwater Standard 8.
- **Appendix D** provides a standard computational method to convert the required water quality volume to a discharge rate for the sizing of flow based manufactured proprietary stormwater treatment practices.
- **Appendix E** provides a checklist that must be completed and submitted with any project that includes Redevelopment.

2 The Massachusetts Stormwater Management Standards

2.1 Historical Overview

In 1996, the Massachusetts Department of Environmental Protection (the “Department” or “MassDEP”) issued the Stormwater Policy. The Massachusetts Stormwater Handbook was published in 1997 as guidance on the Stormwater Policy. The Stormwater Policy provided the framework for establishing Stormwater Management Standards (the “Standards”) which are aimed at encouraging recharge and preventing stormwater discharges from causing or contributing to the pollution of the surface waters and ground waters of the Commonwealth.

MassDEP revised the Stormwater Management Standards and Massachusetts Stormwater Handbook in 2008 to promote increased stormwater recharge, the treatment of more runoff from polluting land uses, Low Impact Development (LID) techniques, pollution prevention, the removal of Illicit Discharges to Stormwater Management Systems, and improved operation and maintenance of Stormwater Control Measures (SCMs). MassDEP applies the Stormwater Management Standards pursuant to its authority under the Wetlands Protection Act, M.G.L. c. 131, § 40, and the Massachusetts Clean Waters Act, M.G.L. c. 21, §§ 26-53. The Stormwater Management Standards were incorporated in the Wetlands Protection Act Regulations (WPA), 310 CMR 10.05(6)(k), and the Water Quality Certification Regulations (WQC), 314 CMR 9.06(6)(a), effective January 2, 2008.

In YEAR, MassDEP revised the Stormwater Management Standards, WPA Regulations 310 CMR 10.05(6)(k), the Massachusetts Stormwater Handbook, and the WQC Regulations, 314 CMR 9.06(6)(a), to provide consistency with the stormwater management requirements of EPA and MassDEP’s joint 2016 Small Municipal Separate Storm and Sewer System (MS4) General Permit and its 2020 modification for Massachusetts to the extent possible, and to update the design storms used to meet the Stormwater Management Standards. Stormwater Management Systems designed to meet the Stormwater Management Standards in accordance with the Massachusetts Stormwater Handbook are also considered to meet the requirements of Section 2.3.6.a of the 2016 Massachusetts Small MS4 General Permit. The updated WPA and WQC regulations and Massachusetts Stormwater Handbook further enhance protection of Wetland Resource Areas in the Commonwealth. The update also continues to protect the eight interests protected by the WPA, restores and maintains the chemical, physical, and biological integrity of water resources as required by the WQC regulations, and strengthens compliance with Total Maximum Daily Loads (TMDL). The eight interests protected by the WPA are:

- Protection of public and private water supply;
- Protection of groundwater supply;
- Flood control;
- Storm damage prevention;
- Prevention of pollution;
- Protection of land containing shellfish;
- Protection of fisheries; and
- Protection of wildlife habitat.

2.2 Applicability

The Stormwater Management Standards and their applicability is defined in the Wetlands Protection Act Regulations at 310 CMR 10.02(2)-(5), 310 CMR 10.05(6)(k)-(q), and 314 CMR 9.06(6)(a)-(g). For phased projects the determination of whether the Stormwater Management Standards apply is made on the entire project including all phases.

The Stormwater Management Standards shall not apply to the following:

1) A single-family house.
2) Housing development and Redevelopment projects comprised of detached single- family dwellings on four or fewer lots, provided that there are no stormwater discharges that may potentially affect a Critical Area.
3) Multi-family housing development and Redevelopment projects, with four or fewer units, including condominiums, cooperatives, apartment buildings and townhouses, provided that there are no stormwater discharges that may potentially affect a Critical Area.
4) Emergency repairs to roads or their drainage systems; provided that emergency certification is obtained pursuant to 310 CMR 10.06.[2]
5) Gardens; provided that there are no new Impervious Surfaces. Gardens do not include greenhouses.

Even when the Stormwater Management Standards do not apply, an Applicant still must implement erosion and sedimentation controls during construction if the project is located in a Wetland Resource Area or associated Buffer Zone as indicated by 310 CMR 10.05(6).[3] For example, a person constructing a single-family house that extends into the Buffer Zone must still control erosion and sedimentation within Wetland Resource Areas and the Buffer Zone to meet requirements at 310 CMR 10.05(6)(b), even though the Project is exempt from the Standards.[4]

2.3 Definition and Explanation of the Stormwater Management Standards

2.3.1 Standard 1: No Untreated Discharges or Erosion to Wetlands

Definition

No New Stormwater Conveyances (e.g. outfalls) may discharge untreated stormwater directly to or cause erosion or scour to wetlands or Waters of the Commonwealth.

Explanation

Standard 1 allows the direct discharge of stormwater to waters and wetlands provided the discharge is adequately treated. The term “treated” refers to the implementation of Stormwater Management Systems that are specifically designed to achieve sediment and contaminant removal at rates that adequately protect groundwater, surface waters, and wetlands in accordance with all applicable statutes, regulations, permits, and approvals, and all other Stormwater Management Standards. The level of treatment required by the other Stormwater Management Standards is based on whether the discharge impacts a Critical Area, is from a land use with a higher potential pollutant load (LUHPPL), whether the discharge is to soils with a rapid infiltration rate, and how much peak rate runoff attenuation and recharge are needed.

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[2] Emergency repairs, while initially exempt from the Stormwater Management Standards, may require subsequent filing of a Notice of Intent in accordance with 310 CMR 10.06.

[3] Also, the NPDES Construction General Permit administered by the U.S. EPA requires construction period controls for any land disturbance of one acre or more.

[4] Provided a Wetlands NOI is required, 310 CMR 10.05(6)(b) requires implementation of erosion and sedimentation controls during construction. See 310 CMR 10.05(6)(k)8. and Erosion and Sedimentation Control appendix to the Massachusetts Stormwater Handbook.

The requirement that stormwater discharges must not cause erosion in wetlands or Waters of the Commonwealth means that there must be no wearing away of the soil or land surface in excess of natural conditions. Stormwater Control Measures (SCMs) and associated pipes and other conveyances that are designed, installed, and maintained in accordance with the Massachusetts Stormwater Handbook will be presumed to meet this Standard. The use of level spreaders, riprap, or other techniques at the point of discharge minimizes erosion and scour. Pursuant to 310 CMR 10.05(6)(k), points of discharge and stormwater management structures, including but not limited to riprap aprons, must not be located in most types of Wetland Resource Areas. For projects subject to jurisdiction under the Wetlands Protection Act, the Applicant shall demonstrate to the Issuing Authority that the discharge velocities will not cause erosion or scouring at the point of discharge or downstream. Discharge velocities from SCMs should take into account factors such as soils, slope and the type of receiving resource.

Stormwater discharges for purposes of the WPA and WQC regulations may be from point or non-point sources. The Municipal Separate Storm Sewer System (MS4) permit regulates point source discharges only.

<u>What Constitutes an Existing Discharge?</u>

The following are considered to be existing stormwater discharges provided that any relocated or combined outlet points are not located in an Area Subject to Protection under M.G.L. c. 131, § 40, other than bordering land subject to flooding, isolated land subject to flooding, land subject to coastal storm flowage, or riverfront area, and provided the annualized pollutant load, annual volume of runoff; and the peak runoff rate for the 2-, 10- and 100-year 24-hour storms is equivalent to or less than existing conditions:

- Existing discharge points created prior to January 1, 2008, where no work is proposed, and where no additional stormwater runoff is directed to it.
- Relocation of a stormwater discharge to provide a greater distance between the discharge and Resource Area, provided the relocation is within the same wetland system as the original discharge point:
    - Relocate an outfall from a bridge deck, bridge foundation, bridge headwall, or other ancillary bridge component to an adjacent land area so that the outfall is farther away from a Wetland Resource Area.
    - Relocate a stormwater discharge along the linear roadway path such that it discharges farther upland of a Wetland Resource Area.
    - Relocate a stormwater outfall to provide a greater time of concentration.
    - And provided that, in relocating a stormwater discharge to provide greater separation from a Resource Area, it is not relocated to be closer to a different Resource Area, have a lower time of concentration, or result in erosion or scour to Wetland Resource Areas.
- Relocation of a stormwater discharge to provide additional treatment and/or improve existing conditions:
    - Relocate a stormwater discharge to install a stormwater control measure.
    - Relocate a stormwater discharge to provide enhanced scour protection.
    - Relocate a stormwater discharge to provide bank stabilization.
    - Provided, in relocating a stormwater discharge to provide greater separation from a Resource Area, it is not relocated to be closer to a different Resource Area, have a lower time of concentration, or result in erosion or scour to Wetland Resource Areas.
- Combining two or more existing stormwater discharges into a single stormwater discharge:

  - Eliminate a stormwater discharge that was not environmentally protective (*e.g.*, causing scour, direct discharge).
  - Redirect runoff to a stormwater discharge structure that is more environmentally protective. (See examples above: greater separation from Resource Area, greater time of concentration, stormwater discharge to stormwater control measure, enhanced scour protection, and bank stabilization).
  - Design any combined discharges to have a higher time of concentration than that of the original separate discharges and shall not result in erosion or scour to Wetland Resource Areas.

- Each of these examples must comply with Standard 7 Redevelopment.

<u>What Constitutes a New Discharge?</u>

A discharge is new when it meets any of the criteria below.[5]

- A new point source, created after January 1, 2008, discharges to a Wetland Resource Area, such as any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged;
- A new point source is created and does not meet the criteria to be considered an existing discharge.
- The discharge point is considered new pursuant to the 2016 Massachusetts Small MS4 permit, Parts 5.1.4, Part 6.4, or Appendix A definition of “New Discharger” and definition of “New Source.”

[5] New Stormwater Discharge means new or increased runoff directed to a resource area from new Impervious Surface or through a New Stormwater Conveyance. Increased runoff means additional stormwater volume or higher discharge rate than currently exists. Stormwater discharges can be from public or privately owned Impervious Surfaces or conveyances.

2.3.2 Standard 2: Peak Rate Attenuation

Definition

Stormwater Management Systems shall be designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates. This standard is to be met on the Project Site at each point of discharge. This standard may be waived for stormwater discharges to coastal Resource Areas as defined in 310 CMR 10.21 to 10.36, unless the discharge is to a coastal Resource Area located up-gradient of an existing or proposed stream crossing, culvert or bridge. The post-development peak discharge rate must be designed to be equal to or less than the pre-development rate from the 2-year, 10-year, and 100-year 24-hour storms to avoid an increase in peak discharge rate from the Project Site. The peak discharge rate computations must be conducted using the NRCS Technical Release WinTR20 Project Formulation Method (Version 3.20 or later versions are permissible) or WinTR55 Small Watershed Hydrology Method (Version 1.00.10 or later versions are permissible). The upper confidence of the precipitation frequencies listed in the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 10 (Version 3.0 or later versions are permissible) multiplied by 0.9 shall be utilized. The NOAA Type C or D storm distribution (NRCS Engineering Field Handbook Chapter 2, National Engineering Handbook Part 650, Massachusetts Supplement for the Implementation of NOAA Atlas 14, Volume 10 Rainfall Data, dated June 17, 2016) or a customized storm distribution developed using the NOAA Atlas 14 upper confidence multiplied by 0.9 shall be utilized.

Explanation

To prevent storm damage and downstream and off-site flooding from the Project Site, Standard 2 requires that the post-development peak discharge rate is equal to or less than the pre-development rate from the 2-, 10-, and 100-year 24-hour storms.[6]

SCMs that slow runoff rates through storage and gradual release, such as extended dry detention basins, and wet basins, must be provided to meet Standard 2. Refer to **Table 2-7** for a list of SCMs that may be used for peak rate attenuation. Applicants can also reduce the peak runoff rate from upstream impervious area by implementing applicable ESSD Credits as described in **Section 4.2**. SCMs designed, constructed, and maintained in accordance with the criteria set forth in the Stormwater Handbook will be presumed to meet this Standard (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies).

Calculating Peak Discharge

For projects subject to jurisdiction under the Wetlands Protection Act, the Issuing Authority relies on WinTR 20 and WinTR55 methods, which estimate the effects of land use changes on runoff volume and peak rates of discharge published by Natural Resource Conservation Service (NRCS). [7] Applicants must calculate peak site discharge rates from pre-existing and post-development conditions at each point of discharge. Peak discharge rates are calculated at a design point (or points), typically the lowest point of discharge at the downgradient property boundary. The topography of the site may require evaluation at more than one design point, if flow leaves the property in more than one direction. An Applicant may demonstrate that a feature beyond the property boundary (*e.g.,* culvert) is more appropriate as a design point.

[6] **Note:** The Stormwater Standards are designed to attenuate, infiltrate and treat stormwater onsite, or in approved offsite stormwater mitigation areas. The Stormwater Standards do not apply to the design of closed drainage conveyances. Design closed drainage conveyances for the safe conveyance of runoff.

[7] NRCS TR 20&55: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=stelprdb1042480; Hydrology Handbook for Conservation Commissioners: https://www.mass.gov/doc/hydrology-handbook-for-conservation-commissioners/download.

Site specific precipitation depths used to calculate peak discharge rates for the 2-, 10- and 100-year 24-hour storms must be obtained from National Oceanic and Atmospheric Administration's (NOAA) Atlas 14, Volume 10.[8] Use NOAA Atlas 14's Partial Duration Series point frequency estimates to find the upper confidence interval, then multiply that value by a scaling factor of 0.9. To perform peak discharge rate analysis based on these design storm depths, rainfall distributions must be developed based on NOAA Atlas 14 to account for higher intensity rainfall associated with these storms. Refer to **Section 6.2.2** for instructions on how to calculate design storm depths and rainfall distributions from NOAA Atlas 14.

Areal reduction factors cannot be used to reduce precipitation depths for stormwater peak runoff rate computations. As indicated by Technical Paper 29, areal reduction factors are used to reduce point source precipitation for large watersheds such as when conducting river flow analysis.[9] As such, they are not appropriate to use for site level development.

[8] NOAA Atlas 14: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma.

[9] Technical Paper 29: https://www.weather.gov/media/owp/oh/hdsc/docs/TP29P4.pdf.

2.3.3 Standard 3: Stormwater Recharge

Definition

Loss of annual recharge to ground water shall be avoided or minimized through the use of infiltration measures including Environmentally Sensitive Site Design, Low Impact Development techniques or practices, Stormwater Control Measures, Best Management Practices, and good operation and maintenance practices. To meet this recharge standard, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques or practices must be used unless demonstrated to be Impracticable based on a written alternatives analysis to be submitted with the Notice of Intent. Other types of Stormwater Control Measures (SCMs) shall only be used to meet those portions of the recharge standard that cannot be fully met by ESSD and LID. ESSD, LID, and where necessary, SCMs should be dispersed throughout a Project Site. This recharge standard must be met on the Project Site. At a minimum, the annual recharge from the post-development site shall approximate the annual recharge from the pre-development conditions. This standard is met when underlying soils have a saturated hydraulic conductivity rate of at least 0.01 inch/hour, the recharge practice is designed to infiltrate the runoff into the ground fully within 72 hours, and a volume of at least one inch of runoff times the impervious area is designed to infiltrate the runoff into the ground. Mounding analysis is required when the vertical separation from the bottom of an exfiltration system to Seasonal High Groundwater Elevation is less than four feet and the recharge system is proposed to attenuate the peak discharge from a 10-year or higher 24-hour storm (e.g., 10-year, 25-year, 50-year, or 100-year 24-hour storm). The mounding analysis must demonstrate that the seasonal high groundwater does not elevate into the infiltration practice, rise above the ground surface, or elevate the water surface of any Resource Areas over a 72-hour period. The 1-inch volume of infiltration is presumed to be provided when the recharge system is sized using one or more of the following methods described in the Massachusetts Stormwater Handbook [2022 Edition]:

a. The Static Method;

b. The Simple Dynamic or Dynamic Field Methods using in-situ Saturated Hydraulic Conductivity Tests;

c. The Continuous Simulation Method using in-situ Saturated Hydraulic Conductivity Tests where the static volume designed to be infiltrated represents at least 70% of the average annual precipitation at the three closest weather stations for which annual precipitation data is available through the NOAA National Centers for Environmental Information (formerly the National Climatic Data Center) within the same major river basin using the Thiessen polygon method, for the climate normal period 1991-2020, demonstrated through continuous simulation by using an automated spreadsheet provided by MassDEP in the Massachusetts Stormwater Handbook [2022 Edition].

d. When Project Sites are composed entirely of NRCS Hydrologic Soil Group D Soil, bedrock within 2-feet of the existing ground surface, hazardous waste sites or solid waste landfill closures, the standard is met when one inch to the Maximum Extent Practicable is provided.

Explanation

The intent of Standard 3 is to ensure that the recharge volume into the ground under post-development conditions is at least as much as the recharge volume under pre-development conditions on an annual average basis.

What is the Required Recharge Volume?

The required **Recharge Volume (Rv)** is the stormwater volume that must be infiltrated – it is calculated as the depth of runoff multiplied by the total post-construction impervious area on site.

- For new development in all soil types except for Hydrologic Soil Group (HSG) D soils, the required Rv is calculated using one-inch of runoff.
- When Project Sites are composed entirely of NRCS Hydrologic Soil Group D Soil, bedrock within 2-feet of the existing ground surface, hazardous waste sites or solid waste landfill closures, the standard is met when one-inch to the maximum extent practicable is provided.
- When a Project Site has a combination of HSG D and other soil types (i.e., HSG A, B, C), determine the required Rv for each impervious area by HSG and then add the volumes. The required Rv is calculated to the maximum extent practicable for HSG D soils. Use a weighted average based on weights of the area of each HSG to determine the Rv.

Refer to **Table 2-1** for a summary of groundwater recharge rules.

ESSD and LID Techniques

To meet Standard 3, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis submitted with the Notice of Intent. Other SCMs shall only be used to meet those portions of the Required Recharge Volume that cannot be fully met by ESSD and LID techniques. See **Section 6.1.4** for more information on the written alternatives analysis. The following resources are available relative to ESSD and LID techniques:

- See **Section 4.2.3** for a list of MassDEP recognized ESSD / LID techniques. Each MassDEP ESSD / LID recognized technique has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**).
- Most MassDEP recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).

SCM Selection for Recharge

The following SCMs may be used to infiltrate stormwater in compliance with Standard 3: applicable ESSD Credits; dry wells; infiltration basins; infiltration trenches; subsurface infiltration structures; leaching catch basins; exfiltrating bioretention areas, exfiltrating tree box filters[10], exfiltrating roof dripline filters, and exfiltrating porous pavement. Some subsurface infiltrators can also be used to infiltrate stormwater in compliance with Standard 3. Refer to **Table 2-7** for a full list of SCMs and applicable SCMs that can be used to provide recharge in compliance with Standard 3.

SCM Design, Construction, and Maintenance

[10] Bioretention areas and treebox filters are an example of a SCM that may be designed to act as either a filtering practice or an infiltration device. Bioretention areas and treebox filters that act solely as filters have an underdrain that captures runoff and conveys it to another SCM before it is discharged to a Surface Water, a wetland, another Surface Water, or another additional SCM. These bioretention areas or treebox filters may be lined. Bioretention areas and treebox filters designed to infiltrate do not have an underdrain. To distinguish the two types of bioretention areas and treebox filters, this Handbook refers to bioretention areas and tree box filters designed to infiltrate as "exfiltrating" and bioretention areas and treebox filters meant for filtration as "filtering".

Infiltration SCMs designed, constructed, operated, and maintained in accordance with the specifications and procedures set forth in the Massachusetts Stormwater Handbook will be presumed to meet Standard 3 (see **Appendix A** for specifications). Procedures in **Section 6.2.3** set forth how to size infiltration SCMs so that they infiltrate the required recharge volume between storms. The sizing process includes subsurface soil evaluations, pretreatment considerations, recharge volume calculation, bottom sizing, and other considerations.

To ensure the long-term operation of infiltration SCMs, pretreatment is required before discharge to an infiltration SCM. At least 44% of TSS must be removed prior to discharge to the infiltration structure for the instances listed by **Table 2-1**. Refer to **Table 2-2** for a list of acceptable pretreatment measures.

Runoff from non-metal roofs may be discharged to a stormwater dry well or other MassDEP recognized stormwater infiltration practice without any pretreatment. [11] Runoff from metal roofs may be discharged to a MassDEP recognized practice that provides stormwater infiltration without pretreatment only if the roof is located outside the Zone II or Interim Wellhead Protection Area of a Public Water Supply and outside an industrial site. Infiltration of runoff from a metal roof that is located within the Zone II or Interim Wellhead Protection Area of a Public Water Supply and/or at an industrial site requires pretreatment by means of a SCM capable of removing metals, such as a sand filter, organic filter, filtering bioretention area or equivalent. Metal roofs are galvanized steel or copper.

When designing infiltration SCMs, adequate subsurface information needs to be obtained.[12] Infiltration systems must be installed in soils capable of absorbing the recharge volume (*i.e.,* not D soils). Infiltration structures must be able to drain fully within 72 hours. In addition, there must be at least a two-foot separation between the bottom of the infiltration structure and the seasonal high groundwater table.

<u>Site Specific Considerations</u>

MassDEP recognizes that it may be difficult to infiltrate the required recharge volume on certain sites because of soil conditions. For sites comprised solely of Hydrologic Soil Group (HSG) D soils and bedrock at or within 2-feet of the land surface, Applicants are required to infiltrate the required recharge volume only to the maximum extent practicable. MassDEP also recognizes that on some sites, there is a risk that infiltrating the required recharge volume may cause or contribute to groundwater contamination. See **Table 2-1** for a list of instances where MassDEP requires infiltration only to the maximum extent practicable.

See Highway Specific Considerations in **Section 5.7** for additional information on the design of roadway projects.

<u>Maximum Extent Practicable for Standard 3</u>

For purposes of Standard 3, “to the maximum extent practicable,” as applied to the sites listed by **Table 2-1**, means that:

1) The Applicant has made all reasonable efforts to meet Standard 3;
2) The Applicant has made a complete evaluation of all possible applicable infiltration measures, including Environmentally Sensitive Site Design that minimizes land disturbance and Impervious Surfaces, Low Impact Development techniques, and structural SCMs; and

[11] As provided in **Section 2.4**, only certain practices are credited by MassDEP with providing stormwater recharge. For instance, a subsurface infiltrator is credited with providing recharge, but a dry water swale is not credited with providing recharge.

[12] The required minimum infiltration rate is 0.01 inches per hour. To determine the infiltration rate, Applicants must perform a soil evaluation using the methodologies set forth in **Section 6.3**.[13] EPA Region 1 Performance Removal Curves via EPA BATT (version 2.1): https://www.epa.gov/npdes-permits/stormwater-tools-new-england#swbmp.

3) If the post-development recharge does not at least approximate the annual recharge from pre-development conditions, the Applicant has demonstrated that they are infiltrating the highest practicable volume of stormwater.

Table 2-1. Rules for groundwater recharge (*Table RR*)

Summary of Requirements
ESSD or LID techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis submitted with the Notice of Intent. Other SCMs shall only be used to meet those portions of the Required Recharge Volume that cannot be fully met by ESSD and LID techniques. See **Section 6.1.4** for more information on the written alternatives analysis. SCMs designed in accordance with the Massachusetts Stormwater Handbook will be presumed to meet Standard 3 (see **Appendix A** for specifications and **Section 6.2.3** for sizing methodologies). Except as expressly provided herein, the entire required recharge volume must be infiltrated. Refer to **Table 2-7** for a list of SCMs that may be used for recharge. **Required recharge volume must be infiltrated to the maximum extent practicable, if**: 1. The site is comprised wholly of HSG Type D soils and bedrock at the land surface; 2. Recharge is proposed at or adjacent to a site that has: • been classified as contaminated; • contamination that has been capped in place; • an Activity and Use Limitation (AUL) that precludes inducing runoff to the groundwater pursuant to M.G.L. c. 21E and the Massachusetts Contingency Plan, 310 CMR 40.0000; • a solid waste landfill as defined in 310 CMR 19.000; or • groundwater from the recharge area that flows directly toward a solid waste landfill or 21E site (a mounding analysis is needed if a site falls within this category, see **Section 6.2.3**). **Infiltration SCM Design Requirements:** 1. At least 44% of the TSS must be removed prior to discharge to the infiltration structure if the discharge is: • within a Zone II or Interim Wellhead Protection Area; • near an Outstanding Resource Water or Special Resource Water; • near a Shellfish Growing Area, cold-water fishery, or bathing beach; • from a land use with higher potential pollutant loads; or • within an area with a rapid infiltration rate (greater than 2.4 inches per hour). 2. Rooftop runoff from non-metal roofs and metal roofs of galvanized steel or copper may be discharged to the ground via a MassDEP recognized stormwater infiltration practice without pretreatment unless: • the metal roof is located in the Zone II or Interim Wellhead Protection Area of a Public Water Supply or at an industrial site. In this case, the discharge of runoff from the metal roof to the ground requires pretreatment by means of a SCM capable of removing metals, such as a sand filter, organic filter or filtering bioretention area. 3. Depth to groundwater: A minimum of two-foot separation between bottom of structure and seasonal high groundwater is required. A mounded system may be used to achieve the required two feet of separation. 4. Minimum Infiltration Rate: 0.01 inches per hour. 5. All infiltration structures must be able to drain fully within 72 hours. **General Setback Requirements for Infiltration SCMs:** 1. See **Section 2.5** for setback requirements.

2.3.4 Standard 4: Pollutant Removal

Definition

Stormwater management systems for new development shall be designed to remove 90% of the average annual post-construction load of Total Suspended Solids (TSS) and 60% of the average annual post-construction load of Total Phosphorus (TP). To meet this TSS/TP removal standard, ESSD or LID must be used unless demonstrated to be Impracticable based on a written alternatives analysis to be submitted with the Notice of Intent. Other SCMs and related stormwater Best Management Practices shall only be used to meet those portions of this TSS/TP removal Standard that cannot be fully met by ESSD and LID. ESSD, LID and, where necessary, SCMs and related stormwater Best Management Practices should be dispersed throughout a Project Site. A long-term pollution prevention plan shall be prepared to eliminate or reduce the generation of runoff of TSS, TP, pathogens, nutrients and other contaminants. This standard is to be met on the Project Site. This standard is met when:

a. *Suitable practices for source control and pollution prevention are identified in a long-term pollution prevention plan (LTPPP) that is submitted with the Notice of Intent and thereafter are implemented and maintained.*

b. *The LTPPP incorporates source reduction measures to eliminate or reduce the generation and runoff of TSS, TP, pathogens, nutrients, and other contaminants such as polycyclic aromatic hydrocarbons. Furthermore, the LTPPP must address measures to properly dispose of snow outside of wetland Resource Areas and minimize snow disposal in the Buffer Zone. Source reductions and pollution prevention measures to be incorporated into the LTPPP include, but are not limited to, restricting fertilizer use, properly covering any solid waste stored exterior to a building so it does not comingle with runoff, prohibiting use of coal tar-based pavement sealants which contain polycyclic aromatic hydrocarbons, restricting use of winter sand application to paved surfaces, and prohibiting use of oil application to unpaved roads and automotive parking areas. To reduce further nutrient loading, the LTPPP shall prohibit fertilizers that contain phosphorus, in accordance with 330 CMR 31.00: Plant Nutrient Application Requirements for Agricultural Land and Non-Agricultural Turf and Lawns; and shall prohibit fertilizers to be applied when precipitation greater than 0.5 inches is forecast in the next 48 hours. The LTPPP shall be presumed to meet these requirements when it includes the source control and pollution prevention measures specified in this regulation and the additional measures listed in the Massachusetts Stormwater Handbook [2022 Edition].*

c. *Environmentally Sensitive Site Design, Low Impact Development techniques or practices, Stormwater Control Measures and related stormwater Best Management Practices are sized:*

    i. *to capture the volume required to meet the 90% TSS and 60% TP pollutant reduction standard using the EPA-PRC or other Substitute EPA-PRC approved by MassDEP listed in 310 CMR 10.05(6)(k)4. Table 1 MassDEP Crosswalk;*

    ii. *to capture the required one-inch water quality volume when discharges are Near or discharge to Critical Areas; from Land Uses with Higher Potential Pollutant Loads, or when no EPA-PRC or other Substitute EPA-PRC approved by MassDEP is listed in 310 CMR 10.05(6)(k)4. Table 1 MassDEP Crosswalk, except for ESSD; or*

    iii. *to meet the TSS and TP pollutant removal reduction standard for the ESSD Credits listed in 310 CMR 10.05(6)(k)4. Table 1 MassDEP Crosswalk. The credits are presumed to be provided when the ESSD is sized in accordance with the dimensional specifications of the Massachusetts Stormwater Handbook Appendix A [2022 Edition].*

d. *Pretreatment for TSS removal is provided in accordance with 310 CMR 10.05(6)(k)4.d.i. through iii. Use of EPA-PRC requires that pretreatment be provided, however, the credit for the pretreatment is already incorporated into the EPA-PRC. Therefore, pretreatment must be provided but no additional TSS pretreatment credits shall be applied to meet the 90% TSS* *removal for those SCMs that have an EPA-PRC. For other SCMs listed in 310 CMR 10.05(6)(k)4. Table 1 MassDEP Crosswalk that require pretreatment, TSS removal credit shall be provided and applied to meet the 90% TSS removal.*

- i. *At least 44% TSS pretreatment is required prior to discharge to an infiltration structure if the discharge is: within a Zone II or Interim Wellhead Protection Area; Near an Outstanding Resource Water or Special Resource Water; Near a Shellfish Growing Area, Cold-water Fishery, or bathing beach; from Land Uses with Higher Potential Pollutant Loads; or within an area with a rapid infiltration rate (greater than 2.4 inches per hour).*
- ii. *At least 25% TSS pretreatment is required for all other discharges to structural treatment SCMs, including infiltration structures, except for rooftop runoff directed to a dry well or roof dripline filters.*
- iii. *Metals pretreatment is provided for runoff from metal roofs located within Zone II or the Interim Wellhead Protection Area of a public water supply and/or an industrial site by a SCM capable of removing metals, such as a sand filter, organic filter or filtering bioretention area. Metal roofs are galvanized steel or copper, regardless if they are coated or painted.*

e. *When a proprietary manufactured separator, proprietary media filter, or other treatment practice is proposed for which no Total Suspended Solid or Total Phosphorus removal credit has been designated at 310 CMR 10.05(6)(k)4. Table 1 MassDEP Crosswalk, written documentation shall be submitted to the Issuing Authority with the Notice of Intent substantiating the removal percentages being claimed and that the structure will treat the 1-inch water quality volume through submission of a computation converting the 1-inch water quality volume to a peak flow rate. The peak flow rate for the computations must be based on the upper confidence of the precipitation frequencies listed in the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 10 (Version 3.0 or later versions are permissible) multiplied by 0.9. Computations based on the U.S. Weather Bureau Technical Paper 40 are not acceptable. Storm distribution must be based on National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Volume 10 (Version 3.0 or later versions are permissible) multiplied by 0.9. Use of the NRCS Type III storm is not acceptable to meet the computation requirement. Computations converting the 1-inch water quality volume to a peak flow rate that are performed in accordance with Appendix D of the Massachusetts Stormwater Handbook [2022 Edition] will be presumed to demonstrate that the structure can treat the 1-inch water quality volume. The Issuing Authority shall review the written documentation on a case-by-case basis and determine whether the use of the proposed Stormwater Control Measure will meet or partially meet the TSS and TP pollutant requirements specified at 310 CMR 10.05(6)(k)4. or10.05(6)(k)7.c., and for proprietary manufactured pretreatment practices, 310 CMR 10.05(6)(k)4.d. However, proprietary manufactured practices designated as pretreatment practices shall only be used for pretreatment. Said proprietary manufactured practices shall be sized to treat at least the first 1 inch of runoff times the impervious area. The written documentation to be submitted to the Issuing Authority shall consist of scientific studies that adhere to the Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practices Demonstrations, August 2001, updated July 2003, published on MassDEP's website and endorsed by the States of California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia (https://www.mass.gov/files/documents/2016/08/rd/swprotoc.pdf). All studies must be conducted in the field. Laboratory studies are not acceptable. The procedures specified in the Massachusetts Stormwater Handbook [2022 Edition] for review of Proprietary Manufactured Stormwater Control Measures provide guidance to Issuing Authorities about how to review scientific studies conducted pursuant to the Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practices Demonstrations.*

Explanation

The intent of Standard 4 is to ensure that Stormwater Management Systems are properly designed and sized to reduce annual average pollutant loads generated by the impervious area under post-development conditions.

Pollutant Removal Requirements

- For new development, Stormwater Management Systems shall be designed to remove 90% of Total Suspended Solids (TSS) and 60% of Total Phosphorus (TP) from the total average annual post-construction load generated from impervious surface area on the site. When a Water Quality Volume (WQv) equal to or greater than 1.0 inch is recharged on site, full credit is provided for Standard 4. The treated WQv must be at least 1.0 inch for the following instances:
  - When there is no applicable EPA Performance Removal Curve or Crosswalk (See "Pollutant Removal Calculation Methods").
  - When discharges are near or to: Critical Areas, Land Uses with Higher Potential Pollutant Loads, soils with rapid infiltration rate (greater than 2.4 inches per hour).
- Projects that discharge stormwater to waterbodies or waterways for which a Total Maximum Daily Load (TMDL) has been developed by MassDEP and approved by the Environmental Protection Agency (EPA) must be designed to implement control measures for pollutants specified in Standard 11 that are causing the impairment.
- TSS Pretreatment of at least 25% must be provided before discharge to most SCMs (see **Table 2-2** for a list of SCMs that require pretreatment). At least 44% TSS pretreatment is required for stormwater discharges to certain areas as summarized by **Table 2-1**.
- Separate calculations must be completed for each stormwater outlet to demonstrate compliance with TSS and TP removal requirements.

What is the Water Quality Volume?

Water Quality Volume (WQv) is the runoff volume requiring treatment – it is calculated as the required runoff depth multiplied by the total post-construction impervious site area. See **Section 6.2.4** for more information on how to compute the WQv.

ESSD and LID Techniques

To meet Standard 4, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis submitted with the Notice of Intent. Other SCMs shall only be used to meet those portions of the TSS/TP removal Standard 4 that cannot be fully met by ESSD and LID techniques. The following resources are available relative to ESSD and LID techniques:

- See **Section 4.2.1** for a list of MassDEP recognized ESSD / LID techniques. Each MassDEP recognized ESSD / LID technique has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**).
- Most MassDEP recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).

Pollutant Removal Calculation Methods

There are three methods that must be used to calculate pollutant removal credit depending on the site.

1) **ESSD Credits:** see **Appendix A** and **Table 2-2**.

2) **EPA Performance Removal Curves**: EPA Region 1 developed pollutant removal performance curves ("EPA Performance Removal Curves", "EPA-PRC") for the Small MS4 Permit. The EPA-PRCs are located in the BMP Accounting & Tracking Tool (BMP-BATT) published by EPA as of [effective date of regulations][13] Graphical and tabular versions of the EPA-PRCs have also been developed by MassDEP (see **Appendix B**). The EPA-PRCs must be used to determine pollutant removal efficiency credits for SCMs with an established curve or an equivalent MassDEP "Crosswalk". SCM naming nomenclature varies between the EPA-PRCs and the Massachusetts Stormwater Handbook. A "SCM Convention Crosswalk" was developed by MassDEP to match SCMs from the Massachusetts Stormwater Handbook to the EPA-PRCs (see **Table 2-2**). For example, a Massachusetts Stormwater Handbook Dry Well may use the "Infiltration Trench" EPA-PRC to calculate pollutant removals. Other Crosswalks have been prepared by EPA and MassDOT – Applicants must use the MassDEP crosswalk.

3) **MassDEP Pollutant Removal Credits**: Some commonly used SCMs do not have an established EPA Performance Curve. MassDEP SCMs without an approved EPA Performance Curve or MassDEP "Crosswalk" equivalent must use a 1.0 inch WQv to size the treatment practice. Pollutant removal credit may be calculated using MassDEP assigned values from **Table 2-2** for SCMs without an EPA Performance Curve or MassDEP "Crosswalk" equivalent.

Refer to **Section 6.2.4** for example computations and demonstrations to meet the Standard 4 pollutant removal requirements, including examples on how to use the EPA Performance Removal Curves, how to use the MassDEP Pollutant Removal Credits, and an example on how to demonstrate 44% pretreatment removal.

[13] EPA Region 1 Performance Removal Curves via EPA BATT (version 2.1): https://www.epa.gov/npdes-permits/stormwater-tools-new-england#swbmp.

How is Pretreatment Addressed by these Methods?

Pretreatment credits are already incorporated into the EPA Performance Removal Curves and the MassDEP pollutant removal credits – *i.e.,* the EPA-PRCs and MassDEP pollutant removal credits assume that the SCM has been designed with proper pretreatment in accordance with the **Appendix A** Structural SCM Specifications and the Massachusetts Stormwater Handbook. Applicants must therefore demonstrate that the required 25% or 44% TSS pretreatment is provided when performing calculations.

*For example, assume that an infiltration basin is being designed to receive runoff from a Land Use with a Higher Pollutant Load (LUHHPL) for a new development project. As indicated by **Table 2-1**, at least 44% TSS pretreatment and a treated Water Quality Volume of at least 1 inch is required for this instance. The Applicant would take the following steps to claim pollutant removal credit:*

1. *Calculate pretreatment credits.*
    a. *Use the **Appendix A** Structural SCM Specifications to identify which pretreatment measures are appropriate for infiltration basins and **Table 2-3** to identify which pretreatment measures are appropriate for LUHPPLs – e.g., sediment forebay, oil grit separator.*
    b. *Use **Table 2-2** to identify the TSS pretreatment credit that is assigned to each pretreatment SCM. For example, sediment forebays and oil grit separators are both assigned a TSS pretreatment credit of 25%.*
    c. *Use the MassDEP Pollutant Removal Worksheet to calculate the pretreatment credit. See **Figure 6-13** for an example calculation where a treatment train of two pretreatment SCMs are used to achieve a TSS pretreatment credit of 44%.*
2. *Calculate pollutant removal credits exclusive of the pretreatment credits.*
    a. *Use the EPA Performance Removal Curves (EPA PRCs) to size the infiltration basin to treat a WQv of at least 1 inch and remove at least 90% TSS and 60% TP <u>exclusive</u> of the 44% TSS pretreatment credit.*
    b. *For example, assume that EPA PRCs are used to size the infiltration basin to remove 96% TSS and 65% TP. A 96% TSS removal credit would be assigned to the sediment forebay, oil grit separator, and infiltration basin combination – no additional TSS removal credit is given for the pretreatment SCMs.*

<u>SCM Treatment Trains and Evaluation of Pollutant Removal at Discharge Points</u>

A Stormwater Management System will typically have several sequential SCMs designed to control flow rates and treat contaminants *(i.e.,* treatment train). The goal is for the treatment train to cumulatively remove the required amount of average annual post-construction TSS and TP load generated from post-construction impervious area on the site.[14]

Evaluate Standard 4 TSS and TP removal credit to determine compliance as follows:

- At the point of discharge (*e.g.,* end of pipe) when only one treatment train is used.

[14] TSS and TP removal is not required at an outfall with only a *de minimus* stormwater discharge. In that event, an Applicant may demonstrate compliance with the TSS and TP removal requirement by using a weighted average. See **Section 6.2.4** for a description of the highly limited circumstances in which a discharge from a stormwater outfall will be considered *de minimus* and the procedures for applying a weighted average.

- Where there is more than one outfall or treatment train within a single sub-catchment draining to the same Resource Area, the pollutant removal standard is demonstrated to be met either at each design point, or by using a weighted average, weighted by area draining to each outfall
- When multiple treatment trains from different sub-catchments drain to one wetland, the pollutant removal standard is met at each hypothetical design point, using a weighted average, weighted by sub-catchment size.
- When multiple treatment trains from different sub-catchments drain to multiple wetlands, the pollutant removal standard is met at one hypothetical design point per each wetland, using weighted average, weighted by sub-catchment size.

When the removal credit is evaluated following this process, 310 CMR 10.05(6)(k)4. is presumed to be met.

How to Calculate Pollutant Removals when a Treatment Train is Used?

For treatment trains, the SCM design removal rates cannot be added directly to arrive at 90% for TSS and 60% TP. Refer to **Section 6.2.4** for an example calculation.

SCM Selection, Design, and Monitoring

SCMs designed, constructed, operated and maintained in accordance with the specifications and procedures set forth in the Stormwater Handbook will be presumed to meet Standard 4 (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies). Standard 4 has been designed in a manner that makes it unnecessary for the permitting authority to verify a TSS or TP load for the site in order to confirm removal rates. Assuming all SCMs are properly designed, the percentage of TSS and TP removed by the entire system shall be calculated by applying the TSS and TP removal rates set forth in the EPA Performance Removal Curves or **Table 2-2** for each SCM in the order in which it is used in the Stormwater Management System. Monitoring is generally not required to confirm removal percentages. Monitoring or sampling may be appropriate to ensure protection of Critical Areas or to verify the effectiveness of alternative technologies that are not included in the EPA Performance Removal Curves or in **Table 2-2**, do not have a specified TSS or TP removal rate, and that have only limited data about their long-term performance. Approved SCM Pollutant removal efficiencies for TSS and TP for individual SCMs are also available in **Appendix A**.

Long-Term Pollution Prevention Plan

Standard 4 requires the development and implementation of suitable practices for source control and pollution prevention. These measures must be identified in a long-term pollution prevention plan (LTPPP). Refer to **Section 4.3.2** for detailed LTPPP guidance.

Table 2-2. SCM Convention Crosswalk and TSS / TP Removal Credits (*Table TSS / TP*)

MassDEP SCM	Applicable EPA Performance Removal Curve	Does SCM Require Pretreatment?[1]	Pollutant Removal Credit	
			TSS	TP
Non-Structural				
Street Cleaning	-	No	3% to 16%[2]	2% to 7%[2]
ESSD Credits				
Credit 1: General ESSD	-	No	90%	60%
Credit 2: Solar ESSD	-	No	90%	60%
Credit 3: Roof Runoff to QPA	Disconnection	No	90%[3]	60%[3]
Credit 4: Road Runoff to QPA	Disconnection	No	90%[3]	60%[3]
Credit 5: Tree Canopy	-	No	EIC Reduction[4]	EIC Reduction[4]
Credit 6: Reduce Impervious Area	-	No	TIA Reduction[5]	TIA Reduction[5]
Credit 7: Buffer Zone Improvement	Disconnection	No	90%[6]	60%[6]
Structural Pretreatment				
Deep Sump Catch Basin	-	No	25%	No Treatment
Oil/Grit Separator	-	No	25%	No Treatment
Proprietary Separator	-	No	≥ 44%[7]	No Treatment (minimum)[7]
Sediment Forebay	-	No	25%	No Treatment
Vegetated Filter Strip (≥ 25-ft length)	-	No	25%	No Treatment
Vegetated Filter Strip (≥ 50-ft length)	-	No	45%	No Treatment
Pea Gravel Diaphragm	-	No	45%[8]	No Treatment
Grass / Gravel Combination	-	No	45%[8]	No Treatment
Structural Treatment				
Bioretention Area (Exfiltrating)[9]	Infiltration Basin	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Bioretention Area (Filtering)[9]	Biofiltration	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Constructed Stormwater Wetland	Gravel Wetland	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Extended Dry Detention Basin	Dry Pond	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Gravel Wetland	Gravel Wetland	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Proprietary Media Filter	-	**Yes**	≥ 60%[10]	≥ 30%[10]
Sand/Organic Filter	Sand Filter	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Tree Box Filter (Exfiltrating)[9]	infiltration Trench	No	Use Applicable EPA-PRC	Use Applicable EPA-PRC

MassDEP SCM	Applicable EPA Performance Removal Curve	Does SCM Require Pretreatment?[1]	Pollutant Removal Credit	
			TSS	TP
Tree Box Filter (Filtering)[9]	Biofiltration	No	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Wet Basin	Wet Pond	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Roof Dripline Filter (Filtering)[9]	Biofiltration	**Varies[11]**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Roof Dripline Filter (Exfiltrating)[9]	Infiltration Trench	**Varies[11]**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Structural Conveyance				
Drainage Channel	-	No	No Treatment	No Treatment
Grass Channel (Biofilter Swale)	Grass Swale	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Water Quality Swale (Dry/Wet)	-	**Yes**	70%	No Treatment
Structural Infiltration				
Dry well	Infiltration Trench	**Varies[11]**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Infiltration Basin	Infiltration Basin	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Infiltration Trench	Infiltration Trench	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Leaching Catch Basin	Infiltration Basin	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Porous pavement	Porous Pavement	**Yes[12]**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Subsurface Infiltrator	Infiltration Basin	**Yes**	Use Applicable EPA-PRC	Use Applicable EPA-PRC
Structural Other				
Dry Detention Basin	-	No	No Treatment	No Treatment
Green Roof	-	No	EIC Reduction[13]	EIC Reduction[13]
Rain Barrels & Cisterns	-	No	EIC Reduction[13]	EIC Reduction[13]

Pollutant Removal Credit Key:

- Purple = Use applicable EPA Performance Removal Curve (EPA-PRC) to calculate pollutant removals.
- Blue = Use MassDEP removal credits indicated in table to calculate pollutant removals.
- White = No pollutant removal credit.

Table Notes (this Table includes additional detail not specified in 310 CMR 10.05(6)(k)(4) Table 1**)**:

1. See **Appendix A** for acceptable pretreatment measures for each SCM.
2. Street Cleaning: Pollutant removal credit is dependent on the type of street cleaner and the frequency of cleaning. See **Appendix A** for more information.
3. ESSD Credit 3 and Credit 4, Runoff to Qualifying Pervious Area (QPA): Removal credit from the EPA Disconnection Curve is based on the ratio of impervious to pervious area and the Hydrologic Soil Group (HSG) of underlying soils – 90% TSS removal credit and 60% TP removal credit is provided

when the Imperious Area (IA) to Pervious (PA) Ratio is as follows: HSG A (1:1 to 1:50), HSG B (1:1 to 1:50), and HSG C (1:2 to 1:50). Refer to **Appendix A** for more information.

4. ESSD Credit 5, Tree Canopy: Consists of a reduction in Effective Impervious Cover (EIC) which may be deducted from the total area of impervious surface that must be managed as required by Standard 3 (Groundwater Recharge), Standard 4 (Pollutant Removal), and the pollutant removal requirements of Standard 7. See **Appendix A** for more information.
5. ESSD Credit 6, Reduce Impervious Area: Consists of a reduction in Total Impervious Area (TIA) which, by definition, is deducted from the total area of impervious surface that must be managed as required by Standard 3 (groundwater recharge), Standard 4 (pollutant attenuation), and the pollutant removal requirements of Standard 7. See **Appendix A** for more information.
6. ESSD Credit 7, Buffer Zone Improvement: Removal credit from the EPA Disconnection Curve is based on the ratio of impervious to pervious area and the Hydrologic Soil Group (HSG) of underlying soils – 90% TSS removal credit and 60% TP removal credit is provided when the Imperious Area (IA) to Pervious (PA) Ratio is as follows: HSG A (1:1 to 1:50), HSG B (1:1 to 1:50), and HSG C (1:2 to 1:50). Refer to **Appendix A** for more information.
7. Proprietary Separator: Higher credit may be provided at the discretion of the Issuing Authority in accordance with 310 CMR 10.05(6)(k)4.e. Pollutant removal credit is determined on a case-by-case basis in accordance with procedures described in **Section 5.3**.
8. Pea Gravel Diaphragm and Grass / Gravel Combination: If properly designed and installed in accordance with the **Appendix A** Structural SCM specifications, these SCMs are presumed satisfy the pretreatment requirement for bioretention areas, infiltration trenches, ESSD Credit 3, ESSD Credit 4, and ESSD Credit 7. TSS pretreatment credit is only available if sheet flow is directed to these SCMs.
9. Bioretention areas, tree box filters, and roof dripline filters may be designed to act as a filtering practice or an infiltration practice. Filtering bioretention areas, tree box filters, and roof dripline filters do not infiltrate and cannot be used receive recharge credit towards Standard 3 – they have an underdrain that captures and conveys runoff downstream. Filtering bioretention areas, tree box filters, and roof dripline filters may be lined. Exfiltrating bioretention areas , tree box filters, and roof dripline filters are designed to provide infiltration.
10. Proprietary Media Filter: Higher credit may be provided at the discretion of the Issuing Authority in accordance with 310 CMR 10.05(6)(k)4.e. Pollutant removal credit is determined on a case-by-case basis in accordance with procedures described in **Section 5.3**.
11. Pretreatment is not required for Dry Wells and Roof Dripline Filters for runoff from non-metal roofs. Runoff from metal roofs may be discharged to a Dry Well or Roof Dripline Filter only if the roof is located outside the Zone II, IWPA of a public water supply, or outside an industrial site.
12. Porous Pavement: Pretreatment for porous pavements consists of use of vacuum or regenerative air street cleaners and good housekeeping practices such as not applying traction agents such as sand to the pavement during the winter.
13. Green Roofs and Rain Barrels & Cisterns: If sized to retain the required 1-inch Water Quality Volume, consists of a reduction in Effective Impervious Cover (EIC) from the roof which may be deducted from the total area of impervious surface that must be managed as required by Standard 3 (Groundwater Recharge) and Standard 4 (Pollutant Removal). See **Appendix A** for more information and specific requirements.

2.3.5 Standard 5: Land Uses with Higher Potential Pollutant Loads

Definition

For Land Uses with Higher Potential Pollutant Loads, source control and pollution prevention shall eliminate or reduce the discharge of stormwater runoff from such land uses to the Maximum Extent Practicable. The written Long Term Pollution Prevention Plan (LTPPP) required by 310 CMR 10.05(6)(k)4.a. shall address source controls and pollution measures. This standard will be presumed to be met if source control and pollution prevention measures listed in the LTPPP are proposed to be implemented in accordance with the Massachusetts Stormwater Handbook [2022 Edition]. All Land Uses with Higher Potential Pollutant Loads must be completely protected from exposure to rain, snow, snow melt and stormwater runoff through source control and pollution prevention measures. This standard shall be presumed to be met when the proponent uses the specific source control and pollution prevention practices determined by the Department to be suitable for such use as provided in the Massachusetts Stormwater Handbook [2022 Edition]. Stormwater discharges from Land Uses with Higher Potential Pollutant Loads shall also comply with the requirements of the Massachusetts Clean Waters Act, M.G.L. c. 21, §§ 26 through 53, and the regulations promulgated thereunder at 314 CMR 3.00: Surface Water Discharge Permit Program, 314 CMR 4.00: Massachusetts Surface Water Quality Standards and 314 CMR 5.00: Ground Water Discharge Permit Program.

Explanation

Land uses with higher potential pollutant loads (LUHPPLs) are defined in 310 CMR 10.04 and 314 CMR 9.02 to include the following: land uses identified in 310 CMR 22.20B(2), 310 CMR 22.20C(2)(a)-(k) and (m), 310 CMR 22.21(2)(a)1. – 8. and 310 CMR 22.21(2)(b)1. – 6., areas within a site that are the location of activities that are subject to an individual National Pollutant Discharge Elimination System (NPDES) permit or the current NPDES Multi-Sector General Permit; auto fueling facilities (gas stations); exterior fleet storage areas; exterior vehicle service and equipment cleaning areas; marinas and boatyards; parking lots with high-intensity-use; confined disposal facilities and disposal sites. LUHPPLs include, but are not limited to:

- The industrial sectors regulated by the NPDES Multi-Sector General Permit Program. These sectors include, but are not limited to, manufacturing: mineral, metal, oil and gas; hazardous waste treatment or disposal facilities; solid waste facilities; wastewater residual landfills; recycling facilities; steam electric plants; transportation facilities; treatment works; and light industrial activity.
- Any land uses that are regulated by an individual NPDES permit or that are subject to individual effluent limits established by EPA.
- Any land uses that MassDEP has determined are not suitable for Zone IIs and Zone As of public water supplies, including, without limitation,[15] the following: automobile junk yards; the removal of sand and gravel within four feet of the historical high water mark; the storage of hazardous materials, liquid petroleum, liquid propane, chemical fertilizers, pesticides, manures, septage, sludge, road-deicing materials or sanding materials; snow or ice that has been removed from roads and is contaminated with de-icing chemicals; cemeteries, mausoleums; bulk oil terminals; commercial washing of vehicles and car washes.

[15] The complete text of the regulations that identify the land uses that are not suitable for Zone As and Zone IIs is set forth in 310 CMR 22.20B(2), 310 CMR 22.20C(2)(a)-(k) and (m), and 310 CMR 22.21(2)(a) 1.-8., and 310 CMR 22.21(b)1.-6. See http://www.mass.gov/dep/water/laws/regulati.htm#dw.

- Exterior fleet storage areas; exterior vehicle service maintenance and cleaning areas; marinas and boatyards; and parking lots with high-intensity-uses (1000 vehicle trips per day or more). Shopping centers, malls, and large office parks typically have high-intensity-use parking lots.
- Confined disposal facilities as defined in 314 CMR 9.02 and disposal sites as defined in M.G.L. c. 21E and 310 CMR 40.0000.

Treatment Requirements for LUHPPLs

Stormwater discharges from LUHPPLs that are treated by the specific structural SCMs determined to be suitable for treating runoff from such land uses will be presumed to meet Standard 5. These SCMs are listed in **Table 2-3**. This applies only to stormwater discharges that come into contact with the actual area or activity on the Project Site that may generate the higher potential pollutant load. Runoff from other portions of the Project Site that does not come into contact with these specific areas or activities and does not mix with the runoff from these areas or activities does not need to meet Standard 5. For example, on the site of a chemical manufacturing plant, runoff from any grassed open space or parking area without high-intensity use, which is separate from the chemical distribution, loading and storage areas, does not need to meet Standard 5.

Stormwater discharges from LUHPPLs include the use a treatment train that provides pollutant removal prior to discharge. The treatment train shall provide for at least 44% TSS removal prior to discharge to the infiltration SCM and shall be designed to treat a WQv of least 1.0 inch. The WQv may be calculated using methods described by Standard 4 (see **Section 6.2.4**). If the land use is one that has the potential to generate runoff with high concentrations of oil and grease such as a high-intensity-use parking lot, gas station, fleet storage area, or vehicle service and equipment cleaning area, include the following in the treatment train: oil grit separator, sand filter, filtering bioretention area or equivalent.[16] However, for high-intensity use parking lots, the surface course of porous pavements (*e.g.,* uppermost layer of porous asphalt or pervious concrete) is credited with providing the appropriate TSS pretreatment, provided there is no run-on from adjacent surfaces such as hot mix asphalt parking areas or from downspouts directed from rooftops (see **Table 2-3**).

Long-Term Pollution Prevention Plan

Source control and pollution prevention are particularly important for LUHPPLs. All projects must prepare and implement a long-term pollution prevention plan (LTPPP) plan to comply with Standard 4. The LTPPP required by Standard 4 must address source control and pollution prevention measures to prevent direct and indirect alterations to LUHPPLs. Refer to **Section 4.3.2** for detailed LTPPP guidance. A detailed industrial source control and pollution prevention plan (SWPPP) is crucial for sites with land uses that have higher potential pollutant loads.[17] Note, an industrial SWPPP is different than the construction period SWPPP that addresses construction period runoff.

[16] Design any SCMs chosen to remove oil and grease (i.e., oil grit separator) in accordance with the specifications set forth in **Appendix A**.

[17] If the land use is also subject to the NPDES Multi-Sector General Permit, a Stormwater Pollution Prevention Plan (SWPPP) will also be required. To avoid duplication of effort, a project Applicant may prepare one document that satisfies the SWPPP requirements of the NPDES Multi-Sector General Permit and the long-term pollution prevention plan requirements of Standards 4 and 5.

Table 2-3. SCMs for Land Uses with Higher Potential Pollutant Loads *(Table LUHPPL)*

Summary of Requirements

- Discharges from certain LUHPPLs may be subject to additional regulatory requirements including the need to obtain an individual or general discharge permit pursuant to the MA Clean Waters Act or Federal Clean Water Act.
- All Applicants must implement source control and pollution prevention.
- All SCMs designed in accordance with the Massachusetts Stormwater Handbook will be presumed to meet Standard 5 (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies).
- The required WQv is at least 1.0 inch times the total impervious area of the post-development site.
- Many land uses have the potential to generate higher potential pollutant loads of oil and grease. These land uses include, without limitation, industrial machinery and equipment and railroad equipment maintenance, log storage and sorting yards, aircraft maintenance areas, railroad yards, fueling stations, vehicle maintenance and repair, construction businesses, paving, heavy equipment storage and/or maintenance, the storage of petroleum products, high-intensity-use parking lots, and fleet storage areas. To treat the runoff from such land uses, use the following SCMs to pretreat the runoff prior to discharge to an infiltration structure: an oil grit separator, a sand filter, organic filter, filtering bioretention area, or equivalent.
- At least 44% TSS removal is required prior to discharge to an infiltration device. For high-intensity use parking lots, the surface course of porous pavements (*e.g.,* uppermost layer of porous asphalt or pervious concrete) is credited with providing the required 44% TSS removal pretreatment, provided there is no run-on from adjacent surfaces such as hot-mix asphalt parking areas and downspouts from rooftops. For bioretention areas, the pretreatment practices specified in **Appendix A** for bioretention are presumed to provide the 44% TSS removal pretreatment. This requirement does not apply to ESSD Credits.
- Proprietary Manufactured Separator SCMs may not be used as a terminal treatment device for runoff from land uses with higher potential pollutant loads. Subsurface infiltrators, even those that have a storage chamber that has been manufactured, are not considered propriety SCMs, since the treatment occurs in the soil below the structure, not in the structure.
- See **Section 2.5** for setback requirements.

Suitable ESSD Credits	
	*Most ESSD Credits are suitable. Refer to **Table 2-7** for general eligibility and to the individual credits for site-specific eligibility requirements (see **Appendix A** for ESSD Credits).
Suitable Structural Pretreatment SCMs	
	Deep Sump Catch Basins
	Catch Basin Inserts (*for Redevelopment and Retrofits only*)
	Oil Grit Separators
	Proprietary Manufactured Separators (see **Section 5.3**)
	Sediment Forebays
	Vegetated Filter Strips (*must be lined*)
	Bioretention Pretreatment Practices (see **Appendix A**)
	Porous Pavement (for High Intensity Parking Lots Only)
Suitable Structural Treatment SCMs (with prior pretreatment)	
Sand Filters, Organic Filters, Proprietary Media Filters, Wet Basins, Filtering Bioretention Areas, Extended Dry Detention Basins, and Constructed Stormwater Wetlands must be lined and sealed unless at least 44% of TSS has been removed prior to discharge to the SCM. Dry Water Quality Swales must be at least 2 feet above seasonal high groundwater.	*Filtering Bioretention Areas and *Filtering Tree Box Filters
	*Filtering Roof Dripline Filters
	*Constructed Stormwater Wetlands
	Dry Water Quality Swales
	Extended Dry Detention Basins
	*Gravel Wetlands
	Proprietary Media Filters. *Proprietary Media Filters may not be used as terminal treatment for runoff from LUHHPLs unless they have been verified for such use through the approved evaluation protocols outlined in **Section 5.3**. Proprietary media filters do not include catch basin inserts.*
	Sand /Organic Filters
	Wet Basins
	*Filtering Porous Pavements (for High Intensity Parking Lots Only)

Suitable Structural Infiltration SCMs (with prior pretreatment)	
	*Exfiltrating Bioretention Areas and *Exfiltrating Treebox Filters
	*Infiltration Basins
	*Infiltration Trenches and *Exfiltrating Roof Dripline Filters
	Leaching Catch Basins
	Subsurface Infiltrators
	*Exfiltrating Porous Pavements (for high Intensity Use Parking Lots Only

Notes:

1. Starred practices (*) denote a MassDEP accepted ESSD / LID technique (see **Table 4-1** for a full list).

2.3.6 Standard 6 Critical Areas

Definition

When stormwater discharges are within the Zone II or Interim Wellhead Protection Area of a public water supply or near or to any other Critical Area, structural and non-structural SCMs shall be implemented to remove pathogens and reduce the temperature of the stormwater being discharged. The written Long Term Pollution Prevention Plan (LTPPP) required by 310 CMR 10.05(6)(k)4.a. shall address source controls and pollution measures to prevent direct and indirect alterations to Critical Areas. When SCMs and BMPs specifically described in the Massachusetts Stormwater Handbook [2022 Edition] as appropriate for Critical Areas are provided, this portion of the standard is presumed to be met. described in Stormwater discharges and all components of structural and nonstructural SCMs, located Near or that discharge to Critical Areas, shall be removed and set back from the receiving water or wetland in accordance with 310 CMR 10.05(6)(q) and receive the highest and best practical method of treatment. Unless a discharge to a Cold-water Fishery is infiltrated or an ESSD practice is used, the temperature of the stormwater shall not exceed 68 degrees F at the discharge point to ensure that there will be no thermal impact to the existing ambient temperature of the receiving water. A "storm water discharge" as defined in 314 CMR 3.04(2)(a) or (b) to an Outstanding Resource Water or Special Resource Water shall comply with 314 CMR 3.00: Surface Water Discharge Permit Program and 314 CMR 4.00: Massachusetts Surface Water Quality Standards. Stormwater Management Systems located in and stormwater discharges to a Zone I or Zone A are prohibited, unless essential to the operation of the public water supply.

Explanation

Critical Areas are Outstanding Resource Waters as designated in 314 CMR 4.00, Special Resource Waters as designated in 314 CMR 4.00, recharge areas for public water supplies as defined in 310 CMR 22.02 (Zone Is, Zone IIs and Interim Wellhead Protection Areas for groundwater sources and Zone As for Surface Water sources), bathing beaches as defined in 105 CMR 445.000, Cold-Water Fisheries as defined in 314 CMR 9.02 and 310 CMR 10.04, and Shellfish Growing Areas as defined in 314 CMR 9.02 and 310 CMR 10.04.

- **Cold-Water Fisheries** are waters in which the mean of the maximum daily temperature over a seven-day period generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round population of cold-water stenothermal aquatic life. Waters designated as Cold-Water Fisheries by the Department in 314 CMR 4.00, and waters designated as Cold-Water Fishery resources by the Division of Fisheries and Wildlife, are Cold-Water Fisheries. Waters where there is evidence based on a fish survey that a cold-water fish population and habitat exist are also cold-water fisheries.
- **A Shellfish Growing Area** is land under the ocean, tidal flats, rocky intertidal shores and marshes and land under salt ponds when any such land contains shellfish. Shellfish Growing Areas include land that has been identified and shown on a map published by the Division of Marine Fisheries as a Shellfish Growing Area, including any area identified on such map as an area where shell fishing is prohibited. Shellfish Growing Areas shall also include land designated by the Department in 314 CMR 4.00 as suitable for shellfish harvesting with or without depuration. In addition, Shellfish Growing Areas shall include areas designated by the local shellfish constable as suitable for shell fishing based on the density of shellfish, the size of the area, and the historical and current importance of the area for recreational and commercial shellfishing.
- **A list of Outstanding Resource Waters** is published in the Surface Water Quality Standards, 314 CMR 4.00.[18] This list includes Class A public water supplies approved by MassDEP and

[18] Surface Water Quality Standards: https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards.

their tributaries, active and inactive reservoirs approved by MassDEP, certain waters within Areas of Critical Environmental Concern, certified vernal pools, and wetlands bordering Class A waters. Wetlands bordering other Class B, SB, or SA ORWs are also Outstanding Resource Waters. Pursuant to the Surface Water Quality Standards, 314 CMR 4.00, MassDEP may designate as Special Resource Waters certain waters of exceptional significance such as waters in national or state parks and wildlife refuges.

- **Bathing beaches** include public and semi-public bathing beaches as defined by the Massachusetts Department of Public Health in 105 CMR 445.000[19]. The Department of Public Health maintains an inventory of public and semi-public bathing beaches.
- **Recharge areas for Public Water Supplies** are defined in the Drinking Water Regulations, 310 CMR 22.02[20], and include the Zone A for surface water supplies and the Zone II and Interim Wellhead Protection Areas for groundwater supplies. [21] The Zone A means the land area between the surface water source and the upper boundary of the bank, the land area within a 400-foot lateral distance from the upper boundary of the bank of a Class A surface water used as a drinking water source as defined in the Surface Water Quality Standards, 314 CMR 4.05(3), and the land area within a 200-foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body. The Zone II means the area of an aquifer that contributes water to a well under the most severe pumping and recharge conditions that can be realistically anticipated. The Interim Wellhead Protection Area is used for groundwater sources for public water supplies that lack a Zone II that has been approved by MassDEP.

Long-Term Pollution Prevention Plan

Source control and pollution prevention are particularly important for Critical Areas. All projects must prepare and implement a Long-Term Pollution Prevention Plan (LTPPP) plan to comply with Standard 4. The LTPPP required by Standard 4 must address source control and pollution prevention measures to prevent direct and indirect alterations to Critical Areas. Refer to **Section 4.3.2** for detailed LTPPP requirements.

Treatment Requirements for Critical Areas

A stormwater discharge within a Zone II or Interim Wellhead Protection Area or near or to an Outstanding Resource Water, a Special Resource Water, a bathing beach, Shellfish Growing Area, or Cold-Water Fishery requires the use of a treatment train that provides 90% TSS removal and 60% TP removal prior to discharge. A treatment train that uses the structural SCMs determined by MassDEP to be suitable for such areas as set forth in **Tables 2-4a** through **Table 2-4d** will be presumed to meet this Standard. With the exception of runoff from a non-metal roof, and runoff from metal roofs located outside the Zone II or Interim Wellhead Protection Area of a Public Water Supply or an industrial site, the treatment train shall provide for at least 44% TSS removal prior to discharge to the infiltration structure. For discharges within a Zone II or Interim Wellhead Protection Area or near or to an Outstanding Resource Water, a Special Resource Water, a Shellfish Growing Area, a bathing beach, or a Cold-Water Fishery, the treatment SCMs must be designed to treat the required Water Quality Volume (WQv), a volume equal to 1.0 inch times the total Impervious Surfaces at the post-development site. All SCMs designed, constructed, operated and maintained in accordance with the specifications set forth in the Massachusetts Stormwater

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[19] Standards for Bathing Beaches: [105 CMR 445.00: State sanitary code chapter VII: Minimum standards for bathing beaches | Mass.gov](https://www.mass.gov).

[20] Recharge Areas: https://www.mass.gov/guides/drinking-water-standards-and-guidelines.

[21] Zone A requirements are not applied to backup drinking water sources pursuant to 310 CMR 22.00. However, any backup drinking water sources designated in the Surface Water Quality Discharge Standards as ORWs, are still Critical Areas, and any new stormwater discharges must be setback from the ORW and provided the highest and best practical method of treatment. For example, see 314 CMR 9.06(6).

Handbook will be presumed to meet Standard 6 (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies).

Table 2-4a. SCMs for Discharges Near or To Shellfish Growing Areas and Bathing Beaches *(Table CA1)*

Summary of Requirements	
• If applicable, Applicant must comply with additional regulations for Coastal Wetlands set forth in 310 CMR 10.21 through 310 CMR 10.37. • SCMs designed in accordance with the Massachusetts Stormwater Handbook will be presumed to meet Standard 6 (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies). • Required WQv is at least 1.0 inch times the total impervious area of the post-development site. • 44% TSS removal must be provided prior to discharge to infiltration SCM. This requirement does not apply to ESSD Credits. • For discharges near or to Shellfish Growing Areas or bathing beaches, proprietary manufactured separators may be used only for pretreatment. Subsurface infiltrators, even those that have a storage chamber that has been manufactured are not proprietary SCMs, since the treatment occurs in the soil below the structure, not in the structure itself. • See **Section 2.5** for setback requirements..	
Suitable ESSD Credits	
	*Most ESSD Credits are suitable. Refer to **Table 2-7** for general eligibility and to the individual credits for site-specific eligibility requirements (see **Appendix A** for ESSD Credits).
Suitable Pretreatment SCMs	
	Deep Sump Catch Basins
	Catch Basin Inserts (*for Redevelopment and Retrofits only*)
	Oil Grit Separators
	Proprietary Manufactured Separators (see **Section 5.3**)
	Sediment Forebays
	Vegetated Filter Strips
	*Filtering and Exfiltrating Porous Pavements (*Surface Course, TSS only*)
Suitable Treatment SCMs (with prior pretreatment)	
Sand Filters, Organic Filters, Proprietary Media Filters, Filtering Bioretention Areas, and Wet Basins must be lined and sealed if at least 44% TSS has not been removed prior to discharge to the SCM.	*Filtering Bioretention Areas and Filtering Treebox Filters
	*Filtering Roof Dripline Filters
	*Constructed Stormwater Wetlands *(highly recommended)*
	*Gravel Wetlands
	Proprietary Media Filters *(Proprietary Media Filters may not be used as terminal treatment for discharges near or to Critical Areas unless they have been verified for such use through the approved evaluation protocols outlined in* ***Section 5.3****. Proprietary media filters do not include catch basin inserts.)*
	Sand /Organic Filters
	Wet Basins
	*Filtering Porous Pavements
Suitable Infiltration SCMs (with prior pretreatment)	
	*Exfiltrating Bioretention Areas and Exfiltrating Treebox Filters
	Stormwater Dry Wells *(runoff from non-metal roofs and runoff from metal roofs located outside of the Zone II or Interim Wellhead Protection Area of a Public Water Supply and outside of an industrial site only.)*
	*Infiltration Basins *(highly recommended)*
	*Infiltration Trenches and *Exfiltrating Roof Dripline Filters
	Subsurface Infiltrators
	*Exfiltrating Porous Pavements

Notes:

1. Starred practices (*) denote a MassDEP accepted ESSD / LID technique (see **Table 4-1** for a full list).

Table 2-4b. Stormwater Discharges Near or To Outstanding Resource Waters, including Vernal Pools and Surface Water Sources for Public Water Systems *(Table CA2)*

<table>
<tr><th colspan="2">Summary of Requirements</th></tr>
<tr><td colspan="2">

Construction Sites of 1-acre or more must file a Notice of Intent (WM 09) with MassDEP requesting approval of the construction period Stormwater Pollution Prevention Plan (SWPPP), if they discharge near or to an ORW.
Stormwater discharges near or to ORWs must receive the highest and best practical method of treatment.
Any SCMs located near certified vernal pool must comply with 310 CMR 10.60[22]. Applicants must perform a certified Vernal Pool Habitat evaluation and demonstrate that the stormwater SCMs meet the performance standard of having no adverse impact on the habitat functions of a certified vernal pool.
Unless essential to operation of a Public Water System, all stormwater SCMs, including any and all of their components, are prohibited within the Zone I and Zone A, including but not limited to, porous pavements.[23]
SCMs designed in accordance with the Massachusetts Stormwater Handbook will be presumed to meet Standard 6 (see Appendix A for specifications and Section 6.2 for sizing methodologies).
Required WQv is at least 1.0 inch times the total impervious area of the post-development site.
At least 44% TSS pretreatment must be removed prior to discharge to infiltration SCMs and 25% TSS removal prior to discharge to any other type of stormwater SCM. This requirement does not apply to ESSD Credits.
For discharges near or to ORWs, only use proprietary manufactured separators for pretreatment. Subsurface infiltrators, even those that have a storage chamber that has been manufactured are not proprietary SCMs, since the treatment occurs in the soil below the structure, not in the structure itself.
See Section 2.5 for setback requirements.

</td></tr>
<tr><td colspan="2">Suitable ESSD Credits</td></tr>
<tr><td></td><td>*Most ESSD Credits are suitable. Refer to Table 2-7 for general eligibility and to the individual credits for site-specific eligibility requirements (see Appendix A for ESSD Credits).</td></tr>
<tr><td colspan="2">Suitable Pretreatment SCMs</td></tr>
<tr><td rowspan="6"></td><td>Deep Sump Catch Basins</td></tr>
<tr><td>Catch Basin Inserts (for Redevelopment and Retrofits only)</td></tr>
<tr><td>Oil Grit Separators</td></tr>
<tr><td>Proprietary Manufactured Separators (see Section 5.3)</td></tr>
<tr><td>Sediment Forebays</td></tr>
<tr><td>Vegetated Filter Strips</td></tr>
<tr><td colspan="2">Suitable Treatment SCMs (with prior pretreatment)</td></tr>
<tr><td rowspan="5">Sand Filters, Organic Filters, Proprietary Media Filters, Filtering Bioretention Areas, and Wet Basins must be lined and sealed if at least 44% TSS has not been removed prior to discharge to the BMP.</td><td>*Filtering Bioretention Areas and Filtering Treebox Filters</td></tr>
<tr><td>*Filtering Roof Dripline Filters</td></tr>
<tr><td>*Constructed Stormwater Wetlands (do not use near certified vernal pool)</td></tr>
<tr><td>*Gravel Wetlands</td></tr>
<tr><td>Proprietary Media Filters (May not be used as terminal treatment for discharges near or to Critical Areas unless they have been verified for such use through the approved evaluation protocols outlined in Section 5.3. Proprietary media filters do not include catch basin inserts.)</td></tr>
</table>

[22] Wildlife Habitat – https://www.mass.gov/lists/water-resources-policies-guidance.

[23] This applies to new development and not to Redevelopment or retrofits to existing buildings or land uses located in Zone A. If the existing buildings and land uses are outside the Zone A and presently discharge to an ORW through an existing conveyance, any increase in stormwater volume associated with new development or Redevelopment may not be routed through the existing conveyance to the ORW.

	Sand /Organic Filters
	Wet Basins (*do not use near certified vernal pool*)
Suitable Infiltration SCMs (with prior pretreatment)	
	*Exfiltrating Bioretention Areas and Exfiltrating Treebox Filters
	Stormwater Dry Wells *(runoff from non-metal roofs and runoff from metal roofs located outside of the Zone II or Interim Wellhead Protection Area of a Public Water Supply and outside of an industrial site only.)*
	*Infiltration Basins *(highly recommended)*
	*Infiltration Trenches *(highly recommended)* and *Exfiltrating Roof Dripline Filters
	Subsurface Infiltrators

Notes:

1. Starred practices (*) denote a MassDEP accepted ESSD / LID technique (see **Table 4-1** for a full list).

Table 2-4c. Stormwater Discharges within Zone A, Zone Is, Zone IIs and Interim Wellhead Protection Areas *(Table CA3)*

Summary of Requirements	
• Unless essential to operation of a Public Water System, all stormwater SCMs, including any and all of their components, are prohibited within the Zone I and Zone A, including but not limited to, porous pavements.[24] • Applicants must comply with local source water protection ordinances, bylaws, and regulations. • The Drinking Water Regulations, 310 CMR 22.21(2)(b)(7)[25], require the development of land use controls in the Zone II that prohibit land uses that result in rendering 15% or 2500 square feet of a lot impervious, whichever is larger, unless a system of artificial recharge that does not degrade groundwater quality is provided. Applicants can comply with these land use controls by designing, constructing, operating and maintaining a Stormwater Management System in compliance with the Stormwater Management Standards. • SCMs designed in accordance with the Massachusetts Stormwater Handbook will be presumed to the meet this Standard (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies). • Required WQv is at least 1.0 inch times the total impervious area of the post-development site. • At least 44% TSS pretreatment must be removed prior to discharge to infiltration SCMs and 25% TSS removal prior to discharge to any other type of stormwater SCM. This requirement does not apply to ESSD Credits. • For discharges near or to Zone I, Zone II, or IWPA, only use proprietary manufactured separators for pretreatment. Subsurface infiltrators, even those that have a storage chamber that has been manufactured are not proprietary SCMs, since the treatment occurs in the soil below the structure, not in the structure itself. • See **Section 2.5** for setback requirements.	
Suitable ESSD Credits	
	*Most ESSD Credits are suitable. Refer to **Table 2-7** for general eligibility and to the individual credits for site-specific eligibility requirements (see **Appendix A** for ESSD Credits).
Suitable Pretreatment SCMs	
	Deep Sump Catch Basins
	Catch Basin Inserts (*for Redevelopment and Retrofits only*)
	Oil Grit Separators
	Proprietary Manufactured Separators (see **Section 5.3**)
	Sediment Forebays
	Vegetated Filter Strips
Suitable Treatment SCMs (with prior pretreatment)	
Sand Filters, Organic Filters, Proprietary Media Filters, Filtering Bioretention Areas, and Wet Basins must be lined and sealed if at least 44% TSS has not been removed prior to discharge to the BMP.	*Filtering Bioretention Areas and Filtering Treebox Filters
	*Filtering Roof Dripline Filters
	*Constructed Stormwater Wetlands *(do not use near certified vernal pool)*
	*Gravel Wetlands
	Proprietary Media Filters *(may not be used as terminal treatment for discharges near or to Critical Areas unless they have been verified for such use through the approved evaluation protocols outlined in **Section 5.3**. Proprietary media filters do not include catch basin inserts.)*

[24] This applies to new development and not to Redevelopment or retrofits to existing buildings or land uses located in Zone A. If the existing buildings and land uses are outside the Zone A and presently discharge to an ORW through an existing conveyance, any increase in stormwater volume associated with new development or Redevelopment may not be routed through the existing conveyance to the ORW.

[25] Drinking Water Regulations – https://www.mass.gov/regulations/310-CMR-22-the-massachusetts-drinking-water-regulations.

	Sand /Organic Filters
	Wet Basins (*do not use near certified vernal pool*)
Suitable Infiltration SCMs (with prior pretreatment)	
	*Exfiltrating Bioretention Areas and Exfiltrating Treebox Filters
	Stormwater Dry Wells *(runoff from non-metal roofs and runoff from metal roofs located outside of the Zone II or Interim Wellhead Protection Area of a Public Water Supply and outside of an industrial site only.)*
	*Infiltration Basins *(highly recommended)*
	*Infiltration Trenches *(highly recommended)* and *Exfiltrating Roof Dripline Filters
	Subsurface Infiltrators

Notes:

1. Starred practices (*) denote a MassDEP accepted ESSD / LID technique (see **Table 4-1** for a full list).

Table 2-4d. Stormwater Control Measures for Cold-Water Fisheries *(Table CA4)*

Summary of Requirements	
• SCMs designed in accordance with the Massachusetts Stormwater Handbook will be presumed to meet the Standard (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies). • Required WQv is at least 1.0 inch times the total impervious area of the post-development site. • At least 44% TSS removal required prior to discharge to infiltration SCMs. This requirement does not apply to ESSD Credits. • For discharges near or to Cold-Water Fisheries, only use proprietary manufactured separators for pretreatment. Subsurface infiltrators, even those that have a storage chamber that has been manufactured are not proprietary SCMs, since the treatment occurs in the soil below the structure, not in the structure itself. • All components of Stormwater Management Systems and discharges must be at least 100-feet from the mean annual high water line of the cold-water fisheries. • See **Section 2.5** for setback requirements.	
Suitable ESSD Credits	
	*Most ESSD Credits are suitable. Refer to **Table 2-7** for general eligibility and to the individual credits for site-specific eligibility requirements (see **Appendix A** for ESSD Credits).
Suitable Pretreatment SCMs	
	Deep Sump Catch Basins
	Oil Grit Separator
	Proprietary Separators (see **Section 5.3**)
	Sediment Forebay
	Vegetated Filter Strips
Suitable Treatment SCMs (with prior pretreatment)	
Sand Filters, Organic Filters, Proprietary Media Filters, Filtering Bioretention Areas and Wet Basins must be lined and sealed unless 44% of TSS has been removed prior to discharge to the SCM. Stormwater infiltration practices may be used, provided at least 44% TSS pretreatment has been provided prior to runoff being directed to the infiltration practice. Grass channels and dry water quality swales must be at least 2 feet above seasonal high groundwater.	*Filtering Bioretention Areas and Filtering Treebox Filters
	*Filtering Roof Dripline Filters
	*Dry Water Quality Swales
	Grass Channels
	Leaching Catch Basins
	Proprietary Media Filters (*may not be used for terminal treatment for discharges near or to Critical Areas unless they have been verified for such use through the approved evaluation protocols outlined in **Section 5.3**. Proprietary media filters do not include catch basin inserts.)*
	Sand /Organic Filters
	*Wet Water Quality Swales
	*Green Roofs
Suitable Infiltration SCMs (with prior pretreatment)	
	*Infiltration Trenches and *Exfiltrating Roof Dripline Filters
	*Infiltration Basins
	Subsurface Infiltrators
	*Exfiltrating Bioretention Areas and Exfiltrating Treebox Filters
	Stormwater Dry Wells *(runoff from non-metal roofs and runoff from metal roofs located outside the Zone II or Interim Wellhead Protection Area of a Public Water Supply or an industrial site only)*

Notes:

1. Starred practices (*) denote a MassDEP accepted ESSD / LID technique (see **Table 4-1** for a full list).

2.3.7 Standard 7: Redevelopment

Definition

Redevelopment Projects shall be subject to the following:

a. *A Redevelopment project is required to meet the following Stormwater Management Standards only to the Maximum Extent Practicable: 310 CMR 10.05(6)(k)2., 310 CMR 10.05(6)(k)3., the pretreatment and structural Stormwater Control Measures and related stormwater Best Management Practice requirements of 310 CMR 10.05(6)(k)5. and 6, and the Setback requirements at 310 CMR 10.05(6)(q). Existing stormwater discharges shall comply with 310 CMR 10.05(6)(k)1. only to the Maximum Extent Practicable.*

b. *Redevelopment projects shall comply with all other requirements of the Stormwater Management Standards and improve existing conditions by reducing the peak discharge rate, increasing stormwater recharge, and removing pollutants such as Total Suspended Solids and Total Phosphorus from the discharge.*

c. *All provisions of 310 CMR 10.05(6)(k)4. apply to Redevelopment Projects, except that Stormwater Management Systems for Redevelopment shall be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS) and 50% of the average annual post-construction load of Total Phosphorus (TP). This standard is to be met on the Project Site unless Impracticable as demonstrated by a written alternatives analysis, in which case Offsite Mitigation for Redevelopment must be implemented to achieve the removal standard of 80% TSS and 50% TP. Offsite Mitigation for Redevelopment may be used to fully meet the 80% TSS and 50% TP removal standard, or to meet the portion of the 80% TSS and 50% TP removal standard that cannot be fully met on the Project Site. Offsite Mitigation for Redevelopment may also be allowed for the requirements of 310 CMR 10.05(6)(k)3 and 310 CMR 10.05(6)(k)11.d. when the written alternatives analysis determines Maximum Extent Practicable cannot be achieved on the Project Site.*

d. *Offsite Mitigation for Redevelopment shall be evaluated in the following order: same Project Site, same Project Locus, adjacent site, same wetland Resource Area, same municipality, and the same stream reach within the Hydrologic Unit Code (HUC) 12 sub-watershed. All instances of Offsite Mitigation for Redevelopment shall be within the same HUC 12 sub-watershed. MassDOT may use the Watershed-scale Accounting Method within the HUC 10 within a three-year period after the final Order is issued to meet the requirements of 310 CMR 10.05(6)(k)7. The Watershed-scale Accounting Method may be used rather than or in addition to meeting 310 CMR 10.05(6)(k)7 on the Project Site, through the Macro-Approach, or by using Offsite Mitigation for Redevelopment, if these options are Impracticable. The implementation of Stormwater Control Measures through the Watershed-scale Accounting Method must be tracked by an annual report available to the Issuing Authority and to MassDEP.*

e. *Retrofit Projects shall comply with 310 CMR 10.05(6)(k)1., 5., 6., 8., 9., and 10. Retrofit Projects shall not have to comply with 310 CMR 10.05(6)(k)2., 3., 4., and 11., except they must improve existing conditions for at least peak discharge rate, recharge, or water quality treatment.*

Explanation

For purposes of the Stormwater Management Standards, Redevelopment projects are defined to include the following:

1) improvement of existing roadways, including widening less than a single lane, adding shoulders, correcting substandard intersections, and improving existing drainage systems;

2) Development, rehabilitation, expansion and phased projects on previously developed sites, provided the Redevelopment results in no net increase in impervious area; and

3) Remedial projects specifically designed to provide improved stormwater management, such as projects to separate storm drains and sanitary sewers.

The portion of a property that is currently undeveloped is not a Redevelopment and thus does not fall under Standard 7. To the extent a project includes development of previously undeveloped areas, the project must comply fully with all the Stormwater Management Standards (see **example** at the end of this section). Redevelopment within previously developed Riverfront Area is defined differently (see 310 CMR 10.58).

Redevelopment Checklist and Written Alternatives Analysis

The Redevelopment Checklist must be completed and submitted with the WPA NOI or WQC Application for any project that includes Redevelopment (see **Appendix E**). The Redevelopment Checklist provides a detailed list of requirements that Redevelopment projects must meet for each Stormwater Standard. If the Redevelopment Checklist demonstrates that full compliance can't be achieved for any applicable Stormwater Standards, or if Standard 4 cannot be fully met, a written alternatives analysis must be completed as detailed by **Section 6.1.4**. The written alternatives analysis must identify Offsite Mitigation alternatives to meet Standard 7 for water quality treatment as detailed by **Section 6.2.7**.

The written alternatives analysis must also be prepared for any applicable project seeking to demonstrate compliance with some or all Standards to the MEP. (See "*Maximum Extent Practicable*" discussion below for a list of applicable projects that are subject to the Stormwater Standards only to the MEP.) Also refer to **Section 6.1.4** for instruction on how to complete the written alternatives analysis.)

Summary of Requirements

Requirements for each Stormwater Standard for Redevelopment projects are listed in **Table 2-5**. As indicated by the Table, Redevelopment projects are subject to certain Stormwater Standards only to the Maximum Extent Practical (MEP). Refer to each Stormwater Standard for a more detailed explanation of requirements and how to meet them. See below section for more information on MEP.

Table 2-5. Requirement summary Redevelopment projects, listed by Standard

Standard No.	Standard Description	Requirement Summary
1	No Untreated Discharges or Erosion to Wetlands	Full compliance is required for new outfalls. Existing outfalls shall be brought into compliance to the Maximum Extent Practicable (MEP).
2	Peak Rate Attenuation	Existing conditions must be improved to the MEP (*i.e.,* reduce peak discharge rate).
3	Stormwater Recharge	Existing conditions must be improved to the MEP (*i.e.,* increase stormwater recharge).
4	Pollutant Removal	Full compliance is required for pollution prevention requirements. Develop a Long-Term Pollution Prevention Plan (LTPPP). See Standard 7 for pollutant removal requirements.
5	LUHPPLs	Full compliance is required for pollution prevention requirements. Develop a LTPPP. Compliance to the MEP for pretreatment and treatment requirements. Must use practices approved by MassDEP for LUHPPLS (**Table 2-3**).

Standard No.	Standard Description	Requirement Summary
6	Critical Areas	Full compliance is required for pollution prevention requirements. Develop a LTPPP. Compliance to the MEP for pretreatment and treatment requirements. Must use practices approved by MassDEP for Critical Areas (**Table 2-4**).
7	Redevelopment	Full compliance is required. Remove at least 80% of the average annual post-construction load of TSS and 50% of the average annual post-construction load of TP.
8	Construction Period Controls	Full compliance is required. Develop a Construction Period Erosion and Sedimentation Control Plan (CPPP).
9	Operation and Maintenance Plan	Full compliance is required. Develop a Long-Term Operation and Maintenance Plan.
10	Illicit Discharges	Full compliance is required. Eliminate all Illicit Discharges to storm drains, wastewater drainage systems, groundwater wells, and Wetland Resource Areas.
11	TMDLs	Use of practices approved by MassDEP for TMDLs will be presumed to the meet the Standard (**Table 2-6**). SCMs sized to remove 80% TSS and 50% TP and that provide recharge to the MEP will be presumed to meet the Standard.

Maximum Extent Practicable

A Redevelopment project is required to meet certain Stormwater Standards only to the Maximum Extent Practicable (MEP) as summarized by **Table 2-5**. For the purpose of Standard 7, “to the maximum extent practicable” is defined by 310 CMR 10.05(6)(o). In addition, the Stormwater Management Standards apply only to the MEP to the following in accordance with 310 CMR 10.05(6)(m):

1. Housing development and Redevelopment projects comprised of detached single-family dwellings on four or fewer lots that have a stormwater discharge that may potentially affect a Critical Area;
2. Multi-family housing developments and Redevelopment projects with four or fewer units, including condominiums, cooperatives, apartment buildings, and townhouses, that have a stormwater discharge that may potentially affect a Critical Area;
3. Housing development and Redevelopment projects comprised of detached single-family dwellings, on five to nine lots, provided there is no stormwater discharge that may potentially affect a Critical Area;
4. Multi-family housing development and Redevelopment projects, with five to nine units, including condominiums, cooperatives, apartment buildings and townhouses, provided there is no stormwater discharge that may potentially affect a Critical Area;
5. Marinas and boatyards provided that the hull maintenance, painting and service areas are protected from exposure to rain, snow, snowmelt, and stormwater runoff;
6. Unpaved footpaths, unpaved and paved bicycle paths, public shared use paths, and other unpaved or paved paths for pedestrian and/or nonmotorized vehicle access (with the exception of wheelchairs and other power-driven mobility devices by individuals with a mobility disability, electric bicycles and electric scooters, emergency vehicles, and vehicles performing periodic maintenance), not including paved sidewalks located near or adjacent to private and public roads; and
7. Maintenance of An Existing Public Roadway.

Project Applicants seeking to demonstrate compliance with some or all of the Standards to the MEP and improve existing conditions shall demonstrate that:

1. They have made all reasonable efforts to meet each of the Standards;

2. They have made a written alternatives analysis of possible stormwater management measures including Environmentally Sensitive Site Design and Low Impact Development techniques or practices that minimize land disturbance and Impervious Surfaces, structural stormwater control measures, Best Management Practices, pollution prevention, erosion and sedimentation control and proper operation and maintenance of stormwater best management practices; and

3. If full compliance with the Standards cannot be achieved, they are implementing the highest practicable level of stormwater management.

Refer to **Section 6.1.4** for more information on the written alternatives analysis.

<u>Improve Existing Conditions</u>

All Redevelopment projects must improve existing conditions. New stormwater controls (retrofitted or expanded) should be incorporated into the design and result in a reduction in annual stormwater pollutant loads from the site. All Redevelopment projects shall also incorporate measures that will address water quantity issues by reducing the peak runoff rate from the site and by increasing recharge. Gear actions to improve existing conditions towards addressing known water quality and water quantity problems such as documented failures to meet the Surface Water Quality Standards, low stream flow, or repeated flood events.

Also refer to **Section 5.2** for special considerations that provide unique opportunities to improve existing conditions for Redevelopment projects, including groundwater recharge areas, Cold-Water Fisheries, and Brownfield Redevelopments.

<u>Offsite Mitigation</u>

As defined by 310 CMR 10.04, Offsite Mitigation is a compliance approach for <u>Redevelopment projects</u> where Stormwater Control Measures (SCMs) are implemented at a location that is not within the Project Site to achieve compliance with Standard 3 (recharge), the pollutant removal requirements of Standard 7, and Standard 11 (TMDLs). Offsite Mitigation <u>must</u> be implemented when the pollutant removal requirements of Standard 7 and Standard 11 cannot be fully met onsite. Offsite Mitigation <u>may</u> be allowed for Standard 3 (recharge) and the recharge requirements of Standard 11 when the written alternatives analysis determines that the Standard cannot be met to the Maximum Extent Practicable onsite. Refer to **Section 6.2.7** for more information on evaluation of Offsite Mitigation alternatives.

<u>Tear Downs</u>

Although Redevelopment, tear downs and replacement of previously developed buildings and Impervious Surfaces should be able to fully meet the 11 Stormwater Management Standards. Tear downs and replacements provide greater opportunity and flexibility to reconstruct a site using Environmentally Sensitive Site Design, Low Impact Development techniques, green roofs, and green parking areas, enhance landscaping, and install structural SCMs than other types of Redevelopment projects, which, for example, may only include full depth reconstruction of an existing parking lot. Although MEP applies to tear downs as a Redevelopment activity, because there is greater flexibility, the expectation is that tears downs should be able to fully meet the Standards. This needs to be addressed in the written alternatives analysis required to demonstrate MEP (see **Section 6.1.4**).

<u>Retrofits</u>

Retrofits are site specific changes designed solely to improve water quality, reduce peak runoff rates, increase recharge, or reduce or eliminate combined sewer overflows (CSO). Retrofits **are not** a component of new development or maintenance.

Retrofit Projects shall comply with Stormwater Management Standards 1, 5, 6, 8, 9, and 10. Retrofit Projects do not have to comply with Standard 2, 3, 4, and 11, except they must improve existing conditions for at least peak runoff rate, recharge, or water quality treatment. Refer to **Section 5.1** for more information on Retrofit projects.

<u>Sites with Combined New Development and Redevelopment</u>

The portion of a property that is currently undeveloped is not Redevelopment and thus does not fall under Standard 7. Development in that portion of the property must fully meet the Wetlands and WQC regulations, including the Stormwater Management Standards. To the extent that a project includes development of previously undeveloped areas, the project must comply fully with all the Stormwater Management Standards. The following example demonstrates how the Stormwater Management Standards apply to a site that includes both new development and Redevelopment.

New Development and Redevelopment Example

Problem Statement. Assume a 5-acre site composed of 2 acres of Impervious Surfaces including parking, a warehouse, and manufacturing plant, and 3 acres of undeveloped areas, including wetlands. The site is proposed to be redeveloped into a mixed-use development with 3 acres of Impervious Surfaces (meaning 1 acre of new impervious area is proposed).

Solution. Because there is one additional acre of impervious surface proposed, stormwater runoff from at least one acre of impervious surface must be directed to SCMs that are designed and constructed to <u>fully</u> meet all the Stormwater Management Standards.

- The remaining two acres of existing Impervious Surfaces included in the project may be treated as a Redevelopment.
- Runoff from the Redevelopment portion of the project may be directed to SCMs that are designed and constructed to meet Standards 2, 3, and the pretreatment and SCM requirements of 5, and 6 to the MEP.
- Any new stormwater outfalls must be designed in compliance with Standard 1. Existing outfalls are required to comply with Standard 1 only to the MEP.
- The Stormwater Management System must also improve existing conditions.
- A long-term pollution prevention plan, an erosion and sedimentation control plan and a long-term operation and maintenance plan must be prepared for the entire site in accordance with the applicable provisions of Standards 4 through 6, 8, and 9. All Illicit Discharges to the stormwater system must be eliminated in accordance with Standard 10.

2.3.8 Standard 8: Construction Period Controls

Definition

A plan to control construction-related impacts including erosion, sedimentation and other pollutant sources during construction and land disturbance activities (construction period erosion, sedimentation and pollution prevention plan) shall be developed and implemented. This standard shall be presumed to be met when the construction period erosion, sedimentation and pollution prevention plan is prepared in accordance with the Massachusetts Stormwater Handbook [2022 Edition]. No construction period runoff may be directed to the post construction SCMs or other BMPs. The construction period erosion, sedimentation and pollution prevention plan shall be submitted with the Notice of Intent for review and approval by the Issuing Authority. A condition shall be included in the Order of Conditions that specifies that failure to comply with the construction period erosion, sedimentation and pollution prevention plan as approved in the Order of Conditions shall be deemed to be noncompliance. Field inspections of construction period BMPs identified in the construction period erosion, sedimentation and pollution prevention plan shall be performed at least once every seven calendar days during the construction period and maintenance or corrective actions shall be taken to ensure compliance. Inspections and maintenance or corrective actions shall be documented in a report and made available to the issuing authority upon request.

Explanation

Construction runoff is one of the leading causes of impairments to wetlands. To minimize these impairments, careful attention must be paid to preparing and implementing a Construction Period Pollution Prevention Plan (CPPP). For all projects subject to jurisdiction under the Wetlands Protection Act, a CPPP that identifies the party or parties responsible for implementing the plan or any components thereof must be submitted with the NOI or WQC application.[26]

Projects that disturb one acre of land or more are required to obtain coverage under the latest NPDES Construction General Permit (CGP) issued by EPA and prepare a Stormwater Pollution Prevention Plan (SWPPP).[27] To avoid duplication of effort, a project Applicant can prepare a single document that satisfies the SWPPP requirements of the CGP and the CPPP requirements of Standard 8. For all projects that are required to obtain coverage under the CGP, the Issuing Authority shall require submission of the SWPPP before land disturbance commences.

> ***Construction Period Pollution Prevention Plan***
>
> Refer to **Section 4.3.3** for a list of minimum requirements, guidance, and resources that may be used to prepare the required CPPP.

Implementation, and Maintenance of Construction Period SCMs

During land disturbance and construction activities, project Applicants must implement controls specified in the CPPP that prevent erosion, control sediment movement, and stabilize exposed soils to prevent pollutants from moving offsite or entering wetlands or waters. Land disturbance activities include demolition, construction, clearing, excavation, grading, filling, and reconstruction.

[26] For projects subject to jurisdiction under the Wetlands Protection Act, the construction period pollution prevention and erosion and sedimentation control plan must be included in the Stormwater Report submitted with the Wetlands Notice of Intent..

[27] EPA NPDES: https://www.epa.gov/npdes.

No post-construction SCMs or BMPs may be used to manage construction period runoff. Many stormwater technologies (infiltration technologies) are not designed to handle the high concentrations of sediments typically found in construction runoff, and thus must be protected from construction-related sediment loadings.

Size sediment traps to provide adequate capacity and retention time to allow for proper settling of fine-grained soils (see **Section 6.2.8** for sizing guidance). Construction period BMPs must be properly operated and maintained in accordance with the CPPP.

Note: The Order of Conditions contains a general condition that requires the responsible party or parties to implement the CPPP as approved by the Conservation Commission, until the site is fully stabilized and the temporary erosion and sedimentation controls are removed.[28] The Conservation Commission may include Special Conditions to ensure the CPPP is properly implemented by the Construction Contractor.

[28] Order of Conditions: https://www.mass.gov/how-to/wpa-form-5-order-of-conditions.

2.3.9 Standard 9: Operation and Maintenance Plan

Definition

> *A long-term operation and maintenance plan shall be developed and implemented to ensure that the stormwater management system functions as designed. This standard is presumed to be met when the maintenance proposed in the long-term operation and maintenance plan occurs with the frequencies listed in Appendix A of the Massachusetts Stormwater Handbook [2022 Edition] and when the plan is otherwise prepared in accordance with the Handbook. The long-term operation and maintenance plan shall be submitted with the Notice of Intent, for review and approval by the Issuing Authority. After a Certificate of Compliance has been issued or the Order of Conditions has expired, a Maintenance Log shall list the maintenance activities and long-term pollution prevention plan measures that have occurred and the specific dates of the maintenance and pollution prevention activities. The Maintenance Log shall be kept up-to-date. The Maintenance Log shall be made available to the Issuing Authority no later than 5 business days after any request.*

Explanation

A long-term Operation and Maintenance (O&M) Plan must be submitted with the NOI or WQC Application. The SCM Specifications include the basic maintenance requirements for each relevant SCM (**Appendix A**). Additional requirements apply for proprietary SCMs as indicated by **Section 5.3**. The maintenance requirements for SCMs should be considered during the selection process. Because maintenance is mandatory, it is logical that SCM selection should gravitate toward measures that are more easily maintained. SCMs installed *above ground* are generally easier to maintain than ones placed *underground.*

For most SCMs, the maintenance requirements include visual inspections (*e.g.,* inspection of sediment forebays) and physical upkeep (*e.g.,* removing and disposing of sediment, and mowing water quality swales). Whatever the maintenance requirements, the Stormwater Management Standards mandate that all stormwater management facilities have a long-term O&M Plan.

The long-term O&M Plan must provide that best practical measures are implemented to conduct maintenance activities in a manner that avoids, minimizes and mitigates adverse impacts to Wetland Resource Areas. SCMs should be designed to minimize maintenance needs wherever possible. Applicants should anticipate future maintenance problems and develop plans to alleviate them as much as possible. Preventative design measures, such as using forebays to trap incoming first-flush sediment, can reduce the future maintenance costs and requirements.

At minimum, include the following in the Long-Term Operation and Maintenance Plan:

- Name of the Stormwater Management System(s) owners;
- The party or parties responsible for operation and maintenance, including how future property owners will be notified of the presence of the Stormwater Management System and the requirement for proper operation and maintenance;
- A plan that is drawn to scale and shows the location of all stormwater SCMs in each treatment train along with all piping, and discharge point(s);
- An accompanying table listing all stormwater SCMs in each treatment train, including a unique identification number (*e.g.,* Basin #1), location description (*e.g.,* southwest corner of site near Smith Road), geographic coordinates, and design purpose (*e.g.,* peak flow attenuation, water quality).
- The routine maintenance tasks to be undertaken after construction is complete for <u>each</u> stormwater SCM (*e.g.,* mowing, sediment clean-out), and a schedule for implementing those tasks;

- Anticipated non-routine maintenance tasks to be undertaken after construction is complete for each stormwater SCM (*e.g.,* repair eroded embankment, replace dead vegetation, replace missing trash rack);A description and delineation of public safety features;
- Training, if any, needed to maintain the Stormwater Management System such as operation of any gate valves to provide for shut down and containment in the event of a fuel spill, including frequency of that training;
- An estimated operations and maintenance budget;
- Operation and maintenance log form;
- Location where the log will be stored; and
- Statement in the O/M plan that it will be made available to the Issuing Authority upon request.

The Operation and Maintenance Plan shall identify best management practices for implementing maintenance activities in a manner that minimizes impacts to Wetland Resource Areas.[29]

Responsibility for Operation and Maintenance Plan

For projects subject to jurisdiction under the Wetlands Protection Act, the Conservation Commission and MassDEP will take the actions set forth below to ensure compliance with Standard 9. Unless and until another party accepts responsibility, the Conservation Commission and MassDEP shall presume that the owner of the SCM is the landowner of the property on which the SCM is located, unless there is a legally binding agreement with another entity that accepts responsibility for the operation and maintenance. If an Applicant envisions that the municipality may accept responsibility for the operation and maintenance of a stormwater SCM, the Applicant shall notify the Conservation Commission and make available to the municipal official responsible for stormwater management the design and operation and maintenance plan for the SCM in order that the municipal official may have an opportunity to review and provide comments to the Conservation Commission within a reasonable period of time prior to the issuance of the Final Order of Conditions. It is recommended that the Conservation Commission solicit comments from the responsible municipal official.

Order of Conditions and Certificate of Compliance

To ensure compliance with Standard 9, the Order of Conditions contains general conditions that require the responsible party to operate and maintain stormwater SCMs in accordance with design plans and the approved O&M plan, maintain an operation and maintenance log and allow inspection of the premises to ensure compliance with the O&M requirements for each SCM.[30] The Conservation Commission may consider adding Special Conditions to ensure that the O&M plan is properly implemented by the responsible party. These same continuing conditions should be included in the Certificate of Compliance.

The Order of Conditions should also include a condition requiring the responsible party to submit an O&M Compliance statement when requesting a Certificate of Compliance. The O&M Compliance Statement should identify the party responsible for implementation of the O&M Plan and state that:

a. the site has been inspected for erosion and appropriate steps have been taken to permanently stabilize any eroded areas;

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[29] Some Applicants may have developed an operation and maintenance plan for stormwater SCMs to meet the requirements of the National Pollutant Discharge System Elimination System (NPDES) Multi-Sector General Permit or the NPDES General Permit for Municipal Separate Storm Sewer Systems (MS4 Permit). To avoid duplication of effort, Applicants may be able to prepare one plan for the operation and maintenance of stormwater SCMs that fulfills the requirements of Standard 9 and the applicable NPDES general stormwater permit. The Operation and Maintenance Plan must be included in the Stormwater Report (see **Section 6.1**)

[30] Order of Conditions: https://www.mass.gov/how-to/wpa-form-5-order-of-conditions.

b. all aspects of the stormwater SCMs have been inspected for damage, wear and malfunction, and appropriate steps have been taken to repair or replace the system or portions of the system so that the stormwater at the site may be managed in accordance with the Stormwater Management Standards;

c. future responsible parties must be notified of their continuing legal responsibility to operate and maintain the structure; and

d. the Operation and Maintenance Plan for the stormwater SCMs is being implemented.

In the case of stormwater SCMs that are serving more than one lot or more than unit, the Applicant should include with the WPA Notice of Intent (NOI) a mechanism for implementing and enforcing the Operation and Maintenance Plan. The Applicant should identify the lots or units that will be serviced by the proposed stormwater SCMs. The Applicant should also provide a copy of the legal instrument (*e.g.,* deed, homeowner's association, utility trust or other legal entity) that establishes the terms of and legal responsibility for the operation and maintenance of stormwater SCMs. In the event that the stormwater SCMs will be operated and maintained by an entity, municipality, state agency or person other than the sole owner of the lot upon which the stormwater management facilities are placed, the Applicant should provide a plan and easement deed that provides a right of access for the legal entity to be able to perform said operation and maintenance functions. It is recommended that the Order of Conditions include a condition requiring that the responsible party provide a copy of the Order of Conditions and the legal instrument to each unit or lot owner at or before the purchase of each unit or lot to be serviced by the stormwater SCMs. When requesting the issuance of a Certificate of Compliance, the Applicant should identify to the Conservation Commission or MassDEP in writing the entity with legal responsibility for the operation and maintenance of the stormwater SCMs and provide a copy of the recorded instrument creating the responsible entity.

<u>Certificate of Compliance Inspections</u>

Prior to issuing a Certificate of Compliance, the Conservation Commission or MassDEP should inspect the site to determine whether the Stormwater SCMs are operating as designed so that the stormwater at the site may be managed in accordance with the Stormwater Management Standards. In conducting the inspection, the Conservation Commission or MassDEP should look for indications that the stormwater SCMs are not functioning as designed. Evidence of problems with stormwater SCMs may include sediment plumes at outfalls, excessive sand and debris in catch basins, oil sheens, stressed vegetation, accumulated litter, and/or failure of the SCM to drain after 72 hours. No Certificate of Compliance should be issued unless and until the stormwater SCMs are functioning in accordance with the Final Order of Conditions and the Stormwater Management Standards.

2.3.10 Standard 10: Illicit Discharges to Drainage System

Definition

All Illicit Discharges to Waters of the Commonwealth and/or the Stormwater Management System are prohibited.

Explanation

Standard 10 prohibits Illicit Discharges to Stormwater Management Systems and to Wetland Resource Areas. The Stormwater Management System is the system for conveying, treating, and infiltrating stormwater on-site, including SCMs and any pipes intended to transport stormwater to the groundwater, a Surface Water, or municipal separate storm sewer system. Illicit Discharges to the Stormwater Management System are discharges that are not entirely comprised of stormwater. Notwithstanding the foregoing, an Illicit Discharge does not include discharges from the following activities or facilities: firefighting, water line flushing, landscape irrigation, uncontaminated groundwater, potable water sources, foundation drains, air conditioning condensation, footing drains, individual resident car washing, flows from riparian habitats and wetlands, dechlorinated water from swimming pools, water used for street washing and water used to clean residential buildings without detergents.

Illicit Discharge Compliance Statement

Applicants of projects within Wetlands jurisdiction must demonstrate compliance with this requirement by submitting to the Issuing Authority an Illicit Discharge Compliance Statement verifying that no Illicit Discharges exist on the site and should also include in the pollution prevention plan measures to prevent Illicit Discharges to the Stormwater Management System, including wastewater discharges and discharges of stormwater contaminated by contact with process wastes, raw materials, toxic pollutants, hazardous substances, oil, or grease. The Illicit Discharge Compliance Statement may be filed with the WPA NOI or WQC Application. If the Illicit Discharge Compliance Statement has not been filed, the Final Order of Conditions shall require the submission of an Illicit Discharge Compliance Statement prior to the discharge of stormwater runoff to the post-construction stormwater best management practices. The Issuing Authority should not issue a Certificate of Compliance until it has determined that the Illicit Discharge Compliance Statement has been submitted, has reviewed the Illicit Discharge Compliance Statement, and has verified that there are no Illicit Discharges at the site.

The Illicit Discharge Compliance Statement should be accompanied by a site map that is drawn to scale and that identifies the location of any systems for conveying stormwater on the site and shows that these systems do not allow the entry of any Illicit Discharges into the Stormwater Management System. The site map should identify the location of any systems for conveying wastewater and/or groundwater on the site and show that there are no connections between the stormwater and wastewater management systems and the location of any measures taken to prevent the entry of Illicit Discharges into the Stormwater Management System. For Redevelopment projects, the Illicit Discharge Compliance Statement shall also document all actions taken to identify and remove Illicit Discharges, including, without limitation, visual screening, dye or smoke testing, and the removal of any sources of Illicit Discharges to the Stormwater Management System.

Many municipal and state agencies that own and operate roadways are also subject to coverage under the NPDES General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (the MS4 Permit). State agencies and municipalities covered by the MS4 Permit are required to have a stormwater management program that includes Illicit Discharge detection and elimination. For roadways covered by the MS4 Permit, the Applicant may demonstrate compliance with Standard 10 by documenting the actions taken to identify and eliminate Illicit Discharges under the MS4 Permit. To prevent duplication of effort, the Applicant may submit copies of reports prepared to satisfy the Illicit Discharge detection and elimination program requirements of the MS4 Permits as its Illicit Discharge Compliance Statement.

Illicit Discharge Resources

An Illicit Discharge Compliance Statement is required to be submitted with the WPA NOI or WQC Application. The following references may be used to identify whether there are any existing Illicit Discharges to the stormwater drainage system on site. If there are any Illicit Discharges on site, the following resources all include information on source tracking and elimination.

- Center for Watershed Protection and R. Pitt (2004). Illicit Discharge Detection and Elimination Guidance Manual, https://www3.epa.gov/npdes/pubs/idde_manualwithappendices.pdf.
- New England Interstate Water Pollution Control Commission (2003). Illicit Discharge Detection and Elimination Manual, http://www.neiwpcc.org/neiwpcc_docs/iddmanual.pdf.
- US Environmental Protection Agency (2012). Draft New England Bacterial Source Tracking Protocol, https://www3.epa.gov/region1/npdes/stormwater/ma/2014AppendixI.pdf.
- Urban Water Resources Research Council (2014). Pathogens in Urban Stormwater Systems, https://www.asce-pgh.org/Resources/EWRI/Pathogens%20Paper%20August%202014.pdf.

2.3.11 Standard 11: Total Maximum Daily Loads

Definition

If the project will discharge stormwater to a wetland Resource Area for which a TMDL has been approved by EPA, or an Alternative TMDL has been accepted by EPA, for phosphorus, nitrogen, pathogens, and/or metals, Source Control Measures shall be identified in the long-term pollution prevention plan required by 310 CMR 10.05(6)(k)4. to eliminate or reduce such pollution and shall thereafter be implemented. The Stormwater Management System, including Environmentally Sensitive Site Design and Low Impact Development, shall be presumed to meet this standard when:

a. Stormwater Control Measures listed in the Massachusetts Stormwater Handbook [2022 Edition] that specifically address any applicable TMDL or Alternative TMDL are implemented;

b. A long-term pollution prevention plan is implemented;

c. For new development, the Stormwater Management System is designed to comply with 310 CMR 10.05(6)(k)3. and 4.; and

d. For Redevelopment, the Stormwater Management System is designed to comply with 310 CMR 10.05(6)(k)7. for recharge to the Maximum Extent Practicable, and the SMS provides water quality treatment for 80% TSS and 50% TP removal and adequate pretreatment.

Explanation

It is part of MassDEP's core mission to protect public health and enhance the quality and value of the water resources of the Commonwealth. MassDEP is also directed (M.G.L. c. 21, § 27(3)) to take all action necessary or appropriate to secure to the Commonwealth the benefits of the Clean Water Act, 33 U.S.C. § 1251 *et seq*., the objective of which is the restoration and maintenance of the chemical, physical, and biological integrity of the Nation's waters. The goal of this standard is to improve success in meeting TMDL goals which will ultimately lead to removal of impaired waters from the Massachusetts Integrated List of Waters – *i.e.,* Section 303(d) list.

Projects that discharge stormwater to waterbodies or waterways for which a Total Maximum Daily Load (TMDL) has been developed by MassDEP and approved by the Environmental Protection Agency (EPA), or for which an Alternative TMDL has been developed, must be designed to implement control measures for the specified pollutants causing the impairment.

Implementation Steps

Use the following steps to implement Standard 11.

- **Step 1**: Identify whether the proposed Project will discharge stormwater to a wetland resource area for which a TMDL has been approved by EPA or for which an Alternative TMDL has been developed by MassDEP.[31] Information on TMDLs may also be found in Appendix F of the 2016 Small MS4 Permit.[32] In addition, refer to MassDEP's website for a TMDL identification tool at https://www.mass.gov/info-details/total-maximum-daily-load-tmdl-viewer. Proceed to Step 2 if the answer to this question is "Yes". Otherwise, proceed to Step 5.
- **Step 2**: Identify which applicable pollutant(s) apply to the TMDL. Applicable pollutants include: Phosphorus, Nitrogen, Pathogens, and Metals. The Northeast Regional Mercury TMDL is not applicable to Standard 11.

[31] Massachusetts TMDL Information: http://mass.gov/dep/water/resources/tmdls.htm.

[32] Appendix F of the 2016 Small MS4 Permit: https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/appendix-f-2016-ma-sms4-gp.pdf.

- **Step 3:** Determine which SCMs are appropriate to treat applicable pollutants (see **Table 2-6**).
- **Step 4:** Design and size selected SCMs in accordance with Standard 3 and 4 requirements (see above Standard 11 language for pollutant removal and recharge requirements).
- **Step 5:** Prepare a long-term pollution prevention plan in accordance with **Section 4.3.2**.
- **Step 6:** Prepare a written summary in the required Stormwater Report demonstrating how the proposed Project intends to meet relevant and applicable TMDLs. If the Project is not subject to a TMDL, provide a statement indicating that Standard 11 is not applicable. Information on the required Stormwater Report is set forth in **Section 6.1**.

Ability of SCMs to remove TMDL Pollutants

Table 2-6 provides a list of SCMs that are appropriate for treating certain target TMDL pollutants. Project Sites that are subject to Standard 11 will be presumed to meet the Standard if SCMs are selected that are, at minimum, generally effective at treating and reducing target TMDL pollutants – *i.e.,* select SCMs with a "Y" from **Table 2-6**). Treatment for the target TMDL pollutant must be provided at all discharge points in accordance with Standard 4. Design, install, and maintain all SCMs in accordance with the **Appendix A** specifications.

Table 2-6. Suitability of SCMs to treat TMDL pollutants[1]

SCM	Pollutant of Concern[2,3,4]				
	TSS	TN	TP	FIB	Metals
Non-Structural SCMs					
Street Cleaning	N	N	N	N	N
ESSD Credits					
Credit 1: General ESSD	Y	Y	Y	Y	Y
Credit 2: Solar ESSD	Y	Y	Y	Y	Y
Credit 3: Roof Runoff to QPA	Y	Y	Y	Y	Y
Credit 4: Road Runoff to QPA	Y	Y	Y	Y	Y
Credit 5: Tree Canopy	Y	Y	Y	Y	Y
Credit 6: Reduce Impervious Area	Y	Y	Y	Y	Y
Credit 7: Buffer Zone Improvement	Y	Y	Y	Y	Y
Structural Treatment SCMs					
Bioretention Area (Exfiltrating)[6]	Y	Y[5]	Y	Y	Y
Bioretention Area (Filtering) [6]	Y	N	N	Y	Y
Constructed Stormwater Wetland	Y	Y	Y	Y	Y
Extended Dry Detention Basin	N	N	N	Y	Y
Gravel Wetland	Y	Y	Y	Y	Y
Proprietary Media Filter[7]	V	V	V	V	V
Sand/Organic Filter	Y	N	N	Y	Y
Tree Box filter (Exfiltrating) [6]	Y	Y	Y	Y	Y
Tree Box filter (Filtering) [6]	Y	N	N	Y	Y
Wet Basin	Y	N	N	N	Y
Roof Dripline Filter (Filtering)[6]	Y	N	N	Y	Y
Roof Dripline Filter (Exfiltrating)[6]	Y	Y	Y	Y	Y
Structural Conveyance SCMs					
Drainage Channel	N	N	N	N	N
Grass Channel	Y	N	N	N	N
Water Quality Swale	Y	N	N	N	N

SCM	Pollutant of Concern[2,3,4]				
	TSS	TN	TP	FIB	Metals
Structural Infiltration SCMs					
Dry well	Y	Y	Y	Y	Y
Infiltration Basin	Y	Y	Y	Y	Y
Infiltration Trench	Y	Y	Y	Y	Y
Leaching Catch Basin	Y	Y	Y	Y	Y
Porous Pavement	Y	Y	Y	Y	Y
Subsurface Infiltrator	Y	Y	Y	Y	Y
Other Structural SCMs					
Dry Detention Basin	N	N	N	N	N
Green Roof	N	N	N	N	N
Rain Barrels & Cisterns	N	N	N	N	N

Key:

- Y = Likely to provide significant reduction of target pollutant.
- V = Varies (see Note)
- N = Unlikely to provide significant reduction of target pollutant.

Table Notes:

1. While some pretreatment SCMs are capable of removing certain TMDL pollutants, they cannot be used as a standalone practice. Pretreatment SCMs are encouraged to be implemented as part of a larger treatment train.
2. Fecal Indicator Bacteria (FIB) category includes: fecal coliform, *E. coli*, and enterococcus.
3. Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.
4. Installation of curb guards help keep trash out of stormwater systems which in turn reduces FIB.
5. Exfiltrating bioretention must have anoxic zone to be suitable for TN removal (see **Appendix A**).
6. Bioretention areas, tree box filters, and roof dripline filters may be designed to act as a filtering practice or an infiltration practice. Filtering bioretention areas, tree box filters, and roof dripline filters do not infiltrate and cannot be used receive recharge credit towards Standard 3 – they have an underdrain that captures and conveys runoff downstream. Filtering bioretention areas, tree box filters, and roof dripline filters may be lined. Exfiltrating bioretention areas , tree box filters, and roof dripline filters are designed to provide infiltration.
7. Proprietary Media Filter: Pollutant removal ability must be determined on a case-by-case basis in accordance with procedures described in **Section 5.3**.

2.4 Ability of SCMs to Meet the Stormwater Standards

There are a variety of SCMs that can be used to meet the Stormwater Standards. The primary categories include: nonstructural, ESSD Credits, and structural. **Table 2-7** provides a summary of each SCM's ability to meet specific Stormwater Standards. The table also indicates whether the SCM is a MassDEP recognized ESSD / LID practice. This Table may be used as a screening tool to select potential SCMs for site designs; however, the ability of any SCM to meet specific Stormwater Standards is contingent on careful design performed in accordance with the **Appendix A** SCM specifications. Refer to **Section 4** for more information on site planning and design, including a more detailed explanation of each SCM type.

ESSD and LID Implementation Requirement

To meet Standard 3 and Standard 4, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis submitted with the Notice of Intent. Other SCMs shall only be used to meet those portions of the Required Recharge Volume (Standard 3) and TSS / TP removal (Standard 4) that cannot be fully met by ESSD and LID techniques. See **Section 6.1.4** for more information on the written alternatives analysis.

The following resources are available relative to ESSD and LID techniques:

- See **Section 4.2.3** for a list of MassDEP recognized ESSD / LID techniques. Each MassDEP ESSD / LID recognized technique has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**).
- Most MassDEP recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).

Table 2-7. Ability of Structural Control Measures to meet specific Standards

SCM	Pretreat. Required?[1]	ESSD / LID ?[2]	Ability to Meet Specific Standards[3]						
			Standard 2: Does SCM Attenuate Peak Flows?[4]	Standard 3: Does SCM Provide Recharge?[5]	Standard 4: Does SCM Remove TSS or TP?[6]	Standard 5: Is SCM Suitable for LUHHPLs[7]	Standard 6: Is SCM Suitable for CAs?[8]	Standard 7: Is SCM suitable for Redev?[9]	Standard 11: Does SCM Remove TMDL Pollutants?[10]
Non-Structural									
Street Cleaning	No	No	No	No	Both	Yes	Yes	Yes	No
ESSD Credits									
Credit 1: General ESSD	No	Yes	No	Yes	Both	No	Yes	Yes	Yes
Credit 2: Solar ESSD	No	Yes	No	Yes	Both	No	No	Yes	Yes
Credit 3: Roof Runoff to QPA	No	Yes	Yes	Yes	Both	Yes	Yes	Yes	Yes
Credit 4: Road Runoff to QPA	No	Yes	Yes	Yes	Both	No	Yes	Yes	Yes
Credit 5: Tree Canopy	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Credit 6: Reduce Impervious Area	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Credit 7: Buffer Zone Improvement	No	Yes	Yes	Yes	Both	No	Yes	Yes	Yes
Structural Pretreatment									
Deep Sump Catch Basin	No	No	No	No	TSS Only	Yes	Yes	Yes	No
Oil/Grit Separator	No	No	No	No	TSS Only	Yes	Yes	Yes	No
Proprietary Separator	No	No	No	No	TSS Only	Yes	Yes	Yes	No
Sediment Forebay	No	No	No	No	TSS Only	Yes	Yes	Yes	No
Vegetated Filter Strip	No	No	No	No	TSS Only	Yes	Yes	Yes	No
Pea Gravel Diaphragm	No	No	No	No	-	Yes	Yes	Yes	No
Grass / Gravel Combination	No	No	No	No	-	Yes	Yes	Yes	No
Structural Treatment									
Bioretention Area (Exfiltrating) [11]	Yes	Yes	Yes	Yes	Both	Yes	Yes	Yes	Varies
Bioretention Area (Filtering)[11]	Yes	Yes	Yes	No	Both	Yes	Yes	Yes	Varies
Constructed Stormwater Wetland	Yes	Yes	Yes	No	Both	Yes	Varies	Varies	Varies
Extended Dry Detention Basin	Yes	No	Yes	No	Both	Yes	No	Varies	Varies

SCM	Pretreat. Required?[1]	ESSD / LID ?[2]	Ability to Meet Specific Standards[3]						
			Standard 2: Does SCM Attenuate Peak Flows?[4]	Standard 3: Does SCM Provide Recharge?[5]	Standard 4: Does SCM Remove TSS or TP?[6]	Standard 5: Is SCM Suitable for LUHHPLs[7]	Standard 6: Is SCM Suitable for CAs?[8]	Standard 7: Is SCM suitable for Redev?[9]	Standard 11: Does SCM Remove TMDL Pollutants?[10]
Gravel Wetland	Yes	Yes	Yes	No	Both	Yes	Varies	Varies	Varies
Proprietary Media Filter	Yes	No	No	No	Both	Yes	Yes	Yes	Varies
Sand/Organic Filter	Yes	No	No	No	Both	Yes	Yes	Yes	Varies
Tree Box Filter (Exfiltrating)[11]	No	Yes	No	Yes	Both	Yes	Yes	Yes	Varies
Tree Box Filter (Filtering)[11]	No	Yes	No	No	Both	Yes	Yes	Yes	Varies
Wet Basin	Yes	No	Yes	No	Both	Yes	Varies	Varies	Varies
Roof Dripline Filter (Filtering)[11]	Varies[12]	Yes	No	No	Both	Yes	Yes	Yes	Varies
Roof Dripline Filter (Exfiltrating)[11]	Varies[12]	Yes	No	Yes	Both	Yes	Varies	Yes	Varies
Structural Conveyance									
Drainage Channel	No	No	No	No	No	No	No	Yes	No
Grass Channel (Biofilter Swale)	Yes	Yes	No	No	Both	No	Varies	Yes	No
Water Quality Swale (Dry/Wet)	Yes	Yes	No	No	TSS Only	Yes	Varies	Yes	No
Structural Infiltration									
Dry well	Varies[12]	Yes	No	Yes	Both	No	No	Yes	Varies
Infiltration Basin	Yes	Yes	Yes	Yes	Both	Yes	Varies	Yes	Varies
Infiltration Trench	Yes	Yes	No	Yes	Both	Yes	Varies	Yes	Varies
Leaching Catch Basin	Yes	No	Yes	Yes	Both	Yes	Varies	Yes	Varies
Porous pavement	Yes	Yes	Yes	Yes	Both	Yes	Varies	Yes	Varies
Subsurface Infiltrator	Yes	No	Yes	Yes	Both	No	Varies	Yes	Varies
Structural Other									
Dry Detention Basin	No	No	Yes	No	No	No	No	Varies	No
Green Roof	No	Yes	Yes	Yes	Yes	No	Varies	Yes	No
Rain Barrels & Cisterns	No	Yes	No	Yes	Yes	No	No	Yes	No

SCM	Pretreat. Required?[1]	ESSD / LID ?[2]	Ability to Meet Specific Standards[3]						
			Standard 2: Does SCM Attenuate Peak Flows?[4]	Standard 3: Does SCM Provide Recharge?[5]	Standard 4: Does SCM Remove TSS or TP?[6]	Standard 5: Is SCM Suitable for LUHHPLs[7]	Standard 6: Is SCM Suitable for CAs?[8]	Standard 7: Is SCM suitable for Redev?[9]	Standard 11: Does SCM Remove TMDL Pollutants?[10]

Ability to Meet Specific Standards Key:

- Yes = Generally has the ability to partially or fully meet specific Standards. See **Notes** for more information.
- Varies = The ability to meet specific standards varies for Standard 6 (based on the type of Critical Area), Standard 7 (site specific conditions), and Standard 11 (by TMDL pollutant type). See **Notes** for more information.
- No = Does not have the ability to partially or fully meet the specific Standard.

Table Notes:

1. Pretreatment: See **Appendix A** for acceptable pretreatment measures for each applicable SCM.
2. ESSD / LID Techniques: See **Section 4.2.3** for more information on MassDEP recognized ESSD and LID techniques. See **Appendix A** for ESSD Credits.
3. Ability to meet specific standards: See **Appendix A** for more information on how individual SCMs can meet specific standards, including required design criteria. In some instances, site-specific limitations may disallow a specific SCM from meeting particular standards. For example, if required setback distances cannot bet met (see **Section 2.5** for setback requirements).
4. Standard 2: See **Appendix A** for the ability of SCMs to attenuate specific 24-hour design storms (*i.e.,* 2-yr, 10-yr, 100-year). Some SCMs such as green roofs generally only have the ability to provide meaningful peak rate attenuation for smaller, more frequent storms.
5. Standard 3: See **Table 2-1** for a summary of recharge requirements.
6. Standard 4: See **Table 2-2** for a summary of pollutant removal credits for each SCM.
7. Standard 5: See **Table 2-3** for more information on the suitability of specific SCMs for Land Uses with Higher Potential Pollutant Loads (LUHHPLs).
8. Standard 6: See **Table 2-4a** through **Table 2-4d** for more information on the suitability of specific SCMs for Critical Areas. In some instances, the suitability **Varies** based on Critical Area type. For example, green roofs are only suitable as an SCM for Cold Water Fisheries as indicated by **Table 2-4c**.
9. Standard 7: All SCMs are capable of being used to meet Standard 7; however, the suitability of some SCMs at will **Vary** at Redevelopment sites based on site constraints such as space limitations (*e.g.,* dry detention basins). SCMs or ESSD techniques that can be used on a micro-scale and that have smaller "footprints" are generally more feasible.
10. Standard 11: The ability of SCMs to treat specific TMDL pollutants **Varies**. See **Table 2-6** for the suitability of individual SCMs to treat specific TMDL pollutants.
11. Bioretention areas, tree box filters, and roof dripline filters may be designed to act as a filtering practice or an infiltration practice. Filtering bioretention areas, tree box filters, and roof dripline filters do not infiltrate and cannot be used receive recharge credit towards Standard 3 – they have an underdrain that captures and conveys runoff downstream. Filtering bioretention areas, tree box filters, and roof dripline filters may be lined. Exfiltrating bioretention areas, tree box filters, and roof dripline filters are designed to provide infiltration.
12. Pretreatment is not required for Dry Wells and Roof Dripline Filters for runoff from non-metal roofs. Runoff from metal roofs may be discharged to a Dry Well or Roof Dripline Filter only if the roof is located outside the Zone II, IWPA of a public water supply, or outside an industrial site.

2.5 Horizontal Setbacks and Vertical Separation Distance Requirements

Stormwater Control Measures (SCMs) and any component of a Stormwater Management System must be setback from wetlands and building foundations and other features in accordance with 310 CMR 10.05(6)(q). Structural SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Horizontal and vertical separation distances listed by **Table 2-8** are presumed to meet the minimum setback requirements. Where there is a conflict between horizontal setbacks and vertical separation distances listed in **Table 2-8** versus other sections of the Stormwater Handbook, the more restrictive setback shall apply. The following miscellaneous requirements also apply:

- **Installation inside or under buildings**. Other than green roofs, rooftop detention, roof gutters and down spouts, SCMs must not be installed inside or under buildings. Introducing stormwater under a building, such as through subsurface chambers, are difficult to maintain and could cause foundation failure.
- **Parking garages**. Drainage from open air parking garages that may include multiple decks is considered wastewater and must meet the Massachusetts State Plumbing Code regulations. As such, drainage from parking garages must not be directed to a Wetland Resource Area or storm drainage system. Significant runoff is not generated in parking garages other than the roof top deck. When a parking garage is subject to review pursuant to the Wetlands Protection Act or 401 regulations, both the Wetlands/401 regulations and State Plumbing Code provisions must be met. Underground floor drains are not allowed in parking garages pursuant to the Underground Injection Control provisions, 310 CMR 27.00.
- **Stormwater Outlets**. Stormwater outlets must not be installed within Land Under Water Bodies and Waterways (LUHWW), Bordering Vegetated Wetlands (BVW), Land Under Ocean, Coastal Beach, Rocky Intertidal Shore, and Coastal Dunes. Stormwater outlets include, but aren't limited to: outfalls, riprap aprons, energy dissipators, and scour pads.
- **Redevelopment**. Horizontal setback and vertical separation requirements apply to Redevelopment projects to the Maximum Extent Practicable (MEP). A written alternatives analysis is required for any Redevelopment projects that seek to meet any horizontal setback and vertical separation distance requirements to the MEP (see **Section 6.1.4**).

How are Setbacks and Separation Distances Measured?

As indicated by **Table 2-8**, there are two types of setback types: horizontal and vertical. Measure setbacks based on the below criteria.

- **Horizontal Setbacks**. Measure all distances along a horizontal plane from the appropriate boundary, edge of SCM, edge of building, structure, or other object. Do not measure distances by following the topography or slope of the land. Measurements must be the shortest distance between the two objects. For example: for an infiltration basin with an earthen berm around the perimeter, the setback from the Resource Area is measured from the outside toe (i.e., bottom) of the infiltration berm wall. When an infiltration practice is entirely subsurface such as a trench, setbacks are to be measured from the side wall.
- **Vertical Separation Distance.** Vertical separation distance is the vertical distance from the lowest engineered portion of the SCM to the top of a feature of concern. The shortest vertical distance is used in measuring the separation distance. For example, the bottom of any infiltration practice, including any media, must be set at least 2-feet above the elevation of seasonally high groundwater.

Table 2-8. Summary of applicable horizontal setbacks and vertical separation distances by SCM[1]

Description	Value	General				Treatment								Infiltration						Other			
		Any Stormwater Discharge	Any Component of Stormwater Management System	Any Recharge Measure	Any ESSD Credit	Bioretention Area	Cons. Wetland	Extend. Dry Det. Basin	Gravel Wetland	Proprietary Media Filter	Sand/Organic Filter	Tree Box filter	Wet Basin	Dry well	Infiltration Basin	Infiltration Trench	Leaching Catch Basin	Porous pavement	Subsurface Infiltrator	All Conveyance SCMs	Dry Detention Basin	Green Roof	Rain Barrels & Cisterns
Horizontal Setback																							
Wetland Resource Area[2]	Outside WRA	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Surface Water of the Commonwealth[4]	≥ 50-ft	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	E[3]	Y	Y	Y	Y	Y
Outstanding Resource Water	Outside ORW	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Special Resource Water	Outside SRW	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
All Critical Areas	Outside CA	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean Annual High Water Line of Cold Water Fishery	≥ 100-ft	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distance from Public Well[5]	Outside Zone I	Y	E[5]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distance from Public Water Supply and Tributaries	Outside Zone A	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distance from Interim Wellhead Protection Area	Outside IWPA	Y	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Distance from Private Well[6]	≥ 100-ft	-	-	Y	-	-	-	-	-	-	-	-	-	Y	Y	Y	Y	Y	Y	-	Y	-	-
Distance from Certified Vernal Pool	≥ 100-ft	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Hydrologic Soil Group D	Outside HSG D	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-
Distance from Soil Absorption System and any component of Septic System	≥ 50-ft	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Building Foundation	≥ 10-ft	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distance from Property Boundary	≥ 10-ft	-	-	Y	-	Y	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y

Description	Value	General				Treatment								Infiltration						Other			
		Any Stormwater Discharge	Any Component of Stormwater Management System	Any Recharge Measure	Any ESSD Credit	Bioretention Area	Cons. Wetland	Extend. Dry Det. Basin	Gravel Wetland	Proprietary Media Filter	Sand/Organic Filter	Tree Box filter	Wet Basin	Dry well	Infiltration Basin	Infiltration Trench	Leaching Catch Basin	Porous pavement	Subsurface Infiltrator	All Conveyance SCMs	Dry Detention Basin	Green Roof	Rain Barrels & Cisterns
Maintenance Access Around Perimeter of SCM[7]	≥ 12-ft	-	-	-	-	-	Y	Y	Y	Y	Y	-	Y	-	Y	Y	-	-	Y	-	Y	-	-
Downslope Distance from Building	20-ft	-	-	-	-	-	-	-	-	-	-	-	-		Y	Y	-	Y	Y	-	-	-	-
Upslope Distance from Building	100-ft	-	-	-	-	-	-	-	-	-	-	-	-		Y	-	-	-		-	-	-	-
Downslope Distance from any Surface Water of the Commonwealth	≥ 150-ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-
Upslope Distance from any Surface Water of the Commonwealth	≥ 100-ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	Y	-	-	-	-	-
Distance from any Slope > 5%	≥ 100-ft	-	-	-	-	Y[7]	-	-	-	-	-	-	-	-	-	Y[7]	-	-	-	-	-	-	-
Distance from any Slope > 15%	≥ 50-ft	-	-	-	-	-	-	-	-	-	-	-	-	-	Y	-	-	-	-	-	-	-	-
Distance from any Slope > 20%	≥ 100-ft	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Y[7]	-	-	-	-	-	-	-
Vertical Separation Distance																							
General groundwater	See Note[8]	-	-	-	-	-	-	Y	Y	Y	Y	Y	-	Y	Y	Y	Y	Y	Y	E[3]	Y	Y	Y
Distance from bottom of SCM to SHGW[9]	2-ft	-	Y	Y	Y	Y	-	Y	E[3]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Distance from bottom of SCM to Berock[9]	2-ft	-	-	-	-	-	-	-	-	-	-	-	-	Y	Y	Y	Y	Y	Y	-	-	-	-

Table Notes:

1. Table Key. "Y" indicates that the requirement applies to the SCM, "E" indicates that there is an exception (see below notes for explanation), "- -" indicates not applicable.
2. Wetland Resource Areas. All SCMs must be located outside of Wetland Resource Areas except for Bordering Land Subject to the Flooding (BLSF), Isolated Land Subject to Flooding (ILSF), Land Subject to Coastal Storm Flowage (LSCSF), and Riverfront Area (RA).

3. **Exceptions**. Install porous pavement at least 100-ft from a Surface Water of the Commonwealth. Wet Water Quality swales do not apply to the "general groundwater" requirement. Gravel wetlands can be built above or below SHGW, but when drainage is from a LUHPPL, design the bottom of the gravel wetland to be at least 2-feet above SHGW.
4. Waters of the Commonwealth. Waters of the Commonwealth include Bordering Vegetated Wetlands and salt marsh.
5. Zone I boundaries. Any component of a Stormwater Management System, including SCMs, must be setback outside of the Zone I boundary unless essential to the operation of a Public Water Supply.
6. Maintenance Access. Formalized access around SCMs is necessary to enable short- and long- term maintenance, and reduction of mosquito larvae. It also provides a buffer along highways to reduce likelihood that snow will be plowed in SCMs. Access for maintenance should be provided through public or private rights-of-way. The access should have a minimum width of 12 feet. As applicable, maintenance access should extend to the forebay, safety bench, outflow structure, and entire perimeter except as otherwise specified in the Stormwater Handbook (*e.g.,* in some cases, the breakdown lane may be used). The maintenance access need not cross the emergency spillway, unless the spillway has been designed and constructed for this purpose. No area subject to protection under M.G.L. c. 131 § 40. other than bordering land subject to flooding, isolated land subject to flooding, land subject to coastal storm flowage, or riverfront area may be altered or filled to provide the access, pursuant to 310 CMR 10.05(6)(k). Minimum maintenance access <u>should be increased</u> under the following conditions:
   - where additional width is needed to maintain the SCMs' slope stability;
   - when side slopes exceed 15%;
   - when the disturbance from use of equipment will be greater than 12 feet;
   - when staging areas for routine and non-routine maintenance will cause a disturbance greater than 12 feet;
   - when material storage (including temporary storage) will cause a disturbance greater than 12 feet (*e.g.,* small footprint bobcats are recommended for 12-foot wide access); or
   - when needed for to allow access for vehicles used by mosquito control districts to treat stormwater basins to prevent mosquito growth.
7. Distance from Slope. Distance from any slope greater than 5% of at least 100 feet applies to <u>surface</u> infiltration trenches. Distance from any slope greater than 20% of at least 100 feet applies to <u>subsurface</u> infiltration trenches. Distance from any slope greater than 5% of at least 100 feet applies to exfiltrating bioretention areas.
8. Installation in Groundwater. When Stormwater Management Systems are installed in groundwater, they can draw down the groundwater level. This is contrary to Standard 3 which requires recharge. Structural Stormwater Management Systems (*e.g.,* pipes, catch basins) and structural SCMs are therefore not allowed to be installed in groundwater. For example, the invert elevation of a catch basin must be installed above the elevation of seasonally high groundwater. This requirement is not applicable to the following: Constructed Stormwater Wetlands, Wet Basins, Wet Water Quality Swales.
9. Distance to SHGW and Bedrock. 2-ft vertical separation distance applies to the lowest engineering portion of the SCM, including media.

3 Legal Framework for Stormwater Management

3.1 Background

In 1996, MassDEP issued the Stormwater Policy that established the Stormwater Management Standards. Since that time, MassDEP has implemented the Stormwater Management Standards utilizing its authority under the Massachusetts Clean Waters Act, M.G.L. c. 21, §§ 26-53, and the Wetlands Protection Act, M.G.L. c. 131, § 40. In accordance with the Wetlands Protection regulations, at 310 CMR 10.05(6)(b), Conservation Commissions and MassDEP must issue Orders of Conditions that require that stormwater be managed in accordance with the Stormwater Management Standards provided in 310 CMR 10.05(6)(k) through (q). Pursuant to its authority under the Massachusetts Clean Waters Act, MassDEP also applies the Stormwater Management Standards when reviewing projects that require a 401 Water Quality Certification for dredge and fill, in accordance with 314 CMR 9.06(6)(a). MassDEP has incorporated the Stormwater Management Standards into the Wetlands Protection regulations, at 310 CMR 10.05(6)(k) through (q), and the 401 Water Quality Certification regulations for dredge and fill, at 314 CMR 9.06(6)(a).

MassDEP continues to apply the Stormwater Management Standards pursuant to its authority under the Massachusetts Clean Waters Act. Acting jointly with the EPA, MassDEP has issued general permits regulating construction dewatering and certain municipal separate storm sewer systems (MS4). As of June 2020, EPA Region 1 ended joint permitting with MassDEP. Applicants may obtain coverage under a jointly issued MS4 General Permit, Construction General Permit (CGP) or Multi-Sector General Permit (MSGP), by MassDEP certified General Permit issued by EPA, or by seeking coverage under a separately issued General Permit from the Surface Water Discharge Program pursuant to 314 CMR 3.06. Through the State's 401 Water Quality Certification, the MS4 General Permit requires compliance with the Stormwater Management Standards.[33]

Pursuant to the Massachusetts Clean Waters Act and the regulations promulgated thereunder at 314 CMR 3.04 and 314 CMR 5.04, MassDEP has authority to make a case-by-case determination that certain stormwater discharges require a permit. For example, MassDEP may require a stormwater discharge to obtain a permit under the state Clean Waters Act if it determines that the discharge is not in compliance with the Stormwater Management Standards and is contaminated with process wastes, raw materials, toxic pollutants, hazardous substances, or oil and grease.

3.2 Stormwater Management and the Wetlands Protection Regulations

The Wetlands Protection Act establishes a public review and permitting process to protect wetland resources and further the interests identified in the Act. These interests are as follows:

- Protection of public and private water supply;
- Protection of groundwater supply;
- Flood control;
- Storm damage prevention;

[33] The 2016 Small MS4 General Permit became effective in 2018, and modifications to it became effective in January 2021. EPA has also issued other NPDES general stormwater permits: a general permit for construction sites that disturb one acre or more of land, the Construction General Permit (CGP), and a general permit for certain industrial activities, the Multi-Sector General Permit (MSGP). The 2017 CGP became effective on June 27, 2019 (and expires February 2022) and the MSGP was issued on June 4, 2015 (and expired in June 2020). For the latest information on all the NPDES stormwater permits, see https://www.epa.gov/npdes-permits/massachusetts-npdes-permits#fgp.

- Pollution prevention;
- Protection of fisheries;
- Protection of land containing shellfish; and,
- Protection of wildlife habitat.

If not properly managed and treated, stormwater discharges to areas subject to jurisdiction under the Act have the potential to impair some or all of these interests. To address this potential impairment, the Wetlands Protection regulations, at 310 CMR 10.05(6)(k), provide that except as expressly provided therein, all industrial, commercial, institutional, office, residential and transportation projects, including site preparation, construction, and Redevelopment in an Area Subject to Protection under the Act or the Buffer Zone, and all point source stormwater discharges from said projects within an Area Subject to protection Under the Act and the Buffer Zone, shall be managed according to the Stormwater Management Standards defined at 310 CMR 10.05(6)(k)1. through 11. Stormwater runoff from both point and non-point sources is regulated. The exceptions for projects or activities that do not have to comply with the Stormwater Management Standards are set forth in 310 CMR 10.05(6)(l) and projects or activities that only need to comply to the maximum extent practicable are set forth in 310 CMR 10.05(6)(m). Please note that erosion and sedimentation controls are still required for projects that involve construction or land disturbance, pursuant to 310 CMR 10.05(6)(b), even when specifically exempted from compliance with the Stormwater Management Standards.

Applicants are not allowed to alter Wetland Resource Areas to comply with the Stormwater Management Standards. Thus, the Wetland Protection regulations, at 310 CMR 10.05(6)(k), expressly provide that SCMs may not be constructed in a Wetland Resource Area other than isolated land subject to flooding, bordering land subject to flooding, riverfront area, or land subject to coastal storm flowage.

3.2.1 Wetland Resource Areas and Buffer Zones

The Wetlands Protection regulations, at 310 CMR 10.02(1)(a) through (f), define “Areas Subject to Protection under the Act” (Wetland Resource Areas) to include the following:

- Coastal wetland areas, *e.g.,* coastal banks, coastal beaches, coastal dunes, land under the ocean, designated port areas, barrier beaches, rocky intertidal shores, land under salt ponds, land containing shellfish, land subject to coastal storm flowage, and salt marsh; and
- Inland wetland areas, *e.g.,* bordering vegetated wetlands (wet meadows, marsh, swamp or bog bordering any creek, river, stream, pond or lake), bank, land under water, land subject to flooding, and the riverfront area.

The Wetlands Protection regulations, at 310 CMR 10.02(2)(b), further define the Buffer Zone to mean the area within 100 feet of certain Wetland Resource Areas. The Wetland Resource Areas that have a Buffer Zone are summarized in 310 CMR 10.02(1)(a) as follows:

any bank		*the ocean*
any freshwater wetland		*any estuary*
any coastal wetland		*any creek*
any beach	*BORDERING*	*any river*
any dune	*ON*	*any stream*
any flat		*any pond*
any marsh		*or any lake*
or any swamp		

3.2.2 Discharge Types

Point Source Discharges

A point source discharge is a discernible, confined, and discrete conveyance of pollutants as opposed to a diffuse non-point source of pollution, which generally involves overland flow. Because a direct point source discharge may result in wetland alterations by changing drainage characteristics, sedimentation patterns, flood storage areas, and water temperature, thereby affecting the physical, chemical or biological characteristics of the receiving waters, the Wetlands Protection regulations, at 310 CMR 10.05(6)(b), require that all Orders of Conditions regulate the quality and quantity of point source stormwater discharges.

The Wetland Protection regulations, at 310 CMR 10.03(4), provide that if the Department has issued a permit pursuant to M.G.L. c. 21, § 43, and/or the U.S. Environmental Protection Agency has issued a federal NPDES (National Pollutant Discharge Elimination System) permit for any new point-source discharge of pollutants, or will issue such a permit, prior to commencement of the discharge, the effluent limitations established in the permit shall be presumed to protect the eight interests identified in M.G.L. c. 131, § 40, with respect to the effects of the discharge on water quality. The permit and any subsequent modification(s) thereto shall be referenced in the Order and deemed incorporated therein. This presumption shall apply only to impacts of the discharge from the source, and not to impacts from construction of the source. This presumption may be overcome only by credible evidence from a competent source that said effluent limitations will not protect the interests identified in M.G.L. c. 131, § 40.

New development and Redevelopment of industrial sites that are required to obtain coverage under the MSGP are also required to comply with the Stormwater Management Standards through the State's 401 Water Quality Certification. Projects covered by the MS4 Permit must comply with General Permit standards.

Non-point Source Discharges

A non-point source discharge is diffuse stormwater runoff, which generally involves sheet or overland flow. Examples of non-point sources are contaminants washed off roads by precipitation, which then sheets off the road and discharges over land into a stream, as well as agricultural runoff. This is in contrast to roadway drainage directed to that same stream from a point source (*e.g.,* curb/gutter, catch basin inlet, closed drain, swale, riprap drain pad or outlet pipe). Proposed activities that only involve non-point source discharges are also subject to the Stormwater Management Standards. For example, subject activities must not increase the peak rate of stormwater discharge (Stormwater Standard 2).

Environmentally Sensitive Site Design (ESSD) may utilize only non-point source discharges, such as sheeting water off rooftops and roads to qualifying pervious areas (see ESSD Credits available in **Appendix A**). Non-point source discharges need to be accomplished in a responsible manner, utilizing pollution prevention to prevent or minimize stormwater runoff from co-mingling with contaminants, and routing runoff over land in such a manner to reduce the likelihood of rilling, which could cause siltation to receiving waters and wetlands.

Stormwater Discharges Outside Wetland Resource Areas

In some cases, a stormwater discharge to Wetland Resource Areas may originate outside a Wetland Resource Area and outside the Buffer Zone. Consistent with 310 CMR 10.05(6)(b), local Conservation Commissions and MassDEP must impose conditions on the quality and quantity of the discharge even though it comes from a source that is located outside wetlands jurisdiction if the Issuing Authority determines that the activity has in fact altered an Area Subject to Protection under M.G.L. c. 131, § 40. Stormwater must be managed so that when the stormwater is discharged within the Wetland Resource Area or Buffer Zone, it complies with the Stormwater Management Standards. The Order of Conditions must include this requirement, even if the project Applicant has to install additional SCMs in an area outside wetlands jurisdiction.[34]

For example, a developer proposes to locate an overflow discharge pipe within the Buffer Zone from an extended dry detention basin that is installed outside the Buffer Zone. Although the Issuing Authority cannot regulate the extended dry detention basin, the Order of Conditions must require that the Stormwater Management Standards be met at the point of discharge, since the overflow pipe is located within jurisdiction. These are referred to as “performance-based” conditions. To ensure that the discharge can meet this performance-based requirement, design the extended dry detention basin in accordance with the specifications and procedures set forth in the Stormwater Handbook (see **Appendix A** for specifications and **Section 6.2** for sizing methodologies), and the Issuing Authority should request information about the design of the extended dry detention basin during the permitting process.

3.2.3 Miscellaneous Wetlands Protection Regulation Topics

Regulatory Requirements After the Fact

As stated earlier, jurisdiction under the Wetlands Protection Act does not extend beyond Wetland Resource Areas and the Buffer Zone. The situation changes if an activity occurring outside jurisdiction results in the alteration of a Wetland Resource Area. In that event, the activity may be regulated after the fact. The Wetlands Protection regulations, at 310 CMR 10.02(2)(d) and 10.05(6)(b), provide that if the Issuing Authority determines that an activity outside the Areas Subject to Protection Under M.G.L. c. 131, § 40, and outside the Buffer Zone, has in fact altered an Area Subject to Protection Under M.G.L. c. 131, § 40, it may require the filing of a Notice of Intent, issue an Enforcement Order, or include in an Order of Conditions any conditions that are necessary to protect the interests of the Act. If the Issuing Authority exercises after-the-fact jurisdiction, it may be extremely costly to a developer, since s/he may have to redesign the project to accommodate SCMs.

[34] Order of Conditions General Condition No. 18 requires compliance with the Stormwater Management Standards.

For example, a Conservation Commission or MassDEP does not have jurisdiction over a stormwater discharge pipe located 105 feet from a bordering vegetated wetland or 205 feet from a perennial stream. However, given this location, it is likely that the first heavy rainstorm will erode the channel and alter the Wetland Resource Area. To avoid the additional costs that may arise from being subject to after-the-fact jurisdiction, a prudent developer should be proactive and implement stormwater management practices to prevent any unauthorized wetland alterations.

Issuing authorities also have authority to regulate activities outside wetlands jurisdiction when additional volumes of stormwater are routed through an existing outfall pipe that results in an alteration of a Wetland Resource Area. The Wetlands Protection regulations, at 310 CMR 10.02(2)(d), provide that an NOI is not required for any activity proposed or undertaken outside of the Areas Subject to Protection under M.G.L. c. 131, § 40 unless and until that activity actually alters the area.

Project Applicants and municipal officials should work together to ensure adequate pretreatment prior to discharge to the MS4. MS4s covered by the MS4 General Permit can ensure such pretreatment by establishing and implementing adequate post construction stormwater controls as required by that permit.

Conversion of Impervious Surfaces to Pervious Surfaces

The Wetlands Protection regulations, at 310 CMR 10.02(2)(b)2.f. and 10.58(6)(b), exempt from regulation under the Act the conversion of impervious to vegetated surfaces in the Buffer Zone and the Riverfront Area, provided erosion and sedimentation controls are implemented during construction and the work does not take place in a Wetland Resource Area other than the Buffer Zone or Riverfront Area. Through this exemption, the Wetlands Protection regulations make it easy for property owners to decrease Impervious Surfaces.

Erosion and Sedimentation Control

The Wetlands Protection regulations also recognize that stormwater discharges may adversely impact Wetland Resource Areas during construction. To prevent this impact, the Wetlands Protection regulations, at 310 CMR 10.05(6)(b), provide that the Order of Conditions shall impose conditions to control erosion and sedimentation within Resource Areas and the Buffer Zone. Erosion and sedimentation control is required, even if the project is a single-family house that is exempt from the requirement to comply with the Stormwater Management Standards. For projects subject to the Stormwater Management Standards, Standard 8, set forth in the Wetlands Protection regulations at 310 CMR 10.05(6)(k)8., the development and implementation of a construction-period erosion, sedimentation and pollution prevention plan is required.

Operation and Maintenance of Stormwater Management Systems

The Wetlands Protection regulations, at 310 CMR 10.02(3), provide that a bordering vegetated wetland, bank, land under water, land subject to flooding, or riverfront area created solely for stormwater management purposes may be maintained without the filing of a Notice of Intent, provided the work is limited to the maintenance of the system, the system was proposed in a Notice of Intent filed before January 2, 2008, and conforms to an Order of Conditions issued after April 1,1983, the area is not altered for other purposes, and the work utilizes best practical measures to avoid and minimize impacts to wetland resource areas outside the footprint of the stormwater management system. The Wetlands Protection regulations, at 310 CMR 10.02(3), have been revised to provide that all Stormwater Management Systems designed and constructed after November 18, 1996, the effective date of the Stormwater Management Standards, may be maintained without the filing of a Notice of Intent. This exemption from filing a Notice of Intent applies to subsurface structures or leaching catch basins within a Wetland Resource Area or Buffer Zone and water quality swales or bioretention areas constructed in an area outside Wetlands jurisdiction for which no Order of Conditions has been issued, provided the Stormwater Management System was designed and constructed in accordance with the Stormwater Management Standards. If the system was constructed in a Wetland Resource Area or associated Buffer

Zone, this exemption applies only if the system was constructed in accordance with all applicable provisions of the Wetlands Protection regulations.

To qualify for this provision, the work must be limited to maintenance and best practical measures must be used to avoid and minimize impacts to Wetland Resource Areas outside the footprint of the Stormwater Management System. Best practical measures are technologies, designs, measures or engineering practices that are in general use to protect similar interests. Work done in accordance with an Operation and Maintenance Plan qualifies for this exemption, provided the plan requires implementation of best practical measures to minimize wetland impacts during maintenance. In the absence of an Operation and Maintenance Plan, the party responsible for maintenance may file a Request for Determination of Applicability requesting the Issuing Authority to determine whether the proposed maintenance activities fall within the exemption.

Jurisdiction Over Stormwater Management Systems

The Wetlands Protection regulations, at 310 CMR 10.02(2)(c), provide that the installation of Stormwater Management Systems designed and constructed on or after November 18, 1996 in accordance with the Stormwater Management Standards do not create any additional Wetland Resource Area or Buffer Zone. The Wetland Protection regulations, at 310 CMR 10.02(4), further provide that review of future modifications to any such systems located within a Wetland Resource Area or Buffer Zone shall be limited to the stormwater functions of the system, compliance with the Stormwater Management Standards, and those performance standards that would apply in the absence of the Stormwater Management System.

For example, a Stormwater Management System that includes a water quality swale, an infiltration basin, and a riprap outlet is designed and constructed in accordance with the Stormwater Management Standards on or after November 18, 1996 in a portion of the site that is outside any Wetland Resource Area and outside the Buffer Zone. No additional Wetland Resource Area or Buffer Zone is created solely as a result of the installation of the Stormwater Management System. Ten years later, the project Applicant proposes to fill in the infiltration basin and replace it with a subsurface structure also located outside a Wetland Resource Area or Buffer Zone. The project Applicant can fill in the infiltration basin and replace it with a subsurface structure without filing a Notice of Intent, Notice of Resource Area Delineation or Request for Determination of Applicability, since both the infiltration basin and the subsurface structure are located in upland. See **Figure 3-1 (Alteration of an upland site SCM)**.

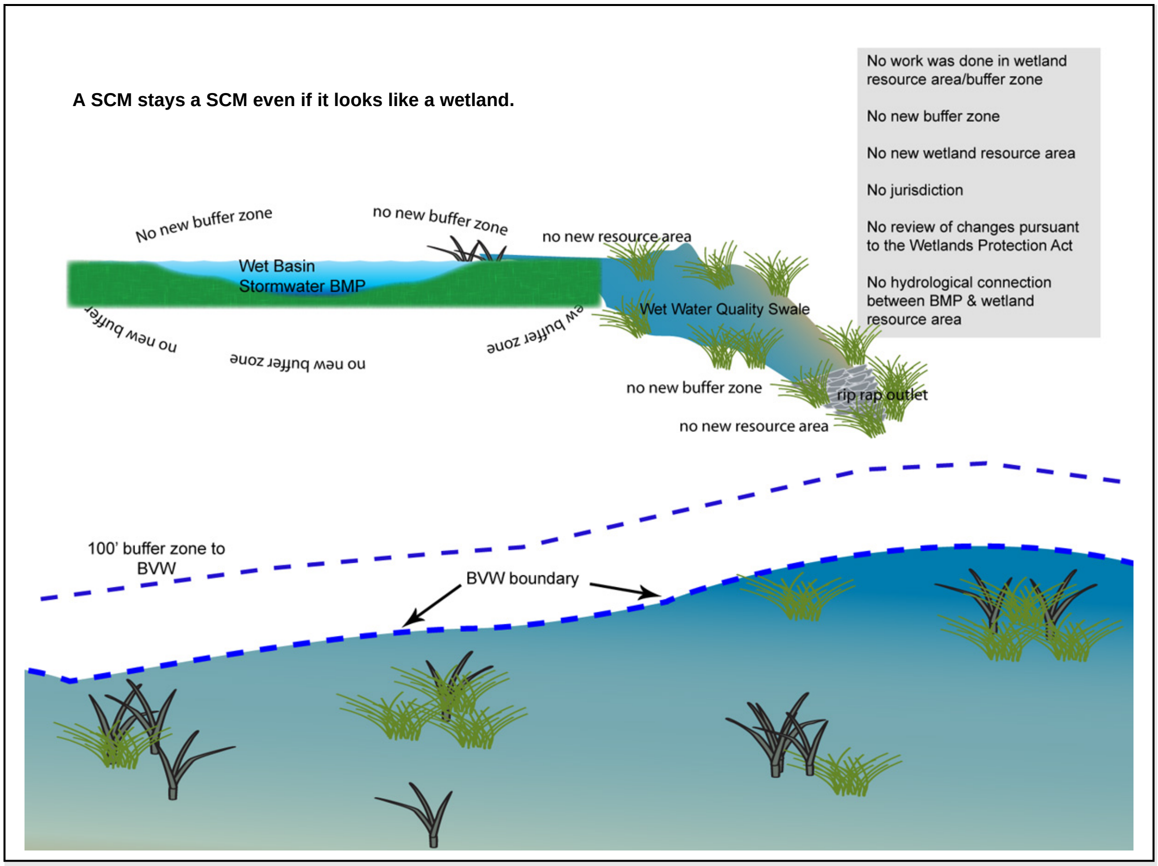

Figure 3-1. An upland site SCM built outside of a Buffer Zone or Wetland Resource Area built in accordance with Stormwater Management Standards after November 18, 1996 does <u>not</u> require a Notice of Intent, Notice of Resource Area Delineation, or Request for Determination of Applicability to modify the SCM.

Alternatively, suppose the entire Stormwater Management System, including the water quality swale, infiltration basin, and riprap outlet, is constructed for stormwater management purposes in the Buffer Zone in accordance with the Stormwater Management Standards on or after November 18, 1996. As with the earlier example, no additional Wetland Resource Area or Buffer Zone is created solely as a result of the installation of the Stormwater Management System. See **Figure 3-2** (**A SCM is not regulated as a wetland**).

Ten years later, the project Applicant proposes to fill in the infiltration basin and replace it with a subsurface structure outside a Wetland Resource Area or Buffer Zone. The project Applicant is required to file a Notice of Intent, Notice of Resource Area Delineation, or Request for Determination of Applicability, since the original Stormwater Management System is located in the Buffer Zone. As part of this filing, the project Applicant has to show that the water quality swale, infiltration basin and riprap outlet are components of a Stormwater Management System constructed in the Buffer Zone on or after November 18, 1996, in accordance with the Stormwater Management Standards.

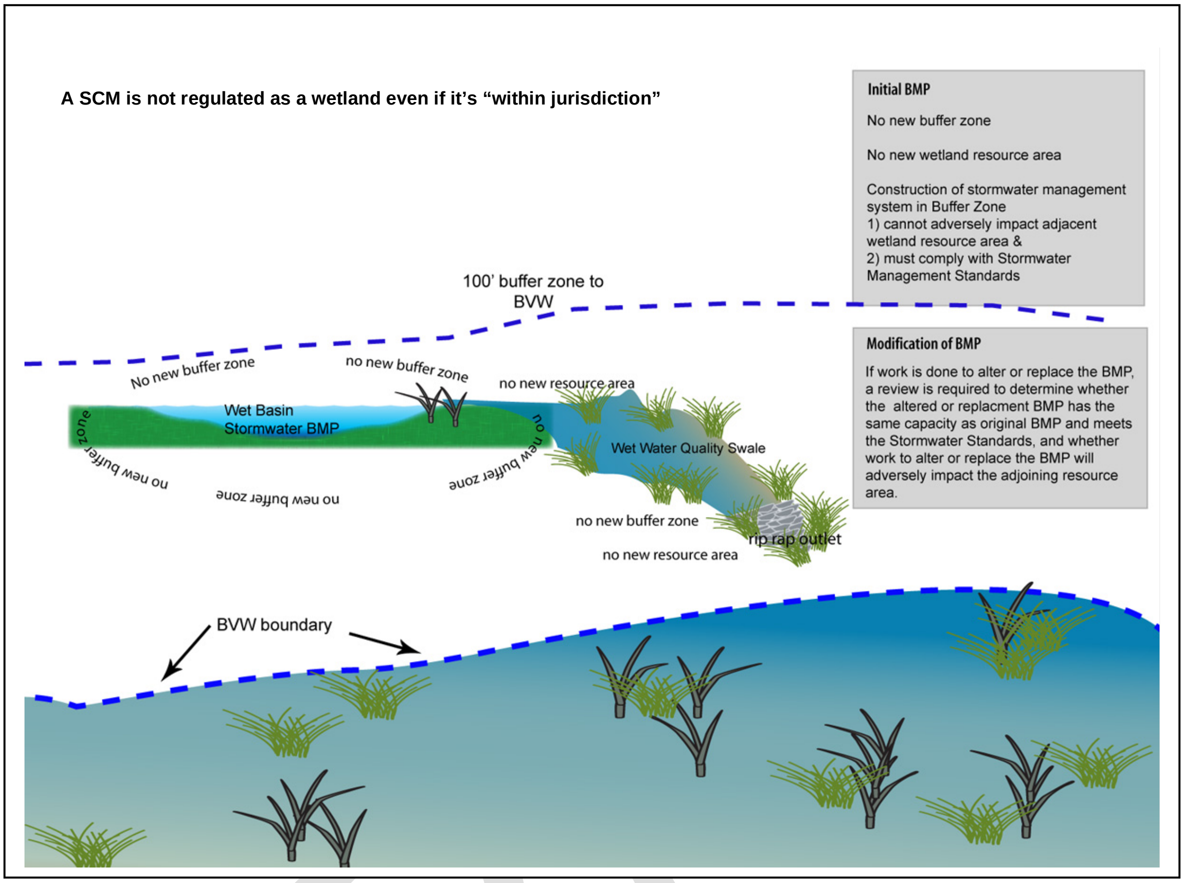

Figure 3-2. A SCM inside of a Buffer Zone or Wetland Resource Area built in accordance with Stormwater Management Standards after November 18, 1996 does require a Notice of Intent, Notice of Resource Area Delineation, or Request for Determination of Applicability to modify the SCM.

In this case, it should be easy for the Applicant to meet this burden by submitting the Order of Conditions permitting the installation of the original Stormwater Management System and the plans referenced therein[35]. The Conservation Commission would then review the proposed change to determine whether (a) the replacement system provides the same design capacity as the initial system to attenuate the peak discharge rate, recharge the groundwater and remove total suspended solids; (b) the replacement system complies with the Stormwater Management Standards to the extent they are applicable including, without limitation, Standard 8 - the erosion and sedimentation control standard; and (c) whether the alteration of the system located in the Buffer Zone adversely affects the adjacent Wetland Resource Area.

Additionally, suppose an Applicant designs and constructs, in accordance with the Stormwater Management Standards on or after November 18. 1996, a Stormwater Management System that includes a water quality swale, infiltration basin, and riprap outlet located on a portion of the site that is outside a Wetland Resource Area and outside the Buffer Zone. The construction of the infiltration basin and water quality swale does not by itself create any additional Wetland Resource Area or Buffer Zone subject to regulation under the Wetlands Protection Act. Over time, however, the Wetland Resource Area expands, moving the wetland boundary and the boundary of the Buffer Zone. The entire Wetland Resource Area, including the expansion, is an Area Subject to Protection Under M.G.L. c. 131, § 40, and any work in that area and associated Buffer Zone requires the Filing of a Notice of Intent, Request for Determination of

[35] 310 CMR 10.02(4) allows for this work to be permitted. Therefore, a Notice of Intent or Request for Determination of Applicability must be submitted prior to undertaking any alterations to stormwater management practices, other than maintenance.

Applicability, or Notice of Resource Area Delineation. See **Figure 3-3 (Wetland expanding towards a SCM)**.

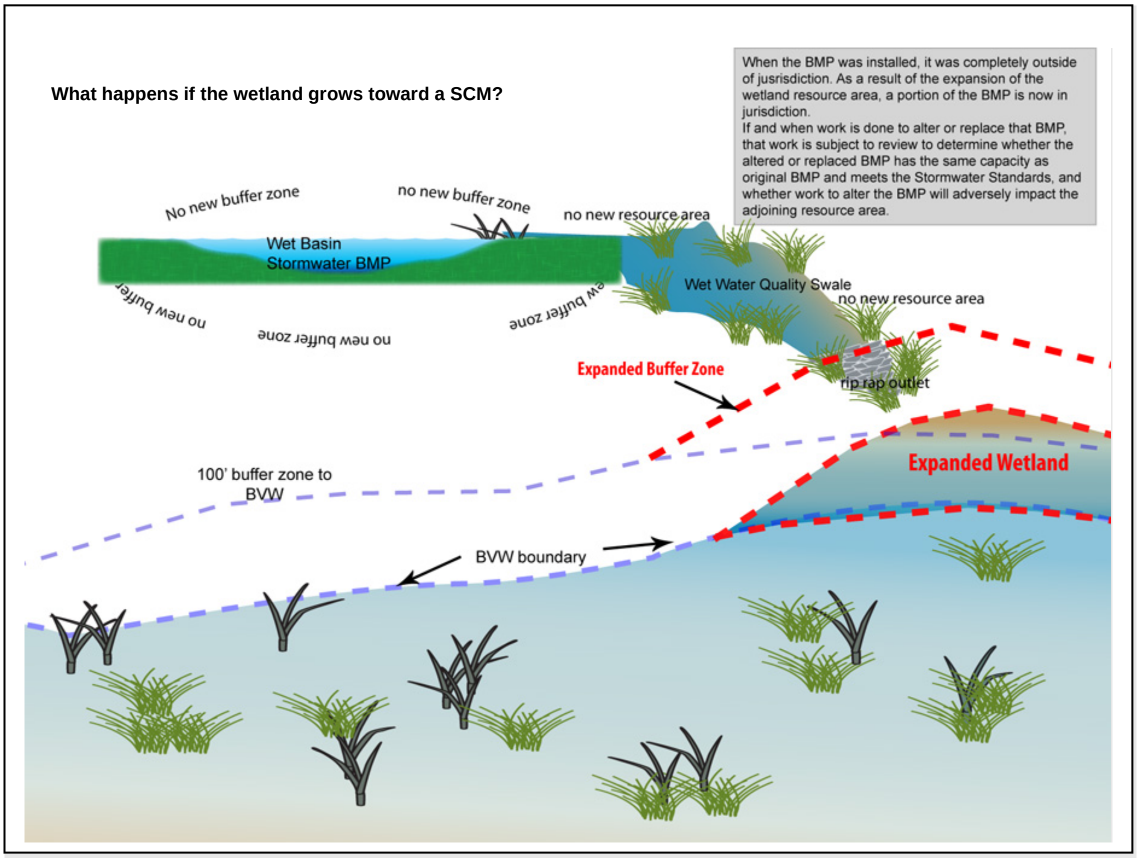

Figure 3-3. A SCM built outside of a Buffer Zone or Wetland Resource Area built in accordance with Stormwater Management Standards after November 18, 1996 may require a Notice of Intent, Notice of Resource Area Delineation, or Request for Determination of Applicability to modify the SCM if the Wetland Resource Area or Buffer Zone has expanded to include portions of the SCM.

Ten years later, the Applicant proposes to fill in the water quality swale, infiltration basin, and riprap outlet, and replace it with a vegetated filter strip, subsurface structure, and riprap outlet, all located outside the boundaries of the expanded Wetland Resource Area and associated Buffer Zone. Because the Wetland Resource Area has expanded, the original riprap outlet is within the Buffer Zone at the time of the proposed work. The alteration of the original riprap outlet within the Buffer Zone requires the filing of a Notice of Intent, Request for Determination of Applicability, or Notice of Resource Area Delineation. See **Figure 3-3**.

Once again, the project Applicant has the burden of proving that the Stormwater Management System was constructed on or after November 18, 1996 in accordance with the Stormwater Management Standards and that the system was originally constructed outside any Wetland Resource Area or Buffer Zone. It would be easy for the Applicant to meet this burden if, prior to constructing the Stormwater Management System, s/he had obtained a Negative Determination of Applicability, an Order of Resource Area Delineation (ORAD), or an Order of Conditions for any work on the project that occurred within a Resource Area or Buffer Zone.

In the absence of a Negative Determination, ORAD, or Order of Conditions, the project Applicant would have to rely on any credible evidence available to prove that the original water quality swale, infiltration basin and riprap outlet is a Stormwater Management System that was originally constructed on or after

November 18, 1996 in accordance with the Stormwater Management Standards in a portion of the site that was outside a Wetland Resource Area or associated Buffer Zone. Obtaining the necessary credible evidence may not be easy. To establish that the system was designed on or after November 18, 1996, the project Applicant may be able to rely on the local approvals, if any, for the Stormwater Management System. To establish that the basin was constructed outside wetlands jurisdiction, the Applicant may be able to rely on other available information, such as wetland maps prepared by MassDEP or other state or local agencies, any Orders or Determinations issued for the site prior to the project or subsequent to the project, any Orders or Determinations for nearby sites, and existing conditions (soils, plants, hydrology) within the portion of the site surrounding the infiltration basin.

Assuming the project Applicant meets the required burden of proof, the Conservation Commission would then review the proposed alteration to determine whether the proposed replacement system provides the same capacity as the original design to attenuate peak discharge rates, recharge the groundwater, and remove total suspended solids, and complies with the Stormwater Management Standards including, without limitation, Standard 8 - the erosion and sedimentation control standard. The Conservation Commission would also determine whether the elimination of the original riprap outlet in the Buffer Zone adversely affects the adjoining Wetland Resource Area.

The Right to Appeal the Order of Conditions

Conservation Commissions and MassDEP issue Orders of Conditions that require compliance with the Stormwater Management Standards as described in the Wetlands Protection regulations. Applicants and others may appeal these conditions to MassDEP in the same way they appeal any other requirements of the Order of Conditions. Moreover, if a Commission issues an Order of Conditions that is inconsistent with the Stormwater Management Standards, MassDEP may intervene unilaterally and issue a Superseding Order that requires compliance with the Standards[36].

3.3 Stormwater, the Federal Clean Water Act, and the State Clean Waters Act.

Stormwater runoff and stormwater discharges are regulated by various state and federal programs. These programs include the federal 401 Water Quality Certification, the state Surface Water Discharge Permit Program regulations, the federal NPDES programs regulating stormwater discharges from municipal sources, construction activities, and industrial activities, the state's Underground Injection Control program, and the state's Green Communities Act to regulate stormwater discharges from solar arrays.

3.3.1 Stormwater and 401 Water Quality Certification

Under Section 401 of the federal Clean Water Act, an Applicant for a federal permit for any activity resulting in a discharge to waters of the United States must obtain certification that the discharge will comply with state water quality standards and other appropriate requirements of state law. Section 404 permits for the discharge of dredged or fill material issued by the U.S. Army Corps of Engineers frequently trigger the State's 401 jurisdiction. Discharges include the filling of wetlands, the redeposit of dredged or excavated material from activities such as mechanized land clearing or ditching, and the placement of piling when it has the effect of fill. Waters of the United States include navigable waters and their tributaries, certain lakes, ponds and impoundments, and wetlands adjacent to jurisdictional waters. States may add conditions to ensure that state water quality standards will be met.

The 401 Water Quality Certification (WQC) program for dredge and fill pursuant to 314 CMR 9.00 has been coordinated with the state's Wetlands Protection Act program. As a result, most projects approved by a Conservation Commission under the Wetlands Protection Act do not need further State review under the 401 WQC dredge and fill program. These projects meet the Stormwater Management Standards

[36] Applicants and others may appeal a Superseding Order issued by MassDEP by requesting an adjudicatory hearing. The rules for requesting an adjudicatory hearing are set forth in 310 CMR 10.05(7)(j).

through compliance with the Wetlands Protection Act. Some types of projects, including those with potentially large wetland impacts and those that are not subject to the Wetlands Protection Act, require an individual 401 Water Quality Certification. Projects requiring an individual 401 Water Quality Certification include activities that will result in the loss of more than 5,000 square feet of bordering and Isolated Vegetated Wetlands and land under water, the discharge of dredged or fill material to Outstanding Resource Waters, real estate subdivisions unless there is a recorded deed restriction providing notice to subsequent purchasers limiting the amount of fill, and the discharge of dredged or fill material to a salt marsh or to rare and endangered species habitat in an Isolated Vegetated Wetland.

For these projects, the 401 Water Quality Certification regulations for dredge and fill include specific provisions for stormwater discharges. The Water Quality Certification regulations for dredge and fill, at 314 CMR 9.06(5), provide:

- No discharge of dredged or fill material is permitted for the impoundment or detention of stormwater for purposes of controlling sedimentation or other pollutant attenuation.
- Discharge of dredge or fill material may be permitted to manage stormwater for flood control purposes only where there is no practicable alternative and provided that BMPs are implemented to prevent sedimentation or other pollution. No discharge of dredged or fill material is permitted for the impoundment or detention of stormwater in Outstanding Resource Waters for any purpose.

The 401 Water Quality Certification regulations for dredge and fill, at 314 CMR 9.06(6)(a), provide that stormwater discharges shall be provided with SCMs to attenuate pollutants and to provide a setback from the receiving water or wetland in accordance with the Stormwater Management Standards. These regulations include the Stormwater Management Standards.

3.3.2 Designation of Stormwater Discharges

Under the Surface Water Discharge Permit Program regulations, 314 CMR 3.00, stormwater discharges other than discharges from MS4s that require coverage under the MS4 General Permit, are exempt from the requirement to obtain an individual or general surface water discharge permit unless MassDEP has made a designation in accordance with 314 CMR 3.04(2)(b).[37] MassDEP may make a designation if it determines that: (1) the discharge is or may be a significant contributor of pollution to Waters of the Commonwealth, (2) the discharge is contaminated by contact with process wastes, raw materials, toxic pollutants, hazardous substances, oil or grease, and does not meet the Stormwater Management Standards, (3) the discharge is subject to effluent limitation guidelines or toxic pollutant effluent standards, or (4) the discharge is located in an industrial plant or plant-associated area and there is a potential for significant discharge of stormwater contaminated by contact with process wastes, raw materials, toxic pollutants or hazardous substances, and the discharge has not obtained coverage under a general permit. Any stormwater discharge designated by MassDEP will be required to obtain a discharge permit or to take other corrective action. Designated stormwater discharges may be permitted by an individual permit, a general permit or an alternative general permit.

3.3.3 Stormwater Discharges and Total Maximum Daily Loads

A Total Maximum Daily Load (TMDL) is the greatest amount of a pollutant that a water body can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation, and fishing. A TMDL specifies how much of a specific pollutant can come from various sources, including stormwater discharges, and identifies strategies for reducing the pollutant discharges from these sources. MassDEP has prepared TMDLs that indicate that in many watersheds action is needed to reduce the concentrations of bacteria,

[37] MassDEP has similar authority to require certain stormwater discharges to the groundwater to obtain a permit. See 314 CMR 5.04.

phosphorus, and nitrogen in stormwater discharges, including, without limitation, implementation of specific SCMs.

Proper selection of non-structural and structural stormwater management practices is an essential component of any plan to reduce these pollutants. These non-structural SCMs begin with Environmentally Sensitive Site Design, pollution prevention and source control. By reducing Impervious Surfaces and allowing stormwater to infiltrate into the ground and by selecting a landscape design that minimizes the need for fertilizers and pesticides, developers can substantially reduce the concentration of pollutants in stormwater runoff from development and Redevelopment projects. Once a project is complete, ongoing action is needed to prevent additional pollutants from entering the Stormwater Management System. Raw materials and wastes should be stored inside or under cover with adequate containment. Snow, sand, deicing chemicals, fertilizers, pesticides, and solid waste should be properly managed. An effective street-sweeping program should be implemented. Structural SCMs that can remove the pollutants of concern must be designed, constructed, operated and maintained. Infiltration SCMs, bioretention areas, constructed stormwater wetlands, and filter systems may be effective tools for reducing the concentration of nutrients and bacteria in stormwater discharges.

If an Applicant is proposing a project that is in the watershed of a water body with a TMDL or Alternative TMDL, and if the project is subject to wetlands jurisdiction, the proposed structural SCMs should be consistent with the TMDL or Alternative TMDL. Because pollution prevention is an interest identified in the Wetlands Protection Act, Conservation Commissions and MassDEP may require the identification of source control measures that eliminate or reduce such pollution when reviewing projects subject to jurisdiction under the Act. Projects subject to the MS4 permit must also demonstrate compliance with any TMDLs that have been established. The TMDL may contain information on appropriate pollution prevention, SCMs or other practices that may be used to meet the TMDL goals. See http://mass.gov/dep/water/resources/tmdls.htm.

3.3.4 Stormwater and the NPDES Program

The federal Clean Water Act authorizes EPA to regulate point sources that discharge pollutants into waters of the United States, including stormwater runoff from drainage systems. Under the National Pollutant Discharge Elimination System (NPDES) Phase 1 Stormwater Program, EPA, since 1990, has issued general permits for MS4s in cities and counties with populations of 100,000 or more, stormwater runoff from specific industrial activities, and stormwater runoff from construction sites that disturb five acres or more of land. In 2003, the NPDES Phase II Stormwater Program took effect, and EPA began regulating MS4s in additional urbanized areas, and stormwater runoff from construction activities that disturb one acre or more of land, through general permits.

Stormwater and the MS4 NPDES General Permit

MassDEP and EPA have jointly issued the Municipal Separate Storm Sewer System (MS4) General Permit. The first MS4 general permit was issued in 2003 and expired in 2008. In Massachusetts, 237 cities and towns applied for and obtained coverage under the 2003 MS4 General Permit. The 2016 MS4 General Permit became effective on July 1, 2018 and covers 263 communities.[38] For a map showing Massachusetts municipalities covered by the MS4 Permit, see EPA's site at http://www.epa.gov/region1/npdes/stormwater/ma.html.

After going into effect, two petitions for review of the 2016 MA MS4 permit were filed by the Center for Regulatory Reasonableness and by Conservation Law Foundation (CLF), Charles River Watershed Association (CRWA), Massachusetts Coalition for Water Resources Stewardship (MCWRS), Franklin Massachusetts, National Association of Homebuilders (NAHB), Home Builders and Remodelers Association of Massachusetts, Inc. (HBRAMA), and the City of Lowell. The appeals were consolidated at

[38] Through the State's Water Quality Certification, the 2016 MS4 Permit requires compliance with the Stormwater Management Standards and the Surface Water Quality Standards.

the D.C. Circuit. *Center for Regulatory Reasonableness, et al. v. EPA*, No. 16-1246 (D.C. Cir.) (2016 Massachusetts Small MS4 General Permit consolidated cases). After mediation that started in 2017, a settlement was reached and the permit was finalized with modifications and went into effect on January 6, 2021.

The MS4 General Permit requires the development and implementation of a stormwater management plan that includes, among other things, six specified control measures to reduce pollutants to the maximum extent practicable.

These measures are as follows:

- **Public education and outreach.** The public education program must provide information on the impact of stormwater discharges and identify steps the public can take to reduce pollutants in stormwater, such as actions to ensure the proper use and disposal of landscape and garden chemicals including fertilizers and pesticides, benefits of on-site filtration of stormwater, and properly disposing of used motor oil or hazardous waste.
- **Public involvement and education.** The public involvement program must be done in compliance with all applicable state and local public notice requirements, including, without limitation, the Open Meetings Law and the Public Records Act. The public must be involved in reviewing and implementing the stormwater management program.
- **Illicit Discharge detection and elimination.** An Illicit Discharge is any discharge to an MS4 that is not comprised entirely of stormwater, discharges from fire-fighting activities, and certain designated non-stormwater discharges. An Illicit Discharge detection and elimination program requires the development of a map of the storm sewer system that identifies the location of all outfalls and the names of all surface waters that receive discharges from those outfalls, and a priority ranking of the outfalls for screening and investigation. As part of this program, there must be a regulatory mechanism that prohibits non-stormwater discharges into the MS4 and provides for appropriate enforcement. The program must include a plan to detect and address non-stormwater discharges through enforcement action through local bylaw or ordinances, including illegal dumping, and to inform public employees, businesses and the general public of the hazards associated with illicit connections and improper waste disposal.
- **Construction site runoff control program.** The construction site runoff control program reduces pollutants from construction activities that result in a land disturbance of greater than or equal to one acre. The construction site runoff control program must include a regulatory mechanism that requires proper management of construction sites, with sanctions to ensure compliance. The program requires (a) sediment and erosion controls including BMPs and design techniques to minimize land disturbance; (b) proper management of wastes, including construction debris, concrete truck wash-out chemicals, litter and sanitary wastes; (c) procedures for site plan review that examine water quality impacts; (d) procedures for public input; and (e) procedures for inspection and enforcement of control measures..
- **Post-construction stormwater management.** The post-construction stormwater management program applies to projects that disturb one acre or more. The program must include a regulatory mechanism with sanctions, requirements for the long-term operation and maintenance of SCMs, and controls to prevent or minimize impacts to water quality.
- **Pollution prevention and good housekeeping in municipal operations.** The pollution prevention and good housekeeping program includes the development and implementation of a program for preventing and reducing the concentration of pollutants found in stormwater runoff from municipal operations, including parks and open space, vehicles and equipment, and municipal buildings. The permittee must also develop a plan for maintenance of the MS4 infrastructure, including inspection and maintenance of catch basins.

The MS4 permit requires the permittee to develop measurable goals for the implementation of the stormwater management program and to report on its progress on meeting those goals. Where the MS4 discharges to an impaired waterbody with a TMDL, the permittee is required to implement additional measures to address the pollutant of concern..

To comply with the MS4 General Permit, many cities and towns have enacted local ordinances, bylaws, and regulations that apply to existing stormwater discharges as well as stormwater discharges from new development and Redevelopment, both during and after construction. These local requirements include construction and post-construction controls on development and Redevelopment projects that disturb one acre or more of land, including projects outside the jurisdiction of the Wetlands Protection Act, and regulations requiring the removal of illicit connections to the MS4. If a TMDL has been established, these regulations may address pollutants other than TSS. Applicants for projects located in municipalities that are covered by the MS4 permit must comply with these local requirements.

Stormwater Discharges and the NPDES Construction General Permit

Construction sites that disturb one or more acres and that discharge stormwater to a surface water of the United States, or to an MS4 that discharges to a surface water of the United States, are required to obtain coverage under the NPDES General Permit for Storm Water Discharges from Construction Activities (also known as the "Construction General Permit" or "CGP") issued by the EPA. Although the state has not joined with EPA in issuing the CGP, Massachusetts has issued a 401 Water Quality Certification for the permit. The Water Quality Certification requires compliance with certain state laws and regulations, including the Massachusetts Clean Waters Act, the Massachusetts Water Quality Standards, and the Surface Water Discharge Permit Program Regulations. If the requirements of the water quality certification are violated, MassDEP has the authority to require that the violations be corrected and to take any action authorized by the General Laws of the Commonwealth, including the Massachusetts Clean Waters Act, and the regulations promulgated thereunder.

The CGP requires the preparation of a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP must include a plan to implement both pollution prevention and erosion and sedimentation control during construction. If the permit covers a stormwater discharge to a water body for which a TMDL has been developed, the SWPPP must document measures taken to assure that waste load allocations in the TMDL will be met. If the permit covers a discharge to an Outstanding Resource Water, the SWPPP must be submitted to MassDEP so that the Department may review it for compliance with the surface water quality standards. The most recent CGP was issued in 2017 and is scheduled to expire in 2022.[39]

Stormwater Discharges from Construction Dewatering

The NPDES Dewatering General Permit (DGP) has expired and EPA is now instructing Applicants to apply for coverage under the NPDES Remediation General Permit (RGP) for the dewatering of uncontaminated water. In addition to stormwater discharges from construction dewatering, the following activities are eligible for coverage under the NPDES Remediation General Permit (RGP): existing, emergency, and new discharges from remediation, dewatering, and dewatering/remediation-related activities. More specifically, eligible activities include (1) petroleum-related site remediation, (2) non-petroleum-related site remediation, (3) contaminate/formerly contaminated site dewatering, (4) pipeline and tank dewatering, (5) aquifer pump testing, (6) well development/rehabilitation, (7) collection structure dewatering/remediation, and (8) dredge-related dewatering. Additionally, discharges authorized under the RGP include discharges to waters of the Commonwealth unless otherwise restricted by the Massachusetts Surface Water Quality Standards, 314 CMR 4.00. Limitations on coverage and special eligibility determinations are listed in Part 1.3 and Part 1.4 of the RGP, respectively.

Stormwater and/or groundwater discharges that are pumped and drained from excavations or other points of accumulation are required to obtain coverage under the NPDES RGP. For coverage under the RGP, a Notice of Intent (NOI) must be submitted to both EPA and MassDEP. Operators seeking authorization to discharge must submit a complete and accurate NOI in accordance with the requirements

[39] For information on the latest Construction General Permit see https://www.epa.gov/npdes/2017-construction-general-permit-cgp.

in Part 3 of the RGP. Operators of existing discharges must submit a NOI no later than ninety (90) days after the effective date of the RGP; operators of emergency discharges must submit a NOI no later than fourteen (14) days after the discharge commences; and, operators of new discharges must submit a NOI no later than seven (7) days prior to the commencement of discharges. To maintain coverage under the RGP, the discharge must meet applicable water quality standards and all effluent limitations and requirements included in Part 2, Part 6, and Part 7 of the RGP. The operator must also meet the monitoring, recordkeeping, reporting, and administrative requirements included in Part 4 and Part 5 of the RGP.

Stormwater Discharges and the Multi-Sector General Permit

Stormwater discharges associated with certain industrial sectors are required to obtain an individual NPDES permit or coverage under the NPDES Multi-Sector General Permit (MSGP). This permit is issued only by EPA and requires that the discharger meet the Massachusetts Surface Water Quality Standards, 314 CMR 4.00, and prepare a SWPPP. If there are stormwater discharges to an Outstanding Resource Water, the discharger must submit the SWPPP to MassDEP.

The SWPPP must identify potential sources of pollutants that may reasonably be expected to affect the quality of the stormwater discharges, describe and ensure implementation of practices to reduce pollutants in stormwater discharges, and ensure compliance with the permit. The SWPPP must include BMPs to minimize pollutants in the discharge so that the discharge will not cause or contribute to violations of state water quality standards. The BMPs should be a suite of stormwater controls that prevent pollution and are economically reasonable and appropriate in light of current industry practice.[40]

If a TMDL has been approved for the receiving water, the SWPPP must be consistent with the TMDL. If at any time after authorization under the MSGP, EPA determines that the discharge may cause or have the reasonable potential to cause or contribute to a violation of state water quality standards, EPA may require the permittee to develop a supplemental action plan to address the water quality concerns or to apply for an individual permit.

The MSGP provides that the discharges must comply with 314 CMR 3.00, 314 CMR 4.00, 314 CMR 9.00 and 310 CMR 10.00. Existing discharges subject to the MSGP do not need to obtain an individual or general state discharge permit unless the discharge is designated by MassDEP in accordance with 314 CMR 3.04(2).

3.3.5 Underground Injection Control Program

The Underground Injection Control (UIC) Regulations, 310 CMR 27.00, require the registration of certain infiltration BMPs. As of the date of publication of this manual, all dry wells, infiltration trenches, subsurface structures, and leaching catch basins must be registered. Depending on the design, bioretention areas may have to be registered.[41]

[40] EPA has developed guidance on preparing a SWPPP for the Multi-Sector General Permit. Applicants preparing long-term pollution prevention plans for sites with land uses with higher potential pollutant loads may find this information helpful. See https://www.epa.gov/sites/production/files/2015-11/documents/swppp_guide_industrial_2015.pdf.

[41] For information on the UIC program and its application to infiltration BMPs, see https://www.mass.gov/underground-injection-control-uic. For information on the UIC Regulations, see https://www.mass.gov/regulations/310-CMR-2700-underground-injection-control.

3.3.6 Stormwater Discharges from Solar Array Sites and the Massachusetts Green Communities Act

MassDEP Wetlands Program Policy 17-1: Photovoltaic System Solar Array Review Policy (“Policy”) sets forth the Department's approach for reviewing ground-mounted solar photovoltaic systems relative to wetland jurisdiction.

The Policy strongly encourages the placement of ground-mounted PVS in upland areas to avoid wetland impacts. PVSs situated in Resource Areas are subject to jurisdiction under M.G.L. c. 131, § 40. They must comply with all regulatory performance standards for permitting projects under the Wetlands Protection Act regulations, including but not limited to, compliance with the Stormwater Management Standards. PVS projects may also be subject to review pursuant to the Massachusetts 401 Water Quality Certification regulations for dredge and fill.

The Policy provides direction on siting PVSs, standards of review for determining compliance with Bordering Vegetated Wetlands performance standards and stormwater management design methods to address attenuation of peak rates of runoff caused by land development (310 CMR 10.05(6)(k)2.), recharge (310 CMR 10.05(6)(k)3.), control of TSS from Impervious Surfaces (excluding solar panels) (310 CMR 10.05(6)(k)4.), and adequate erosion and sedimentation controls (310 CMR 10.05(6)(k)8.). The Photovoltaic System Solar Array Review Policy is available on the MassDEP website at https://www.mass.gov/guides/wetlands-information#-wetlands-policies.

4 Site Planning and Design

4.1 Overview of the Site Planning Process

The primary goals in site planning where alterations are proposed to Wetland Resource Areas and buffers are to avoid, minimize, and mitigate alterations to Wetland Resource Areas; reduce the peak runoff rate of stormwater caused by land development; recharge groundwater to offset the loss caused by land development; and remove contaminates in the runoff that otherwise will impair Resource Areas. When planning site development, key factors to keep in mind are to avoid and minimize alterations to Resource Areas, maintain natural topography, minimize disturbance to vegetation, and be cognizant of physical constraints, such as high groundwater and distance to Resource Areas.

4.1.1 Who Does Site Planning for Stormwater?

Site planning is the responsibility of the project Applicant. Certain components of site planning may require technical expertise (*e.g.,* hydrology, engineering, landscaping), and in such cases, professional consultants and/or design engineers should do comprehensive site planning. Before and during the permit review process, collaborative efforts among various parties, including developers, consultants, technical staff, planning boards, and Conservation Commission, frequently lead to final design plans that meet mutual goals.

4.1.2 What Documentation is Required?

The Massachusetts Wetlands Protection and 401 Water Quality Certification regulations for dredge and fill require site plans and other documentation to be submitted with the Notice of Intent or Water Quality Certification applications to incorporate measures that reduce the peak runoff rate, gradually recharge groundwater and remove contaminates present in stormwater. Required documentation and site plans are described in more detail in **Section 6**.

4.1.3 Who Reviews Site Plans for Stormwater Management?

Site plans are reviewed by the Conservation Commission when the project is proposed within a Wetland Resource Area or Buffer Zone. Such projects require the filing of a Notice of Intent and issuance of a permit known as an Order of Conditions. MassDEP will review the site plans if the Order is appealed or if a 401 Water Quality Certification is required. Sites that disturb more than 1 acre of land must apply for the Construction General Permit with the U.S. EPA. Stormwater Pollution Prevention Plans (SWPPPs) must be reviewed by MassDEP when work is proposed under a Construction General Permit near an Outstanding Resource Water of the Commonwealth (MassDEP WM 15) or when an underground injection well is proposed (MassDEP Underground Injection Control, 310 CMR 27.00).

If a municipality has been designated a Municipal Separate Storm Sewer System (MS4) by the U.S. Environmental Protection Agency, the site plan will be reviewed under a bylaw or ordinance adopted by the municipality. In the case of subdivisions, the municipal planning board will review the site plan under the authority of the Massachusetts Subdivision Control Act or local regulations. Other local review may be required, for instance by the municipal department of public works if runoff is to be directed to stormwater drain located a public street, or other local departments.

4.1.4 What Stormwater Control Measures are Used for Site Planning and Design?

A Project Applicant must design and implement a range of Stormwater Control Measures (SCMs) to meet the Stormwater Management Standards during the site planning process.

What are Stormwater Control Measures?

Stormwater Control Measures (SCMs) are structural or nonstructural techniques for managing stormwater to prevent or reduce non-point source pollutants from entering surface or ground waters.

- **Nonstructural SCMs** include a combination of source controls (*e.g.,* street cleaning), some types of Low Impact Development (LID) techniques, Environmentally Sensitive Site Design (ESSD) techniques (*e.g.,* protecting buffer area), and pollution prevention measures.
- **Structural SCMs** are practices that have been specifically designed, constructed, and installed for the purposes of conveying, collecting, storing, discharging, recharging, or treating stormwater. Structural SCMs are not naturally occurring and are not designed as wetland replication areas Structural SCMs include some LID techniques (*e.g.,* bioretention areas), basins, and many other features.

Consider design of SCMs in the following order of priority:

- **ESSD and LID Techniques.** Design the Project Site using Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques to preserve natural vegetation, minimize Impervious Surfaces, slow down times of concentration, and reduce runoff. See **Section 4.2** for more information on ESSD and LID techniques.
- **Source Controls and other nonstructural SCMs.** Use source controls and other nonstructural SCMs to minimize the volume of runoff and the contact of stormwater with potential pollutants. See **Section 4.3** for more information on non-structural SCMs and source controls.
- **Structural SCMs.** Design, construct and maintain structural SCMs to attenuate peak flows, capture and treat runoff, and provide recharge to groundwater. See **Section 4.4** for more information on structural SCMs.

The remainder of this Chapter provides detailed information on each SCM type.

4.1.5 Integrating ESSD, Source Controls, and Structural SCMs

The time to integrate ESSD, source controls and pollution prevention measures into the Stormwater Management System is during site design. During the planning process, an Applicant should identify small scale source controls and pollution prevention measures, such as placing a roof over a fueling area, or landscaping with native vegetation to minimize the need for fertilizers. These measures can reduce the requirements for structural stormwater SCMs, prevent the discharge of pollutants to receiving waters, and result in substantial cost-savings on infrastructure and paving.

During the site planning process, Applicants should also consider the locations of structural SCMs, and the need to provide ongoing access to those SCMs for maintenance. Some SCMs, such as infiltration basins, have specific site and construction requirements. The Applicant should identify site constraints, such as depth to groundwater and nearby septic systems or wells, so the SCM will not fail or adversely affect on-site septic systems or wells.

Site planning can help identify the most appropriate points to direct discharges from SCMs. To avoid erosion, Applicants should locate discharge points on low slopes and stable soils away from the edges of wetlands. Where suitable, Applicants should use infiltration trenches for surface runoff and dry wells for uncontaminated runoff from non-metal roofs. The Stormwater Management System should be designed with an emphasis on the use of Small-Scale Controls to treat and infiltrate stormwater at the source, to disconnect from storm drains, and to minimize the size of structural SCMs designed to meet recharge requirements and attenuate peak flows.

The costs of rehabilitating or retrofitting failed Stormwater Management Systems can be significant. These costs can be avoided by addressing stormwater runoff from the start. With careful planning, an Applicant can design a Stormwater Management System that meets the Stormwater Management Standards, reduces the cost of stormwater management, facilitates long-term maintenance, and enhances the marketability and aesthetic qualities of the development.

4.2 Environmentally Sensitive Site Design and Low Impact Development Techniques

Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques must be used to reduce stormwater runoff and protect wetland resources areas throughout a Project Site unless impracticable.[42] The Wetlands Regulations, at 310 CMR 10.04, and the 401 Water Quality Certification Regulations, at 314 CMR 9.02, define ESSD and LID as follows:

- **Environmentally Sensitive Site Design**: ESSD is design that incorporates Low Impact Development (LID) techniques or practices to prevent the generation of stormwater and non-point source pollution by reducing Impervious Surfaces, disconnecting stormwater sheet flow paths and treating stormwater at its source, maximizing open space, minimizing disturbance, protecting natural features and processes, and/or enhancing wildlife habitat.
- **Low Impact Development**: LID means innovative Stormwater Management Systems that are modeled after natural hydrologic features. LID manages rainfall at the source using uniformly distributed, decentralized, micro-scale controls. LID uses small, cost-effective landscape features located at the lot level. LID takes the form of techniques (*e.g.,* porous pavement) or practices (*e.g.,* reduced front yard setback).

Where Can I Find More Information on ESSD and LID Techniques?

- See **Section 4.2.1** for a list of MassDEP recognized ESSD / LID techniques.
- See below sections for more information on designing with ESSD and LID techniques.
- Each MassDEP ESSD / LID recognized technique has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**).
- Most MassDEP recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).

4.2.1 MassDEP Recognized ESSD Techniques

MassDEP considers the following measures to be ESSD / LID as listed in the Stormwater Report Checklist (**Table 4-1)**. See **Section 6.1** for more information on the Stormwater Report Checklist. Each MassDEP ESSD / LID recognized technique has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**). Most MassDEP recognized ESSD / LID

[42] Other SCMs shall only be used to the meet those portions Standard 3 (*i.e.,* Required Recharge Volume) and Standard 4 (*i.e.,* TSS / TP removal) that cannot be fully met by ESSD and LID techniques (see **Section 2.3.3** and **Section 2.3.4**).

techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).

Table 4-1. Summary of MassDEP recognized ESSD / LID techniques

MassDEP Recognized ESSD / LID Technique
Environmentally Sensitive Site Design (**ESSD Credit 1**)
Environmentally Sensitive Site Design for Solar Arrays (**ESSD Credit 2**)
Rooftop Runoff Directed to Qualifying Pervious Areas (**ESSD Credit 3**)
Roadway, Driveway, or Parking Lot Rooftop Runoff Directed to Qualifying Pervious Areas (**ESSD Credit 4**)
Tree Canopy Enhancement and Protection (**ESSD Credit 5**)
Reduce Impervious Area at Redevelopment Sites (**ESSD Credit 6**)
Protect or Enhancing Buffer Areas (**ESSD Credit 7**)
Preserve and Use Natural Drainage Systems (*e.g.,* use of “country drainage” versus curb and gutter conveyance and pipe
No Disturbance to any Wetland Resource Areas
Small Scale Controls
Green Stormwater Infrastructure and / or Structural LID Practices: • Bioretention cells (exfiltrating and filtering) • Constructed stormwater wetlands (including gravel wetland designs) • Treebox filters (exfiltrating and filtering) • Water quality swales • Grass channels • Green roofs • Porous Pavement • Cisterns • Infiltration basins[1] • Infiltration trenches • Roof dripline filters (exfiltrating and filtering) • Dry wells

Notes:

1. LID techniques manage rainfall and pollutants at the source using uniformly distributed decentralized micro-scale controls to minimize the impact of a project on groundwater and inland and coastal wetland resources. As such, infiltration basins will typically be most effective when designed to be smaller in scale and dispersed throughout the landscape.

4.2.2 Principles of Environmentally Sensitive Site Design

Conventional development strategies treat stormwater as a secondary component of site design, usually managed with "pipe-and-basin" systems that collect rainwater and discharge it off-site. In contrast, ESSD embraces hydrology as an integrating framework for site design, not a secondary consideration. Existing conditions influence the placement of roadways, buildings, and parking areas, as well as the nature of the Stormwater Management System. ESSD is a multi-step process that involves identifying important natural features, locating buildings and roadways in areas less sensitive to disturbance, and designing Stormwater Management Systems that create relationships between development and natural hydrology. The attention to natural hydrology, small scale controls, nonstructural approaches, and vegetation results in a more attractive, multifunctional landscape with development and maintenance costs comparable to or less than conventional strategies that rely on pipe-and-basin approaches.

An overview of some commonly used ESSD techniques that minimize the creation of new runoff, enhance groundwater recharge, and remove pollutants are listed below.

- **Avoid and minimize alterations to Resource Areas**, public and private drinking waters (including groundwater sources). Identifying the Resource Area boundaries is also important to meet setback requirements.
- **Fit the development to the terrain**. Match road patterns to landforms. For example, in rolling terrain, local streets should branch from collector streets, ending in short loops or cul-de-sacs along ridgelines. Grids may be more appropriate in areas where the topography is characteristically flat. Preserve natural drainage ways to reduce nutrient migration by interrupting and bending the road grid around them. Grass channels, vegetative buffers, or water quality swales can be constructed along street right-of-ways or on the back of lots to convey runoff without abrupt changes in the direction of flow.
- **Maintain as much of the existing natural vegetation and topsoil as possible**. Established vegetation and existing topsoil slows runoff and promotes groundwater recharge.
- **Minimize Impervious Surfaces.** Replacing natural vegetation and soils with Impervious Surfaces leads to increased runoff volume and velocity, larger pollutant loads, and may adversely affect long-term hydrology and natural systems through flooding and channel erosion. Careful site planning can reduce the impervious area created by pavement and roofs, the volume of runoff and pollutant loading requiring control, and the reliance on extensive conveyance networks to discharge stormwater runoff to receiving waters adversely impacting water quality.
- **Minimize the creation of steep slopes***.* Steep slopes have significant potential for erosion and increase sediment loading. Avoid using slopes greater than 2:1 (unless necessary to minimize impacts to Wetland Resource Areas).
- **Minimize placement of new structures or roads over porous or erodible soils***:* Porous soils provide the best and most inexpensive mechanism for infiltrating stormwater, reducing runoff volume and peak discharges, and providing groundwater recharge and treatment by infiltration and adsorption through the soil strata. Applicants should avoid disturbing unstable soils that are likely to erode.
- **Reproduce Pre-development Hydrologic Conditions.** The goal of matching pre-development hydrologic conditions should be addressed at the site planning level. The full spectrum of hydrologic conditions, including peak discharge, runoff volume, infiltration capacity, base flow levels, groundwater recharge, and maintenance of water quality, can be examined through a comprehensive approach involving the entire site and even offsite areas contributing runoff to the site. Peak discharges, runoff volume, infiltration recharge, and water quality are directly related to the amount and location of impervious area required by development plans.
- **Use Green Stormwater Infrastructure**. Green stormwater infrastructure is defined as Stormwater Management Systems that mimic nature and treat stormwater at its source by

allowing stormwater to infiltrate, by reducing storm flows to sewer systems or Resource Areas, and by harvesting stormwater for reuse. Green Stormwater Infrastructure includes SCMs such as bioretention that uses plant or soils systems for treatment, porous pavement, cisterns, and landscaping. Applicants should seek to distribute Green Stormwater Infrastructure throughout the site.

4.2.3 Applicable Project Types

ESSD can be applied to both residential and nonresidential developments as well as Redevelopment projects to limit land disturbance and preserve important natural features. ESSD begins with assessing the environmental and hydrologic conditions of a site and identifying important natural features such as streams and drainage ways, floodplains, wetlands, water supply protection areas, high-permeability soils, steep slopes, erosion-prone soils, woodland conservation areas, farmland, and meadows. This investigation helps to determine which "conservation areas" should be protected from development and construction impacts, and which site features (such as natural swales) should be incorporated into the Stormwater Management System.

The site analysis also identifies a "development envelope" where development can occur with minimal impact to hydrology and other ecologic, scenic, or historic features. In general, the development envelope includes upland areas, ridge lines and gently sloping hillsides, and slowly permeable soils outside of wetlands, leaving the remainder of the site in a natural undisturbed condition. It is important to protect mature trees and to limit clearing and grading to the minimum amount needed for buildings, access, and fire protection. Converting wooded areas to lawns increases the volume of runoff that must be managed.[43] The design should confine construction activity, including stockpiles and storage areas, to those areas that will be permanently altered, and clearly delineate the construction fingerprint.

4.2.4 Are there Limitations to Environmentally Sensitive Site Design?

Some ESSD site designs that seek to cluster development and reduce lot coverage may conflict with local land use regulations or public perceptions about what type of development is desirable. For example, ESSD on a compact multi-story building may be more visible than that of a single-story building with a larger footprint. To address this problem, developers, advocates, and regulators who recognize the value of Environmentally Sensitive Site Design must educate the public on what ESSD can look like.

4.2.5 What are Some Examples of Environmentally Sensitive Site Design?

The links below provide examples of ESSD and practical guidance for implementing ESSD and LID techniques. In addition, refer to the ESSD Fact Sheets in **Appendix A** for specific examples of how ESSD can be integrated into a variety of different site types (*i.e.,* new residential vs. road Redevelopment vs. commercial Redevelopment).

Additional Resources and Links for Environmentally Sensitive Site Design

- Low Impact Development Design Strategies: An Integrated Design Approach; Prince George's County, Maryland, Department of Environmental Resources; June 1999.

[43] Converting wooded areas to lawns increases the peak volume of runoff that must be attenuated in accordance with Standard 2. Standard 4 requires Applicants that convert wooded areas to lawns to include proper management of fertilizers, herbicides, and pesticides in their pollution prevention plan. The EPA lists urban forestry as a stormwater management BMP. See https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands.

- Low Impact Development Evaluation: Suggested Revisions to Existing Bylaws and Regulations; Wallace, C., (2009). MAPC Memorandum to Town of Wilmington. 6.30.2009.
- Better Site Design: A Handbook for Changing Development Rules in Your Community; Center for Watershed Protection; 1998. Site Planning for Urban Stream Protection; Thomas Schueler; Center for Watershed Protection; 1995.
- Conservation Design for Subdivisions: A Practical Guide for Creating Open Space Networks; Randall Arendt; Island Press; 1996. https://islandpress.org/book/conservation-design-for-subdivisions https://www.villageofhoward.com/184/Environmentally-Sensitive-Design
- EPA Green Infrastructure. https://www.epa.gov/green-infrastructure
- "Site Analysis." James A. LaGro, Jr.; John Wiley and Sons; 2001 *An Introduction to Better Site Design*; Article 45 from Watershed Protection Techniques; Center for Watershed Protection; 2000.
- Massachusetts Low Impact Toolkit, Fact Sheet #1; Low Impact Site Design http://www.mapc.org/wp-content/uploads/2017/11/LID_toolkit_factsheets_1-3.pdf

4.3 Nonstructural Approaches: Source Control and Pollution Prevention

Source controls can reduce the types and concentrations of contaminants in stormwater runoff and improve water quality. Source controls cover a wide range of practices including local bylaws and regulations, materials management at industrial sites, fertilizer and pest management in residential areas, reduced road salting in winter, erosion and sediment controls at construction sites, and comprehensive snow management. Non-structural approaches and Best Management Practices (BMPs) must be incorporated into the Long Term Pollution Prevention Plan (LTPPP) required to be submitted with the Notice of Intent or Water Quality Certification Application, when a new development or Redevelopment project proposes alterations to a Wetland Resource Area. See **Section 4.3.2** for information on how to prepare the LTPPP.

Effective site planning is essential to source control and pollution prevention. Reducing Impervious Surfaces and runoff volumes prevents the transport of pollutants. The guiding principle for pollution prevention is to minimize the volume of runoff and the contact of stormwater with potential pollutants. Because nonstructural practices can reduce stormwater pollutant loads and quantities, the size and expense of structural SCMs (or in rare cases, even the need for structural SCMs) can be reduced, thereby affording substantial cost savings.

The sections below provide a description of selected nonstructural SCMs and BMPs that can be used to reduce pollution sources. Also refer to the "Operating and Source Controls" section of **Appendix A** for specific pollution prevention measures for use at certain industrial and commercial facilities, snow disposal measures, and deicer storage. For more information, the Massachusetts Clean Water Toolkit provides a detailed summary of additional nonstructural SCMs, source controls, and BMPs that are not covered by the below sections.[44]

4.3.1 Street and Parking Lot Cleaning

Street and parking lot cleaning is a source control that is commonly used by municipalities and private entities (*e.g.,* commercial shopping areas or office parks). Street and parking lot cleaning is eligible to obtain pollutant removal credit for TSS and TP required by Standard 4 (see **Table 2-2**). The TSS and TP pollutant removal credit is dependent on the type of street cleaner, the frequency of the cleaning (*e.g.,* once per week, once per month, etc.) and the longevity of the cleaning (3-months, 6-months, 9-months, year-round, etc.). Refer to **Appendix A** for a Fact Sheet with detailed information on Street and Parking Lot Cleaning, including eligibility requirements to obtain pollutant removal credit for Standard 4Street and parking lot cleaning are applicable to new development and Redevelopment projects.

4.3.2 Long-Term Pollution Prevention Plans

Standard 4 requires the development and implementation of suitable practices for source control and pollution prevention. These measures must be identified in a long-term pollution prevention plan (LTPPP). The LTPPP must be submitted with the NOI or WQC Application. For sites with Land Uses with Higher Potential Pollutant Loads (LUHPPLs) (Standard 5) and Critical Areas (Standard 6), additional measures must be addressed in the LTPPP. This section describes what should be included in the LTPPP. The LTPPP must be implemented thereafter.

Industrial dischargers that are covered by the NPDES Multi-Sector General Permit are required to prepare an industrial Stormwater Pollution Prevention Plan (SWPPP). An industrial SWPPP prepared in accordance with the requirements of the Multi-Sector General Permit can be used to fulfill the source control and pollution prevention plan requirements of Standards 4, 5, and 6.

[44] Massachusetts Clean Water Toolkit: https://megamanual.geosyntec.com/npsmanual/default.aspx.

Likewise, many state agencies and municipalities are covered by the NPDES General Permit for Municipal Separate Storm Sewer Systems (*i.e.,* MS4 Permit) that require the implementation of good housekeeping and pollution prevention. State and local agencies subject to the MS4 Permit may be able to develop one plan that fulfills the source control and pollution prevention requirements of the Stormwater Management Standards and the MS4 Permit.

Purpose

The purpose of the required LTPPP is to:

- identify potential sources of pollution that may affect the quality of stormwater discharges; and
- describe and ensure the implementation of practices to reduce the pollutants in stormwater discharges.

General Requirements

The LTPPP shall incorporate source reduction measures to eliminate or reduce the generation and runoff of pathogens, nutrients, and other contaminants such as polycyclic aromatic hydrocarbons. The LTPPP must also address measures to properly dispose of snow outside of wetland resource areas and minimize snow disposal in the Buffer Zone. Source reductions and pollution prevention measures to be incorporated into the LTPPP include, but are not limited to:

- restricting fertilizer use;
- properly covering any solid waste stored exterior to a building so it does not comingle with runoff;
- prohibiting use of coal tar-based pavement sealants which contain polycyclic aromatic hydrocarbons;
- restricting use of winter sand application to paved surfaces; and
- prohibiting use of oil application to unpaved roads and automotive parking areas.

The LTPPP should also include procedures for the following:

- good housekeeping;
- storing materials and waste products inside or under cover;
- vehicle washing;
- routine inspections and preventative maintenance of stormwater SCMs;
- spill prevention and response;
- maintenance of lawns, gardens, and other landscaped areas;
- storage and use of fertilizers, herbicides, and pesticides;
- pet waste management;
- operation and management of septic systems;
- proper management of deicing chemicals and snow disposal[45];
- measures to restrict the use of winter sand application to paved surfaces;

[45] Snow Disposal Guidance: https://www.mass.gov/guides/snow-disposal-guidance; Deicing Storage Guidance: https://www.mass.gov/guides/guidelines-on-road-salt-storage

- measures to reduce generation of runoff and nutrients;
- measures to minimize the use of any identified hazardous materials; and
- measures to divert stormwater from potential pollutant sources.

The LTPPP should also provide that stockpiles of soil, mulch, or other erodible materials be contained and stabilized to prevent the discharge of sand to wetlands or water bodies, and, where feasible, covered. If a Total Maximum Daily Load (TMDL) has been developed that indicates that use of fertilizers containing nutrients must be reduced, the LTPPP shall also include a nutrient management plan. See **Section 2.3.11** for information on TMDL requirements. The LTPP shall also prohibit fertilizers that contain phosphorus, in accordance with 330 CMR 31.00 Plant Nutrient Application Requirements for Agricultural Land and Non-Agricultural Turf and Lawns; fertilizers to be applied when precipitation greater than 0.5 inches is forecast in the next 48 hours. The LTPPP may be prepared as a separate document or combined with the Operation and Maintenance Plan required by Standard 9.[46]

Refer to the "*Operating and Source Controls*" section of **Appendix A** for more information on operating and source control SCMs for certain industrial and commercial facilities, snow disposal measures, and deicer storage.

Additional Requirements for Standard 5

To mitigate the potential impact of stormwater discharges from Land uses with Higher Potential Pollutant Loads (LUHPPLs), the LTPPP must include measures in addition to the "General Requirements" listed above. Include provisions in the LTPPP for placing all industrial materials or activities in a storm-resistant shelter to prevent exposure to rain, snow, snow melt and runoff, or by placing all materials and wastes stored outside in sealed containers on Impervious Surfaces with adequate containment. Also include provisions in the LTPPP to provide for the use of emergency shut-offs where appropriate to isolate the system in the event of an emergency spill or other unexpected event. Emergency shutdown and containment practices include but are not limited to: gate valves and plugs.

Standard 5 expressly provides that stormwater discharges from LUHPPL must comply with all applicable laws, regulations, permits and approvals, including 314 CMR 3.00, 314 CMR 4.00, and 314 CMR 5.00. Pursuant to 314 CMR 3.00 and 314 CMR 5.00, MassDEP has authority to require a discharge permit or other corrective action if it determines that a stormwater discharge is contaminated by contact with process wastes, raw materials, toxic pollutants or hazardous substances, oil and grease, or is a significant contributor of pollution to Waters of the Commonwealth.

Finally, additional pollution prevention measures apply to certain LUHPPLs located within the Zone II of a Public Water Supply area. These land uses include:

- landfills and open dumps,
- landfills handling wastewater residuals and/or septage,
- automobile graveyards and junkyards,
- stockpiling and disposal of snow or ice removed from highways,
- petroleum fuel oil and heating oil bulk stations and terminals,
- wastewater treatment plants permitted pursuant to 314 CMR 5.00,
- hazardous waste facilities subject to regulation under 310 CMR 30.00,

[46] Applicants are required to prepare a Stormwater Report that includes both the long- term pollution prevention plan (LTPPP) and the operation and maintenance plan. See **Section 6.1** for information on the Stormwater Report.

- waste oil retention facilities,
- treatment works for the remediation of contaminated ground or surface waters,
- floor drainage systems,
- storage of any of the following materials: sludge, septage, sodium chloride, chemically treated abrasives or other chemicals used for the removal of ice or snow, chemical fertilizers, animal manures, liquid hazardous materials or petroleum products.

The LTPPP must include measures to prevent the land use from coming into contact with rain, snow, snowmelt and runoff.

Additional Requirements for Standard 6

To mitigate the potential impact of stormwater discharges from to or near Critical Areas, the LTPPP shall address source control and pollution prevention measures to prevent direct and indirect alterations to Critical Areas. At minimum, the LTPPP should consider the following for applicable Critical Areas:

- **Shellfish Growing Areas and Bathing Beaches**. Measures to reduce pathogen loading such as enhanced trash segregation and covering.
- **Outstanding Resource Waters, including Vernal Pools**. Establish no vegetation mowing and pruning at least 100-feet from the Resource Area, including no application of fertilizers or pesticides. Include measures to reduce salting practices
- **Stormwater Discharges within Zone I's, Zone II's, and IWPAs**. Measures to prevent contaminants from being placed on Impervious Surfaces that will mobilize.
- **Cold-Water Fisheries**. Measures to reduce temperature of runoff (*e.g.,* additional tree planting to provide shade over paved surfaces) and reduce salting practices.

In addition to the "General Requirements" listed above, the LTPPP should address proper management of snow and deicing chemicals. To protect Critical Areas, road salt should be properly stored within a Zone II or Interim Wellhead Protection Area or near an Outstanding Resource Water, Special Resource Water, Shellfish Growing Area, bathing beach or Cold-Water Fishery. The use of salt for the deicing of Impervious Surfaces should be minimized within water supply protection areas and any area near an Outstanding Resource Water, Special Resource Water, freshwater beach, or Cold-Water Fishery.

The long-term pollution prevention strategies for sites near Critical Areas should also incorporate designs that allow for shutdown and containment where appropriate to isolate the system in the event of an emergency spill or other unexpected event. Practices for shutdown and containment include, but are not limited to: gate valves and plugs.

4.3.3 Construction Period Erosion and Sedimentation Control and Pollution Prevention

Construction period erosion and sedimentation control is an essential component of pollution prevention. Construction period activities increase the potential for erosion and sedimentation at a site. Variability in terrain, soils, and vegetation makes erosion control unique to each development. The purpose of this section is to provide an overview of construction period erosion and sediment control and pollution prevention practices as they relate to the Stormwater Standards and guidance on how to meet them.

Construction Period Erosion Sedimentation and Pollution Prevention Plan Requirements

Standard 8 requires erosion and sedimentation controls to be implemented during construction. A Construction Period Erosion, Sedimentation and Pollution Prevention Plan (CPPP) is required to be prepared and submitted with the NOI or WQC Application. Keep a copy of the CPPP at the construction site, along with an inspection log and a maintenance log. The inspection and maintenance logs must be made available to Conservation Commissions and MassDEP upon request. Use the *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas* to prepare the CPPP (see **Appendix C**).

Construction sites that disturb at least **one acre of land**, or will disturb less than one acre of land but are part of a common plan of development that will ultimately disturb one or more acres of land are required to obtain coverage under the NPDES Construction General Permit (CGP) and prepare a SWPPP. A SWPPP prepared in accordance with the CGP satisfies the erosion and sedimentation control plan requirement of Standard 8, provided it addresses the additional requirements of a CPPP, including measures to prevent sedimentation to any Wetland Resource Area or open or closed drainage system draining to a Resource Area.[47]

At minimum, include items described below in the CPPP.

Contact List

A contact list of all parties who will be engaged in construction activities at the site and/or will be responsible for implementing the CPPP or any component(s) thereof.

Project Narrative

- A description of the nature of construction activities including the size of the property, the total area expected to be disturbed by construction activities, and the maximum area expected to be disturbed at any one time. Avoid wholesale clearing and grubbing the site at once.
- A detailed, dynamic, construction-phase plan for sequencing construction and stormwater management activities that minimizes land disturbance by ensuring that vegetation is preserved to the maximum extent practicable, and disturbed portions of the site are stabilized as quickly as possible. Include a description of potential erosion risks that may be encountered and a list of construction period BMPs that will be used to address those risks in the CPPP.
- A list and description of all potential pollutant generating activities on-site (*e.g.,* sediment, fertilizers, pesticides, paint, caulk, sealant, solvents, fuels) that could be discharged in stormwater from the construction site.

Description of SCMs.

- Identify all stormwater management activities that are needed during land disturbance and construction, including source control and pollution prevention measures, construction period BMPs to address erosion and sedimentation, stabilization measures, and procedures for operating and maintaining the BMPs, especially in response to wet weather events and freezing temperatures.
- Identify construction period BMPs based on phase.

Site Plans

- Site development plan that clearly depicts the proposed work, site boundaries, and Resource Area boundaries (see **Section 6.1** for more information on site plan requirements).
- Construction sequencing plans by phase, including site topography, drainage patterns, and delineated subcatchments designed to minimize land disturbance at any one time.

[47] For projects subject to jurisdiction under the Wetlands Protection Act, the construction period pollution prevention and erosion and sedimentation control plan must be included in the Stormwater Report submitted with the Notice of Intent. In rare instances, for highly complex projects, where the Applicant demonstrates that submission of the Final CPPP with the Notice of Intent is not possible, the Issuing Authority has the discretion to issue an Order of Conditions with a Draft CPPP, and authorizing a project prior to submission of the Final CPPP. All Orders of Condition shall provide that no work, including site preparation and land disturbance, may commence unless and until a Final CPPP that meets the requirements of Standard 8 has been approved by the Issuing Authority.

- Erosion and sedimentation control plan drawings
    - o Depict all Resource Area boundaries
    - o Depict any existing open or closed drainage systems, including but not limited to catch basins in the vicinity of stockpiles, and any conveyance systems near proposed work that ultimately discharge to Wetland Resource Areas.
    - o Depict limit of work and describe how it is marked.
    - o Depict any stormwater discharge points.
    - o Show all proposed construction period BMPs (*e.g.,* construction entrance, perimeter controls, inlet protection, sediment traps, sediment basins, stockpile locations, swales/berms, check dams, site stabilization measures).
- Vegetation planning, including tree protection.
- Detail drawings and specifications for erosion control BMPs, including sizing calculations. See **Section 6.2.8** for sizing criteria for sediment traps and sediment basins.

Procedures for inspection, maintenance, and corrective action

Describe the procedures, including inspection and use of maintenance log templates, that will be followed to maintain BMPs, to conduct site inspections, and to perform corrective maintenance. Provide a description of the location on the construction site where the inspection and maintenance logs will be maintained. The maintenance logs must be made available to Conservation Commissions and MassDEP upon request. See "*Operation, Inspection, and Maintenance"* Section below for more information, including required inspection frequency.

Site Planning and Design of Construction Period SCMs

The following sections provide a description of general planning steps to be used to plan and design an effective CPPP.

Assess the Site

The first step in controlling erosion and sedimentation is to assess the site for possible erosion and sediment problems. Erosion and sedimentation hazards associated with site development include increased water runoff, soil movement, sediment accumulation, and higher peak flows caused by the following factors.

- Removal of plant cover and a large increase in soil exposed to erosion by wind and water.
- Changes in drainage areas caused by grading, diversions or road construction.
- A decrease in the area of soil which can absorb water because of construction of streets, building, sidewalks or parking lots.
- Changes in volume and duration of water concentrations caused by altering steepness, distance and surface roughness.
- Soil compaction by heavy equipment, which can reduce water intake of soils to 1/20 or less of the original rate.
- Prolonged exposure of unprotected sites and service areas to poor weather conditions.
- Altering the groundwater regime in a way that may adversely affect drainage systems, slope stability, survival of existing vegetation and establishment of new plants.

- Exposing subsurface materials that are too rocky, too acidic or otherwise unfavorable for establishing plants.
- Obstructing streamflow by new buildings, dikes and landfills.
- Inappropriate timing and sequencing of construction and development activities.
- Abandonment of sites before construction is completed.

Site Planning and Construction Sequencing

Because any modification of a site's drainage features or topography requires protection from erosion and sedimentation, the CPPP should include site planning and construction sequencing. The staging of construction activities will typically depend upon these site factors:

- Existing soil limitations
- Existing slope and construction grading limitations
- Drainage problems
- Exposed soils during construction

The staging of construction activities to reduce sedimentation and the designation of areas to leave undisturbed during construction will reduce the size of construction SCMs, which reduces construction costs. In developing a construction sequencing plan, the following factors should be considered.

- **Review and consider all existing conditions in the initial site selection for the project**. Select portions of the site that are suitable for the project rather than force the terrain to conform to development needs. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding, and highly erodible soils severely limit a site's use, while level, well-drained areas offer few restrictions. Control seepage and high water table conditions. Any modification of a site's drainage features or topography requires protection from erosion and sedimentation.
- **Prevent Direct Discharges to Wetland Resource Areas**. The site must be graded during construction to prevent direct discharges to Wetland Resource Areas and to avoid or minimize channelized stormwater flow from the Buffer Zone directly into Wetland Resource Areas. Adequate upgradient erosion and sediment controls must be installed and maintained at all times during construction.
- **Limit disturbance.** Careful site selection will help on this point. The site, or corridor, should be able to accommodate the development with a minimum of grading. The development plan should fit its topographic, soil, and vegetative characteristics with a minimum of clearing and grading. Natural cover should be retained and protected wherever possible. Critically erodible soil, steep slopes, stream banks, and drainage ways should be identified. The development must be planned to minimize or eliminate disturbance of these vulnerable areas.
- **Stabilize and Protect Disturbed Areas as Soon as Possible**. Two methods are available for stabilizing disturbed areas: mechanical (or structural) methods and vegetative methods. In some cases, both are combined in order to minimize or avoid erosion. Disturbance of large land areas can lead to significant erosion during the construction phase and sedimentation impacts to Resource Areas. Conduct work in stages or manageable sections whenever possible, in order to minimize soil exposure and soil mobilization at any one time. In all cases, the level of stormwater controls shall be commensurate with the level of disturbance. Temporary land stabilization measures, such as mulching and erosion control blankets, are required for all disturbed surfaces until permanent native or naturalized vegetative cover is established.

- **Keep Stormwater Runoff Velocities Low.** The removal of existing vegetative cover during development and the resulting increase in impermeable surface area after development will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control. If exposed soils will be present during frozen conditions, calculations of runoff velocities must consider the surface of the site to be impervious (with RCN 98).
- **Protect Disturbed Areas from Stormwater Runoff***.* Construction BMPs can be utilized to prevent water from entering and running over the disturbed area. Diversions and other control practices intercept runoff from higher watershed areas, store or divert it away from vulnerable areas, and direct it toward stabilized outlets.
- **Retain Sediment within the Corridor or Site Area***.* Sediment can be retained by two methods: filtering runoff as it flows and detaining sediment-laden runoff for a period of time so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion.

<u>**Construction Period Erosion and Sedimentation Control and Pollution Prevention Measures**</u>

In addition to construction sequencing, the erosion and sedimentation control plan must include source control and pollution prevention measures, construction period BMPs to address erosion and sedimentation, procedures for operating and maintaining the BMPs especially in response to wet weather events, actions to control mosquitoes during construction, and stabilization measures. See **Section 5.4** for information on mosquito control. Pollution prevention activities include storing construction materials away from Wetland Resource Areas and catch basin inlets and preserving natural vegetation wherever possible.

Specify the structural SCMs to be used during construction in the CPPP. The *Massachusetts Erosion and Sediment Control Guidelines* list 45 different kinds of Construction Period BMPs (*e.g.,* Check Dams, Dust Control, Inlet Protection, Perimeter Controls, Sediment Basins) (see **Appendix A**). The BMPs selected for the project should reflect the needs identified in the project's erosion and sediment control plan. The erosion and sedimentation control plan must include design cross-sections and required freeboard for each construction period BMP.

When considering which control measures to use, always evaluate the consequences of a measure failing. Failure of a practice may be hazardous or damaging to both people and property. For example, a large sediment basin failure can have disastrous results; low points in dikes can allow them to overflow and cause major gullies. Distinguish the BMPs used during construction from the SCMs that will be used to handle stormwater <u>after</u> construction is completed and the site is stabilized. Many stormwater SCMs (e.g., infiltration practices) are not designed to handle the high concentrations of sediments typically found in construction runoff, and thus must be protected from construction-related sediment loadings. All construction period BMPs must be properly designed, and sediment traps or basins must be sized to provide adequate capacity and retention time to allow for proper settling of fine-grained soils.

Operation, Inspection, and Maintenance of Construction Period Best Management Practices

Include a schedule in the CPPP for implementation of stormwater management activities during land disturbance and construction that establishes a sequence in which these activities will be implemented as the project proceeds. The schedule should also state when temporary practices will be removed and how disturbed areas and any areas designated for waste disposal will be stabilized.

The CPPP shall specify who is responsible for maintenance of construction period BMPs, and when maintenance will be provided. The maintenance schedule shall be based on site conditions, design safeguards, construction sequence, and anticipated weather conditions. For each construction period BMP, the CPPP should specify the amount of allowable sediment accumulation, and how the accumulated sediment will be disposed.

Inspections

The CPPP shall include a description of how the site will be inspected and maintained during land disturbance. Field inspections of construction period BMPs defined in the CPPP shall be performed and documented at least once every seven (7) calendar days during the construction period – maintenance or corrective actions shall be performed based on results of the field inspections and documented in a written report. Written inspection reports must be made available to the Issuing Authority upon request. Note that performing inspections once every seven (7) calendar days is a minimum requirement. Inspections should be performed as follows:

- An inspection during or immediately following initial installation of any sediment controls.
- An inspection before significant rain or snowfall.
- An inspection within 24 hours of the occurrence of a storm event of 0.25 inches or greater, or the occurrence of runoff from snowmelt to cause a discharge. There are two options to determine if a storm event of 0.25 inches or greater has occurred on the Project Site:
    - Keep a properly maintained rain gauge on site; or
    - Obtain the storm event from a weather station that is representative of the Project Site's location.
- Final inspection of projects nearing completion to ensure that temporary controls have been removed, stabilization is complete, drainage ways are in proper condition, and the final contours agree with the proposed contours on the approved plan.

At minimum, Include the following items in each inspection report:

- the date and time of inspection;
- names and titles of personnel making the inspection;
- a summary of findings, including any necessary maintenance or corrective actions, and accompanying photo documentation; and
- rain gauge or weather station readings that triggered the inspection.

Construction Period Control Plan and Pollution Prevention Plan References:

- Massachusetts Department of Environmental Protection, 2003, Erosion and Sediment Control Guidelines for Urban and suburban Areas: A Guide for Planners, Designers, and Municipal Officials, https://www.mass.gov/doc/complete-erosion-and-sedimentation-control-guidelines-a-guide-for-planners-designers-and/download
- U.S. EPA, 2007, Developing Your Stormwater Pollution Prevention Plan: A Guide for Construction Sites, EPA-833-R-06-004, https://www.epa.gov/sites/default/files/2015-10/documents/sw_swppp_guide.pdf
- U.S. EPA, 2007, Developing Your Stormwater Pollution Prevention Plan: A Guide for Construction Sites, EPA-833-R-06-004, Appendix A, SWPPP Template for Un-authorized States,[48] https://www3.epa.gov/npdes/pubs/sw_swppp_template_unauthstates.doc
- U.S. EPA, 2007, Developing Your Stormwater Pollution Prevention Plan: A Guide for Construction Sites, EPA-833-R-06-004, Appendix A, SWPPP Template for Authorized States,https://www.epa.gov/sites/default/files/2016-01/sw_swppp_template_authstates.doc

[48] EPA Region 1 is currently the permitting authority for the Construction General Permit.

- U.S. EPA, Example SWPPPs, https://www3.epa.gov/npdes/pubs/exampleswppp_smallcommercial.pdf
- U.S. EPA, *Stormwater Management for Industrial Activities: Developing Pollution Prevention Plans and Best Management Practices* (EPA-832-R-92-006)
- U.S. EPA, 2017, Construction General Permit for Small and Large Construction Activities, https://www.epa.gov/npdes/epas-2017-construction-general-permit-cgp-and-related-documents.

4.3.4 Other Important Pollution Prevention and Source Control Measures

There are many other effective pollution control and source control measures that Applicants, citizens and municipalities can undertake to reduce pollutant loads in stormwater, including the following[49]:

- Lawn and garden activities, including application and disposal of lawn and garden care products, and proper disposal of leaves and yard trimmings. Effective measures include: applying pesticides and fertilizers properly, including: timing; application reduction; providing buffer areas (preferably natural vegetation) between surface waters and lawn and garden activities; limiting lawn watering and landscaping with climate-suitable vegetation; providing guidelines for what to expect from landscaping and lawn care professionals; and providing composting guidelines, if not covered elsewhere under solid waste efforts. *"More than Just a Yard: Ecological Landscaping Tools for Massachusetts Homeowners."* https://www.mass.gov/doc/more-than-just-a-yard-ecological-landscaping-tools-1/download *and Guide to Lawn and Landscape Water Conservation,* https://www.mass.gov/doc/guide-to-lawn-landscape-water-conservation-0/download
- **Turf management,** on golf courses, parks, and recreation areas. Many of the measures described above are applicable to turf management and should be implemented by caretakers responsible for golf courses and parks and recreation areas (including municipal employees, in some cases).
- **Pet waste management.** Pooper-scooper laws for pets should be enacted and implemented. Public outreach is essential to the effectiveness of these laws. Priority Resource Areas, such as bathing beaches and Shellfish Growing Areas, may need to exclude pets at least for the summer months or at other critical use times. Specific controls for horses and the control of manure may be needed. **<**https://megamanual.geosyntec.com/npsmanual/bmpfactsheetmenu.aspx>
- **Integrated Pest Management (IPM)** effectively prevents and controls pests (including weeds) in a way that maximizes environmental benefits at a reduced cost to growers. IPM involves applying an array of techniques and control strategies for pest management – with a focus on using them in the proper amounts and determining when they are most needed. By choosing from all possible pest control methods (*e.g.,* biological controls and beneficial organisms) and rotating methods, resistance to repeated chemical controls can be delayed or prevented. **<**https://megamanual.geosyntec.com/npsmanual/bmpfactsheetmenu.aspx>
- **Proper storage, use, and disposal of household hazardous chemicals,** including automobile fluids, pesticides, paints, and solvents. Information should be provided on chemicals of concern, proper use, and disposal options. Household hazardous waste collection days should be sponsored whenever feasible. Recycling programs for used motor oil, antifreeze, and other products should be developed and promoted.
- **Storm drain stenciling** involves labeling storm drain inlets with painted messages warning citizens not to dump pollutants into the drains. The stenciled messages are generally a simple phrase to remind passersby that the storm drains connect to local waterbodies and that dumping pollutes those waters. Some storm drain stencils specify which waterbody the inlet drains to or name the particular river, lake, or bay. Commonly stenciled messages include: "No Dumping.

[49] **Appendix A** lists source control and pollution prevention measures for certain land uses, as well as snow disposal and deicing storage guidelines.

Drains to Water Source," "Drains to River," and "You Dump it, You Drink it. No Waste Here." Pictures can also be used to convey the message, including a shrimp, common game fish, or a graphic depiction of the path from drain to waterbody. Communities with a large Spanish-speaking population might wish to develop stencils in both English and Spanish, or use a graphic alone. **<**https://megamanual.geosyntec.com/npsmanual/bmpfactsheetmenu.aspx>

- **Proper operation and maintenance of septic systems***.* Knowledge of proper operation and maintenance of septic systems should be promoted to avoid serious failures.
- **Car Washing.** This management measure involves educating the general public, businesses, and municipal fleets (public works, school buses, fire, police, and parks) on the water quality impacts of the outdoor washing of automobiles and on how to avoid allowing polluted runoff to enter the storm drain system. Outdoor car washing has the potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions in many watersheds, as the detergent-rich water used to wash the grime off our cars flows down streets and into storm drains. Commercial car wash facilities often recycle their water or are required to treat their wash-water discharge prior to release to the sanitary sewer system. As a result, most stormwater impacts from car washing are from residents, businesses, and charity car wash fundraisers that discharge polluted wash water to the storm drain system. See **Appendix A** for vehicle washing information. **<**https://megamanual.geosyntec.com/npsmanual/bmpfactsheetmenu.aspx>
- **Commercial operations and activities,** including parking lots, gas stations, and other local businesses. Recycling, spill prevention and response plans, and proper material storage and disposal should be promoted. Using dry floor cleaners and absorbent materials and limiting the use of water to clean driveways and walkways should be encouraged. Care should be taken to avoid accidental disposal of hazardous materials down floor drains. Floor drains should be inventoried.
- **Department of Public Works Facilities (DPWs).** Because of the nature of the activities they perform, such as storing and managing sand, salt, and chemicals, and fueling and maintaining trucks and other equipment, DPWs are in a unique position to prevent a wide range of compounds from becoming stormwater pollutants. MassDEP has developed a Fact Sheet specifically for DPWs: **<**https://megamanual.geosyntec.com/npsmanual/bmpfactsheetmenu.aspx>
- Other efforts, including water conservation and litter control, can be tied to nonpoint source pollution control.

4.3.5 Local Bylaws and Regulations

Local bylaws, ordinances, and regulations are among the best mechanisms to institute many of the nonstructural controls described above, because they can cover a wide range of pollution prevention issues that fall below federal thresholds or for which no threshold exists. These bylaws are generally proposed by planning boards or Conservation Commissions, in consultation with other local officials. Stormwater bylaws and earth removal or sediment and erosion control bylaws are among the most common types of local initiatives. Stormwater bylaws establish requirements for site planning and pollution prevention plans in conjunction with design and construction activities, and give the local office authority on enforcement against Illicit Discharges into storm sewer networks. Earth removal or erosion and sediment control bylaws focus specifically on construction activities and controlling soil erosion problems. Many local boards of health have adopted pet waste control bylaws.

The EPA Region 1 and MassDEP jointly issued 2003 MS4 permit required that municipalities covered under the permit establish sediment and erosion control as well as Illicit Discharge enforcement bylaws by 2008. The EPA Region 1 and MassDEP jointly issued the 2016 MS4 permit and added a further requirement that all municipalities covered under the permit must establish a post-construction stormwater management bylaw by July 2021. This bylaw must require that all new development and Redevelopment projects remove a specified percentage of the average annual Total Suspended Solids and Total Phosphorus load from Impervious Surfaces of sites that are greater than 1 acre. The local authority may elect to create smaller size site thresholds for this pollutant removal requirement to capture a greater number of development projects and thereby work towards meeting TMDL requirements.

MS4 permittees that are not municipalities are known as non-traditional MS4 permittees and include public universities, departments of transportation, hospitals, prisons, and other state or federal facilities. In Massachusetts, these include MS4s owned and operated by the Commonwealth of Massachusetts, counties or other public agencies within the Commonwealth of Massachusetts, and properties owned and operated by the United States (Federal Facilities) within the Commonwealth of Massachusetts. These permittees may not have authority to enact an ordinance, by-law, or other regulatory mechanism. In this case, non-traditional MS4 permittees without the authority to enact an ordinance are required to create written policies or procedures to meet the requirements outlined in the permit related to sediment and erosion control, Illicit Discharges, and post-construction stormwater management by July 2021.

When a proposed project is within a MS4 and subject to approval pursuant to the Wetlands Protection or 401 WQC regulations for dredge and fill, the MS4 entity that is administering the bylaw/ordinance within the MS4 should coordinate with the Conservation Commission. Coordination ensures that the same set of rules will be applied, or if the rules are different, the more stringent rule will apply. For example, if the municipal planning board is the MS4 permitting authority for a new development proposed in a Riverfront Area, the planning board should coordinate with the Conservation Commission.

EEA's Smart Growth / Smart Energy Tool Kit (http://www.mass.gov/envir/smart_growth_toolkit/) includes model bylaws for LID development. Technical assistance with the development of local bylaws is available from the Massachusetts Coastal Zone Management Office, or the NRCS Community Assistance Program. Other groups such as regional planning agencies or nonprofit groups such as Massachusetts Association of Conservation Commissions or the Massachusetts Audubon Society may be able to provide assistance with bylaw development.

4.4 Structural Stormwater Control Measures

This section presents information about the structural Stormwater Control Measures (SCMs) that may be used to manage stormwater runoff in accordance with the Stormwater Management Standards. Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless impracticable. Other SCMs shall only be used to meet those portions Standard 3 (*i.e.,* Required Recharge Volume) and Standard 4 (*i.e.,* TSS / TP removal) that cannot be fully met by ESSD and LID techniques (see **Section 2.3.3** and **Section 2.3.4**). It is therefore recommended that project Applicants evaluate the feasibility of implementing ESSD techniques, LID techniques, and non-structural controls to the maximum extent practicable before proceeding with design of structural SCMs. See **Section 4.2** for more information on ESSD and LID techniques.

Project Applicants should consult this section when selecting and evaluating SCMs for a given development or Redevelopment. Conservation Commissions and other issuing authorities should become familiar with the information presented here to learn whether a SCM is appropriate for a Project Site, if a drainage system meets the Stormwater Management Standards, and what actions are required to operate and maintain the SCM.

Note that the SCMs described in this chapter address *post-construction* stormwater management. Refer to **Section 4.3.3** and **Appendix C** for information on construction period BMPs. Also note that **Section 5.3** provides additional information on evaluation of innovative and emerging stormwater management technologies such as proprietary separators.

4.4.1 The Classes of Structural SCMs

Structural SCMs are grouped according to the principal methods of stormwater management: pretreatment, treatment, conveyance, and infiltration. *Some SCMs fall into several categories, because they serve several functions*. For example, some bioretention areas are designed to act as a filter (*i.e.,* "filtering bioretention areas"), and others are designed to infiltrate (*i.e.,* "exfiltrating bioretention areas"). A brief description of each structural SCM class is provided below. Refer to **Appendix A** for specifications for individual structural SCMs. **Table 2-7** summarizes the ability of each SCM to meet specific Stormwater Standards, including whether pretreatment is required.

Structural Pretreatment SCMs

The first SCMs in a treatment train typically remove the coarse sediments that can clog other SCMs. The settling process generates sediment that must be routinely removed. Maintenance is especially critical for pretreatment SCMs, because they receive stormwater containing the greatest concentrations of suspended solids during the first flush. Some pretreatment devices such as the Oil Grit Separator are required to pretreat the runoff from certain land uses with higher potential pollutant loads, such as gas stations and high intensity use parking lots[50]. The most common pretreatment SCMs include: Deep Sump Catch Basins, Oil Grit Separators, Proprietary Separators, Sediment Forebays, and Vegetated Filter Strips.

Pretreatment SCMs can be configured as on-line or off-line devices. On-line systems are designed to treat the entire water quality volume. Off-line practices are typically designed to receive a specified discharge rate or volume. A flow diversion structure or flow splitter is used to divert the design flow to the off-line practice. To receive TSS removal credit, oil grit separators and deep sump catch basins must be configured as off- line devices.

Structural Treatment SCMs

Structural Treatment SCMs are generally referred to as Gray Infrastructure. Gray Infrastructure was developed in the 1950's mainly to shunt runoff off roadways as quickly as possible, and to control the peak runoff rate. Newer structural treatment measures may fall under a category known as Green Infrastructure (*e.g.,* gravel wetlands). Refer to **Table 4-1** for a list of MassDEP recognized Green Infrastructure SCMs. There are three main types of Treatment SCMs: 1) Stormwater Treatment Basins; 2) Constructed Stormwater Wetlands; and 3) Filtration SCMs. They are more specifically described below.

- **Stormwater Treatment Basins:** These SCMs provide peak rate attenuation by detaining stormwater and settling out suspended solids. The basins that are most effective at removing pollutants have either a permanent pool of water or a combination of a permanent pool and extended detention, and some elements of a shallow marsh. Stormwater treatment basins include Extended Dry Detention Basins and Wet Basins.
- **Constructed Stormwater Wetlands:** Constructed stormwater wetlands are designed to maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention, and settling. There are five basic constructed stormwater wetlands: shallow marsh systems, basin / wetland systems, extended detention wetlands, pocket wetlands, and gravel wetlands. Gravel wetlands remove pollutants by filtering stormwater through a gravel substrate.
- **Filtration SCMs**: Filtration systems use media to remove particulates from runoff. They are typically used when circumstances limit the use of other types of SCMs, such as where space is limited–particularly in a highly urbanized setting–or when it is necessary to capture particular industrial or commercial pollutants (*e.g.,* hydrocarbons). In these circumstances, other SCMs might be cost-prohibitive or not as effective. Filtered runoff may be collected and returned to the conveyance system, or allowed to partially exfiltrate into the soil. Filtration SCMs include: Filtering Bioretention Areas and Rain Gardens, Proprietary Media Filter, Sand Filters/Organic Filters, and Treebox Filter.

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[51] Additional information on retrofitting stormwater SCMs can be found in the Urban Stormwater Retrofit Practices Manual. See https://owl.cwp.org/?mdocs-file=5456.

Structural Conveyance SCMs

Structural conveyance SCMs collect and transport stormwater to other SCMs for treatment and/or infiltration. These practices may also treat runoff through infiltration, filtration, or temporary storage. A water quality swale usually functions as a runoff conveyance channel and a filtration practice. The vegetation or turf also prevents erosion, filters sediment, and provides some nutrient uptake benefits. Conveyance SCMs include: Drainage Channels, Grass Channels, and Dry and Wet Water Quality Swales.

Infiltration SCMs

Infiltration systems are designed primarily to reduce the quantity of stormwater runoff from a particular site. Infiltration techniques reduce the amount of surface flow and direct the water back into the ground. Infiltration practices typically cannot provide channel protection and overbank or extreme flood detention storage. Infiltration SCMs include: Exfiltrating Bioretention Areas and Rain Gardens, Dry Wells, Infiltration Basins, Infiltration Trenches, Leaching Catch Basins, Porous Pavement, and Subsurface Infiltrators

Other SCMs

Some structural SCMs do not fit into any of the categories set forth above. These SCMs include the following: Dry Detention Basins, Green Roofs, and Rain Barrels and Cisterns.

Accessories

SCM accessories are devices that enable SCMs to operate as designed. SCM accessories include the following: Check Dams, Level Spreaders, Outlet Structures, Catch Basin Inserts, and other miscellaneous features such as Aprons.

4.4.2 The Structural SCM Selection Process

Once ESSD and LID techniques, pollution prevention, and source control measures have been planned, if necessary, Applicants should integrate structural SCMs into design of the overall Stormwater Management System. For the most part, structural SCMs are engineered systems that are typically made of natural materials such as grass and plants, or manufactured materials like steel, fiberglass, and concrete. They act as the last line of defense in protecting the Commonwealth's waters from stormwater pollution. Structural SCMs can be highly effective in removing pollutants from stormwater if properly designed and maintained.

The following sections provide guidance for choosing appropriate structural SCMs for a site by explaining the basic considerations for their use.

Initial Site Planning Considerations

When designing a Stormwater Management System for any site, the project Applicant, working together with planners and design engineers, should ask the following questions:

- How can the Stormwater Management System be designed to meet the standards for stormwater quantity and quality most effectively?
- What are the opportunities to meet the stormwater quality standards and the stormwater recharge and peak discharge standards simultaneously?
- What opportunities exist to use comprehensive site planning to minimize the need for structural controls?

- To what extent can Environmentally Sensitive Site Design (ESSD) and Low Impact Development techniques (LID) be incorporated to minimize or eliminate the required implementation extent of Structural SCMs?
- Are there Critical Areas on or adjacent to the Project Site?
- Does the project involve stormwater discharges from land uses with higher potential pollutant loads?
- What are the physical site constraints?
- Given the site conditions, which SCM types are most suitable?
- What type of development is being proposed and what pollutants does this land use typically generate?
- Is the future maintenance reasonable and acceptable for this type of SCM?
- Has adequate access been provided for maintenance?
- Is the SCM option cost-effective?
- Does the stormwater discharge near or to an impaired surface water?
- Has a TMDL been developed?
- Are SCMs available to remove the pollutant of concern?

The project Applicant should consider whether a system of several SCMs is more appropriate for a site than a single SCM structure. Too often, stormwater controls are added to a site plan in its final stages. When planning for stormwater management is done as an afterthought, Applicants are not likely to select the most environmentally appropriate and cost-effective practices for controlling runoff.

By engaging in early planning, the Applicant can focus on the entire site and identify the best available locations for reducing, infiltrating and treating runoff. Early stormwater management planning can also allow the Applicant to combine SCMs into treatment trains. With a treatment train, one or more of the measures can fail without undermining the integrity of the overall site control strategy.

Including stormwater management in the early stages of the planning process gives Applicants the opportunity to consider whether a decentralized system comprised of SCMs scattered throughout the site may provide greater environmental benefits at less cost than a centralized system that transports all runoff to a single location for treatment and disposal. Through early planning, an Applicant may discover that a decentralized system that uses dry wells for roof runoff, relies on water quality swales rather than curbs and gutters to convey street runoff to additional SCMs, and installs infiltration trenches in front of an extended dry detention basin, is the most cost-effective and environmentally protective approach to achieving compliance with the Stormwater Management Standards. See **Section 4.2** and **Appendix A** for information on ESSD, small scale controls, and decentralized planning.

Stormwater Quantity Management

For new development and Redevelopment, existing conditions are assessed and compared to post-development. For new development, approximating a site's pre-development hydrology, including the natural cover, is the primary goal of stormwater quantity management. A site's post-development hydrology can be controlled through a combination of stream bank/channel erosion control (2-year 24-hour storm events) and flood control (10-year 24-hour and 100-year 24-hour storm events). **Table 2-7** indicates the types of quantity controls provided by specific SCMs. For Redevelopment, the analysis relies on existing conditions. However, to meet 310 CMR 10.05(6)(o), an improvement to existing conditions must be demonstrated. This means that even if there is no increase in peak runoff rate between existing and proposed conditions, a Redevelopment project must reduce the peak runoff rate to demonstrate that there will be an improvement to existing conditions.

Stormwater Quality Management

When designing Stormwater Management Systems and screening SCM technologies to meet the water quality management standards, ask the following questions:

- Does runoff from the project drain to or near a sensitive resource or Critical Area?
- Is runoff from a LUHPPL?
- Based on existing and post-development conditions, what is the volume of stormwater to be treated for water quality?
- What is the best combination of ESSD practices and SCMs to achieve required TSS and TP removal percentages on an average annual basis?
- Does the stormwater discharge impact an impaired surface water? If so, what pollutants are the cause of that impairment? Which SCMs can remove that pollutant?

Table 2-7 indicates the types of pollutant removal provided by specific structural SCMs and includes of summary of suitability by land use type (*i.e.,* LUHPPLs and Critical Areas). An Applicant must also consider additional pollutants if the development or Redevelopment will affect a surface water that is the subject of a Total Maximum Daily Load (TMDL) that indicates the concentrations of certain pollutants in stormwater runoff must be reduced. In that event, the Applicants must design, construct, operate and maintain a Stormwater Management System that is consistent with the TMDL. See **Table 2-6** for a list of structural SCMs that are suitable for treating specific target TMDL pollutants.

Stormwater Recharge

When designing Stormwater Management Systems to meet the recharge standard, ask the following questions:

- Based on existing and post-development conditions, what is the volume of stormwater to be recharged to groundwater?
- Will the infiltration SCM exfiltrate stormwater to the ground within a Zone II or Interim Wellhead Protection Area or an area with a rapid infiltration rate (greater than 2.4 inches per hour)?
- Is the infiltration SCM near or proposed to discharge to a Critical Area (see Standard 6)? If yes, setbacks must be met.
- What is the distance between the recharge practice and BVW, Land Under Water and Waterbodies, Land Under Ocean, Salt Marsh, or other water of the United States within the Commonwealth? Are setbacks met?
- What is the distance is private drinking water wells or subsurface wastewater treatment systems (Title 5 septic systems)? Are setbacks met in accordance with **Section 2.5**?
- What pretreatment measures are needed to ensure that the infiltration SCM can continue to operate as designed?

Table 2-7 indicates the types of pollutant removal provided by specific structural SCMs and includes of summary of suitability by land use type (*i.e.,* LUHPPLs and Critical Areas). Also refer to **Section 2.5** for a summary of required setbacks.

Site Suitability/SCM Suitability

In choosing an effective SCM system, it is necessary to determine the most suitable combinations of SCMs based on the characteristics of the site. The basic site requirements for each structural SCM are included in the technical specifications (**Appendix A**). Site suitability is a major factor in choosing SCMs.

Physical constraints at a site may include soil conditions, watershed size, depth to water table, depth to bedrock and slope. For Redevelopment projects, physical constraints may include compacted soils or the presence of underground utilities. In some cases, a SCM may be eliminated as an option because of site constraints. Often, however, SCMs can be modified or combined with other SCMs and adapted to site conditions to create an efficient system capable of meeting the Stormwater Management Standards.

The following subsections briefly address the physical site conditions that affect SCM selection.

Soil Suitability

Generally, dry detention basins and extended dry detention basins are suitable in a broad range of soil conditions, but wet basins may have difficulty maintaining water levels in very sandy soils. Soil type is of particular importance to infiltration SCMs. Infiltration practices sited in soils with low permeability require a larger bottom area to infiltrate the required volume over a 72-hour period. Where infiltration practices are planned, confirm that the soils have adequate permeability. See **Section 6.3** for a summary of required soil evaluation procedures.

Drainage Area/Watershed to be Served

The size of the contributing area may be a limiting factor in selecting the appropriate SCM practices. Recommendations for appropriate contributing watershed areas are included in the discussion for each technology. Proper site planning can often overcome area constraints. Basins typically require large contributing drainage areas in order to function properly, while infiltration SCMs require smaller drainage areas. For technologies that require large contributing watersheds, additional offsite runoff may be routed to the SCM to increase flows. Conversely, portions of the total runoff can be routed to smaller individual SCMs to allow for the use of lower capacity SCMs. Keep in mind that some SCMs may have more rigorous maintenance and inspection requirements. Drainage area for peak runoff rate includes offsite areas that contribute runoff to a site. The Drainage area for Standards 3 and 4 include just the impervious areas on site. Refer to **Section 6.5** for information on identifying and calculating impervious areas.

Depth to Water Table

Depth to the seasonal high groundwater table is an important factor for stormwater treatment practices, especially infiltration SCMs. If the seasonal high groundwater table extends to within two feet of the bottom of an infiltration SCM, the site is seldom considered suitable. In such instances, porous media may be placed to achieve the required 2-foot separation (see **Section 2.5**). The groundwater table acts as an effective barrier to exfiltration through the SCM media and soils below and can prevent an infiltration SCM from draining properly. Depending on soil conditions, depth to the groundwater table is also an important factor in reducing the risk of microbial contamination. For constructed stormwater wetlands and wet basins, a groundwater table at or near the surface is desirable. Areas with high groundwater tables are generally more conducive to siting these types of SCMs.

Depth to Bedrock

The depth to bedrock (or other impermeable layers) is a consideration for siting facilities that rely upon infiltration. Bedrock impedes the downward exfiltration of stormwater and prevents infiltration SCMs from draining properly. An area is generally not suitable for infiltration SCMs, if bedrock is within two feet of the bottom of the SCM (see **Section 2.5**). Similarly, stormwater basin SCMs are not feasible if shallow bedrock lies beneath the area to be excavated.

Slopes

Site slopes restrict the types of SCM that can be used. Water quality swales and infiltration trenches are not practical when slopes exceed 20%. To achieve water quality benefits and credit for pollutant removal, Applicants may not site water quality swales or grass channels on slopes greater than 5%. Where there are steeper slopes, the Stormwater Management System must be carefully designed to prevent stormwater runoff from bypassing the treatment SCMs and causing erosion and off-site flooding. In addition, siting systems near the toe of slope may also cause failure by seepage of groundwater into the treatment system. This applies to both recharge and other types of treatment systems.

Thermal Enhancement

The water in wet basins and constructed stormwater wetlands warms up rapidly in summer. Warm water released from SCMs can be lethal to cold-water aquatic organisms (e.g., cold-water fish in rivers and streams) and organisms that live in Vernal Pools. Do not use wet basins and CSWs SCMs in areas adjacent to designated cold-water streams. See **Table 2-4b** (for Vernal Pools) and **Table 2-4d** (for Cold-Water Fisheries) which limit SCMs that can be utilized in cold-water Resource Areas and vernal pools.

Proximity to Critical Animal Habitats or Endangered Species

Some SCMs can be lethal traps for small animals such as frogs, salamanders, and turtles. Sediment forebays and dry detention basins with excessively steep or vertical side slopes (e.g., concrete steps) or improperly located catch basins can prevent a trapped animal from escaping. ESSD and LID techniques may be more suitable for managing stormwater while at the same time, protecting indigenous animal populations and rare and endangered species. Elevate any fencing around a stormwater SCM at least 6-inches above the ground, to allow for passage of small mammals.

Proximity to Septic Systems and Water Supplies

When evaluating the suitability of infiltration SCMs such as infiltration trenches, infiltration basins and dry wells, it is critical to consider setback requirements mandated under other state programs such as those addressing septic systems and drinking water supplies. See **Section 2.5** for more information on setback requirements.

Proximity to Foundations

Infiltration of stormwater can cause seepage into foundations when SCMs are located too close to buildings; MassDEP requires a setback of at least 10 feet for all types of pretreatment and treatment practices (except for green roofs and rain barrels), and greater setbacks up to 100 feet for infiltration SCMs. See **Section 2.5** for more information on setback requirements.

Public Acceptance

Aesthetics are important in gaining acceptance of SCMs. SCMs can either enhance or degrade the amenities of the natural environment and the adjacent community. Careful planning, landscaping and maintenance can make a SCM an asset to a site. Frequently, ownership and maintenance responsibilities for SCMs in new developments fall on adjacent property owners. If adjacent residents will be expected to pay for maintenance, education and acceptance of the SCM are necessary.

4.4.3 SCM Treatment Trains

SCMs in series incorporate several stormwater treatment mechanisms in sequence to enhance the treatment of runoff. Known as “stormwater treatment trains,” they consist of a combination of source control measures, ESSD / LID features, and structural SCMs to maximize pollutant removal and subsurface recharge. Combining nonstructural and structural measures in series rather than using a single method of treatment improves the levels and reliability of pollutant removal. The effective life of a SCM can be extended by combining it with pretreatment SCMs, such as a vegetated filter strip or sediment forebay, to remove sediment prior to treatment in the downstream “units.” Sequencing SCMs can also reduce the potential for re-suspension of settled sediments by reducing flow energy levels or providing longer flow paths for runoff. Refer to **Section 4.2** for more information on the incorporating of

ESSD techniques into site designs and to **Appendix A** for Fact Sheets that describe specific techniques in detail.

The most suitable components for a treatment train depend on the pollutants to be removed. Pollutants in stormwater fall into two groups: suspended solids and dissolved pollutants. Particle sizes greater than 0.45 micron are considered suspended solids. Pretreatment SCMs (*e.g.,* sediment forebay, oil grit separator) are ordinarily designed to remove suspended solids that have larger particle sizes than the dissolved solids removed by treatment practices that rely on settling (*e.g.,* extended dry detention basins and wet basins s) or filtration (*e.g.,* sand filters and filtering bioretention areas).

There are many combinations of structural SCMs that can be placed in a treatment train to maximize suspended solids removal. According to Minton (2006), some of the more common ones include:

- A sediment forebay discharging to a wet basin flowing into a constructed stormwater wetland
- A water quality swale flowing into a wet basin or a constructed stormwater wetland
- An oil grit separator connected to a sand or organic filter
- A sediment forebay discharging to an extended dry detention basin connected to a sand filter
- A water quality swale discharging to a vegetated filter strip connected to an infiltration trench.

4.4.4 SCMs for by Land Uses with Higher Potential Pollutant Loads

Certain SCMs are more suitable for some land uses than others. Some types of urban land uses contribute higher than normal pollutant loadings of solvents, oils, lubricants, fertilizers, grease, and/or bacteria. **Table 2-3** presents the applicability and use of SCMs for various land uses with higher potential pollutant loads.

4.4.5 Redevelopment Projects

Refer to **Section 2.3.7** for definition and more information on Redevelopment project requirements. Redevelopment project requirements are found at 310 CMR 10.05(6)(k)7. and 314 CMR 9.06(6)(a)7. There are fewer stormwater SCM options for heavily urbanized areas compared to less urbanized areas, because of the restrictions inherent in building in urbanized areas. The primary barrier is space, or more precisely, lack of space.

This limitation eliminates many space-intensive options (*e.g.,* extended dry detention basins) and makes SCMs that have smaller "footprints" more attractive (*i.e.,* small scale controls). Environmentally Sensitive Site Design or Low Impact Development practices must be used for Redevelopment. The highest practicable level of Environmentally Sensitive Site Design and Low Impact Development practices must be implemented. For example, in some cases, Redevelopments can reduce impervious areas to establish or expand vegetative buffers between a site and wetlands (see **Appendix A** for ESSD Credits that are applicable to Redevelopment projects). In other instances, the size of parking stalls in a parking lot may be able to be reduced, so overall, the amount of pervious area on a site can be increased. See **Section 4.2** for information on ESSD techniques and **Appendix A** for Fact Sheets that describe specific ESSD techniques in more detail.

Engineering Concerns

It is not acceptable for Redevelopments to rely on the existing municipal drainage system to meet the Stormwater Management Standards. The peak runoff rate must be reduced for Redevelopment projects in order to demonstrate an improvement. This means the peak runoff reduction must occur before the runoff is directed to a municipal drain. However, it is recognized that some runoff on Redevelopment sites may be reconfigured and be directed to existing municipal drains. Whenever new runoff is to be directed to a municipal storm drain, Applicants must obtain permission from the MS4 or municipality, evaluate the existing drainage system to determine its maximum flow rate, and its capacity to accept new drainage to avoid overloading the existing system. Overloading an existing drainage network can lead to surcharging, cause localized flooding, and scour of wetlands below the outlet.

SCM selection must include engineering considerations such as available head, hydraulic grade lines, and the presence of pipeline bottlenecks that may cause surcharging and worsen localized flooding.

The presence of other utilities in streets, such as natural gas lines, water mains, electric cable conduits, and sanitary sewers, must also be evaluated. These may limit increasing the size of a stormwater drainage pipe, can greatly reduce the amount of land available for Redevelopment SCMs, or limit the ability to excavate, making SCM siting and sizing difficult.

Suitable SCMs for Redevelopment Projects

Given these constraints, the most suitable SCMs for Redevelopment generally include, in order of preference:

- ESSD techniques and Green Stormwater Infrastructure Practices (see **Section 4.2**), including ESSD Credits provided in **Appendix A**;
- nonstructural practices and source control such as street sweeping (see **Section 4.3**); and
- structural SCMs with limited footprints (See **Table 2-7**).

Appendix E provides a detailed "Redevelopment Checklist" to help Conservation Commissions and Applicants determine which SCMs are most appropriate for Redevelopment in each case and what types of improvements they provide.

Additional references and links for Redevelopment Projects:

U.S. Department of Transportation, Federal Highway Administration Stormwater BMPs in an Ultra-Urban Setting: Selection and Monitoring: https://www.environment.fhwa.dot.gov/Env_topics/water/ultraurban_bmp_rpt/3fs15.aspx

California Stormwater Quality Association BMP Handbooks | California Stormwater Quality Association (casqa.org)

Center for Watershed Protection, Urban Stormwater Retrofit Manual (http://www.wrc.udel.edu/wp-content/uploads/2017/02/Urban-Stormwater-Retrofit-Manual-3.pdf)

4.4.6 Maintenance Requirements

An Operation and Maintenance Plan is required to be prepared and submitted with the NOI and/or WQC application pursuant to 310 CMR 10.05(6)(k)9. and 314 CMR 9.06(6)(a)9. **Section 2.3.9** provides more information on Operation and Maintenance requirements, including a detailed list of items to include in the Operation and Maintenance Plan.

The Structural SCM Specifications also include the basic maintenance requirements for each control (**Appendix A**). The maintenance requirements for SCMs must be considered during the selection process. Because maintenance is mandatory, it is logical that SCM selection should gravitate toward measures that are more easily maintained. In general, SCMs installed *above ground* are easier to maintain than ones placed *underground.* Further, SCMs that incorporate *natural vegetation* as part of the pollutant removal process, such as bioretention areas, require less maintenance than *engineered and pre-fabricated systems*. For most SCMs, the maintenance requirements include visual inspections (*e.g.,* inspection of sediment forebays) and physical upkeep (*e.g.,* removing and disposing of sediment, and mowing water quality swales).

5 Miscellaneous Stormwater Topics

This chapter covers the following subjects:

- Retrofits to existing stormwater management measures.
- Special considerations for retrofit projects.
- Proprietary manufactured stormwater control measures.
- Mosquito control measures that minimize breeding in stormwater treatment practices.
- Stormwater management practices for solar arrays.
- Public shared used paths converted from former railway beds.
- State highway design considerations.

5.1 Retrofitting Existing Stormwater Management Measures

5.1.1 Introduction

What are Retrofits?

For purposes of stormwater management, Retrofits are site specific changes designed solely to improve water quality, reduce peak runoff rates, increase recharge, or reduce or eliminate combined sewer overflows (CSO). Retrofits are not a component of new development, or maintenance.

How can Retrofit Projects Comply with the Stormwater Standards?

Retrofit projects shall comply with Stormwater Management Standards 1, 5, 6, 8, 9, and 10. Retrofit projects shall not have to comply with Standard 2, 3, 4, and 11, except they must improve existing conditions for at least peak runoff rate, recharge, or water quality treatment. Retrofits must meet setback requirements are summarized by **Section 2.5**.

Refer to the 2022 New England Stormwater Retrofit Manual for more information on stormwater retrofits: https://snepnetwork.org/stormwater-retrofit-manual/.

Retrofitting existing SCMs can reduce some of the adverse stormwater quantity and quality impacts caused by existing land developments. For example, beginning in the 1970s, many new developments were constructed with dry detention basins. Many of these facilities were built to attenuate the peak flow impacts of the 10-year, 25-year, and/or 100-year 24-hour storms. Because smaller storms are typically responsible for degrading water quality and eroding stream banks, it makes sense to retrofit such facilities to control these smaller storm events.

Another important benefit of retrofitting stormwater management facilities is the opportunity to correct site nuisances, maintenance problems, and aesthetic concerns. Retrofitting also allows a community to keep pace with new stormwater management regulations and objectives. It can help a community address a particular stormwater quantity or quality problem that has developed as a result of deficiencies in existing stormwater management facilities, or a basin-wide problem that has been identified in a TMDL. Constructing new Stormwater Management Systems at future land development sites will not be sufficient to bring all the Waters of the Commonwealth into compliance with the state’s water quality standards.

5.1.2 Planning Considerations

In addition to basic considerations such as need and cost, two important factors should be considered when evaluating retrofit possibilities: 1) health and safety; and 2) effectiveness. Review these factors thoroughly before undertaking a stormwater management measure retrofit to justify the cost and effort and ensure the retrofit's long-term success.

Health and Safety

A retrofit should not increase health and safety risks in any way. For example, the storage volume in an existing dry detention basin presently used for stormwater quantity control must not be reduced to provide new stormwater quality enhancement without ensuring that the lost quantity storage will not adversely increase peak basin outflows and cause downstream flooding or erosion.

Effectiveness

In many retrofit situations, it may not be possible to upgrade the stormwater management measure to meet all current groundwater recharge and stormwater quality and quantity standards. This means that relative performance improvements for a range of retrofits should be evaluated to determine which one represents the optimum combination of effectiveness, viability, and cost. The final retrofit selected for an existing stormwater measure will have to be based on its relative rather than absolute effectiveness. In such relative determinations, both the costs and benefits of the evaluated retrofits become more influential factors than when an absolute performance standard is used. The section below provides guidance on the SCMs and land use types that may be most suitable for retrofitting.

5.1.3 Retrofits to Specific Land Use Types and Existing SCMs

Many SCMs or land uses can be effectively retrofitted depending on site conditions and the water quantity or quality objectives trying to be achieved.[51] The objective of stormwater retrofitting is to remedy problems associated with, and improve water quality mitigation functions of, older, poorly designed, or poorly maintained Stormwater Management Systems. Prior to the development of the stormwater standards, site drainage design did not require stormwater detention for controlling post-development peak flows. As a result, drainage, flooding, and erosion problems can be common in many older developed areas of the state. Furthermore, most of the dry detention basins throughout the state have been designed to control peak flows, without regard to water quality mitigation. Therefore, many existing dry detention basins provide only minimal water quality benefit. Incorporating stormwater retrofits into existing developed sites or into Redevelopment projects can reduce the adverse impacts of uncontrolled stormwater runoff.

This section describes installing peak runoff rate reduction, recharge, and water quality treatment controls where none exist or by modifying existing previously installed controls. Retrofits are discussed for land uses first and then retrofits to existing stormwater controls second.

Landscaped Areas, Parking Lots, and Roadways

Parking lots, landscaped areas, and certain roadways offer ideal opportunities for a wide range of stormwater retrofits:

1. Incorporate bioretention areas into parking lot islands and landscaped areas; tree planter boxes can be converted into functional bioretention areas, rain gardens, or treebox filters to reduce and treat stormwater runoff.

[51] Additional information on retrofitting stormwater SCMs can be found in the Urban Stormwater Retrofit Practices Manual. See https://owl.cwp.org/?mdocs-file=5456.

2. Remove curbing and add slotted curb stops. Curbs along the edges of parking lots can sometimes be removed or slotted to re-route runoff to vegetated filter strips, water quality swales, grass channels, or bioretention facilities. The capacity of existing swales may need to be evaluated and expanded as part of this retrofit option.
3. Incorporate new treatment practices such as bioretention areas, sand filters, and constructed stormwater wetlands at the edges of parking lots.
4. Catch basin sumps can be deepened and hoods added. Grates that allow trash to pass through can be replaced with grates with smaller orifices.
5. Curb guards can be installed in vertical curb faces to prevent trash from bypassing the horizontal inlet grates.
6. In overflow parking or other low-traffic areas, asphalt can be replaced with porous pavement.
7. Older catch basins without sumps can be replaced with catch basins having four-foot-deep sumps. Sumps provide storage volume for coarse sediments, assuming that accumulated sediment is removed on a regular basis. Hooded outlets, which are covers over the catch basin outlets that extend below the standing water line, can also be used to trap litter and other floatable materials. Leaching catch basins can be installed adjacent to deep sump catch basins to achieve pollutant removal. Be aware, however, that many products are being touted as catch basin inserts, but the effectiveness of these devices can vary significantly.

Dry Detention Basin Retrofits

Traditional dry detention basins can be modified to become extended dry detention basins, wet basins, or constructed stormwater wetlands for enhanced pollutant removal. This is one of the most commonly and easily implemented retrofits, since it typically requires little or no additional land area, capitalizes on an existing facility for which there is already some resident acceptance of stormwater management, and involves minimal impacts to environmental resources (Claytor, Center for Watershed Protection, 2000).

There are numerous retrofit options that will enhance the removal of pollutants in detention basins:

- Excavate the basin bottom to create more permanent pool storage.
- Raise the basin embankment to obtain additional storage for extended detention.
- Modify the outfall structure to create a two-stage release to better control small storms while not significantly compromising flood control detention for large storms.
- Increase the flow path from inflow to outflow and eliminate short-circuiting by using baffles, earthen berms or micro-pond topography to increase residence time.
- Incorporate stilling basins at inlets and outlets.
- Regrade the basin bottom to create a wetland area near the basin outlet or revegetate parts of the basin bottom with wetland vegetation to enhance pollutant removal, reduce mowing, and improve aesthetics.
- Create a wetland shelf along the perimeter of a wet basin to improve shoreline stabilization, enhance pollutant filtering, and enhance aesthetic and habitat functions.
- Create a low maintenance “no-mow” wildflower ecosystem in the drier portions of the basin.
- Provide a high flow bypass to avoid resuspension of captured sediments/pollutants during high flows.
- Eliminate low-flow bypasses.

Drainage Channel Retrofits

Existing channelized streams and drainage conveyances such as drainage channels can be modified to reduce flow velocities and enhance pollutant removal. Weir walls or riprap check dams placed across a channel create opportunities for ponding, infiltration, and establishment of wetland vegetation upstream of the retrofit. In-stream retrofit practices include stream bank stabilization of eroded areas and placement of habitat improvement structures (*i.e.,* flow deflectors, boulders, pools/riffles, and low-flow channels) in natural streams and along stream banks. In-stream retrofits may require an evaluation of potential flooding and floodplain impacts resulting from altered channel conveyance, as well as requirements for local, state, or federal approval for work in wetlands and watercourses.

Sand Filter Retrofits

Sand Filter Retrofits are suitable where space is limited, because they consume little surface space and have few site restrictions. Since sand filters cannot treat large drainage areas, retrofitting many small individual sites may be the only option. This option may be expensive.

Storm Drain Outfalls

New stormwater treatment practices can be constructed at the outfalls of existing drainage systems. The new stormwater treatment practices are commonly designed as *off-line devices* to treat the first flush volume and bypass larger storms. Water quality swales, bioretention areas, sand filters, constructed stormwater wetlands, and wet basins are commonly used for this type of retrofit. Other stormwater treatment practices may also be used if there is enough space for construction and maintenance.

5.2 Special Considerations for Redevelopment Projects

Redevelopment projects present unique challenges for controlling stormwater. It is possible that site constraints may prevent a Redevelopment project from complying with one or more of the Stormwater Management Standards. Even if a Redevelopment project cannot meet all of the Standards, there may be ample opportunity to improve existing site conditions depending on the other water quality or quantity issues in the watershed. Refer to **Section 2.3.7** for Redevelopment project requirements and to **Section 6.2.7** for other Redevelopment project resources.

The remainder of this section describes special considerations that provide unique opportunities to improve existing conditions.

5.2.1 Groundwater Recharge Areas

Redevelopment projects located within Groundwater Recharge Areas (Zone II, Interim Wellhead Protection Areas (IWPA), aquifer protection districts, etc.) should place a high priority on ground water recharge SCMs.

- **Disconnecting Rooftop Runoff:** In some instances, building roof drains connected to the stormwater drainage system can be disconnected and re-directed to vegetated filter strips, bioretention facilities, or infiltration structures (dry wells or infiltration trenches). There is also an ESSD Credit available for disconnecting rooftop runoff and re-directing it to a qualifying pervious area (see **Appendix A**, ESSD Credit 3).
- **Use of Porous Paving Materials:** Existing impermeable pavement in overflow parking or other low-traffic areas can sometimes be replaced with alternative permeable materials such as modular concrete paving blocks, modular concrete or plastic lattice, or cast-in-place concrete grids. Site-specific factors including traffic volumes, soil permeability, maintenance, sediment loads, and land use should be carefully considered prior to selection.
- Use other ESSD and LID techniques and available ESSD Credits (see **Appendix A**).

5.2.2 Cold-Water Fisheries

Redevelopment projects adjacent to Cold-Water Fisheries should place a high priority on mitigating potential thermal impacts. Techniques to consider include:

- **Maintain Time of Concentration:** Time of concentration (Tc) is based on the flow path and length, ground cover, slope and channel shape. When development occurs, Tc is often shortened due to the impervious area, causing greater flows to occur over a shorter period of time. Increasing the Tc will help to reduce the thermal impact of stormwater runoff from warm surface areas. Options to consider include:
  - Increasing the length of the runoff flow path.
  - Increasing the surface roughness of the flow path.
  - Detaining flows on site.
  - Minimizing land disturbance.
  - Creating flatter slopes.
- **Disconnecting Impervious Areas**: Breaking up large impervious expanses with vegetated zones will reduce the potential temperature increases of stormwater flowing across hot pavement. There are also ESSD Credits available for disconnecting Impervious Surfaces and re-directing them to a qualifying pervious area (see **Appendix A,** ESSD Credit 3 and ESSD Credit 4.).
- Use other ESSD and LID techniques and available ESSD Credits (see **Appendix A**). For example: increase tree canopy over Impervious Surfaces (ESSD Credit 5), implement ESSD to reduce the overall impervious cover of the site (ESSD Credit 7), and expand or enhance the existing buffer area (ESSD Credit 8).

5.2.3 Brownfield Redevelopment

Redeveloping urban and non-urban Brownfield Sites (which in Massachusetts includes most "disposal sites" under the Massachusetts Contingency Plan [MCP]) are a Commonwealth priority, with ramifications for urban sprawl as well as the remediation of historically contaminated properties. Applicants of Brownfield Redevelopment projects should evaluate SCMs that will prevent the significant uncontrolled mobilization or remobilization of soil or ground water contamination. SCM considerations at these sites should consider such factors as:

- The location of stormwater infiltration units with respect to contaminated areas.
- Ground water mounding effects on the rate and direction of migration of ground water contaminants
- The location of outfalls.
- Water quality SCMs.

5.2.4 Runoff to Waters Identified as Impaired

Projects that discharge stormwater to waterbodies or waterways for which a Total Maximum Daily Load (TMDL) has been developed by MassDEP and approved by the Environmental Protection Agency (EPA) must be designed to implement control measures for the specified pollutants causing the impairment in accordance with Standard 11. Refer to **Section 2.3.11** for requirements.

5.2.5 Runoff to Areas of Localized Flooding

Project Applicants must also understand the potential impacts of runoff in areas prone to localized stormwater flooding and river or coastal flooding (*e.g.,* Bordering Lands Subject to Flooding and Lands

Subject to Coastal Storm flowage). For example, stormwater drainage systems located in BLSF or LSCSF may not function when flooded. When completing the Redevelopment checklist (see **Appendix E**), Applicants should consider the capacity of the receiving water and/or storm drainage system, including tailwater effects. When evaluating discharges to areas subject to localized stormwater flooding or river or coastal flooding, the Applicant should evaluate the ability to maintain and/or improve existing site cover and reduce runoff volume.

5.3 Proprietary Manufactured Stormwater Control Measures

5.3.1 Background

What are Proprietary Manufactured SCMs?

Proprietary Manufactured Stormwater Control Measures (SCMs) are manufactured systems that use gravity separation, filtration, absorption/adsorption, vortex principles, coagulation, biological processes (*e.g.,* nutrient uptake by vegetation), and other unit processes to meet the Stormwater Management Standards. There are two main types of Proprietary Manufactured SCMs currently utilized in Massachusetts and included in the Stormwater Handbook: 1) Proprietary Manufactured Separators and 2) Proprietary Manufactured Media Filters (see **Appendix A** for specifications).

What are the Regulatory Requirements for Proprietary Manufactured SCMs?

As indicated by 310 CMR 10.05(6)(k)4.e, when a proprietary manufactured separator, proprietary media filter, or other treatment practice is proposed for which no Total Suspended Solid or Total Phosphorus removal credit has been designated by **Table 2-2** (Table TSS / TP), written documentation shall be submitted to the Issuing Authority with the Notice of Intent substantiating the removal percentages being claimed. The Issuing Authority shall review the written documentation on a case-by-case basis and shall have the discretion to approve or deny the use of the proposed stormwater control measure to meet or partially meet the TSS and TP pollutant requirements specified at 310 CMR 10.05(6)(k)4., 10.05(6)(k)4.d., and 10.05(6)(k)7.c. However, proprietary manufactured practices designated as pretreatment practices shall only be used for pretreatment. Said proprietary manufactured practices shall be sized to treat at least the first 1-inch of runoff times the impervious area.

The written documentation to be submitted to the Issuing Authority shall consist of scientific studies that adhere to the *Technology Acceptance Reciprocity Partnership (TARP) Protocol for Stormwater Best Management Practices Demonstrations* updated July 2003 (https://www.mass.gov/files/documents/2016/08/rd/swprotoc.pdf). All studies must be conducted in the field. Laboratory studies are not acceptable.

What is the Purpose of this Section?

This section provides guidance and procedures that Issuing Authorities may use to review applications when a Proprietary Manufactured SCM is proposed for which no TSS or TP removal credit has been designated by **Table 2-2**. Issuing authorities may approve or deny use of Proprietary Manufactured SCMs.

What are Some Limitations of Proprietary Manufactured SCMs and How Should They be Used?

Proprietary Manufactured SCMs have limitations. Most can only treat small runoff volumes. Further, many proprietary practices are only designed to provide water quality treatment, thus when used as a stand-alone practice, they are not capable of meeting all Stormwater Management Standards by themselves, unless they are paired with other practices in a treatment train. Proprietary Manufactured SCMs shall only be used as follows when a project is subject to review pursuant to the WPA or 401 WQC regulations:

- **Redevelopment**. Proprietary Separators may only be used as a pretreatment practice to meet the TSS pretreatment provisions specified in Stormwater Standard Numbers 3 - 6. Proprietary Separators may never be used as a stand-alone practice or at the terminal end of a treatment train. Proprietary Media Filters may be used as a terminal treatment practice.
- **New development**. Proprietary Separators may only be used as a TSS pretreatment practice to meet pretreatment provisions contained in Stormwater Standards 3 - 6, Proprietary Media Filters may be used as a terminal treatment practice.

All Proprietary Manufactured Separators and Media Filters must be sized to treat at least the first 1-inch of runoff times the impervious drainage area without resuspension or bypass of previously suspended solids (*i.e.,* 1-inch Water Quality Volume as outlined in **Section 2.3.4**). All Proprietary Manufactured SCMs must be placed or configured to be offline, and contain an internal or external bypass to prevent resuspension of previously trapped solids. All Proprietary Manufactured Separators and Media Filters shall also be sized using MassDEP's Standard Method to Convert Water Quality Volume to a Flow Rate (see **Appendix D**). Refer to **Table 5-1** for a matrix of appropriate use for Proprietary Manufactured SCMs.

Table 5-1. Appropriate use of proprietary manufactured separators and media filter SCMs

Project Type	**Standard 2**	**Standard 3**	**Standard 4**	**Standard 5**	**Standard 6**	**Standard 7**
	Peak Rate Attenuation	Groundwater Recharge	Pollutant Removal	LUHPPL	Critical Areas	Redevelopment
Retrofits	NO	PT	PT, T	PT, T	PT, T	PT, T
Redevelopment	NO	PT	PT, T	PT, T	PT, T	PT, T
New Development	NO	PT	PT, T	PT, T	PT, T	NA, NA

Table Key:

NO = Does not meet Standard

NA = Not applicable

PT = Pretreatment by Proprietary Separators Only (not by Proprietary Filters)

T = Treatment by Proprietary Filters Only (may be used as a stand-alone treatment practice, provided pretreatment is provided.

5.3.2 Proprietary Manufactured SCM Exceptions

The two types of SCMs that are not classified as Proprietary Manufactured SCMs for the purposes for the Stormwater Management Standards are Subsurface Infiltrators and Manufactured Biofilters.

Subsurface Infiltrators

Subsurface infiltrators, even those that have manufactured storage chambers, are not treated as Proprietary Manufactured SCMs for purposes of the Stormwater Management Standards, since the treatment occurs in the soil below the structure not within the structure itself. This applies to just the subsurface infiltrator itself (typically a polyethylene chamber), and not to any proprietary pretreatment practice that may be associated with the subsurface infiltrator, such as hydrodynamic separators, media filters, or geotextile fabrics used to partition all or a portion of the runoff for suspended solids separation. Even though no review is required to establish a TSS/TP removal rate, the practices must be sized properly to treat at least the first 1-inch of runoff using the Static Method without bypass or resuspension of previously trapped sediments (see **Appendix A**). Pretreatment measures that may be associated with Subsurface Infiltrators may be traditional practices (*e.g.,* Deep Sump Catch Basins) or proprietary. **Note**: When a proprietary practice is proposed for pretreatment of a Subsurface Infiltrator (such as geotextile fabrics used to partition sediment in the runoff), it is subject to the review process described herein.

Manufactured Biofilters

Manufactured biofilters (*i.e.,* Organic Filters) include both a filter/growing media and vegetation component. Manufactured biofilters are not treated as Proprietary Manufactured SCMs for purposes of the Stormwater Management Standards. Manufactured biofilters have been characterized as organic filters in Massachusetts since 1997 and need not undergo review as a Proprietary Manufactured SCM. Even though no review is required to establish a TSS/TP removal rate, the practices must be sized properly to treat at least the first 1-inch of runoff with bypass or resuspension of previously trapped sediments. When sized using a peak flow rate, the MassDEP Volume to Peak Flow Rate conversion method shall be utilized (see **Appendix D**). Alternatively, they can be sized using the 1-inch Water Quality Volume, where the void spaces in the filter/growing media contain a volume of at least 1-inch times the impervious area.

5.3.3 Proprietary Manufactured SCM Advantages and Disadvantages

There are multiple advantages and disadvantages of Proprietary Manufactured SCMs. Advantages may include:

- Useful for pretreatment of TSS.
- Can be an excellent choice in ultra-urban or other constrained sites.
- Useful for retrofits and Redevelopments to improve water quality of existing stormwater discharges.

Disadvantages or limitations may include:

- Should be sized carefully to achieve design removal efficiencies.
- Efficiency may be affected by size of sediment and rate of sediment loading.
- Should ensure regular maintenance to achieve design removal efficiencies.
- Only appropriate for terminal treatment for runoff from LUHPPLs or discharges near or to Critical Areas, when clear demonstration is made that the practice is capable of removing industrial contaminants associated with the LUHPPL or constituents that may be harmful to the Critical Area (*e.g.,* pathogens to prevent them from entering public swimming areas or Shellfish Growing Areas).

5.3.4 Evaluating Proprietary Manufactured Stormwater Control Measures

The evaluation of Proprietary Manufactured SCMs for individual projects must be conducted on a case-by-case basis through the NOI or WQC application review process. Methods to determine the exact TSS and/or TP removal percentage that an Issuing Authority is to credit to such devices towards meeting TSS treatment and pretreatment requirements are described in the sections below. This same process is applicable for determining removal of other constituents, such as pretreatment of metals from metal roofs or pathogens associated with a TMDL. To receive full credit for Stormwater Management Standard 4 as a stand-alone practice associated with a retrofit or Redevelopment project, the Proprietary Manufactured SCM must be capable of treating the entire 1-inch water quality volume without bypass or resuspension of previously trapped constituents. Note that Proprietary Manufactured Separators may only be used for Pretreatment as part of a treatment train and are never allowed to be used as a stand-alone treatment practice.

A Note on Previous Evaluation Methodologies

Proprietary Manufactured SCMs were previously evaluated through the Massachusetts Strategic Envirotechnology Partnership (STEP), Massachusetts Stormwater Technology Evaluation Project (MASTEP), and/or Technology and Acceptance Reciprocity Partnership (TARP).

- Due to changes in funding, STEP no longer exists as a program to evaluate new technologies or to update existing reports. Previous verifications through STEP are no longer valid.
- Due to changes in funding, MASTEP no longer exists as a program to provide a searchable database of verified technical information on stormwater SCMs.
- Reviews conducted under the auspices of TARP have not been granted written reciprocity by Massachusetts and are not acceptable for verification. Reviews conducted by the New Jersey Corporation for Advanced Technology (NJCAT) and the New Jersey Department of Environmental Protection (NJDEP) are not considered TARP reviews as they vary from the written study protocol that had been agreed by the TARP States.

All evaluations of proprietary SCMs for individual projects must therefore be performed on a **case-by-case basis** as described by the below sections.

Impaired Waters with TMDLs

When a TMDL has been established by MassDEP and approved by EPA, the Applicant shall submit data to the Issuing Authority as part of the Notice of Intent or Water Quality Certification application to justify the removal claims to meet or exceed the waste load or load allocation concentrations specified in the TMDL. These parameters currently include Nitrogen, Phosphorus, Pathogens and Metals. See **Section 2.3.11** for more information.

Evaluation Methodology

The evaluation of Proprietary Manufactured SCMs for individual projects is conducted on a case-by-case basis through the NOI or WQC application review conducted by the Issuing Authority (*i.e.,* Conservation Commission, MassDEP) as described by the steps below.

Step One: Information to be submitted as part of the WPA NOI or WQC application

As more fully set out below, issuing authorities require sufficient information to evaluate proposed uses of Proprietary Manufactured SCMs. The Applicant must submit sufficient analytical information to the Issuing Authority so that it can evaluate the Proprietary Manufactured SCM to meet the 25% / 44% TSS pretreatment requirement, 90% TSS / 60% TP or 80% TSS / 50% TP treatment requirements, and/or the TMDL requirements.

The Conservation Commission or MassDEP upon appeal may reasonably deny the use of a proposed technology, if it finds that:

a) There is not sufficient information to assess the effectiveness of the technology; or
b) Based on the available information, the proposed use of the technology does not meet the requirements of the Stormwater Management Standards.

Information to be submitted with NOI or WQC application:

1) Third party field studies substantiating the TSS, TP and other removal claims (*e.g.,* pathogens when there is a TMDL). Laboratory studies alone are not sufficient for this purpose. Field studies must follow the TARP Tier II field Protocol. Prior reviews conducted by STEP, MASTEP, or through TARP by other States (*e.g.,* NJCAT) are not acceptable for this purpose. Acceptable third party studies include, but are not limited to, academic institutions, studies published in peer reviewed journals, and United States Geological Survey (USGS). Treatment efficiency must take into account dissolved, suspended or particulate constituents that bypass the device or are resuspended. Constituents that bypass the device or are resuspended and discharged to Resource Areas are not treated. The TARP Tier II field protocol is located as MassDEP's web site at: https://www.mass.gov/doc/stormwater-best-management-practice-demonstration-tier-ii-protocol-for-interstate-reciprocity/download.
2) Computations for the discharge rate using MassDEP's Standard Method to Convert Required Water Quality Volume to a Discharge Rate for Sizing Flow Based Manufactured Proprietary Stormwater Treatment Practices (see **Appendix D**).
3) A complete written description of the proprietary technology or product including a discussion of the advantages of the technology when compared to conventional stormwater treatment systems and LID practices, including:
   - **Size**: What volume is it designed to hold and/or treat? How is the system sized to meet the performance standards in order to handle the required water quality volume, rate of runoff, and types of storms? EPA has not established a Performance Removal Curve and the MassDEP Crosswalk has not assigned any removal curves to Proprietary Manufactured Separators or media filters. Standard 4 requires treatment for the first 1-inch water quality volume. The 1-inch Water Quality Volume may be converted to a peak flow rate using the method established by MassDEP.[52] Other methods to convert the 1-inch Water Quality Volume to a peak flow rate are not allowed.
   - **Technical description, schematic and process flow diagram**: How does it work? What are the technical configurations of the unit? Are there any pretreatment requirements? How does it fit in combination with other treatment systems?
   - **Capital costs and installation process**: What does this size system cost? Are there any consumable materials that need to be replaced and if so, how often and how much do they cost? How will the system be installed and who will supervise the installation to ensure that it is done properly? What mistakes can happen during installation? Is any special handling, installation techniques or equipment required?
   - **Potential disadvantages at this site**: Any physical constraints? Weight or buoyancy issues? Durability issues? Energy requirements?
   - **Operation and Maintenance (O&M) requirements and costs**: New technologies often do not have long-term data on O&M requirements, so it is particularly important that an Applicant provide all available information for evaluation. Are there any consumable materials that need to be replaced (*e.g.,* filter media cartridges) and if so, how often and how much do they cost?
4) Information on how well the alternative technology works must be submitted:
   - Data needs to be collected in the field accordance with the TARP Tier II protocol.
   - Laboratory data must not be relied upon in determining removal efficiency.
   - Flow proportional sampling must be submitted from field testing of full-scale practices that is representative of the potential range of precipitation events in a typical year and

[52] MassDEP worked with an advisory committee including representatives from proprietary SCM manufacturers to develop a methodology to convert the Required Water Quality Volume to a flow rate. The resultant document entitled *Standard Method to Convert Required Water Quality Volume to a Discharge Rate for Sizing Flow Based Manufactured Proprietary Stormwater Treatment Practice* is available at **Appendix D**.

located at sites similar to the conditions of the installation under review. The TARP Tier II protocol requires at least 50% of the total annual precipitation to be sampled, which is approximately 24-inches of precipitation/year based on the NOAA 1981-2010 Climate Normals for Massachusetts. The flow proportional sampling must cover a minimum of at least 70% of the total storm flow, including as much of the first 20% of the storm as possible.

- The data to be submitted must note the date of each storm, the total storm depth (in inches), length of time the precipitation occurred (in hours), the influent and effluent concentration (in mg/L), and list whether bypass or resuspension occurred. The influent and effluent data must be paired. Non-paired data is not acceptable. Storms must be more than 0.1-inches. There must be a minimum inter-event period of at least 6-hours.
- Calculation of TSS and/or TP removal rates utilizing the data must be presented. The calculations need to be conducted using the Efficiency Ratio and Summation of Loads methods. Removal rates should show removal of various particle sizes across the full range of operating conditions including maximum, minimum and optimal conditions for reliable performance.
- Information on any system failures, what those failures were, and how were they corrected.
- Copies of any articles from peer-reviewed, scientific or engineering journals.
- References along with contact information from other installations.

5) Operation and Maintenance (O&M) Plan:

- To ensure that the system will function as designed, all Stormwater Management Systems must have a written O & M plan in accordance with Stormwater Management Standard 9. MassDEP stresses the importance of routine maintenance for all stormwater control technologies. A number of alternative technologies perform very well, but only if they are installed and maintained as specified by the manufacturer. For example, some alternative wet vaults may be able to achieve a high TSS removal rate, but only if they are cleaned often enough to prevent entrainment of previously trapped sediment.
- Include the following in the O&M Plan:
    - Identify access points to all components of the stormwater system;
    - Specify equipment, personnel, and training needed to inspect and maintain system;
    - Include a list of any safety equipment and safety training required for personnel;
    - Set forth a suggested frequency of inspection and cleaning; and
    - Provide a sample inspection checklist and maintenance log.
- Refer to Standard 9 for further O&M guidance (**Section 2.3.9**).

<u>Step Two: Evaluate the submitted information</u>

An Issuing Authority (Conservation Commission or MassDEP) may want to ask the questions during the review process to determine whether a proposed use of an alternative technology, either as a stand-alone product or in combination with other stormwater control practices and technologies, meets all of the Stormwater Management Standards. The following questions are suggested:

- **Why is this technology being proposed for this site?** Possible reasons are the alternative technology provides a higher level of environmental protection, uses less land area, and is less expensive on a capital or operation and maintenance cost basis. The performance data and other information provided with the application must support these claims. For example, if the Applicant proposes an alternative technology, because it is less expensive to maintain than a conventional stormwater control technology system, the Applicant must submit information supporting that claim.

- **How convincing is the performance data?** Applicants must be able to demonstrate that their calculations show satisfactory performance in a laboratory, and preferably, adequate field-testing results. Were performance data (laboratory or field) collected by the technology developer or by independent organizations? Independent third party data is required to be submitted, but may not always be available. If applicable, do the data and calculations support the TSS and TP removal claims? Is the site similar to other locations where the alternative technology is already properly operating? The greater the similarity in key factors (*e.g.,* soil conditions, climate, sediment loading rates, surficial geography, slopes), the greater the likelihood that the technology will properly work at the proposed site.
- **Are the data sets complete?** If there are any gaps, why? Is the influent and effluent data paired? Are you satisfied with the reasons given as to why there are gaps? For example, if the influent data is not paired with effluent data for certain storms, was it censored from the analysis as required? If maintenance data are provided for a two-year period, and there is a six-month gap in the record, a reasonable explanation for the gap should be provided. Is there enough information to persuade the Issuing Authority that the technology will work as proposed?
- **If there have been failures, either in the laboratory or in real settings, is the Applicant able to adequately explain the reasons for the failure?** Examples could be poor design, improper sizing, and higher sediment loading than anticipated, extreme hydrologic events, poor installation, or poor maintenance. If it was a design problem, has the design of the technology been modified to address the problem? For failures that were not design related, what corrections were made to prevent future failure? Were systems rechecked to see if they were functioning properly after corrections were made?
- **If only limited data are available, is it possible to assess how the technology will work over its expected life?** If seasonality is an issue, the Commission should see data collected over a full change of seasons that reflect a normal weather year, or at least an estimate of normal annual operations based on available data. Can the technology function well for the full range of storm events that must be controlled? If not, is there a way to address this problem?
- **Is it possible that a technology may effectively meet one Standard, but hamper compliance with other Standards?** For example, a technology might increase the rate of TSS removal, but limit the annual recharge. The Applicant should provide documentation to help the Commission make this evaluation. Do the advantages of the technology potentially outweigh its disadvantages?
- **Check any references provided by the Applicant to find out whether previous installations are properly functioning.** If the information indicates that other Conservation Commissions have previously approved this technology for use in their municipalities, check with those Commissions to verify that the system has performed properly. Were there unexpected operation and maintenance costs? If there were problems, did the vendor assist in resolving them?
- **Check that the submitted information meets applicable requirements of each Stormwater Management Standard.** See the Detailed Proprietary Manufactured SCM Evaluation Guidance below for more information (**Section 5.3.4**).

<u>Step Three: Make a decision on the filings</u>

- **If sufficient information exists**: If there appears to be sufficient information, the Conservation Commission or MassDEP must issue a decision approving (with or without special conditions) or denying the use of the proposed technology to meet the Stormwater Management Standards. There may be instances where the Conservation Commission or MassDEP may want to add conditions to the Order of Conditions to ensure the proper functioning of the alternative stormwater control technology. If covered in a local wetlands bylaw, a Conservation Commission may wish to require a bond to be posted to pay for any repairs that may be necessary if the alternative system does not perform as designed. Particular attention to inspection and maintenance is advised and should be included in the conditions.

- **Approval**: If a Conservation Commission or MassDEP approves the use of a Proprietary Manufactured SCM, that approval is limited to the SCM proposed in the Wetlands Notice of Intent or the application for the Water Quality Certification. If a project Applicant wants to substitute a different Proprietary Manufactured SCM for the Proprietary Manufactured SCM approved by the Issuing Authority, the project Applicant must obtain the approval of the Issuing Authority before proceeding with the substitute.

- **Denial:** If a Conservation Commission or MassDEP denies the use of a proprietary technology, it must specify the reasons in writing. Because these decisions are subject to appeal, written documentation is critical.

- **If insufficient information exists**: If the Issuing Authority determines there is not sufficient information to adequately evaluate the proposed technology, the Issuing Authority may either deny the project based on the lack of information (and specify what information is lacking in the denial) or ask the Applicant to supply additional information.

  Note: If an Issuing Authority denies the specific use of a Proprietary Manufactured SCM, the reasons should be specified in writing. This written documentation is important, because denials are subject to appeal and may be overturned, if, for example, it is demonstrated upon appeal that adequate information was provided to the Issuing Authority or practice meets specific stormwater standards and DEP's specifications contained in **Appendix A**.

5.3.5 Detailed Proprietary Manufactured SCM Evaluation Guidance for each Stormwater Management Standard

These questions should be used to address specific questions issuing authorities may have about the effectiveness of Proprietary Manufactured SCMs to meet a specific Stormwater Management Standard. This guidance is not intended as a mandatory checklist that every Applicant or Applicant must submit for every Proprietary Manufactured SCM.

Applicants, Applicants, Proprietary Manufactured SCM manufacturers, and issuing authorities can use the following questions to determine if the information submitted about a Proprietary Manufactured SCM is sufficient to allow the proposed use. Using these questions will help Applicants and reviewers determine whether a sufficient evaluation of the Proprietary Manufactured SCM has been performed, identify where deficiencies may be present, and reasonably predict the performance of a Proprietary Manufactured SCM at the Project Site.

General Information

1) Has the Applicant provided a detailed description of the characteristics of the site, described how the proposed proprietary product addresses the unique stormwater management requirements of the site, and shown that the proprietary product is in compliance with the Stormwater Management Standards? Has the Applicant shown that the SCM is advantageous to the site? Have LID and site design techniques been considered when developing the site design? Items to consider include but are not limited to:
   - What is the SCM's proposed use: pretreatment or treatment? Separator, filtration, or other use? See **Table 5-1** for guidance on appropriate Proprietary Manufactured SCM use.
   - Is the project for new development, Redevelopment, or a retrofit?
   - Are there site constraints that limit what other SCMs can be used?
   - Is it in an area of higher potential pollutant loads? *See Standard 5 (only SCMS listed in **Table 2-3** may be used to treat discharge from LUHPPLs).*

- Is there discharge to or near a Critical Area? *See Standard 6 (only SCMS listed in **Table 2-4a-d** may be used to treat discharge near or to Critical Areas).*
- Is there a high flow contribution from off-site?
- Is there a high TSS contribution anticipated from site soils, winter sand application, or other source?
- Are there TMDL requirements applicable to the site? *See Standard 11*
- Are there other reasons that specific pollutants in addition to TSS must be treated (*e.g.,* Phosphorus, Nitrogen, Bacteria, metals, hydrocarbons)?

2) Has the Applicant provided documentation that the sizing of the device is correct? Is there any reason to allow a smaller size than proposed? Has the Applicant demonstrated that the device meets both of the following?
   - The Stormwater Management Standards; and
   - The sizing procedures and calculations established by the manufacturer and verified through field testing.
3) Has the Applicant provided documentation that the product manufacturer's performance claims have been verified through laboratory and/or field-testing? Does the evaluation indicate that the device will work well on this specific site?
4) Has the product been approved for use by other agencies in other states; if so, for what pollutants, pollutant levels and/or land use?
5) Is the product intended for construction period erosion and sedimentation control? If so, has the Applicant provided documentation that the product is effective for such use? See Standard 8.
6) Are there compelling site-specific reasons why the Proprietary Manufactured SCM should be used (*e.g.,* severe location or space constraints, need to reduce a specific pollutant, flooding, filter devices proposed)?

Information Required to Address Specific Stormwater Management Standards

Stormwater Standard 1: No Untreated Discharges

See **Section 2.3.1** for a definition and explanation of this Stormwater Standard.

1) Does the use of the product enable the Applicant to provide adequate treatment for its new discharges? Treatment in this context means reduce peak runoff rates, provide stormwater recharge, and remove TSS/TP or other constituents when there is a TMDL.
2) Does the use of the product enable the Applicant to retrofit an existing discharge, achieving an improvement over existing conditions? *See Standard 7.*
3) Is the product either alone or in combination with a treatment train designed to prevent erosion and scour to Wetland Resource Areas?

Stormwater Standard 2: Peak Rate Attenuation

See **Section 2.3.2** for a definition and explanation of this Stormwater Standard.

Does the product reduce peak rates of runoff? If so, has the Applicant documented this function with hydrologic/hydraulic data in field studies?

1) How is product performance affected by peak discharges?
2) Has the Applicant documented its performance with hydrologic/hydraulic analysis through field studies?

3) Is the product susceptible to re-suspension and flushing of captured contaminants during a 24-hour, 2-year, 10-year, or 100-year storm?
4) Is the product designed to prevent such re-suspension and flushing? Is this documented in the field studies? Was the particle size in those studies comparable to that used to calculate the performance and size of the Proprietary Manufactured SCM?
5) Is the product designed to be offline? All Proprietary Manufactured SCMs must be placed or configured to be offline, or contain an internal or external bypass to prevent resuspension of previously trapped solids.
6) Is the product subject to damage or filling by sediment during a river flood event or a coastal flood?

Stormwater Management Standard 3: Recharge

See **Section 2.3.3** for a definition and explanation of this Stormwater Standard.

Is the product proposed as part of a recharge system? If so,

1) Is it a pretreatment device intended to remove particulates and/or other pollutants prior to discharge to a recharge SCM?
2) Does it provide both pretreatment and recharge?

Stormwater Management Standard 4: Pollutant Removal

See **Section 2.3.4** for a definition and explanation of this Stormwater Standard.

Does the product provide water quality treatment?

1) Does the product remove TSS and/or TP sufficient to provide pretreatment or treatment at sufficient levels to meet MassDEP requirements?
   - Pretreatment: At least 25% TSS or 44% TSS removal
   - Treatment: For new development, at least 90% TSS and 60% TP removal. For Redevelopment, at least 80% TSS and 50% TP removal.
2) If a Proprietary Manufactured Separator, was the device only proposed for pretreatment?

   Note: Separators are only allowed to be used as a pretreatment practice, not treatment.
3) If a Proprietary Media Filter that is allowed to be used as a treatment practice, is adequate TSS pretreatment proposed to minimize filter clogging?
4) Has the Applicant provided sufficient information to verify that the product provides adequate pollutant removal in accordance with Standard 4 requirements?
   - As applicable for stormwater treatment separators, has the Applicant provided computations for the Water Quality Volume to a discharge rate using the MassDEP's Standard Method to Convert Required Water Quality Volume to a Discharge Rate for Sizing Flow Based Manufactured Proprietary Stormwater Treatment Practices (**see Appendix D**)?
   - As applicable, has the Applicant provided computations demonstrating that the device meets required TSS and/or TP percent removals as a function of treated upstream impervious area?
5) Does the product provide for control or prevention of re-suspension, scour, and/or flushing of captured solids or other contaminants treated by the product?

6) Has the product been sized to treat at least the 1-inch Water Quality Volume, as verified by field testing? If a product is sized based on flow rate, was the MassDEP method used to convert the 1-inch Water Quality Volume to a peak flow rate?
7) Does the product treat other pollutants, and if so, has Applicant provided performance documentation (with documented verification)?
8) Is the proposed use of the product in the correct sequence in the "treatment train"?
   - Pretreatment (*e.g.,* coarse particle separation)
   - Terminal treatment (*e.g.,* fine particle settling)
   - Polishing treatment (*e.g.,* filtration, bacteria absorption or adsorption)
   - Infiltration
9) How will the future use of the site influence the kinds of pollutants to be treated and loading rates of those pollutants (*e.g.,* residential may mean more nutrients, a roadway may mean coarser TSS)?

<u>Stormwater Management Standard 5: Land Use with Higher Potential Pollutant Loads</u>

See **Section 2.3.5** for a definition and explanation of this Stormwater Standard.

The Stormwater Management Standards limits the type of stormwater systems that may be used for treatment in LUHPPL. For new development, Proprietary Manufactured SCMs[53] may be used in LUHPPL <u>ONLY</u> as a pretreatment device to one of the devices listed in the Stormwater Management Handbook as suitable for such areas or land uses. See **Section 2.3.5** and **Appendix A** for *Proprietary Separators and Proprietary Media Filters.* For Redevelopment sites, these systems may be used for discharges from LUHPPLs <u>ONLY</u> if site constraints prevent use of the devices determined by MassDEP to be suitable for such land uses. Since the devices listed by MassDEP for discharges LUHPPL were selected based on their ability to capture or treat constituents in addition to TSS (such as toxics, pathogens, nutrients, or temperature), proprietary systems proposed for Redevelopment projects in these areas must provide similar capabilities.

1) Is the pretreatment or treatment practice proposed listed in **Table 2-3** for use with discharges from LUHPPL?
2) Is the product used consistent with the source control requirements of the Stormwater Management Standards?
3) Does the technology provide pretreatment prior to discharge to a technology that has been determined to be suitable for runoff LUHPPL?
4) What pollutants are associated with the LUHPPL? What demonstration can be provided that shows that the proposed SCM is capable of removing and/or treating those pollutants?
5) Does the LUHPPL have the potential to generate stormwater runoff that has high concentrations of oil and grease? If so, has the technology been proposed in addition to an oil grit separator or sand filter or as an alternative method of achieving oil and grease removal in place of an oil grit separator or sand filter? If the technology is proposed in place of an oil grit separator or sand filter, what evidence is there that the technology is effective in removing oil and grease?

<u>Stormwater Management Standard 6: Critical Areas</u>

See **Section 2.3.6** for a definition and explanation of this Stormwater Standard.

[53] Subsurface infiltrators, even if they have manufactured storage chambers, are not Proprietary Manufactured SCMs, since the treatment occurs in the soil below the structure, not in the structure itself.

The Stormwater Management Standards limits the type of SCMs that may be used for treatment in Critical Areas. For new development, proprietary SCMs[54] may be used in or near Critical Areas ONLY as a pretreatment device to one of the devices listed in the Stormwater Management Handbook as suitable for such areas. See **Section 2.3.6** and **Appendix A** for *Proprietary Separators and Proprietary Media Filters.* For Redevelopment sites, these systems may be used for discharges to or near Critical Areas ONLY if site constraints prevent use of the devices determined by MassDEP to be suitable for such areas.

Since the devices listed by MassDEP for discharges to or near Critical Areas were selected based on their ability to capture or treat constituents in addition to TSS (such as toxics, pathogens, nutrients, or temperature), proprietary systems proposed for Redevelopment projects in these areas should provide similar capabilities.

1) Is the pretreatment or treatment practice proposed listed in **Table 2-4a-d** for use with discharges near or to Critical Areas?
2) Is the product used for pretreatment prior to discharge to a technology that the Department has determined is suitable for the particular Critical Area?
3) Does the product have any operating characteristics that could adversely affect the Critical Area, such as:
    - Thermal impacts to Coldwater Fisheries.
    - Release of bacteria to Shellfish Growing Areas, bathing beaches.
    - Release of previously captured pollutants (scour).
4) If the device is otherwise appropriate, are setback requirements met (*e.g.,* not located in Zone I or A, unless essential to operation of a public water system)? The setbacks that apply to practices listed in the MassDEP Stormwater Handbook also apply equally to Proprietary Manufactured SCMs.

Stormwater Management Standard 7: Redevelopment

See **Section 2.3.7** for a definition and explanation of this Stormwater Standard.

Stormwater Management Standard 8: Construction Period Controls

See **Section 2.3.8** for a definition and explanation of this Stormwater Standard.

Proprietary Separators and Media Filters are not intended to serve as erosion and sediment control practices. No construction period runoff shall be directed to separators or media filters. However, some other types of Proprietary Manufactured products may be intended solely for erosion and sedimentation control during constructions. Some examples may include geotextile blankets or Polyacrylamides (PAM).

1) Is the product intended to control erosion and sedimentation during the construction process or for post-construction stormwater treatment?
2) If intended for erosion and sedimentation control, has the Applicant documented this function? How does it fit into the construction period erosion, sedimentation and pollution prevention plan (CPPP)?
3) Is the product susceptible to adverse impact by erosion and sedimentation during construction, and if so, has the Applicant documented how the product will be protected from such impact?

[54] Subsurface structures, even if they have manufactured storage chambers, are not Proprietary Manufactured SCMs, since the treatment occurs in the soil below the structure, not in the structure itself.

Stormwater Management Standard 9: Operation and Maintenance

See **Section 2.3.9** for a definition and explanation of this Stormwater Standard.

1) Has the Applicant completely described the installation, operation, and maintenance of the device? Has the Applicant documented how the required maintenance will be done and who will do it?
2) Has the Applicant included a copy of the manufacturer's installation, inspection, operation, and maintenance procedures in the project O&M plan?
3) Is the proposed Proprietary Manufactured SCM included in the project's O&M plan?
4) Does the product require special materials or equipment for cleaning? If so, what materials or equipment are necessary?
5) Has the O&M plan funding accounted for such equipment and materials?
6) Does the inspection or maintenance of the device require confined space entry protocols?
7) Is the frequency of maintenance and cleaning documented by pollutant loading/removal estimates, experience at other installations, or other information demonstrating that the proposed frequency is adequate?
8) How will the future use of site influence O&M needs? More frequent? Less frequent?

Stormwater Management Standard 10: Illicit Discharges

See **Section 2.3.10** for a definition and explanation of this Stormwater Standard.

1) Have steps been taken to prevent Illicit Discharges from entering the Proprietary Manufactured SCM?

Stormwater Management Standard 11: Total Maximum Daily Loads

See **Section 2.3.11** for a definition and explanation of this Stormwater Standard.

1) Is the product capable or removing the applicable TMDL constituent (*i.e.,* Nitrogen, Phosphorus, Metals, Pathogens)? See **Section 2.3.11** for more information.
2) Does the product treat the specific pollutants required by the TMDL?
3) Is the product capable of meeting Standard 3 (recharge) or Standard 4 (water quality)?
4) Is the product sized to meet Standard 3 or Standard 4?
5) Has the MassDEP Water Quality Volume to Peak Flow Rate conversion method been used, if the product is being sized based on flow rate (see **Appendix D**)?

5.3.6 Sources of Information about Proprietary Manufactured SCMs

There are other sources of information that may be helpful.

- **Center for Watershed Protection***:* This national non-profit provides resource information for local officials (http://www.cwp.org/).
- **International Stormwater Best Management Practices Database:** This website, hosted by EPA and American Society of Civil Engineers, features over 700 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance, and other study-related publications https://www.bmpdatabase.org/)

- **NJDEP Stormwater Manufactured Treatment Devices**: Information on treatment is available (http://www.nj.gov/dep/stormwater/treatment.html). This information, along with information from NJCAT, varies from the TARP Tier II field protocol, so is not acceptable to verify TSS and TP removal claims.
- **University of Connecticut**: UCONN's stormwater website has information about the interrelationship between increased stormwater runoff and associate pollutants (https://nemo.uconn.edu/ms4/index.htm).
- **University of New Hampshire Stormwater Center:** The UNH Stormwater Center provides information on stormwater technologies **(**https://www.unh.edu/unhsc/**)**
- **State of Washington Department of Ecology:** Stormwater treatment technologies are reviewed and certified by the Washington state Technology Assessment Protocol-Ecology (TAPE) program (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies)
- **Wisconsin Department of Natural Resources**: Wisconsin DNR provides a link to the SLAMM Model (Source Loading Management Model) which is useful to predict pollutant loads (https://dnr.wisconsin.gov/topic/Stormwater/standards/slamm.html)

5.4 Mosquito Control in Stormwater Management Practices

Both aboveground and underground SCMs have the potential to serve as mosquito breeding areas. Good design, proper operation and maintenance, and treatment with larvicides can minimize this potential. Incorporate the measures described in this section into the:

1) Construction Period Erosion Control/Pollution Prevention Plan;
2) Long-Term Pollution Prevention Plan; and
3) Post-Construction Operation/Maintenance Plan.

All SCMS should include maintenance access. In many cases, these amount to a 12-foot wide pathway around the full perimeter of the practice in accordance with the setback requirements listed in **Section 2.5**.

SCMs must dewater within three days (72 hours) to reduce the number of mosquitoes that mature to adults, since the aquatic stage of many mosquito species is seven to ten days. Massachusetts has had a 72-hour dewatering rule in its Stormwater Management Standards since 1996. The current technical specifications for SCMs set forth in **Appendix A** also concur with this practice by requiring that all stormwater practices designed to drain, do so within 72 hours.

Some stormwater practices are designed to include permanent wet pools. These practices – if maintained properly – can limit mosquito breeding by providing habitat for mosquito predators. Additional measures that can be taken to reduce mosquito populations include increasing water circulation, attracting mosquito predators by adding suitable habitat, and applying larvicides.

The Massachusetts State Reclamation and Mosquito Control Board (SRMCB), through the Massachusetts Mosquito Control Districts, can undertake further mosquito control actions specifically for the purpose of mosquito control pursuant to Massachusetts General Law Chapter 252.[55] The SRMCB specifies mosquito control methods and develops guidance relevant to SCMs for mosquito control projects.

The SRMCB and Mosquito Control Districts are not responsible for operating and maintaining SCMs to reduce mosquito populations. The owners of property that construct the SCMs or municipalities that "accept" them through local subdivision approval are responsible for their maintenance. The SRMCB is composed of officials from MassDEP, Department of Agricultural Resources, and Department of Conservation and Recreation. The nine Mosquito Control Districts overseen by the SRMCB are located throughout Massachusetts, covering 176 municipalities.

5.4.1 Construction Period Stormwater Control Measures for Mosquito Control

To minimize mosquito breeding during construction, it is essential that the following actions be incorporated into the CPPP to minimize the creation of standing pools and be implemented during construction:

- **Minimize Land Disturbance:** Minimizing land disturbance reduces the likelihood of erosion. It also minimizes mosquito breeding by reducing silt in runoff that will cause construction period controls to clog and retain standing pools of water for more than 72 hours.
- **Catch Basin Inlets:** Inspect and refresh filter socks, stone dams, hay bale barriers on a regular basis to ensure that any stormwater ponded at the inlet drains within eight hours after precipitation stops. Filter fabric stretched under the inlet grate is not sufficient to provide inlet

[55] SRMCB: https://www.mass.gov/state-reclamation-and-mosquito-control-board-srmcb.

protection. Periods shorter than 8-hours may be necessary to avoid hydroplaning in roads caused by water ponded at the catch basin inlet. Treat catch basin sumps with larvicides such as *Bacillus sphaericus* (*Bs*) using a licensed pesticide applicator. Inlet protection must not be removed during construction.

- **Check Dams:** If temporary check dams are used during the construction period to lag peak rate of runoff or pond runoff for exfiltration, inspect and repair the check dams on a regular basis to ensure that any stormwater ponded behind the check dam drains within 72 hours.
- **Sediment Traps**: Design construction period sediment traps to dewater within 72 hours after precipitation. Because these traps are subject to high silt loads and tend to clog, treat them with the larvicide *Bs* after it rains from June through October, until the first frost occurs.
- **Construction Period Open Conveyances:** When temporary manmade ditches are used for channelizing construction period runoff, inspect them on a regular basis to remove any accumulated sediment to restore flow capacity to the temporary ditch.
- **Disturbed Surfaces:** Revegetating disturbed surfaces reduces sediment in runoff that will cause construction period controls to clog and retain standing pools of water for greater than 72 hours.
- **Sediment Fences/Hay Bale Barriers:** When inspections find standing pools of water beyond the 24-hour period after a storm, take action to restore barrier to its normal function.

Refer to **Section 4.3.3** for more information on CPPP requirements.

5.4.2 Selection of Post-Construction Stormwater Treatment Practices

Some SCMs are less conducive to mosquito breeding. Mosquito control begins with Environmentally Sensitive Site Design (ESSD) that minimizes Impervious Surfaces and reduces the amount of stormwater runoff (see **Section 4.2** for more information on ESSD) Utilizing green roofs can potentially reduce runoff from smaller storms. Storage media must be designed to dewater within 72 hours after precipitation.

Mosquito control continues with the selection of structural SCMs that are unlikely to become breeding grounds for mosquitoes, such as:

- **Bioretention Areas/Rain Gardens/Sand Filter:** Bioretention areas, rain gardens, and sand filters tend not to result in mosquito breeding. If any level spreaders, weirs, or sediment forebays are used as part of the design, inspect them and correct them as necessary to prevent standing pools of water for more than 72 hours.
- **Infiltration Trenches:** Infiltration trenches tend not to result in mosquito breeding. If any level spreaders, weirs, or sediment forebays are used as part of the design, inspect them and correct them as necessary to prevent standing pools of water for more than 72 hours.
- **ESSD Credits:** The ESSD Credits outlined in **Appendix A** may also be effective at reducing mosquito breeding. For example, disconnecting runoff and re-directing it to a Qualifying Pervious Area (QPA) reduces the amount of stormwater that must be conveyed to a treatment practice (see ESSD Credit 3 and ESSD Credit 4). Similar outcomes would be expected from implementation and expansion of tree canopy (ESSD Credit 5), buffer area improvements (ESSD Credit 8), and reductions in impervious area for Redevelopment projects (ESSD Credit 7).

Another mosquito control strategy is to select SCMs that can become habitats for mosquito predators, such as:

- **Constructed Stormwater Wetlands:** Habitat features can be incorporated in constructed stormwater wetlands to attract dragonflies, amphibians, turtles, birds, bats, and other natural predators of mosquitoes.
- **Wet Basins:** Wet basins can be designed to incorporate fish habitat features, such as deep pools. Introduce fish in consultation with Massachusetts Division of Fisheries and Wildlife. Vegetation within wet basins designed as fish habitat must be properly managed to ensure that

vegetation does not overtake the habitat. Proper design to ensure that no low circulation or "dead" zones are created may reduce the potential for mosquito breeding. Introducing bubblers may increase water circulation in the wet basin.

Effective mosquito controls require Applicants to design structural SCMs to prevent ponding and facilitate maintenance and, if necessary, the application of larvicides. Examples of such design practices include the following:

- **Basins:** Provide perimeter access around wet basins, extended dry detention basins and dry detention basins for both larviciding and routine maintenance. Control vegetation to ensure that access pathways stay open.
- **SCMs Without a Permanent Pool of Water:** All structural SCMs that do not rely on a permanent pool of water must drain and completely dewater within 72 hours after precipitation. This includes dry detention basins, extended dry detention basins, infiltration basins, and dry water quality swales. Use underdrains at extended dry detention basins to drain the small pools that form due to accumulation of silts. Wallace indicates that extended dry extended detention basins may breed more mosquitoes than wet basins. It is, therefore, imperative to design outlets from extended dry detention basins to completely dewater within the 72-hour period.
- **Energy Dissipators and Flow Spreaders:** Currier and Moeller, 2000 indicate that shallow recesses in energy dissipators and flow spreaders trap water where mosquitoes breed. Set the riprap in grout to reduce the shallow recesses and minimize mosquito breeding.
- **Outlet Control Structures:** Debris trapped in small orifices or on trash racks of outlet control structures such as multiple stage outlet risers may clog the orifices or the trash rack, causing a standing pool of water. Optimize the orifice size or trash rack mesh size to provide required peak rate attenuation/water quality detention/retention time while minimizing clogging.
- **Rain Barrels and Cisterns:** Seal lids to reduce the likelihood of mosquitoes laying eggs in standing water. Install mosquito netting over inlets. The cistern system should be designed to ensure that all collected water is drained into it within 72 hours.
- **Subsurface Infiltrators, Deep Sump Catch Basins, Oil Grit Separators, and Leaching Catch Basins:** Seal all manhole covers to reduce likelihood of mosquitoes laying eggs in standing water. Install mosquito netting over the outlet (CALTRANS, 2004).

5.4.3 Long-Term Pollution Prevention Plan

Include measures in the LTPPP required by Standard 4 to minimize creation of standing pools of water. See **Section 4.3.2** for more information on the required LTPPP.

5.4.4 Operations and Maintenance

Include proper maintenance of post-construction stormwater controls (e.g., deep sump catch basins, wet basins) in the O&M Plan required by Standard 9 to minimize mosquito breeding. Components that should be considered in the O&M Plan are listed below. See **Section 2.3.9** for more information on the required O&M Plan.

- **Maintenance Accessway:** Inspect accessway at least once per year, to level any surfaces, repair ruts, side slope, or revegetate.
- **Check dams:** Inspect permanent check dams on the schedule set forth in the O&M Plan. Inspect check dams 72 hours after storms for standing water ponding behind the dam. Take corrective action if standing water is found.
- **Cisterns:** Apply Bs larvicide in the cistern if any evidence of mosquitoes is found. Specify how often larvicides should be applied to waters in the cistern in the O&M Plan.

- **Water Quality Swales:** Remove and properly dispose of any accumulated sediment as scheduled in the O&M Plan.
- **Larvicide Treatment:** Include measures to minimize mosquito breeding in the O&M plan such as larviciding.

  The party identified in the O&M Plan as responsible for maintenance should see that larvicides are applied as necessary to the following stormwater treatment practices: catch basins, oil/grit separators, wet basins, wet water quality swales, dry extended detention basins, infiltration basins, and constructed stormwater wetlands. The O&M Plan should ensure that all larvicides are applied by a licensed pesticide applicator and in compliance with all pesticide label requirements.

  The O&M Plan should identify the appropriate larvicide and the time and method of application. For example, Bs, the preferred larvicide for SCMs, should be hand-broadcast.[56] Alternatively, Altosid, a Methopren product, may be used. Because some practices are designed to dewater between storms, such as dry extended detention and infiltration basins, the O&M Plan should provide that larviciding should be conducted during or immediately after wet weather, when the detention or infiltration basin has a standing pool of water, unless a product is used that can withstand extended dry periods.

Mosquito Control References

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Virginia Department of Conservation and Recreation, 2003, Vector Control, Mosquitoes and Stormwater Management, Stormwater Management Technical Bulletin No. 8, http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=74300258C6D461257E317B2065FC13EB?doi=10.1.1.227.7175&rep=rep1&type=pdf

[56] *Bacillus thuringienis israelensis* or *Bti* is usually applied by helicopter to wetlands and floodplains

5.5 Photovoltaic System Solar Array Review

MassDEP Wetlands Program Policy 17-1: Photovoltaic System Solar Array Review is available on MassDEP's website.[57] This section addresses stormwater management during construction period and post-construction for photovoltaic systems (PVS).

5.5.1 Construction Period Erosion and Sediment Control

The large acreage of clearing and/or grading, steep slopes, compressed construction timelines, and lack of oversight are some of the many factors that present a high risk of erosion during the construction phase of a PVS project. A Construction Period / Pollution Prevention Plan (CPPP) is required to be submitted as part of the NOI review pursuant to Standard 8 to minimize detachment of soils and sedimentation to Wetland Resource Areas **Provision of perimeter controls alone is not sufficient to meet Standard 8.** In addition to perimeter controls, the plan must demonstrate that land disturbance will be minimized at any one time to prevent erosion and sedimentation to Resource Areas. Prior to commencement of any work on the site, adequate erosion and sedimentation control measures shall be implemented, including any necessary controls not specifically referenced in the plans(s) of record, and they shall be maintained in effect throughout the entire project and until the site has become permanently stabilized with adequate vegetative or landscape cover. Structural failure of any erosion and sedimentation controls and subsequent discharge of stormwater constitutes a violation of the stormwater standards.

Prepare and submit the CPPP with the NOI or WQC application in accordance with **Section 4.3.**3. At a minimum, also include the following PVC specific considerations in the CPPP.

- Minimize land disturbance at any one time to reduce construction period runoff. Avoid wholesale clearing and grubbing the entire site at once. Clearly state the maximum land disturbance to occur at any one time at any time (*e.g.,* 1-acre) and phase the land disturbance – the destabilized land surfaces from each phase should be fully stabilized before proceeding to the following phase. Include Plans that depict each land disturbance phase.
- Destabilization of sloped surfaces such as hillsides must be minimized. When destabilization of sloped surfaces is necessary, minimize disturbance at any one time. Incorporate BMPs to protect all disturbed surfaces such as constructing temporary or permanent terraces, soil roughening perpendicular to the fall line of the slope, and the use of blankets or mulches to protect all disturbed surfaces.
- Grade the site during construction to prevent direct discharges to Wetland Resource Areas and to avoid or minimize channelized stormwater flow from the Buffer Zone directly into Wetland Resource Areas.
- Design and implement temporary sediment traps and temporary siltation basins that are be sized with a volume sufficient to store the runoff from the 2-year 24-hour storm.
- Additional space is devoted to construction period SCMs, if necessary, with Photovoltaic panel installation delayed in these areas until the majority of the site is stabilized.
- Preservation of natural vegetative cover in areas adjacent to the arrays, and maximize setbacks to Wetland Resource Areas.

[57] MassDEP Wetlands Program Policy 17-1: https://www.mass.gov/guides/massdep-wetlands-program-policy-17-1-photovoltaic-system-solar-array-review.

- Installation of an adequate depth of top soil to ensure good soil base for grass turf cover. MassDEP recommends top soil depth be at least 6-inches. Inclusion of temporary blankets such as mulching over disturbed surfaces until permanent grass turf cover is established;
- Construction of PVS panel supports and PVS panel installation utilize low impact construction techniques such as low-pressure wheels on construction vehicles.
- The Source Reduction Plan required by 310 CMR 10.05(6)(k)4 proposes no herbicides/pesticides on the grassed areas or rights-of-way into the site and minimal use of fertilizers.
- The finished site has at least 90% herbaceous cover comprised of native species (including areas under PVS panels).

5.5.2 Post-construction Stormwater Management

PVS projects must be designed to comply with the Stormwater Management Standards. Access roads, parking areas, and rooftops of buildings or structures associated with PVS arrays are fully subject to the Stormwater Management Standards. Compacted gravel roads proposed as part of a PVS project are considered to be impervious. Standards of particular relevance include:

1) **Standard 2:** Peak rate control and flood prevention
2) **Standard 3:** Recharge
3) **Standard 4:** Water Quality Treatment
4) **Standard 11:** Total Maximum Daily Loads

ESSD for Solar Projects

Solar projects within the Buffer Zone or other jurisdictional Resource Area may receive ESSD Credit for implementation of Environmentally Sensitive Site Design Practices (ESSD). Refer to ESSD Credit 2 in **Appendix A** for criteria to meet the Credit. PVS array designs which do not qualify for ESSD Credit shall demonstrate compliance with the Stormwater Management Standards; however, no stormwater recharge or TSS / TP treatment shall be required when the ground surface under and adjacent to the PVS arrays is on a slope less than 5% and consists of gravel/crushed stone or is planted and maintained with native vegetative cover sufficient to provide adequate infiltration and eliminate all surface water runoff during the 2-year 24-hour storm specified in **Section 2.3.2**.

See below sections for discussion on Stormwater Standards of particular relevance.

- **Standard 2.** Select the Runoff Curve Number (RCN) using methods described by Standard 2 (see **Section 2.3.2** and **Section 6.2.2**). For peak rate attenuation, the RCN computations shall be reflective of the final land cover type being proposed below the panels and between the rows of panels. Further, the land cover type must accurately reflect the existing condition in the stormwater calculations and not utilize a U.S. Natural Resources Conservation Service TR55 RCN that mischaracterizes the site.

  When modeling runoff from post construction solar arrays, the TR55 RCN for the cover type selected for the area within the array should reflect the proposed cover type beneath the panels, and should not be modeled as impervious. TR55 RCNs for agricultural lands, including cultivated lands, should not be used to characterize post-development conditions. This means that RCNs for “Pastures” and “Meadow” should not be used to characterize post-construction land use cover. The minimum RCNs that may be used to characterize vegetated post construction land use cover are open space (*e.g.,* lawn, parks, etc.). Higher RCNs may be utilized for conservatism to characterize post construction land cover. Applicants are cautioned to appropriately evaluate the existing land cover type to avoid post-construction issues arising from stormwater runoff.

When calculations show an increase in peak off-site discharge, include a combination of the following stormwater management measures in the design to mitigate peak flows: grading modifications (such as terracing or berms); infiltration trenches; bioengineering techniques; or non-structural practices (*e.g.,* establishment of a suitably sized and graded buffer area between the panels and vegetated wetlands or land under water).

- **Standard 3**. For the purposes of Standard 3, groundwater recharge of at least 1 inch is required. Designing the site to meet ESSD Credit 2 meets the groundwater recharge requirement. See **Section 2.3.3** and **Section 6.2.3** for more information on Standard 3.
- **Standard 4.** For purposes of Standard 4, TSS and TP removal is required. Designing the site to meet ESSD Credit 2 meets the 90% TSS and 60% TP removal requirement. See **Section 2.3.4** and **Section 6.2.4** for more information Standard 4.
- **Standard 11.** Projects that discharge stormwater to waterbodies or waterways for which a Total Maximum Daily Load (TMDL) has been developed by MassDEP and approved by the Environmental Protection Agency (EPA) must be designed to implement control measures for the specified pollutants causing the impairment in accordance with Standard 11 (See **Section 2.3.11**).

Finally, the depth to groundwater and the depth to bedrock must be determined throughout the site to aid in the design and siting of stormwater SCMs, to prevent permanent groundwater breakout due to grading, and to verify during construction that temporary sedimentation control basins won't intercept groundwater.

Long-Term Maintenance

A long-term Operation and Maintenance Plan ("O&M Plan") is required by Standard 9. Prepare the O&M Plan in accordance with **Section 2.3.9**. At a minimum, also include the following PVC specific considerations in the O&M Plan.

- Proper maintenance of turf to ensure the site remains adequately stabilized. Precipitation running off the smooth panel surface results in a decreased time of concentration compared to water flowing over land (**Figure 5-1**). The resultant dripline may cause erosion of soil which results in sedimentation in Resource Areas unless vegetation is maintained properly. Once erosion begins along a dripline, down a slope, or along an access road, rilling may occur, or gullies may form that expand over time. Devoid of topsoil, these unstable features will serve as an ongoing source of sediment if they go unnoticed and are not repaired.
- A post-construction inspection schedule to verify that vegetation proposed beneath the panels, within the aisles, and within any shading buffers is established according to the cover types modelled in the hydrology calculations, and that all areas of the project are stable with no erosion or erosive features;
- Proposed measures to remedy problems found during inspections;
- A proposed schedule of long-term SCM and vegetation maintenance activities.

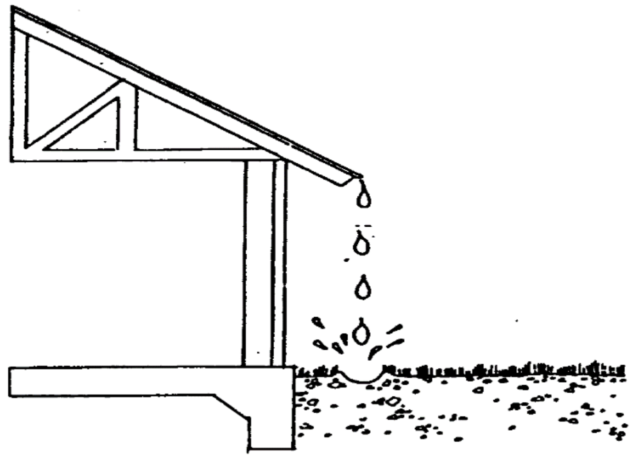

Figure 5-1. Precipitation from a solar panel surface may result in erosion of the soil and development of a concentrated dripline

5.6 Public Shared Use Paths Converted from Former Railway Beds

Public shared use paths are accessible paved and unpaved paths restricted solely to pedestrian and non-motorized vehicle travel (with the exception of wheelchairs and other power-driven mobility devices by individuals with a mobility disability, electric bicycles and electric scooters, emergency vehicles, and vehicles performing periodic maintenance). They are located either on public property or on private property pursuant to an easement that provides for public access (e.g., former railway bed).

If a different alignment within the right-of-way is advantageous to reduce Resource Area alterations, locating the proposed route outside the footprint of the rail bed may be considered. The linear configuration of these routes, the limited potential project area, and public safety requirements limit the choice of Stormwater Control Measures (SCMs) that may be used on site. Public shared use path projects are required to meet the Stormwater Management Standards to the maximum extent practicable pursuant to 310 CMR 10.05(6)(m)6, 310 CMR 10.24(7)(c)8.h., and 310 CMR 10.53(3)(u)9.

At minimum, the following shall be submitted with the Notice of Intent:

- Construction plans depicting all of proposed construction period BMPs and post construction period SCMs;
- The Stormwater Report Checklist;
- Long-Term Pollution Prevention Plan (310 CMR 10.05(6)(k)4.) (see **Section 4.3.2**);
- Construction Period Erosion, Sedimentation and Pollution Prevention Plan (310 CMR 10.05(6)(k)8.) (see **Section 4.3.3**);
- Operations and Maintenance Plan (310 CMR 10.05(6)(k)9.) (see **Section 2.3.9**); and
- A written alternatives analysis of possible stormwater management measures, in accordance with 310 CMR 10.05(6)(o), demonstrating the highest practicable level of stormwater management is proposed to be implemented (see **Section 6.1.4**).
- The following approach shall be followed for implementing the highest practicable level of stormwater management on public shared use path projects. This approach can be applied to Stormwater Standards 2, 3, and 4 (310 CMR 10.05(6)(k)2. – 4.). The goal of public shared use path projects is to implement SCMs and BMPs to the maximum extent practicable. Public shared use path design shall minimize impact caused by stormwater by directing stormwater runoff laterally to the sides of the public shared use path to a suitable pervious area.
- A suitable pervious area is a naturally vegetated and undisturbed area. Native vegetation should be left undisturbed, but invasive plant species may be removed and replaced with native vegetation.
- The soils of the suitable pervious area should be relatively permeable soils, and not include compacted soils such as, but not limited to, compacted railroad ballast, stone dust surfaces, and surfaces located immediately adjacent to the public shared use path that have been engineered.
- The suitable pervious area should have a length and width equal to or greater than the length and width of the contributing impervious area. For example, if the public shared use path is 10 feet wide, the suitable pervious area should be 10 feet adjacent to the public shared use path. Five (5) feet to either side of the public shared use path also meets this criterion.
- Suitable pervious areas shall not include Bordering Vegetated Wetlands, Isolated Vegetated Wetlands, Land Under Water Bodies and Waterways, Land Under Ocean, Salt Marsh, Certified Vernal Pools, Vernal Pool Habitat (within 100-feet of Vernal Pools) if the area is within an area

subject to protection under the M.G.L. c. 131 § 40, Zone I or Zone A of a Public Water Supply, Interim Wellhead Protection Areas, or areas that contain rare and endangered species habitat.

- For sections of public shared use paths that pass-through Wetland Resource Area, the public shared use path should be pitched to drain away from the Resource Area. In these locations, if suitable upland areas are located on the side of the public shared use path opposite of the Resource Area, said areas may be used as suitable pervious areas for the purpose of stormwater management.
- The suitable pervious area should have a slope less than or equal to 5.0% to avoid the creation of concentrated flows.

The following are SCMs or BMPs that may be utilized for the project when a project Applicant demonstrates that the public shared use path project cannot fully meet the approach detailed above.

- Reducing the public shared use path to the minimum width necessary through the Resource Area.
- Pitch the drainage away from the Resource Area.
- Install vegetated filter strips parallel to public shared use path in accordance with MassDEP specification (see **Appendix A**).
- Install infiltration trenches parallel to the public shared use path in accordance with MassDEP specification (see **Appendix A**).
- Install micro-depressions parallel to the public shared use path to reduce the lateral velocity of runoff.
- Where a drainage system is proposed to be utilized or the longitudinal slope of the public shared use path exceeds 5% for a distance of at least 100-feet, SCMs listed in **Table 2-7** should be considered to address peak runoff rate attenuation, recharge, and TSS/TP treatment.

The Long Term Pollution Prevention Plan shall prohibit the following activities: application of fertilizers and herbicides, pavement sealing with coal-tar based sealers, snow clearing beyond the shoulder, winter sand and salt application, and the application of deicing and anti-icing agents.

After the issuance of a Certificate of Compliance, the public shared use path vegetation cutting for public safety and pavement repair and resurfacing, limited to the Buffer Zone and riverfront area and conducted in accordance with 310 CMR 10.02(2)(b)2.r. are not subject to the Wetlands Protection regulations provided the work is performed solely within the Buffer Zone or riverfront area in a manner so as to reduce the potential for any adverse impacts to Resource Areas during construction and with post-construction measures implemented to stabilize any disturbed areas.

Any Order of Conditions permitting the construction of a pubic shared-use path should include on-going conditions regarding the following maintenance activities: no mowing of vegetation in the suitable pervious area should occur; a brush trimmer should be used only within the 2-foot recovery safety zone located along each side of the path; to the extent possible, leaves should be removed from the public shared use path utilizing vacuum type street cleaners (*e.g.* Regenerative Air Sweepers) or by hand methods; and rotary brush sweepers should not be utilized.

5.7 State Highway Specific Considerations

There are several classes of roadways projects. These are new roadways where widening is a lane width or greater, redeveloped and improved roadways where widening is less than a single lane, and maintenance of a roadway, where there is no widening or pavement is removed. Different standards apply to each class of roadway project. New roadways must fully comply with the Stormwater Management Standards, but may be implemented in accordance with applicable State Highway Specific Considerations listed in this section. Redeveloped and improved roadways must comply with the Stormwater Management Standards to the Maximum Extent Practicable and meet the 80% TSS / 50% TP removal requirement. Maintenance projects are just required to meet the Stormwater Management Standards to the Maximum Extent Practicable. Some requirements such as preparing and implementing a Construction Period Erosion and Sediment Control Plan (CPPP), Long Term Pollution Prevent Plan (LTPPP), Post Construction Operation and Maintenance Plan, and Maintenance Log, apply to all three types of roadway projects.

All Stormwater Control Measures, including closed drainage networks and outfalls along State Highways that are owned, operated and controlled by the MassDOT Highway Division and those public roadways owned and operated by municipalities when the criteria listed under Applicability are met, must follow the pollutant removal credits, design process, and design specifications listed in the Massachusetts Stormwater Handbook when new development or Redevelopment is proposed, unless the specification to be substituted is listed below.

Other than the Highway Specific Considerations, all other specifications listed in the Massachusetts Stormwater Handbook shall fully apply to MassDOT highway projects. By meeting the conditions listed below, the Massachusetts Stormwater Handbook design specifications at 310 CMR 10.05(6)(k) and 314 CMR 9.06(6)(a) are presumed to be met. As outlined in this section, certain municipal roadway projects may also implement the Highway Specific Considerations using the procedures described in this paragraph. The municipal roadway projects include those that are funded by MassDOT and designed to MassDOT specifications, and municipal roadway projects not funded by MassDOT.

The pollutant removal credits and design specifications below apply solely to MassDOT Highways and if specified, to municipal roads funded by MassDOT and designed to MassDOT specifications and/or municipal projects that are not MassDOT funded, and do not apply to other transportation projects such as railroads, airports, footpaths, and bicycle paths, institutional, residential, commercial, recreational, and other land uses, except as noted below. These special considerations recognize the following.

1) MassDOT Highway Division is the only entity regulated by the Transportation Separate Storm Sewer System (TS4) permit.
2) Highway transportation linear shaped projects may necessitate use of linear shaped treatment systems that differ from polygon shaped treatment systems used as part of typical site development.
3) MassDOT discharges stormwater to multiple Wetland Resource Areas located along highway routes (in contrast to site development where there may only be a discharge to a single wetland).
4) MassDOT Highway Division owns and operates the largest stormwater drainage network in the Commonwealth.

The TS4 permit contains numerous enforceable requirements that compel MassDOT Highway Division to meet applicable water quality standards to ensure the chemical, physical, and biological integrity of waters and wetlands. As such, the Highway Specific Considerations described in this section are not available for other types of land uses, unless specified in the ‘applicability’ part of this section.

The following Highway Specific Special Considerations may be used by MassDOT to comply with the Massachusetts Stormwater Handbook specifications required at 310 CMR 10.05(6)(k) and 314 CMR 9.06(6)(a). The following Special Considerations may also be used for municipal roadway projects funded by MassDOT and designed to MassDOT specifications, and/or to municipal roadway projects not funded by MassDOT, but only where specified further in this section. As indicated under “applicability”, some of these Special Considerations apply only to new development or Redevelopment projects, while others apply to both project types.

1. **TSS/TP Treatment Credit and Recharge Credit for MassDOT Linear Practices (Bioretention Linear Practice, Wet Pond Linear Practice, and Infiltration Linear Practice)**

- **Standards:** 310 CMR 10.05(6)(k), 310 CMR 10.05(6)(k)3.-4., 314 CMR 9.06(6)(a), and 314 CMR 9.06(6)(a)3.-4.
- **Discussion**: TSS and TP removal credits are provided to the designs specified below to encourage the placement of linear shaped treatment practices in landscaped highway medians and vegetated areas located adjacent to highway shoulders. TSS removal credit is provided for bioretention, wet basins, and infiltration practices, regardless of their configuration.
- **Conditions:**
  - 25% TSS and 44% TSS removal pretreatment shall be provided for Bioretention, Wet Basin, and Infiltration Linear Practices only through the use of MassDEP prescribed pretreatment practices. All MassDEP prescribed pretreatment practices shall be sized in accordance with MassDEP pretreatment specifications. Pretreatment credits shall be in accordance with **Table 2-2**. No pretreatment credits shall be added to terminal treatment practices since the pretreatment is already factored into the terminal treatment credits provided by EPA Performance Removal Curves and MassDEP Crosswalk as described by **Section 2.3.4**.
  - Required recharge volume (310 CMR 10.05(6)(k)3. And 314 CMR 9.06(6)(a)3.) is available for the Infiltration Linear Practice, only below the elevation of the check dam crown. Recharge volume is available for the Bioretention Linear Practice provided it is designed to meet the Massachusetts Stormwater Handbook specifications for Exfiltrating Bioretention (regardless of shape). No recharge credits shall be allowed to wet pond linear practices.
  - The water quality volume (310 CMR 10.05(6)(k)4. And 314 CMR 9.06(6)(a)4.) is only available for the volume below the elevation of the berm crown for each pool in the Wet Pond and Infiltration Linear Practices. The water quality volume for the Bioretention Linear Practice is limited to the 12-inch maximum ponding depth.
  - The Bioretention Linear Practice shall include triple shredded wood chips, biochar, or drinking water residuals blended into the bioretention soil mix that follows the MassDEP design specification for bioretention areas and rain gardens, except it shall not include any compost. Bioretention designed to exfiltrate shall not include any underdrains. Bioretention practices designed as a filter shall include an overflow drain(s) and underdrain.
- **Applicability:** New development and Redevelopment (MassDOT roadway projects, MassDOT funded municipal roadway projects that meet MassDOT design specifications, and municipal roadway projects that are not funded by MassDOT).

2. **Use of MassDOT Linear Practices for Peak Runoff Rate Reduction**

- **Standards:** 310 CMR 10.05(6)(k), 310 CMR 10.05(6)(k)2., 314 CMR 9.06(6)(a), and 314 CMR 9.06(6)(a)2.
- **Discussion:** Peak runoff reduction is credited to linear configured practices.
- **Conditions:**
  - *Wet Basin Linear Practice* - This is a series of linear shaped wet basins trained together. The peak runoff rate reduction volume (310 CMR 10.05(6)(k)2. and 314 CMR 9.06(6)(a)2.) is limited to the volume located in elevation above the permanent wet pools.

Flow velocity and discharge rate between ponds and the downstream most outlet shall be set so no scour occurs to any vegetation or soil.

- *Infiltration Linear Practice* - This is a series of linear shaped basins trained together with outlets separated by check dams (berms). The peak runoff rate reduction volume is limited to the portion of the confined channel located in elevation above the check dam crown. Additionally, the volume of the runoff that infiltrates may be “discarded” from the peak runoff rate per unit time over the 24-hour storm, in accordance with the standard method to perform peak rate reduction computations in recharge practices described in **Section 6.2.2**. The infiltration practices shall be vegetated with native turf grasses. Flow velocity and discharge rate shall be set so no scour occurs to any vegetation, infiltration media, or soil.
- *Bioretention Linear Practices* may be used to meet Standard 2 provided:
  - The linear bioretention is configured as a treatment train in a series of linear cells.
  - The upgradient most cell, the cell highest in elevation, is designed with a slope of no more than one percent (1%) and a ponding depth no deeper 12-inches to treat all or a portion of the water quality volume. This portion shall be modeled as a “pond”, with a peak water surface no greater than 12-inches above grade.
  - The cells lower in elevation than the upgradient cell shall have a ponding depth no deeper than 12-inches and a maximum slope to not exceed one percent (1%). Each of the lower linear bioretention cells shall be modeled as a “pond” with peak water surface of 12-inches above grade at the downstream end.
  - Flow velocity and discharge rate shall be set so no scour occurs to any vegetation, bioretention media, or soil.
  - The ponded water shall be held no more than 24-hours, so that peak runoff reduction is available for a subsequent storm. Peak runoff computations shall evaluate a 26-hour period to demonstrate no runoff occurs beyond 24-hours for the 2-year, 10-year and 100-year 24-hour storms. Design storms must be based on NOAA Atlas 14 data with a scaling factor, as described in **Section 6.2.2**.

- **Applicability:** New development and Redevelopment (MassDOT roadway projects, MassDOT funded municipal roadway projects that meet MassDOT design specifications, and municipal roadway projects that are not funded by MassDOT).

3. <u>MassDOT Deep Sump Catch Basins Inlet Grate Specifications</u>

- **Standards:** 310 CMR 10.05(6)(k), 310 CMR 10.05(6)(k)4., 314 CMR 9.06(6)(a), and 314 CMR 9.06(6)(a)4.
- **Discussion:** Use of inlet grates to deep sump catch basins other than the MassDEP specification are allowed provided the listed Conditions are met. Inlet grates prevent coarse solids, including trash, from entering Wetland Resource Areas and limit the inlet flow reducing the potential for resuspension of previously trapped solids.
- **Conditions:**
  - The inlet grates are limited to the following MassDOT designs:
    - Cascade grates consist of 20 openings approximately 4.4-inch by 2.7-inch in effective size (at the angle of the openings);
    - Standard municipal (rectangular) grates consisting of 36 openings approximately 2-inch by 2-inch in size; and
    - Parallel bar grates consisting of 10 openings approximately 1.2-inch by 21 inches in size.

        - Other inlet grate designs, but only when approved in writing by the MassDEP Wetlands Program.
    - Catch Basins designed for pretreatment must be in accordance with the Design Specifications and illustration for Deep Sump Catch Basins in MassDOT's Stormwater Handbook for Highways and Bridges (2004 pp. 5-13, 14, 15) which show the "Standard Frame and Grate" covering the entire catch basin inlet without a curb cut.
    - Inlets combining a grate with an "open curb inlet," "curb opening inlet," or "combination inlet" configuration (as defined by the Federal Highway Administration, Highway Engineering Circular 12 published in 1984 or 22 published in 2013), or "open throat" inlet, shall not receive any TSS pretreatment credit, for the purposes of 310 CMR 10.05(6)(k)4. and 314 CMR 9.06(6)(a)4. TSS pretreatment credit is available to "open curb inlet," "curb opening inlet," or "combination inlet" only when vertical curb inlet grates are provided

- **Applicability:** Redevelopment only (MassDOT roadway projects, municipal roadway projects funded by MassDOT that meet MassDOT design specifications).

4. <u>Deep Sump Catch Basin Hoods</u>

- **Standards:** 310 CMR 10.05(6)(k), 310 CMR 10.05(6)(k)4., 314 CMR 9.06(6)(a), and 314 CMR 9.06(6)(a)4.
- **Discussion:** Hoods are required in all deep sump catch basins except as provided below. Hoods provide spill control, floatables trapping, and inhibit movement of gases to the atmosphere from the drainage system. They may be constructed from multiple materials, including cast iron and plastic. More frequent maintenance removes trapped floatables and oils, that otherwise with less frequent maintenance will become resuspended and discharged to Wetland Resource Areas.
- **Conditions:**
    - Hoods may be constructed from multiple materials, including plastic.
    - Drainage from Impervious Surfaces of adjacent land uses shall not be directed to the public drainage system located in a State highway or public roadway.
    - The drainage system shall be inspected to ensure there are no Illicit Discharges such as sanitary sewage.
    - MassDOT shall, at a minimum, install hoods in the deep sump catch basin outlets in the following locations (which are specified in its Mass Highway, 2004, Storm Water Handbook, Deep Sump Catch Basin, page 5-14):
        - Along roadways in commercial areas;
        - Within rest areas;
        - In MassDOT maintenance yards;
        - Where combination inlets are used (a combination inlet has both an open curb inlet and a grate inlet); and
        - Along highways where no other containment device is provided for a stormwater discharge to or near a "Critical Area." MassDOT may propose alternative plans that afford equivalent protection based on risk of spills and proximity to Critical Areas, subject to review and approval by the Issuing Authority for compliance with 310 CMR 10.05(6)(k)1-10 and 314 CMR 9.06(6)(a)1-10.
- **Applicability:** Redevelopment only (MassDOT roadway projects, municipal roadway projects funded by MassDOT that meet MassDOT design specifications).

5. <u>Operation and Maintenance Approach</u>

- **Standard:** 310 CMR 10.05(6)(k)9., 314 CMR 9.06(6)(a)9.

- **Discussion:** Operation and maintenance at a frequency less than that specified in **Appendix A** of the Massachusetts Stormwater Handbook may be allowed, provided that the conditions specified below are met. MassDOT owns and operates the largest drainage system in the Commonwealth. They are not able to maintain the drainage system at the frequencies specified in the Massachusetts Stormwater Handbook.
- **Conditions:**
  - MassDOT shall implement the following:
    - Until an interim and final Operation and Maintenance (O&M) plan is approved in writing by MassDEP, MassDOT shall submit a O&M plan to the Issuing Authority as part of filing each individual Wetlands Notice of Intent, meeting the O&M plan specifications and BMP maintenance frequencies specified in the MassDEP Stormwater Handbook.
    - *Interim O&M Plan* - MassDOT shall submit a proposal to MassDEP, for its review and approval, proposing interim measures to maintain SCMs at a sufficient frequency to ensure that pollutant reduction credits awarded or credited as part of Wetlands permitting will continue to be achieved. After receipt of written approval, MassDOT must submit and Individual Project Specific O&M plan to the Issuing Authority as part of filing each individual Wetlands Notice of Intent, meeting the O&M plan specifications and BMP maintenance frequencies specified in the Interim approved O&M Plan. The Interim Plan shall be superseded by the Final O&M plan, after the Final O&M plan is approved.
    - *Final O&M Plan -* MassDOT shall submit a proposal to MassDEP, for its review and approval, proposing a final plan to maintain BMPs at a sufficient frequency to ensure that pollutant reduction credits awarded or credited as part of Wetlands permitting will continue to be achieved. After receipt of written approval, MassDOT must submit an Individual Project Specific O&M plan to the Issuing Authority as part of filing each individual Wetlands Notice of Intent, meeting the O&M plan specifications and BMP maintenance frequencies specified in the Final approved O&M Plan. The Final O&M plan shall supersede the Interim Plan.
    - *Individual Project Specific* O&M *Plan -* This is a project specific plan submitted to an Issuing Authority as part of a Wetlands NOI on a case-by-case basis. The Individual Project Specific Plan is tailored to the work proposed as part of a Project, and must be consistent with the interim or final O&M plan, depending on whichever one is legally effective.
    - *Maintenance Log -* MassDOT shall make available, no later than five business days after request, a maintenance log that is easily accessible to Conservation Commissions (*e.g.* web based), listing municipality name, roadway name, Wetlands NOI File number, SCM numerical designation (*e.g.* Infiltration Basin 1), annual frequency for routine and non-routine maintenance, and dates when the routine and non-routine maintenance was conducted, and specify the maintenance tasks that were conducted. The maintenance log shall be updated by MassDOT on a regular basis. This log may be combined with the log required to be maintained by the TS4 permit, provided it lists the MassDEP required criteria.
  - Maintenance is required to be on-going to ensure that pollutant reduction credits awarded or credited as part of Wetlands permitting will continue to be achieved and does not expire upon issuance of a Certificate of Compliance.
- **Applicability:** New development and Redevelopment (MassDOT only).

6. Macro-Approach

- **Standards:** 310 CMR 10.05(6)(k)2. to 4., 310 CMR 10.05(6)(k)7, 314 CMR 9.06(6)(a)2. to 4, and 314 CMR 9.06(6)(a)7..
- **Discussion:** Stormwater Management Standards are required to be met on site, except for Redevelopment where Offsite Mitigation is allowed when onsite measures are not practicable. In addition to the Offsite Mitigation allowed for all Redevelopment project types pursuant to 310 CMR 10.05(6)(k)7. and 314 CMR 9.06(6)(a)7., MassDOT may provide offsite stormwater mitigation for new development or Redevelopment provided the following conditions are met.
- **Conditions:**
    - The Issuing Authority allows use of the Macro-approach with the Massachusetts Stormwater Standards 2, 3, 4, and the pollutant removal requirements of 7 when MassDOT demonstrates:
        - MassDOT has made all reasonable efforts to meet the Stormwater Management Standards 2, 3, 4, and the pollutant removal requirements of 7 on the Project Site at the specific Wetland Resource Area/Buffer Zone being altered.
    - A written alternatives analysis is submitted with the Notice of Intent that it is not practicable to meet Stormwater Management Standard 2, 3, 4, and the pollutant removal requirements of 7 at each existing and proposed stormwater outfall and within the same general area of each Wetland Resource Area (see **Section 6.1.4**, “General Written Alternative Analysis Structure”, for information on what must be included in the written alternatives analysis). “Practicable” is defined at 310 CMR 10.04. “Small scale controls” at each Wetland Resource Areas/Buffer Zone being altered must be considered by MassDOT as part of the written alternatives analysis (see **Appendix A** for a fact sheet with more information on small scale controls). When full compliance cannot be achieved on the Project Site, the highest practicable level of stormwater management shall be demonstrated to be provided within the same general area of each Wetland Resource Area being altered and the remainder shall be provided utilizing the Macro-approach. The Macro-approach may be utilized anywhere within the Project Locus, but only when within the same subwatershed. Subwatershed boundaries shall be those defined as Hydrologic Unit Code 12 (HUC12) or smaller (*e.g.* HUC14, HUC16) by the National Watershed Boundary Dataset (WBD) distributed by the USGS/NRCS.[58] The use of the HUC12 boundary data distributed by MassGIS is not acceptable, since it is not updated as often as the USGS/NRCS version.
    - When using the Macro-approach, as much peak runoff reduction, water quality treatment, and recharge as possible shall be provided at the specific location where a Wetland Resource Area is proposed to be altered, and the balance shall be provided elsewhere along the Project Locus, but only within the same subwatershed, or as otherwise provided below.
    - Stormwater Management Standard 2 (post-development peak discharge rates to Resource Areas do not exceed pre-development peak discharge rates): Design points may be combined to analyze peak runoff rate at one point rather than at each outfall, provided the stormwater runoff hydrographs are combined at the combined design point utilizing the NRCS Unit Hydrograph method specified in National Engineering Handbook, Part 630, Chapter 16, for the 2-year, 10-year, and 100-year 24-hour storms. When using the macro-approach, the peak runoff reduction shall be to the same Wetland Resource Area (*e.g.,* if a proposed project discharges to the Charles River, the peak runoff rate must be reduced to the Charles River, not the Mystic River).
    - Stormwater Management Standard 3 (loss of annual recharge to groundwater to Resource Areas shall be eliminated or minimized): Mitigation to offset the loss of annual recharge caused by new and/or existing Impervious Surfaces being redeveloped may be

[58] WBD HUC12 data is available through the web at: https://hydro.nationalmap.gov/arcgis/rest/services/wbd/MapServer or https://www.usgs.gov/national-hydrography/watershed-boundary-dataset.

demonstrated to be met on a weighted average basis, weighted by the drainage area to each Wetland Resource Area proposed to be altered, using the recharge targets explicitly specified by MassDEP in the Wetlands/Water Quality Certification regulations and/or Massachusetts Stormwater Handbook. When using the macro-approach for new development, the recharge shall be provided to the same Wetland Resource Area. When using the macro-approach for Redevelopment, the off-site stormwater mitigation rules shall apply (first evaluate providing recharge at adjacent site within the same Project Locus, then same wetland system, then same municipality, and then same HUC12 subwatershed. In no circumstances, may the stormwater mitigation be provided in a different subwatershed)

- Stormwater Management Standard 4 (for new development, remove 90% of the average annual post-construction load of TSS and 60% Total Phosphorus to Resource Areas): The 90% TSS / 60% TP removal may be demonstrated to be met at a final outfall or Qualifying Pervious Area using a weighted average, weighted by the drainage area directed to each stormwater outfall and Qualifying Pervious Area. Qualifying Pervious Area is defined in **Appendix A** (see "Disconnection to Qualifying Pervious Area" Fact Sheet).
- Stormwater Management Standard 7 (for Redevelopment, remove 80% of the average annual post-construction load of TSS and 50% Total Phosphorus to Resource Areas): The 80% TSS / 50% TP removal may be demonstrated to be met at a final outfall or Qualifying Pervious Area using a weighted average, weighted by the drainage area directed to each stormwater outfall and Qualifying Pervious Area. Qualifying Pervious Area is defined in **Appendix A** (see "Disconnection to Qualifying Pervious Area" Fact Sheet).
- Disproportionate impacts to any one Wetland Resource Area shall be demonstrated to be avoided on a case-by-case basis.
  - The macro-approach cannot be used for the following, which constitute disproportionate impacts to Wetland Resource Areas:
    - Any stormwater discharge or recharge to or near a Critical Area.
    - Any stormwater discharge or recharge to or near a flow impaired basin that diverts water away from that basin.
      - Flow impaired basins are those identified by the MassDEP Sustainable Water Management Initiative (SWMI) with a "Net Groundwater Depletion." These are depicted on a map available at MassDEP's website at: https://www.mass.gov/doc/net-groundwater-depletion-statewide-map/download

- **Applicability:** Both new development and Redevelopment projects (MassDOT roadway projects, and MassDOT funded municipal roadway projects that meet MassDOT specifications).

7. Pollutant Removal via the Watershed-scale Accounting Method for Redevelopment

- **Standards:** 310 CMR 10.05(6)(k)7 and 314 CMR 9.06(6)(a)7
- **Discussion:** Compliance with the pollutant removal requirements of Stormwater Management Standard 7 must be achieved either on the Project Site, via Offsite Mitigation (see **Section 6.2.7**), or via the Macro-approach (i.e., Project Locus). If a written alternatives demonstrates that the pollutant removal requirements of Stormwater Management Standard 7 cannot be met by these three methods, mitigation may be provided through compensatory stormwater control measures (SCMs) that mitigate the onsite shortfall via the Watershed-scale Accounting Method as described in this Specific Consideration. The following conditions must be met to use the Watershed-scale Accounting Method. This method is only allowable for Redevelopment projects.
- **Conditions:**

- The project is a MassDOT-owned and maintained roadway, or a MassDOT-funded roadway project where MassDOT agrees to the long-term maintenance of the SCMs (or provides written agreement with responsible entity).
- MassDOT demonstrates via a written alternatives analysis that is submitted with the Notice of Intent that the pollutant removal requirements of Stormwater Management Standard 7 cannot be met for Redevelopment projects on the Project Site, by using the Macro-approach, or through Offsite Mitigation (see **Section 6.2.7**). See **Section 6.1.4** for information to include in the written alternatives analysis).
- When full compliance with the pollutant removal requirements of Stormwater Management Standard 7 cannot be achieved on the Project Site, by using the Macro-approach, or through Offsite Mitigation, the pollutant removal deficit for TSS and TP may be calculated quantitatively and compensated through the Watershed-scale Accounting Method. The pollutant removal deficit is expressed as TSS / TP percent removal for the impervious area of the MassDOT roadway or other facility.
- The Watershed-scale Accounting Method may be utilized anywhere within the same Hydrologic Unit Code 10 (HUC10 or smaller as defined by the National Watershed Boundary Dataset (WBD) distributed by the USGS/NRCS.
- Under the Watershed-scale Accounting Method, MassDOT will maintain and expand upon MassDOT's Impaired Waters Program (IWP) initially developed to improve the quality of stormwater runoff discharging to "impaired" water bodies (303(d) list) from highways. The IWP expansion, now referred to as the Watershed-scale Accounting Method includes waters not on the 303(d) list where water quality improvements can be made.
- MassDOT's already-constructed IWP SCMs, in addition to future Watershed-scale Accounting Method SCMs, may qualify for pollutant removal credits for projects with TSS / TP percent removal deficits.
- The Watershed-scale Accounting Method's tracking and accounting system includes the following information:
    - MassDEP Wetlands File Number or 401 WQC number and name of the project where the shortfall occurred
    - MassDEP Wetlands File Number or 401 WQC number through which those SCMs were constructed (if within a wetland resource area or buffer zone, within another town, within the same town but approved at a different time etc.)
    - SCM location (street address if one assigned and latitude/longitude coordinates)
    - Name of water and/or type of wetland resource area they discharge into
    - Design storage volume, treated impervious cover, and contributing drainage area, and TSS / TP pollutant removal percentages.
    - Design documentation that complies with the *Massachusetts Stormwater Handbook* and the **Appendix A** SCM Specifications
    - 303(d) list category of the water (if applicable)
    - Construction date
    - As-builts
    - Certification that it continues to operate as designed
    - Last maintenance date including what the last inspection entailed.
- The electronic SCM list is submitted to MassDEP yearly within 90-days of close of the MS4 or other separate storm sewer system permit reporting period.
- Methods to calculate pollutant removal follow the Stormwater Management Standard 7 and the *Massachusetts Stormwater Handbook.* Cumulative deficits are tracked per HUC 10.

- New SCMs are designed according to the *Massachusetts Stormwater Handbook* with appropriate resource area setbacks and then added to the electronic list with the previously-listed parameters along with project status (pre-construction, monitoring year 1, post-monitoring maintenance, etc.). When a proposed design includes drainage from a non-MassDOT roadway, a demonstration is made that the MassDOT drainage design, including the treatment SCM, treats both the offsite and Project Site runoff volume, to be claimed as a credit. MassDOT should attempt to work cooperatively with an interconnected system in instances of discharges impacting either system. Constructed projects are included and maintained according to the DOT Special Consideration for the Operation and Maintenance Approach.
- Approved IWP / Watershed-scale Accounting Method SCMs can compensate for pollutant removal shortfalls on more than one project if total SCM removal percentages can be sufficiently divided and appropriately allocated on an area weighted basis. The SCM cannot have been used previously as mitigation to meet Wetland or WQC regulation requirements for stormwater management. The SCMs may only be used once as mitigation for Projects. When a stand-alone SCM is used for mitigation to meet the Wetlands Protection or WQC regulations for stormwater management, MassDOT updates the electronic tracking and accounting list to note the SCM was used for Project mitigation and notifies EPA in the quarterly reporting.
- The tracking and accounting system includes the O/M Plan details as required in the DOT Specific Consideration for the Operation and Maintenance Approach and the LTPPP details including dates of performed maintenance.
- To receive full pollutant removal credit, the IWP projects are implemented within 3 years of the permit receipt, monitored for 3 years and maintained in accordance with the approved MassDOT O&M plan. Credit will be allowed for SCMs that have been built within the appropriate area within a rolling 10-year timeframe.

- **Applicability:** Redevelopment only (MassDOT only).

6 Documenting Compliance with the Stormwater Management Standards

6.1 Stormwater Report Explanation

A Stormwater Report must be submitted to document compliance with the Stormwater Management Standards. For projects that are subject to the Stormwater Management Standards and regulated by the Wetlands Protection Act Regulations (310 CMR 10.00), and/or the Water Quality Certification Regulations (314 CMR 9.00), the Stormwater Report and completed MassDEP "Checklist for Stormwater Report" form must accompany the Wetlands Notice of Intent or Water Quality Certification application.[59]

6.1.1 Who Prepares the Stormwater Report?

The Stormwater Report must be prepared by or under the direction of a Registered Professional Engineer (RPE) licensed to do business in the Commonwealth pursuant to MGL Chapter 112 Section 81R. The RPE must perform the required calculations. The Stormwater Report Certification and Checklist must be stamped and signed by the RPE.

6.1.2 Who Reviews the Stormwater Report?

For projects subject to jurisdiction under the Wetlands Protection Act, MassDEP and Conservation Commissions have the opportunity to review the Stormwater Report when Wetland NOIs are submitted for new development and Redevelopment in Wetland Resource Areas and Buffer Zones. MassDEP also has the opportunity to review the Stormwater Report for Water Quality Certification Applications or when there is an appeal of a decision issued by a Conservation Commission.

6.1.3 Site Plans

Site plans must accompany the Stormwater Report. At minimum, depict the following on the site plans:

- Site locus map;
- Site boundaries, existing conditions, proposed conditions;
- Jurisdictional Resource Area boundaries and their respective Buffer Zone;
- Critical Areas, LUHPPLs, and any areas on the site where the infiltration rate is greater than 2.4 inches per hour;
- Soil evaluation data and Hydrologic Soil Groups as required by **Section 6.3.5**.
- Drainage areas (*i.e.,* subcatchments) and all discharge points (both "points of interest" and outfalls") for existing and proposed conditions at a scale that enables verification of supporting calculations, including clearly demarcating the extent of all impervious area;
- Location of soil borings, test pits, or field evaluations;
- Proposed location of all post-construction SCMs, including identification of areal extent of all ESSD and LID techniques; and
- Construction period controls as required by the Construction Period Pollution Prevention Plan (CPPP) (see **Section 4.3.3**).

[59] The MassDEP "Checklist for Stormwater Report" form is available from the MassDEP website. https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards#-stormwater-report-tools-.

- For Projects with a mixture of new development and Redevelopment, Plans must clearly demarcate the extent of the new development and Redevelopment areas. Any runoff from offsite that drains into or through the Project Site must be clearly depicted and addressed in the SCM sizing.

6.1.4 Written Alternatives Analysis Requirements

The Stormwater Standards require that a written alternatives analysis accompany the Wetlands NOI or WQC Application for any of the instances listed below.

1) For all projects that cannot fully meet Standard 3 and Standard 4 with MassDEP recognized ESSD / LID techniques alone.
2) For Redevelopment projects and other applicable projects specified at 310 CMR 10.05(6)(m) and 314 CMR 9.06(6)(c) seeking to demonstrate compliance to the Maximum Extent Practicable (MEP).
3) For Redevelopment projects that cannot fully comply with Standard 7 pollutant removal requirements (*i.e.,* 80% TSS and 50% TP).
4) For MassDOT Projects that are proposing to implement the Macro-Approach (see **Section 5.7**).

Each instance is explained in more detail in the sections below. It is possible that some projects will be required to evaluate alternatives for all of these instances. It is acceptable to prepare just one (1) written alternatives analysis provided that the written alternatives analysis meets all requirements listed below.

General Written Alternative Analysis Structure

Include the following items in the alternatives analysis:

- Identify and describe all feasible alternatives to meet each applicable requirement.
- Summarize a comparison of all feasible alternatives including the principal differences among them.
- Identify the selected alternative that will be used to meet each applicable requirement. If full compliance cannot be achieved, explain how the selected alternative provides the highest practicable level of stormwater management.

Successfully screened alternatives should be presented with adequate cross-sectional and/or site plans and supporting data. All practicable existing technologies and methodologies should be addressed in this manner, and those alternatives identified as impracticable should be supported by sufficient and specific evidence. The analysis can only end upon exhaustion of all practicable alternatives. Detailed data, such as building code citations should be provided. Easements, rights-of-way, and “zone setbacks” may constitute legitimate legal logistical constraints. However, these should be thoroughly documented by the Applicant through citation and correspondence.

Instance 1: Projects that Cannot Meet Standard 3 and Standard 4 with ESSD / LID Techniques

Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis. Other types of SCMs shall only be used to the meet those portions of Standard 3 (*i.e.,* Required Recharge Volume) and Standard 4 (*i.e.,* TSS / TP removal) that cannot be fully met by ESSD and LID techniques. This evaluation is required by 310 CMR 10.05(6)(k)3., and 4 and 9.06(6)(a) 3 and 4.

The written alternatives analysis must demonstrate that Applicants have made all reasonable efforts to implement ESSD / LID techniques at the highest practicable level. Include the following in the written alternatives analysis:

- All previously summarized items (see "*General Written Alternatives Analysis Structure*").
- A description of what considerations were made to reduce or remove the extent of proposed work from jurisdictional Resource Areas (*e.g.,* Buffer Zone).
- A description of how all MassDEP recognized ESSD / LID techniques and ESSD Credits were considered, whether they were feasible, and to what extent they could be implemented.

ESSD and LID Resources

- See **Section 4.2.3** for a list of MassDEP recognized ESSD / LID techniques. Each MassDEP ESSD / LID recognized has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**).
- Most MassDEP recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).

Instance 2: Redevelopment and Other Applicable Projects Seeking Compliance to the MEP

A Redevelopment project is required to meet certain Stormwater Standards only to the Maximum Extent Practicable (MEP) as summarized by **Table 2-5**. In addition, the Stormwater Standards apply only to the MEP for other applicable projects specified at 310 CMR 10.05(6)(m) and 314 CMR 9.06(6)(c). Other applicable projects include, but are not limited to: marinas, boatyards, footpaths, bike paths, and other paths for pedestrian and/or nonmotorized vehicle access.

Applicants seeking to demonstrate compliance with some or all of the Stormwater Management Standards to the MEP must submit a written alternatives analysis with the NOI or WQC Application. Following 310 CMR10.05(6)(o) and 314 CMR 9.06(6)(e), the written alternatives analysis shall demonstrate the following.

1) The Applicant has made all reasonable efforts to meet each of the Standards and other applicable requirements (e.g., **Section 2.5** horizontal setbacks and vertical separation distance).
2) The Applicant has performed an alternatives analysis of possible stormwater management measures including Environmentally Sensitive Site Design and Low Impact Development techniques that minimize land disturbance and Impervious Surfaces, structural stormwater control measures, best management practices, pollution prevention, erosion and sedimentation control and proper operation and maintenance of stormwater best management practices.
3) If full compliance with the Standards cannot be achieved, the highest practicable level of stormwater management is being implemented.

Also include the following items in the written alternatives analysis:

- All previously summarized items (see "*General Written Alternatives Analysis Structure*").
- If the ESSD / LID requirement cannot be met, include all components listed previously (see "*Projects that Cannot Meet Standard 3 and Standard 4 with ESSD / LID Techniques*").
- A description of what considerations were made to meet other applicable requirements (e.g., **Section 2.5** horizontal setbacks and vertical separation distance.

Instance 3: Redevelopment Projects that cannot Fully Comply with Standard 7

The Stormwater Management System for Redevelopment projects must be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS) and 50% of the average annual post-construction load of Total Phosphorus (TP). Applicants that are unable to fully meet the 80% TSS and 50% TP removal must submit a written alternatives analysis with the NOI or WQC Application that identifies and implements Offsite Mitigation alternatives. Include the following items in the written alternatives analysis:

- All previously summarized items (see "*General Written Alternatives Analysis Structure*").
- If the ESSD / LID requirement cannot be met, include all components listed previously (see "*Projects that Cannot Meet Standard 3 and Standard 4 with ESSD / LID Techniques*").
- If the Applicant is proposing to meet any Stormwater Standards to the MEP (*e.g.,* Standard 3), include all components listed previously (see "*Redevelopment and Other Applicable Projects Seeking Compliance to the MEP*).
- A detailed summary of Offsite Mitigation alternatives, evaluated in the following order: same Project Site, same Project Locus, adjacent site, same Wetland Resource Area, same municipality, and the same stream reach within the Hydrologic Unit Map (HUC) 12 sub-watershed.

The off-site location is expected to provide an equivalent pollutant removal or recharge on an area weighted basis. The impervious off-site area must also be equal to or greater than the untreated impervious on-site area to provide sufficient runoff volume to equal the runoff volume from the onsite location. Refer to **Section 6.2.7** for more information on offsite mitigation, including a detailed description of the process, example calculations, and site selection guidance.

6.2 Required Documentation Including Computations for Each Stormwater Standard

As more fully set forth below, the Stormwater Report must include demonstrations and subsequent computations to document compliance with the Stormwater Management Standards. A summary of required demonstrations for each Stormwater Standard are provided in **Table 6-1**. The sections below include detailed information relative to each Standard's requirements. References that may be useful in conducting each computation are listed at the end of each Standard's section.[60]

Designing with ESSD and LID Techniques

To meet Standard 3 and Standard 4, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis submitted with the Notice of Intent. Other SCMs shall only be used to meet those portions of the Required Recharge Volume (Standard 3) and TSS / TP removal (Standard 4) that cannot be fully met by ESSD and LID techniques. See **Section 6.1.4** for more information on the written alternatives analysis.

As with traditional designs and stormwater controls, computations must be provided demonstrating that the ESSD and LID practices are sized and designed properly to meet the Stormwater Standards. See **Section 2.3.3** for a list of MassDEP recognized ESSD / LID techniques. Refer to **Appendix A** for ESSD Credits that can be used to help meet this requirement.

[60] Although MassDEP has endeavored to make sure that requirements in the regulations and other sections of the Massachusetts Stormwater Handbook are consistent, if there is a discrepancy between the information listed in this section and elsewhere in this document, the most restrictive requirements must be applied.

Table 6-1. Summary of required demonstrations for each Stormwater Standard

Std.	Description	Required Demonstrations
1	Untreated Discharges	• Demonstrate that there are no new untreated discharges to wetlands or Waters of the Commonwealth. • Demonstrate that there is no erosion or scour to wetlands or Waters of the Commonwealth by performing required computations.
2	Peak Rate Attenuation	• Demonstrate that the Stormwater Management System is designed so that the post-development peak discharge rates do not exceed pre-development peak discharge rates for the 2-, 10-, and 100-year 24-hour storms, and each discharge point.
3	Stormwater Recharge	• Demonstrate that the Stormwater Management System is designed to infiltrate the required recharge volume. (*ESSD and LID techniques must be used unless impracticable*.)
4	Pollutant Removal	• Demonstrate that source control and pollution prevention measures have been identified in a Long-term Pollution Prevention Plan (LTPPP). • Demonstrate that the Stormwater Management System is designed to remove the required amount of TP and TSS (see Standard 7). (*ESSD and LID techniques must be used unless impracticable*.)
5	LUHPPLs	• If the project includes a LUHPPL, demonstrate that source controls and pollution prevention measures are identified in the LTPPP. • Demonstrate that the treatment practices are approved by MassDEP to treat drainage from LUHPPL.
6	Critical Areas	• If the project includes any discharges near or to a Critical Area, demonstrate that source control and pollution prevention measures are identified in the LTPPP. • Demonstrate that the treatment practices are approved by MassDEP to treat drainage near or to Critical Areas.
7	Redevelopment	• Complete the Redevelopment Checklist and provide computations demonstrating that 80% TSS and 50% Total Phosphorus removal will be achieved. • Prepare a written alternatives analysis for allowable Standards proposed to be met to the MEP or if the 80% TSS / 50% TP removal cannot be fully met. Offsite Mitigation alternatives must be used to meet the 80% TSS / 50% TP removal requirement. • A summary of requirements for each Stormwater Standard for Redevelopment projects is provided by **Table 2-5**.
8	Construction Period Controls	• Complete a Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan (CPPP) and submit it with the Notice of Intent. • Demonstrate that proposed control measures are properly sized. • Specify whether coverage is required under the EPA Construction General Permit.
9	O&M Plan	• Submit an Operation and Maintenance Plan.
10	Illicit Discharges	• Identify whether any Illicit Discharges exist to Resource Areas, groundwater or the existing stormwater drainage system, and remove them. • Include measures to prevent future Illicit Discharges in the LTPPP. • Complete and submit a signed Illicit Discharge Compliance Statement.
11	TMDLs	• If applicable, demonstrate that suitable SCMs are proposed and properly sized to treat applicable TMDL pollutants in accordance with Standards 3 and 4.

Note: This Table provides a high level summary of required demonstrations for each standard. Refer to subsequent sections of this Chapter and other sections of the Stormwater Handbook for more detailed information and required computations for each Standard.

6.2.1 Standard 1: No Untreated Discharges or Erosion to Wetlands

Required Demonstrations and Computations

Demonstrations and computations covered by this section include:

- ❑ Demonstrate that there are no new untreated discharges to wetlands or Waters of the Commonwealth. To demonstrate that all new discharges are adequately treated, use required computations to demonstrate compliance with Standards 2 through 6 (see **Section 2.3.1** for definition of “new” vs. “existing” discharges).
- ❑ Demonstrate that there is no erosion or scour to wetlands or Waters of the Commonwealth by performing the below computations.

New outfalls and riprap splash pads or aprons are components of Stormwater Management Systems and as such are prohibited from being placed in most types of Resource Areas, pursuant to 310 CMR 10.05(6)(k). Setting the outlets back from Bordering Vegetated Wetlands and Land Under Water Bodies and Waterways will reduce the likelihood of erosion or scour to Resource Areas. To evaluate whether a new or untreated discharge will cause erosion or scour, the first step is to determine the stormwater discharge velocity at each outlet or flow path. The second step is to perform computations and select materials or practices to reduce velocity of the discharged stormwater and stabilize flow paths to prevent erosion. Provide computations for both point sources and sheet flow. Computations performed in accordance with the below steps demonstrating that new discharges will not cause or contribute to erosion or scour in wetlands or Waters of the Commonwealth in the post-construction condition will be presumed to meet Standard 1.

- **Step 1.** Determine the maximum stormwater discharge velocity at each outlet or flow path for all conveyances.

  The maximum discharge or velocity is dependent on the size of the conveyance. Include gravitational forces in the computations when proposing to discharge stormwater above the receiving practice. Factor tailwater conditions in the receiving wetland into the analysis. For sheet flow, the maximum velocity to evaluate is the runoff from the 2-year 24-hour storm. The Registered Professional Engineer (RPE) shall select an accepted method to determine maximum velocity. Such methods may include, but are not limited to: Manning’s Equation. Normal depth assumptions may be utilized, provided the channel cross section and roughness are relatively uniform.

- **Step 2**. Determine the ability of the ground surface to resist erosion at each outlet or flow path for all conveyances.

  Determine the allowable sheer stress, the ability of ground or lining materials to resist erosion from the velocity computed in **Step 1.** Note that banks opposite from a stormwater discharge point may also need to be evaluated to assess their ability to resist scour when banks are close to the outlets (*e.g.,* a narrow stream channel). Banks are prohibited from being armored pursuant to 310 CMR 10.05(6)(k). In situations where computations indicate a Bank will be scoured by a stormwater discharge, set the outlet further back or relocate it to a location where no scour is expected to occur. The ability of the ground surface to resist erosion may be evaluated by performing computations to estimate the size/weight of stone or bioengineered materials needed to resist the force of water or comparing the discharge velocity against a “permissible velocity table” that provides information on the ability of different types of materials/vegetation to resist shear. See **Table 6-2** for an example permission velocity table. The references that follow include several different computational methods and permissible velocity tables that are acceptable.

  Manage any discharges that are determined to potentially cause erosion or scour relative to permissible velocity by selecting materials or practices to reduce velocity or stabilize the ground to withstand the shearing force caused by the discharged stormwater. Some practices that reduce runoff velocity include creating flatter slopes, terracing, and level spreading. Ground stabilization measures include vegetation and armoring.

Table 6-2. Example permissible velocity table[1]

Channel Slope	Lining [2]	Permissible Velocity (feet/second)
0 - 5%	Tall fescue Kentucky bluegrass	5
	Grass-legume mixture	4
	Red fescue Redtop Sericea lespedeza Annual lespedeza Small grains	2.5
5 - 10%	Tall fescue Kentucky bluegrass	4
	Grass-legume mixture	3
Greater Than 10%	Tall fescue Kentucky bluegrass	3

Notes:

1. Table modified from Schwab, G. O., Fangmeier, D.A., Elliot, W.J., and Frevert, R.K., 1992, Soil and Water Conservation Engineering, 4th Edition, John Wiley and Sons
2. Before selecting a vegetated lining, consult the list of plants banned for sale, trade, purchase, or distribution in Massachusetts by the Department of Agricultural Resources, pursuant to M.G.L. Chapter 128 Section 2 and Sections 16 through 31A. See Massachusetts Prohibited Plant List | Mass.gov.

Standard 1 References

Fletcher, B.P. and Grace, J.L., Jr., 1974, Practical Guidance for Design of Lined Channel Expansions at Culvert Outlets, Technical Report H-74-9, U.S. Army Engineer Experiment Station, Vicksburg, MS., page A12 (specifies methods for sizing riprap blanket dimensions from discharges from circular, square, rectangular and other shaped outlets)

Huffman, R.L., Fangmeier, D.A., Elliot, W.J., Workman, S.R., 2013, Soil and Water Conservation Engineering, 7th Edition, ASABE Publication 801M0313. https://soilwater7edition.wordpress.ncsu.edu/

Gribbon, John E., 2013, Hydraulics and Hydrology for Stormwater Management, 4th Edition, Chapter 5.5, Storm Sewer Outfalls, Delmar Publishers, Albany, NY (computation methods)

Lindeburg, Michael R., 2005, Civil Engineering Reference Manual for the PE Exam, 10th Edition (general reference, computational methods)

Schwab, G. O., Fangmeier, D.A., Elliot, W.J., and Frevert, R.K., 1992, Soil and Water Conservation Engineering, 4th Edition, John Wiley and Sons (permissible velocity table) https://www.wiley.com/en-us/Soil+and+Water+Management+Systems%2C+4th+Edition-p-9780471109730

U.S. Agricultural Research Service, 1987, Stability Design of Grass-Lined Open Channels, Agricultural Handbook No. 667. Online at:

https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17766.wba (computational methods)

U.S. Army Corps of Engineers, Engineering and Design - Hydraulic Design of Flood Control Channels, Engineering Manual (EM) 1110-2-1601. Online at: https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/?udt_43544_param_page=6 (computational methods)

U.S. Army Corps of Engineers, Drainage and Erosion-Control Structures for Airfields and Heliports, Technical Manual (TM) 5-820-3/AFM 88-5, Chapter 5. Online at: https://www.wbdg.org/FFC/ARMYCOE/COETM/ARCHIVES/tm_5_820_3.pdf (computation methods)

U.S. Army Corps of Engineers, Hydraulic Design Criteria, Sheets 722-1 to 722-7. Online at: https://www.publications.usace.army.mil/USACE-Publications/Engineer-Manuals/?udt_43544_param_page=6 (computational methods)

U.S. Federal Highway Administration, 2006, Hydraulic Design of Energy Dissipators for Culverts and Channels, Hydraulic Engineering Center Circular No. 14 (HEC-14). Online at: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf (computational methods)

U.S. Federal Highway Administration, 2005, Design of Roadside Channels with Flexible Linings, Hydraulic Engineering Circular Number 15 (HEC-15), Third Edition. Online at: http://www.fhwa.dot.gov/engineering/hydraulics/pubs/05114/05114.pdf (computational methods)

U.S. Federal Highway Administration, 2009, Urban Drainage Design Manual, Hydraulic Engineering Circular Number 22 (HEC-22), Third Edition, Storm Drain Outfalls, Section 7.1.5. Online at: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/10009/10009.pdf (general reference)

U.S. Natural Resources and Conservation Service (NRCS), National Handbook of Conservation Practices. Online at Handbook of channel design for soil and water conservation : Oklahoma Agricultural Experiment Station : Free Download, Borrow, and Streaming : Internet Archive (practices to reduce erosion)

U.S. Soil Conservation Service (SCS). 1966. Handbook of Channel Design for Soil and Water Conservation (SCS-TP-61). Online at: https://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/TRsTPs/TP61.pdf (permissible velocity table)

U.S. Soil Conservation Service (SCS). 1979. Engineering Field Manual for Conservation Practices, (Structures – Chapter 6, Grassed Waterways - Chapter 7). Washington, D.C., Chapter 7. Online at: https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/manage/hydrology/?cid=stelprdb1043063 (computation methods, permissible velocity table, practices)

Young, G.K., et al, 1996. HYDRAIN – Integrated Drainage Design Computer System: Version 6.0 – Volume VI: HYCHL, FHWA-SA-96-064 (computational methods)

6.2.2 Standard 2: Peak Rate Attenuation

Required Computations or Demonstrations

Demonstrate that the Stormwater Management System is designed so that the post-development peak discharge rates do not exceed pre-development peak discharge rates for the 2-, 10-, and 100-year 24-hour storms. Computations and demonstrations covered by this section include:

- ❑ Calculate rainfall depth for required design storms.
- ❑ Apply calculated rainfall depth to a rainfall distribution for required design storms.
- ❑ Identify or verify Hydrologic Soil Groups (HSGs) used to assign Runoff Curve Numbers (RCNs) for peak runoff analysis in accordance with the "*Soil Evaluation Procedures*" presented by **Section 6.3**.
- ❑ As applicable, assign Runoff Curve Numbers (RCNs) for porous pavement and green roofs.
- ❑ The design should provide for an emergency spillway for any peak rate control structure that requires an embankment. The emergency spillway's purpose is to protect against embankment failure, in the event the primary outlet cannot handle flows discharging form the impoundment.

Additional computations and demonstrations covered by <u>other</u> sections include:

- Refer to **Section 6.4** for information on calculating the contributing drainage area for peak rate computations.
- Refer to **Section 6.5** for the definition of impervious area for use in assigning Runoff Curve Numbers for peak rate computations.
- If applicable, refer to **Section 6.2.4** for information on sizing one SCM to meet multiple stormwater standards.
- Setbacks must be met in accordance with **Section 2.5**.

Note: Perform peak rate attenuation computations for required design storms using methods described in the *Hydrology Handbook for Conservation Commissioners*. [61] The following caveats apply.

- Rainfall depth and distributions must be computed in accordance with the below sections. The rainfall depth and distribution computation methods presented in the *Hydrology Handbook for Conservation Commissioners* have been superseded.
- Applicants may incorporate exfiltration into peak rate reduction calculations for applicable infiltration SCMs as described in the "*Incorporating Exfiltration into Peak Rate Calculations*" section below.

[61] Hydrology Handbook for Conservation Commissioners: https://www.mass.gov/doc/hydrology-handbook-for-conservation-commissioners/download.

What Tools are Available to Assist with Required Calculations?

MassDEP has created a suite of tools to assist Applicants in preparing certain calculations required by the Stormwater Standards. The following tools are available for Standard 2:

- A spreadsheet-based tool to identify and download the appropriate regional rainfall distribution based on site location (see "*Preparing Rainfall Distributions based on NOAA Atlas 14 Data*" for more information)

This tool is available at: https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards.

Obtaining Rainfall Depth from NOAA Atlas 14

Site specific rainfall depths used to calculate peak discharge rates for the 2-, 10- and 100-year 24-hour storms must be obtained from National Oceanic and Atmospheric Administration's (NOAA) Atlas 14, Volume 10.[62] Use NOAA Atlas 14's Partial Duration Series point frequency estimates to find the upper 90th confidence interval at each point of interest, then multiply that value by a scaling factor of 0.9.

Steps to Obtain Site-Specific Design Storm Depths

1) Navigate to NOAA Atlas 14: https://hdsc.nws.noaa.gov/hdsc/pfds/ (Nationwide) or https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma (Massachusetts only)
2) Navigate to Massachusetts either by clicking or using "drop-down" tool in upper left to select Massachusetts.
3) Navigate to the Project Site, either by using latitude/longitude or street address. Drag the red cross to refine the "point of interest" as needed (**Figure 6-1**).
4) Make sure defaults are enabled for Data Type (Precipitation Depth is default), Units (English is default) and Time Series Type (Partial Duration is default)
5) Scroll down to tabular precipitation frequency statistics.
6) To determine design storm, select return period on horizontal row, and time length on the vertical column (**Figure 6-2**).
7) Each cell contains three values: the fitted value (Bolded), the lower confidence value, and the upper confidence value.
8) Use the **upper confidence cell value, and multiply it by 0.9**. This is the value that is required to be used for design.

[62] NOAA Atlas 14: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma.

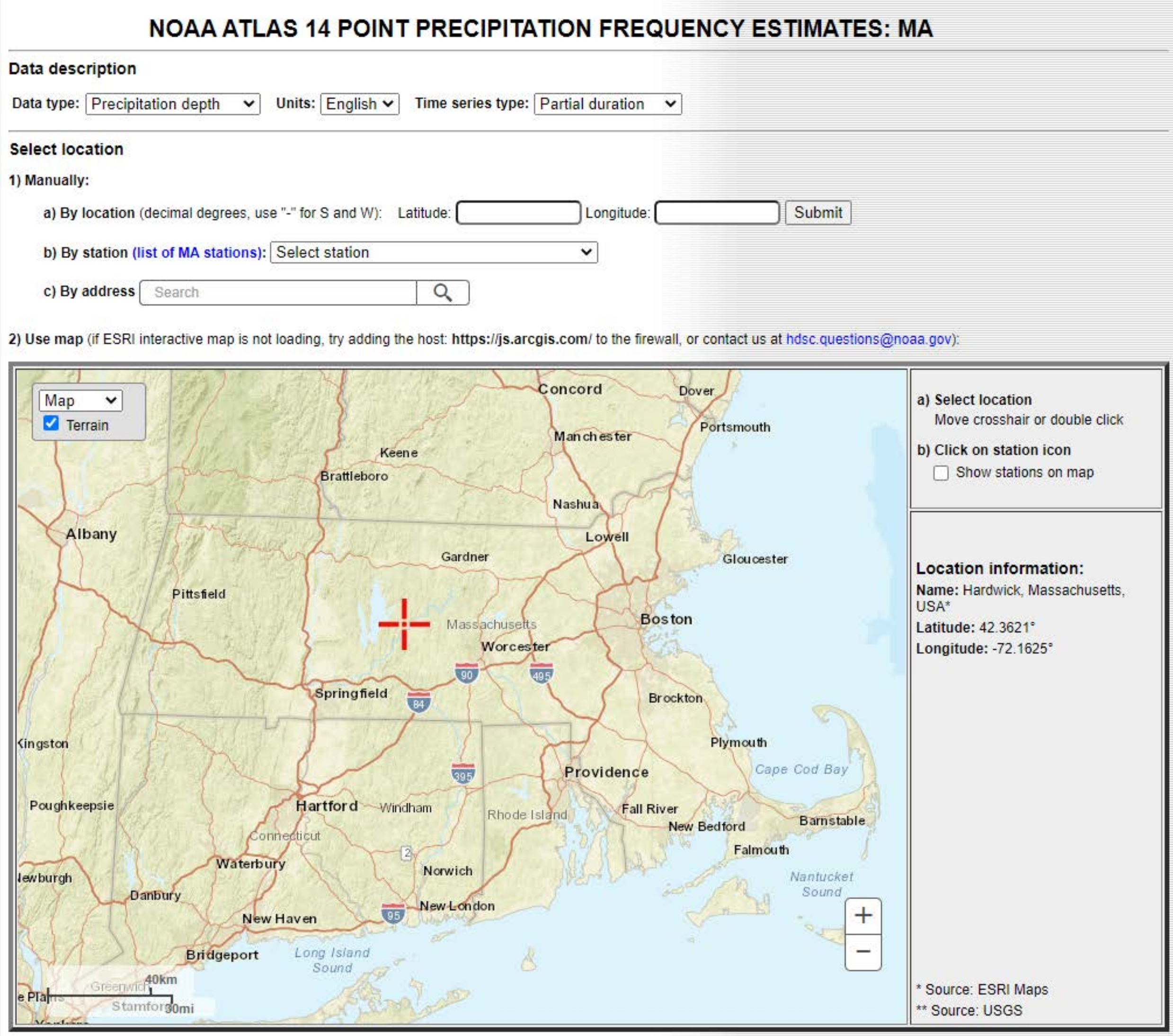

Figure 6-1. NOAA Atlas 14 graphical interface. Red cross indicates “point of interest”

(Point of interest may also be identified using geographic coordinates, station name, or address.)

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 10, Version 3

PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.338** (0.265-0.430)	**0.393** (0.308-0.501)	**0.483** (0.377-0.617)	**0.558** (0.434-0.717)	**0.662** (0.496-0.883)	**0.742** (0.543-1.01)	**0.822** (0.581-1.15)	**0.906** (0.612-1.31)	**1.02** (0.661-1.52)	**1.11** (0.699-1.69)
10-min	**0.479** (0.376-0.609)	**0.557** (0.437-0.710)	**0.685** (0.535-0.876)	**0.791** (0.615-1.02)	**0.938** (0.703-1.25)	**1.05** (0.770-1.43)	**1.16** (0.824-1.63)	**1.28** (0.866-1.85)	**1.44** (0.937-2.16)	**1.57** (0.990-2.39)
15-min	**0.563** (0.442-0.716)	**0.655** (0.514-0.835)	**0.806** (0.630-1.03)	**0.931** (0.722-1.20)	**1.10** (0.827-1.47)	**1.24** (0.905-1.68)	**1.37** (0.969-1.92)	**1.51** (1.02-2.18)	**1.70** (1.10-2.54)	**1.84** (1.17-2.81)
30-min	**0.761** (0.597-0.968)	**0.886** (0.695-1.13)	**1.09** (0.851-1.39)	**1.26** (0.980-1.62)	**1.50** (1.12-2.00)	**1.68** (1.23-2.28)	**1.86** (1.31-2.60)	**2.05** (1.38-2.96)	**2.30** (1.49-3.44)	**2.50** (1.58-3.81)
60-min	**0.959** (0.752-1.22)	**1.12** (0.876-1.42)	**1.38** (1.08-1.76)	**1.59** (1.24-2.05)	**1.89** (1.42-2.52)	**2.12** (1.55-2.88)	**2.35** (1.66-3.29)	**2.58** (1.75-3.74)	**2.90** (1.89-4.34)	**3.15** (1.99-4.81)
2-hr	**1.21** (0.956-1.53)	**1.42** (1.12-1.79)	**1.75** (1.38-2.22)	**2.03** (1.59-2.59)	**2.41** (1.83-3.22)	**2.69** (2.00-3.68)	**3.00** (2.16-4.26)	**3.36** (2.28-4.84)	**3.91** (2.54-5.82)	**4.38** (2.78-6.64)
3-hr	**1.38** (1.09-1.74)	**1.62** (1.28-2.04)	**2.02** (1.59-2.55)	**2.35** (1.84-2.98)	**2.80** (2.13-3.73)	**3.13** (2.34-4.27)	**3.49** (2.54-4.97)	**3.95** (2.68-5.67)	**4.67** (3.04-6.92)	**5.29** (3.37-8.00)
6-hr	**1.70** (1.36-2.13)	**2.03** (1.62-2.55)	**2.57** (2.04-3.23)	**3.02** (2.38-3.82)	**3.64** (2.79-4.84)	**4.09** (3.08-5.57)	**4.59** (3.38-6.55)	**5.24** (3.57-7.48)	**6.29** (4.11-9.28)	**7.23** (4.61-10.9)
12-hr	**2.07** (1.66-2.58)	**2.53** (2.03-3.14)	**3.26** (2.61-4.07)	**3.88** [illegible]	**4.72** (3.64-6.24)	**5.34** (4.04-7.23)	**6.02** (4.45-8.53)	**6.90** (4.72-9.79)	**8.32** (5.45-12.2)	**9.57** (6.13-14.3)
24-hr	**2.45** (1.98-3.02)	**3.02** (2.44-3.73)	**3.96** (3.19-4.91)	**4.75** (3.79-5.91)	**5.82** (4.51-7.64)	**6.61** (5.03-8.89)	**7.48** (5.55-10.5)	**8.59** (5.89-12.1)	**10.4** (6.81-15.1)	**11.9** (7.65-17.7)
2-day	**2.81** (2.28-3.44)	**3.49** (2.83-4.28)	**4.60** (3.72-5.66)	**5.52** (4.44-6.83)	**6.78** (5.29-8.84)	**7.71** (5.90-10.3)	**8.74** (6.52-12.2)	**10.0** (6.92-14.1)	**12.1** (8.01-17.5)	**14.0** (8.99-20.6)
3-day	**3.06** (2.50-3.74)	**3.80** (3.10-4.64)	**5.01** (4.07-6.14)	**6.01** (4.85-7.41)	**7.39** (5.78-9.59)	**8.39** (6.44-11.2)	**9.51** (7.11-13.2)	**10.9** (7.55-15.2)	**13.2** (8.74-19.0)	**15.2** (9.82-22.3)
4-day	**3.30** (2.70-4.01)	**4.08** (3.34-4.97)	**5.36** (4.36-6.55)	**6.42** (5.19-7.89)	**7.88** (6.18-10.2)	**8.94** (6.88-11.9)	**10.1** (7.59-14.1)	**11.6** (8.05-16.2)	**14.1** (9.30-20.2)	**16.2** (10.4-23.6)
7-day	**3.97** (3.27-4.80)	**4.83** (3.98-5.86)	**6.25** (5.12-7.60)	**7.43** (6.05-9.08)	**9.05** (7.13-11.6)	**10.2** (7.90-13.5)	**11.5** (8.67-15.9)	**13.2** (9.16-18.2)	**15.8** (10.5-22.6)	**18.1** (11.7-26.3)
10-day	**4.63** (3.83-5.59)	**5.54** (4.57-6.69)	**7.04** (5.78-8.52)	**8.27** (6.76-10.1)	**9.98** (7.87-12.8)	**11.2** (8.67-14.7)	**12.6** (9.45-17.2)	**14.3** (9.95-19.7)	**16.9** (11.3-24.1)	**19.2** (12.5-27.8)
20-day	**6.67** (5.55-7.99)	**7.64** (6.34-9.16)	**9.22** (7.63-11.1)	**10.5** (8.65-12.7)	**12.3** (9.75-15.5)	**13.7** (10.6-17.6)	**15.1** (11.3-20.1)	**16.7** (11.7-22.8)	**19.1** (12.8-26.9)	**21.0** (13.6-30.2)
30-day	**8.38** (7.00-10.00)	**9.37** (7.82-11.2)	**11.0** (9.13-13.2)	**12.3** (10.2-14.9)	**14.2** (11.2-17.7)	**15.6** (12.0-19.9)	**17.0** (12.6-22.4)	**18.5** (13.0-25.1)	**20.6** (13.8-28.9)	**22.2** (14.5-31.8)
45-day	**10.5** (8.81-12.5)	**11.5** (9.65-13.7)	**13.2** (11.0-15.8)	**14.6** (12.1-17.5)	**16.5** (13.1-20.5)	**18.0** (13.9-22.7)	**19.5** (14.4-25.3)	**20.9** (14.7-28.1)	**22.6** (15.3-31.6)	**23.9** (15.6-34.1)
60-day	**12.3** (10.3-14.5)	**13.3** (11.2-15.8)	**15.1** (12.6-17.9)	**16.5** (13.7-19.8)	**18.5** (14.7-22.8)	**20.1** (15.5-25.2)	**21.6** (15.9-27.8)	**22.9** (16.2-30.8)	**24.5** (16.6-34.1)	**25.6** (16.7-36.4)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Estimates from the table in CSV format: Precipitation frequency estimates Submit

Figure 6-2. Example NOAA Atlas 14 results table

The 10-year 24-hour storm result is circled. The upper and lower 90% confidence interval is provided (i.e., 3.79 inches to 5.91 inches). To determine the design storm depth for compliance with the Stormwater Management Standards, take the Upper Confidence in the cell (5.91-inches) and multiply that by 0.9. The resulting design storm depth for the 10-year 24-hour storm at the example location is 5.32-iches. ***Do not use 4.75-inches.***

Preparing Rainfall Distributions based on NOAA Atlas 14 Data

Rainfall distributions must be prepared when conducting a NRCS TR-20 / TR-55 peak discharge rate analysis. Rainfall distributions must be based on NOAA Atlas 14 which contains updated rainfall frequency data for Massachusetts.

What Types of Rainfall Distributions are Allowable?

Peak rate analysis has historically been performed based on two primary distribution types in Massachusetts: 1) The NRCS Type III distribution based on Technical Paper 40; and 2) The Type A, B, C, and D distributions from the Northeast Regional Climate Center (NRCC).

The NRCS and NRCC distributions may no longer be used for the purposes of meeting Standard 2. Rainfall distributions must be based on the NOAA Atlas 14 precipitation-frequency data as described below.

There are two allowable options for preparing rainfall distribution data. Both options must be prepared using site-specific rainfall depths as described previously.

Option 1: Use Site-Specific Distributions

The first option is to develop site-specific distributions based on precipitation depth data from NOAA Atlas 14. Version 3.10 and later of the Project Formulation Hydrology computer program (WinTR-20) [63] includes a routine to allow users to import a downloaded NOAA Atlas 14 data file directly into TR-20. This process entails navigating to the NOAA Atlas 14 website, obtaining precipitation frequency estimates for the design site as described above, then downloading and importing the data into WinTR-20. The result of this process is a suite of site-specific 24-hour rainfall distributions for relevant design storms (*e.g.,* 2-, 10-, and 100-year storms). Customized rainfall distributions may also be developed using NOAA 14 with some proprietary versions of WinTR20. Consult with the software manufacturer to see if customized distributions may be developed using the NOAA Atlas 14 data. Step-by-step instructions of the process to develop site-specific rainfall distributions based on site-specific NOAA Atlas 14 data are provided by Chapter 6 of the WinTR-20 User Guide (version 3.10).[64]

Option 2: Use Regional Distributions

The second option is to use regional distributions developed by the NRCS for use with the Engineering Field Handbook Chapter 2 computer program (EFH-2[65]). These distributions are based on New England NOAA Atlas 14 data and may be imported into the Small Watershed Hydrology computer program (WinTR-55[66]), WinTR-20, or proprietary hydrologic modeling software. These distributions are herein referred to as the NRCS NOAA Type A, Type B, Type C, and Type D distributions. As indicated by **Figure 6-3**, just the NRCS NOAA Type C ("*Type N10_C")* and NRCS NOAA Type D (*Type N10_D")* distributions are applicable to Massachusetts. See **Figure 6-4** for a plot of these regional distributions.[67]

[63] NRCS WinTR-20: https://directives.sc.egov.usda.gov/ViewerFS.aspx?hid=46576.

[64] Win-TR-20 User Guide: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=18654.wba.

[65] NRCS EFH-2: https://www.nrcs.usda.gov/sites/default/files/2022-12/EFH%20page%202-15.A-N%20%28Shown%20as%202-14.A-N%29.pdf.

[66] NRCS WinTR-55: https://data.nal.usda.gov/dataset/small-watershed-hydrology-wintr-55.

[67] Source for **Figure 6-3** and **Figure 6-4** is the June 2016 MA Supplement to Chapter 2 of the NRCS Field Handbook, https://www.nrcs.usda.gov/sites/default/files/2023-05/North%20Dakota%20EFH-2%20Supplement%20-%205-31-2023.pdf.

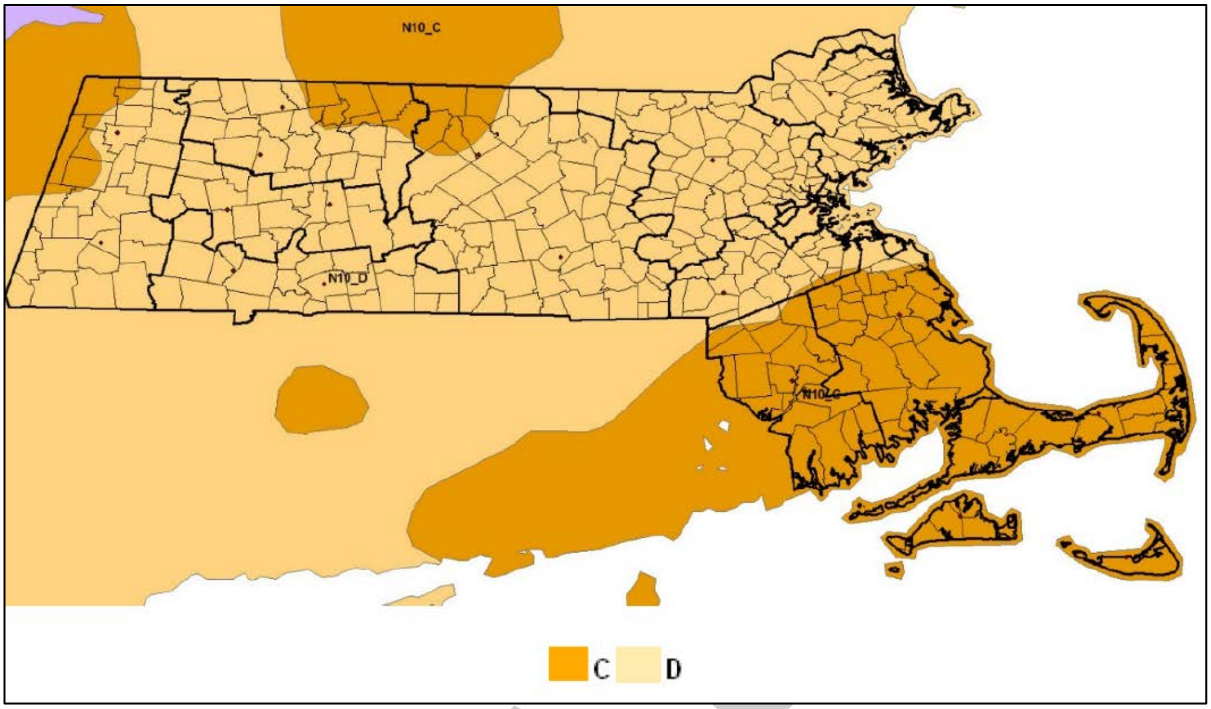

Figure 6-3. Location of NRCS NOAA Type C and NRCS Type D regional rainfall distributions Massachusetts developed by NRCS for the June 2016 Massachusetts Supplement to Chapter 2 of the Engineering field Handbook.

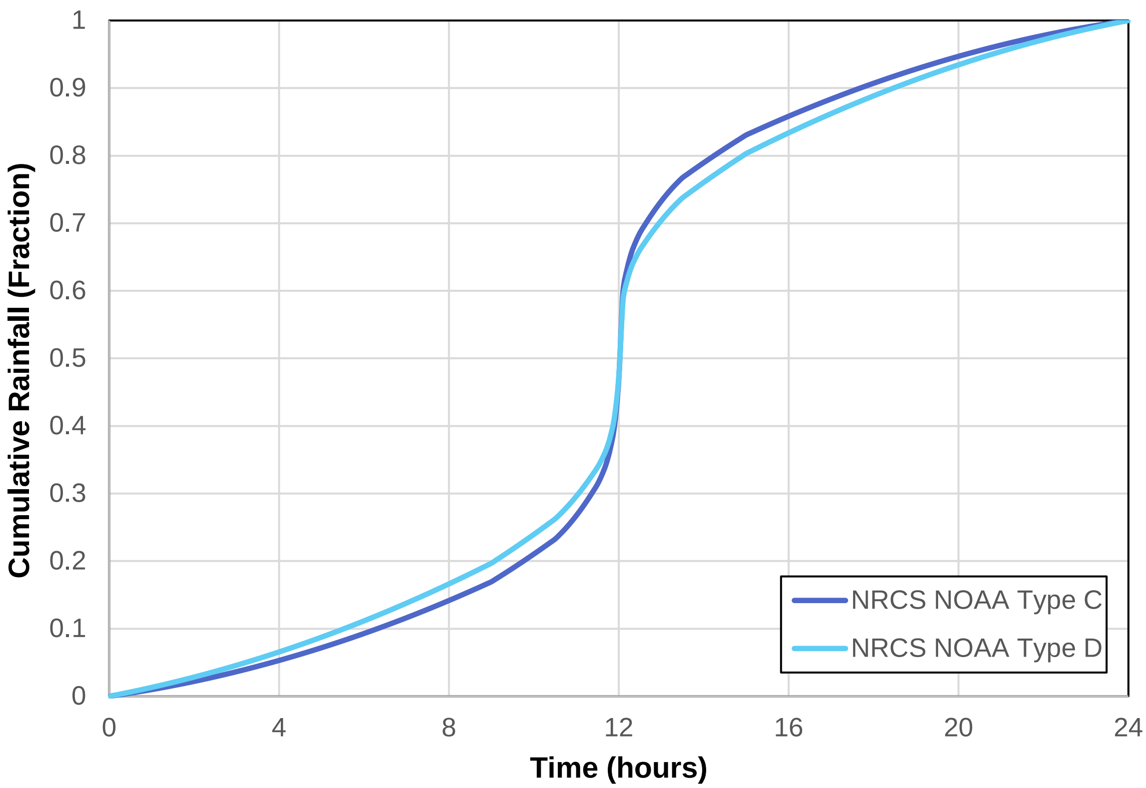

Figure 6-4. Updated dimensionless NRCS NOAA Type C and Type D rainfall distributions for Massachusetts developed by NRCS for the June 2016 Massachusetts Supplement to Chapter 2 of the Engineering field Handbook.

Use Caution with Built-In "NOAA" Distributions

WinTR-55, WinTR-20, and leading proprietary software packages include several built-in rainfall distributions with similar names (*e.g.,* "NOAA_A", "NOAA_B", "NOAA_C", "NOAA_D"). As of April 2023, these distributions were developed for the Midwest and other regions in the U.S, and are not applicable to New England or New York State. They must **not** be used for analysis.

The following steps may be used to develop distributions using the Massachusetts Regional NRCS NOAA Type C and Type D distributions with site-specific rainfall data obtained from NOAA Atlas 14 using WinTR20 or WinTR-55. For proprietary versions of WinTR20 and WinTR55, consult with the software manufacturer on how to import the Massachusetts Regional NOAA Type C and D rainfall distributions.

- **Step 1**. Important NOAA Atlas 14 rainfall distributions into WinTR-55. As of April 2023, the Massachusetts NRCS NOAA Type C, and Type D distributions are not available in WinTR-55; however, they may be imported. Tabular versions of these distributions obtained from the NRCS are available for download at MassDEP's website at: https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards. The NRCS NOAA Type C distribution is named "*Type N10_C.tbl*" and the NOAA Type D distribution is named "*Type N10_D.tbl".* Once downloaded, save the distributions in the WinTR-55 folder under: *C:\Users\YourUsername\AppData\Roaming\WinTR-55\RainfallDistributions*.
- **Step 2.** Obtain site-specific rainfall depths from NOAA Atlas 14 for relevant 24-hour return periods as described previously (see "*Rainfall Depth from NOAA Atlas 14*"). The values for Hardwick, MA depicted by **Figure 6-2** are provided by **Table 6-3** as an example.

Table 6-3. Example NOAA Atlas 14 rainfall amounts for 24-hour return period events for Hardwick, MA

Return Period	Example 24-Hour Rainfall Amounts	
	Upper Confidence Value (in)	Upper Confidence Value x 0.9 (in)
1-yr	3.02	2.72
2-yr	3.73	3.36
5-yr	4.91	4.42
10-yr	5.91	5.32
25-yr	7.64	6.88
50-yr	8.89	8.00
100-yr	10.50	9.45

- **Step 3**. Determine which rainfall distribution to use based on the site location (*i.e.,* NRCS NOAA Type C or NRCS NOAA Type D) (see **Figure 6-3**). For this example, Hardwick, MA is located in Worcester County and should use a NOAA Type D distribution. A lookup table of which distribution to use based on Town is available for download on MassDEP's website at https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards.
- **Step 4.** Open Win-TR55, select "Global Data" from the top menu, then select "Storm Data". Enter in the appropriate rainfall distribution type and the 24-hour rainfall amounts. For this example, use the NRCS NOAA Type D distribution (*i.e.,* "Type N10_D") and rainfall values from **Table 6-3**. Refer to **Figure 6-5** for a screenshot of this example.

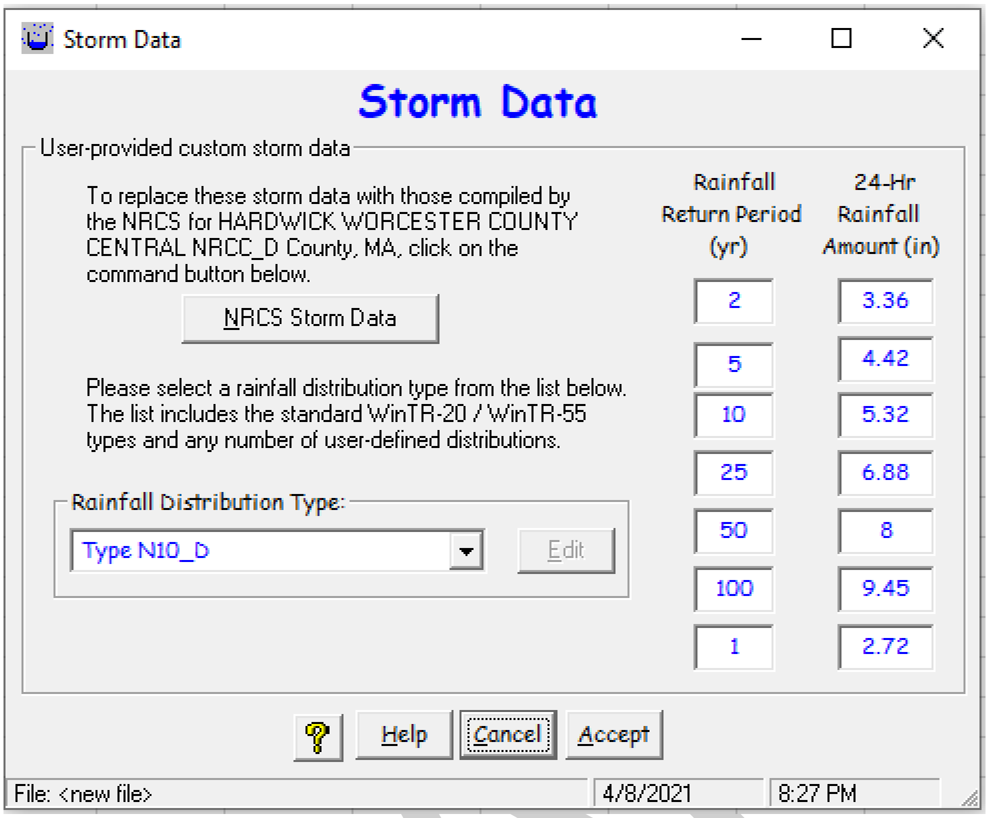

Figure 6-5. Screenshot from WinTR-55 depicting the storm data window with the selected distribution and example 24-hour rainfall depths

How is a Rainfall Distribution Applied to a Site-Specific Rainfall Depth?

The rainfall distributions generated by these two approaches represent the cumulative fraction of rainfall from the beginning to the end of the design storm. The dimensionless rainfall distributions begin at a value of zero and end at a value of one. WinTR-55, WinTR-20, and other proprietary software packages multiply each value in the dimensionless distribution by the site-specific rainfall depth for the selected design storm at each time step to determine how much rainfall has fallen over a given time.

For example, assume that the total rainfall from the 10-year, 24-hour storm for a particular site is 5.32 inches. The value of the NRCS NOAA Type C Regional Distribution at 10 hours is approximately 0.21 (**Figure 6-3**). Therefore, approximately 21% of the total rainfall (1.1 inches) is generated during the first 10 hours of the design storm.

Hydrologic Soil Group Determination

In preparing peak rate attenuation calculations using the U.S. NRCS TR 20/TR 55 methods described in the *Hydrology Handbook for Conservation Commissioners*, the existing Hydrologic Soil Groups (HSG) must be determined. The NRCS Soil Surveys, published by county, list the HSGs.[68] The NRCS Soil Survey information must be field verified using the Soil Evaluation procedure described in **Section 6.3**. Field determined HSGs must be used in preparing engineering computations for Standards 2, 3, and 4.

Curve Numbers for Green Roofs and Porous Pavements

NRCS has not published Runoff Curve Numbers (RCNs) for Green Roofs and Porous Pavements. Runoff characteristics vary by green roof design (*e.g.,* extensive, intensive, vegetation selected, etc.) and porous pavement design (*e.g.,* open jointed paving blocks, asphalt, concrete, depth of filter course, underlying parent material, proposed sub-grade compaction). Empirically derived RCNs developed by the NRCS for all land uses range from 30 to 100 – low numbers represent low runoff potential and higher numbers indicate high runoff potential. When green roofs and porous pavements are proposed, the Registered Professional Engineer (RPE) will need to assign a runoff curve number to compare pre- and post-development conditions for the 2-year, 10-year, and 100-year storms.

- **Green Roofs**. For green roofs, use a **RCN of 86**. If the Green Roof is a combination of traditional roofing and green roofing, develop a composite curve number by using a RCN of 98 for the traditional roof portion and RCN of 86 for the Green Roof portion.
- **Porous Pavements**. For porous pavements use a **RCN of 80**. If the porous pavement is a combination of traditional impervious hot mix asphalt pavement and porous pavement, develop a composite curve number using a RCN of 98 for impervious pavement and a RCN of 80 for the porous pavement portion.

Incorporating Exfiltration into Peak Rate Calculations

As indicated by **Table 2-7**, there are several Structural SCMs that may be used for both recharge and peak rate attenuation. The *Hydrology Handbook for Conservation Commissioners* provides detailed information on the design and sizing of Structural SCMs for peak rate control, including staged outlet control configurations. The *Hydrology Handbook for Conservation Commissioners* does not provide a standardized method to include exfiltration as a peak reduction mechanism. The below method may be used to incorporate exfiltration into peak rate reduction calculations for applicable SCMs. Design and sizing of SCMs for peak control is an iterative process. Some steps may be repeated multiple times until all design criteria are met.

- **Step 1, Selection:** To use this method, the selected SCM must be suitable for peak flow attenuation (Standard 2) and recharge (Standard 3). Refer to **Table 2-7** for a list of structural SCMs that can meet specific Stormwater Standards. **Appendix A** provides more detailed information on the ability of each SCM to meet the Stormwater Standards. For example, some SCMs such as leaching catch basins will typically only be able to provide peak rate attenuation for small sites or small storms. Other SCMs may only provide peak rate attenuation through use of a reduced Runoff Curve Number (*e.g.,* Porous Pavement) – those SCMs are not applicable to the methods presented in this section.
- **Step 2, Sizing and Configuration.** Design the sizing and configuration of the SCM in accordance with recommended procedures from Chapter 6 of the *Hydrology Handbook for Conservation Commissioners* for peak rate control. The SCM must also be sized to capture the groundwater recharge volume using one of the methods presented by Section **6.2.3**.

[68] NRCS Web Soil Survey: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm.

- **Step 3, Exfiltration Rate.** A soil evaluation must be performed in accordance with the "Soil Evaluation Procedure" presented in **Section 6.3** to determine the Hydrologic Soil Group (HSG) at the soil layer where the recharge is proposed. Underlying soil layers may be different than the surface layer. The NRCS Soil Survey only represents the top 60-inches of the soil, so infiltration structures excavated below that level may have a different Hydrologic Soil Group. The design exfiltration rate may then be assigned by selecting the *saturated hydraulic conductivity* value from **Table 6-4** that corresponds to the identified HSG and the layer where infiltration is proposed. Field measured in-situ saturated hydraulic conductivity values shall not be used for peak rate computations. Note **Table 6-4** reflects the rates used by the NRCS to assign soils to a Hydrologic Soil Group, and not the Rawls Rates.
- **Step 4, Exfiltration Rate Method**. Proprietary modeling software that uses NRCS TR20 and TR55 methods may be used to perform peak rate reduction calculations for evaluated design storms.
    - Model the SCM as a "pond" with an associated stage-storage curve and properly designed outlet control structure and emergency spillway designed in accordance with **Appendix A**. Additional storage shall not be assumed to be provided by media, stone, or other subsurface materials.
    - Assume a constant exfiltration rate (*i.e.,* in/hr) over the bottom area of the infiltration practice using the design *saturated hydraulic conductivity* value selected in **Step 3** for the duration of the simulated event.
    - Only consider the bottom surface. No credit shall be given for sidewall exfiltration.
    - The peak runoff rate attenuation analysis using the NRCS TR20/TR55 evaluation procedure evaluates the 24-hour storm. Although no infiltration is credited after 24-hours for purposes of peak runoff rate reduction, the hydrograph should be evaluated over at least a 26-hour period for Standard 2 analysis to ensure the runoff volume is not truncated.
    - Use a time step or 0.1-hours or smaller to ensure that the peak is captured. The smallest time step in WinTR20 or WinTR55 is 0.1 hours, but some proprietary versions of TR20 can use smaller time steps.[69]

Standard 2 References

Carter, Timothy L., Rasmussen Tod C., 2006, Hydrologic behavior of vegetated roofs, Journal of the American Water Resources Association, 42(5): 1261-1274

Ferguson, Bruce K., 2005, Porous Pavements, CRC Press, Taylor and Francis Group

North Carolina Division of Water Quality, 2007, Stormwater Best Management Practices Manual, Chapter 18, Online at: https://deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-permit-guidance/stormwater-SCM-manual
http://h2o.enr.state.nc.us/su/documents/SCMManual_WholeDocument_CoverRevisedDec2007.pdf

Nyman, David, 2002, Hydrology Handbook for Conservation Commissions, Massachusetts Department of Environmental Protection. Online at: https://www.mass.gov/doc/hydrology-handbook-for-conservation-commissioners/download.

U.S. NRCS, 2019, National Engineering Handbook, Part 630 Hydrology, Chapter 4, Storm Rainfall Depth and Distribution, online at:
https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=43924.wba

[69] The peak rate reduction analysis is performed by evaluating a 24 hour design storm; however, the SCM must also be appropriately sized to drawdown the required recharge volume within 72 hours as detailed by **Section 6.2.3**.

U.S. NRCS, 1986, Urban Hydrology for Small Watersheds Technical, Release 55. Online at: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=22162.wba

U.S. NRCS, 2005, Win Technical Release 20. Online at: https://directives.sc.egov.usda.gov/ViewerFS.aspx?hid=46576

U.S. NRCS, Win Technical Release 55. Online at: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=22162.wba

U.S. ACOE, HEC-HMS (Hydrologic Modeling System). Online at: https://www.hec.usace.army.mil/software/hec-hms/default.aspx

6.2.3 Standard 3: Stormwater Recharge

Required Computations or Demonstrations

Demonstrate that the Stormwater Management System is designed to infiltrate the required recharge volume. Computations and demonstrations covered by this section include:

- ❑ Calculate *Required Recharge Volume.*
- ❑ Calculate storage sizing for infiltration SCMs.
- ❑ Perform bottom area sizing for infiltration SCMs (*i.e.,* 72-hour drawdown analysis).
- ❑ If applicable, perform water budgeting analysis.
- ❑ If applicable, perform capture area adjustment.
- ❑ If applicable, perform groundwater mounding analysis.
- ❑ If applicable, perform slope stability analysis.

Additional computations and demonstrations covered by <u>other</u> sections include:

- ❑ Perform soil evaluation to determine which infiltration rates will be used to perform computations in accordance with **Section 6.3** ("*Soil Evaluation Procedures*").
- ❑ Calculate contributing drainage area (see **Section 6.4**) and impervious area (see **Section 6.5**).
- ❑ Refer to the MassDEP *Hydrology Handbook for Conservation Commissioners* (Chapter 8) for more information on recharge computations.
- ❑ If applicable, size one SCM to meet multiple stormwater standards (see **Section 6.2.4**).

Summary of Recharge Requirements

The following requirements apply to the design of recharge SCMs. These requirements affect design computations, so the following brief synopsis is provided.

- ❑ **Required Recharge Volume.** The Required Recharge Volume is at least 1 inch of runoff depth multiplied by the total post construction area for HSG A, B, and C soils. HSG D soils must provide recharge to the Maximum Extent Practicable (MEP). This 1-inch volume is the same for the Static and both Dynamic methods, however the Simple Dynamic and Dynamic Field method assume that 1-inch of runoff is being infiltrated at the same that it is being dosed to the infiltration practice, so effectively the practice is sized to a volume less than 1-inch. The Continuous Simulation method translates the local annual recharge depth (approximately 34-inches per year), to iteratively size the volume of the infiltration practice to achieve the long-term annual volume, rather than the 1-inch sizing.
- ❑ To meet the recharge standard, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis to be submitted with the Notice of Intent. Other SCMs and related stormwater Best Management Practices shall only be used to meet those portions of this TSS/TP removal Standard that cannot be fully met by ESSD and LID. See **Section 6.1.4** for more information on the written alternatives analysis.
- ❑ **Sizing Storage Volume.** Infiltration SCM storage volume may be sized using the *Static Method*, *Simple Dynamic Method*, *Dynamic Field Method, or Continuous Simulation Method*. These methods are described in more detail herein.

- ❑ **Minimum saturated hydraulic conductivity.** Must be at least 0.01 inches/hour at the actual location and soil layer where infiltration is proposed. No stormwater recharge systems shall be sited in soils that infiltrate at a rate lower than 0.01 inches/hour since rates lower than that are incapable of recharging the 1-inch volume in a 72-hour period. For each evaluation method (*i.e., Static, Simple Dynamic, Dynamic Field, and Continuous Simulation*), determine whether the soils exfiltrate faster than 0.01 inches/hour based on field analyses in accordance with **Section 6.3** "*Soil Evaluation Procedures*".
- ❑ **TSS Pretreatment.** TSS Pretreatment must be provided before discharge to all infiltration SCMs, except for the ESSD Credits. See **Table 4-5** for a list of SCMs that require pretreatment. At least 44% TSS pretreatment is required for stormwater discharges to certain areas as summarized by **Table 2-1**. At least 44% TSS pretreatment is also required when the "*Simple Dynamic*" method or "*Field Dynamic*" method is proposed.
- ❑ **Location of Pre- and Post-Recharge.** Provide stormwater recharge at the same site to the same Wetland Resource Area where it is "lost," not to a different wetland on the same site (see "Water Budgeting"). This is especially critical when groundwater supported wetlands are located at a site. Offsite Mitigation may be allowed for Redevelopment purposes as described in **Section 6.2.7**.
- ❑ **Slope Stability Analysis.** A slope stability analysis should be performed if the recharge basin or recharge area is proposed within 50 feet of a 3:1 or steeper slope. If breakout is determined to be possible, then plans to eliminate this should be presented.
- ❑ **Infiltration Practices with Storage Provided in Voids Between Stone, Media, or Other Medium.** Computations for such practices should take into account that storage is only provided in the void spaces between the stones, media, or other medium. The porosity or void volume is a percentage and does not have units such as inches or millimeters. The maximum amount of void storage that one should claim for practices that use stone or gravel is 0.35 or 35%. Void spaces should be lower for practices that don't use gravel or stone such as bioretention areas, tree box filters, and sand filters. In these instances, the maximum void space should be 0.20 or 20%.
- ❑ **Seasonal High Groundwater Elevation.** The bottom of any infiltration practice, including any media or stone, must be set at least 2-feet above Seasonal High Groundwater.
- ❑ **Required Setbacks**. See **Section 2.5** for required SCM setbacks and how to measure them.

Information Needed from Geotechnical Observations

A soil evaluation must be undertaken for field verification of soils at the specific location and soil layer where recharge will occur in accordance with **Section 6.3** "*Soil Evaluation Procedures*". The following field tests and analyses are required depending upon which sizing method is selected: 1) soil textural analysis, 2) depth to seasonal high groundwater, 3) in-situ *saturated hydraulic conductivity*, 4) hydrologic soil group determination; and 5) name of soil series.

Calculating Recharge Volume

SCMs must be sized to have adequate storage to hold the *Required Recharge Volume*. The following steps are covered by this section:

- **Step 1:** Calculate the *Required Recharge Volume*;
- **Step 2:** Size the storage volume to hold the *Required Recharge Volume*; and
- **Step 3:** Size the bottom area of the recharge practice to drawdown within 72 hours.

Step 1: Calculating the Required Recharge Volume

Calculate the *Required Recharge Volume* as indicated by **Equation 6-1**. The *Required Recharge Volume* equals the target runoff depth times the total impervious area at the post-development site.

$$\mathbf{R_v = F \cdot \mathit{IA}}$$ **Equation (6-1)**

Where,

R_v is *Required Recharge Volume*

F is the Target Depth Factor, 1-inch for all soil types (see "*Summary of Recharge Requirements*").

IA is area of Impervious Surfaces on site.

The recharge Target Depth Factor (F) is uniformly distributed over all Hydrologic Soil Groups. Attention must be given to ensure consistency in units – for example, the Target Depth Factor must be converted to feet if IA is expressed as square feet.

Example Calculation to Determine the Required Recharge Volume

Problem Statement. Assume a ten (10) acre site. 5.0 acres are proposed to be developed for a retail use. A section of the entrance roadway is to be bridged over a stream that is classified as land under water. As such, the roadway is subject to the Wetlands Protection Act Regulations and the Stormwater Management Standards. Of the 5.0 acres, the Applicant proposes to create a 2 acre paved parking lot, 1 acre of asphalt roadway and concrete walkways, and 1.5 acres for the construction of new buildings. Landscaping is planned for 0.5 acres of the site and the remaining 5.0 acres are proposed to remain forested. Determine the *Required Recharge Volume*.

Solution: The *Required Recharge Volume* is determined only for the Impervious Surfaces. The 5.0-acre forested area and the 0.5-acre landscaped area are not impervious areas. Although converted from forest, the landscaped area is pervious area for purposes of Standard 3. Use **Equation 6-1** to determine the *Required Recharge Volume* for the impervious area on the post construction site.

$Rv = F \cdot IA$

$Rv = F \cdot [(IA_{parking}) + (IA_{roadway\ and\ walkway}) + (IA_{rooftops})]$

Rv = (1.0 inch/12 inches/foot)(2 acres + 1 acre + 1.5 acres)

Rv = .375 acre-feet

Rv = (375 acre-feet)(43,560 square feet/acre)

Rv = 16,335 cubic feet **or** 605 cubic yards

<u>Step 2: Sizing Storage Volume</u>

The storage volume is the volume of the basin, chamber, or voids that must be constructed to hold the *Required Recharge Volume*. Four methods may be used to determine the Storage Volume:

1. The "*Static" Method*
2. The "*Simple Dynamic" Method;*
3. The "*Dynamic Field" Method*; or the
4. *Continuous Simulation Method*

The "*Static*" Method assumes that there is no exfiltration until the entire recharge device is filled to the elevation associated with the *Required Recharge Volume*. The two "*Dynamic"* Methods assume stormwater exfiltrates into the groundwater as the storage chamber is filling. The *"Simple Dynamic"*

Method assumes that the *Required Recharge Volume* is discharged to the infiltration SCM over 2 hours and exfiltrates over the 2-hour period at the *in-situ saturated hydraulic conductivity rate*. The "*Dynamic Field"* Method assumes that the *Required Recharge Volume* discharges to the infiltration SCM over 12 hours and infiltrates at no more than 50% of the *in-situ saturated hydraulic conductivity rate*.[70] The "*Static"* Method produces a larger storage volume than either *Dynamic* Method and produces the most conservative result. The "*Dynamic Field"* Method may only be used for sizing an infiltration SCM that is used for disposal of stormwater – pollutant removals required by Standard 4 must occur prior to directing runoff to the infiltration SCM).

All four of these methods require field verification of soils at the specific location and soil layer where recharge is proposed in accordance with **Section 6.3** "*Soil Evaluation Procedures*".
If using the "*Static"* Method, go to **Step 2a**. If using either *Dynamic* Method or the *Continuous Simulation Method*, skip **Step 2a** and go to **Step 2b**.

The *Required Recharge Volume* computations are typically conducted for the entire site. When there are multiple Wetland Resource Areas located on a site in different drainage areas, perform the *Required Recharge Volume* computations using those individual drainage areas, so the post-project stormwater recharge more closely mimics the natural pre-development hydrology. This is especially important in those instances where jurisdictional areas rely on groundwater input for their hydrology, such as Isolated Lands Subject to Flooding, Isolated Vegetated Wetlands, Vernal Pools, and Intermittent Streams. Providing the required stormwater recharge within another drainage area away from the groundwater supported wetlands, could alter the groundwater supported wetlands, reducing its aerial size.

Step 2a: Static Method

This method requires the least amount of time.

a. Assume the entire *Required Recharge Volume* determined under **Step 1** is discharged to the infiltration device before infiltration begins.

b. Size the volume of the basin, chamber or total voids to hold the *Required Recharge Volume* determined under **Step 1**.

c. Go to **Step 3** to confirm that the bottom of the infiltration SCM is large enough to drain completely within at least 72 hours. If the bottom area of the infiltration SCM is not sufficiently large enough to drain completely in 72-hours, the basin floor will need to be iteratively sized larger until the 72-hour drawdown time is achieved.

Example Calculation Using the "Static" Method to Size the Storage Volume

Problem Statement: Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). The soils are classified as Hydrologic Soil Group "A." An infiltration structure is proposed to meet Stormwater Standard 3. Use the *"Static"* Method to determine the storage volume of the infiltration structure.

Solution: The *Required Recharge Volume* is based on 1.0 inch of runoff from the total post-construction impervious area on site. Using **Equation (6-1)***:*

$$Rv = F \cdot IA$$

$$Rv = [(1.0 \text{ inch}/12 \text{ inches/foot})][(0.75 \text{ acre})(43{,}560 \text{ square feet/acre})]$$

[70] 50% is used as a factor of safety to represent the anticipated long-term exfiltration rate due to clogging of the underlying media/soil that occurs over time.

Rv = [0.083 feet][(0.75 acre)(43,560 square feet/acre)]

Rv = 2,722.5 cubic feet

Assuming that the stored runoff will exfiltrate completely into the ground within 72 hours in accordance with **Equation 6-5**, the infiltration structure must have a storage volume of 2,722.5 cubic feet.

Calculating Recharge Volume for Infiltration SCMs

If the infiltration SCM is filled with stone (*e.g.,* dry well, infiltration trench), media (*e.g.,* bioretention area), sand (sand filter), or other media, the excavated volume of the SCM must be determined to account for these items in the SCM. The minimum excavated volume is determined by **Equation 6-2**:

$$\textbf{Excavated Volume} = \frac{\mathbf{R_v}}{\mathbf{n}} \qquad \textbf{Equation (6-2)}$$

Where,

R_v is the *Required Recharge Volume.*

n is the porosity or percentage of void space between the stone, media, sand, or other medium.

Assuming *n* = 0.35 (35% voids) between the stone for the previous example, the minimum Excavated Volume for design purposes would be:

$$\text{Excavated Volume} = \frac{2{,}722.5 \text{ cubic feet}}{0.35} = 7{,}778.6 \text{ cubic feet}$$

Notes:

1. The maximum amount of void storage is 35% (n = 0.35) for gravel or stone filled practices, and 20% (n = 0.20) for other practices that rely on media, sand, or other medium. If the practice has a mixture of media types, use the lowest value for conservatism.
2. For specific SCMs, the Design Storage Volume (DSV) to hold the Rv may be calculated based on the 2016 MA Small MS4 Permit, Attachment 3 to Appendix F, Table 3-5 (https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/appendix-f-attach-3-2016-ma-sms4-gp-mod.pdf). Refer to **Table 2-2** for a "crosswalk" that relates SCMs from the 2016 Small MA Permit to the Stormwater Handbook.

Step 2b: "Simple Dynamic" and "Dynamic Field" Methods

Where an Applicant chooses to size the recharge practice to take into account the fact that stormwater is exfiltrating from the recharge practice at the same time that the storage chamber is filling, one of the two methods specified in this Handbook must be used. These methods are referred to as the "*Simple Dynamic"* and "*Dynamic Field"* Methods. They result in smaller storage volumes than would otherwise be required by the "*Static"* Method. In Hydrologic Soil Group B, C, and D soils, all three methods produce similar sized storage. However, in sandy soils (Hydrologic Soil Group A), the "*Simple Dynamic"* and "*Dynamic Field"* Methods can produce smaller storage requirements. Since the "*Simple Dynamic"* and "*Dynamic Field"* Methods are less conservative than the *"Static"* Method, maintenance over the life of the recharge practice is especially critical to ensure that the recharge practice will function as designed over the long-term.

"Simple Dynamic" Method

The "*Simple Dynamic"* Method requires *In-situ saturated hydraulic conductivity* testing at the actual location and soil layer where exfiltration is proposed in accordance with the "Soil Evaluation Procedures" presented by **Section 6.3**. TSS pretreatment must be provided.

The "*Simple Dynamic"* Method is more conservative than the *"Dynamic Field"* Method, because it limits the allowable infiltration time that is used to reduce size of the infiltration SCM to the peak two hour period of a "typical storm". The *"Simple Dynamic"* Method can be performed by using the equations set forth below.

$$\mathbf{R_v} = \mathbf{F} \cdot IA \qquad \textbf{Equation (6-1)}$$

$$\mathbf{A} = \frac{\mathbf{R_v}}{(\mathbf{D} + \mathbf{K} \cdot \mathbf{T})} \qquad \textbf{Equation (6-3)}$$

$$\mathbf{V} = \mathbf{A} \cdot \mathbf{D} \qquad \textbf{Equation (6-4)}$$

Where,

R_v is the *Required Recharge Volume*

F is the Target Depth Factor (see "Summary of Recharge Requirements")

IA is area of Impervious Surfaces on site

A is the minimum required surface area of the bottom of the infiltration structure.

V is the Storage Volume determined in accordance with the *"Simple Dynamic"* Method.

D is a depth of the infiltration facility.[71]

K is the field measured *in-situ saturated hydraulic conductivity* at the actual location and soil layer where infiltration is proposed, and

T is the allowable drawdown during the peak of the storm (use 2 hours)

Example Calculation Using the "Simple Dynamic" Method to Size the Storage Volume

Problem Statement: Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). Based on results of field testing performance in accordance with **Section 6.3** "*Soil Evaluation Procedures*", the in-situ saturated hydraulic conductivity was measured to be 7.5 inches/hour at the actual location and soil layer where infiltration is proposed. An infiltration structure that is 4 feet deep is proposed to meet Standard 3. Determine the storage volume of the infiltration structure, using the "*Simple Dynamic"* Method.

Solutions: Use **Equation 6-1** to calculate the required recharge volume.

R_v = F · impervious area

R_v = [(1.0 inches/12 inches/foot)][(0.75 acre)(43,560 square feet/acre)]

R_v = [0.083 feet][32,670 square feet]

R_v = 2,722.5 cubic feet

Use **Equation 6-3**, and **Equation 6-4** to calculate the storage volume.

[71] If the infiltration facility is a practice that uses stone or another media such as a dry well, only the void spaces must be considered. In those circumstances, use n·D instead of D, where n is the percent porosity of the stone or other media. See **Equation 6-2**.

$A = R_v \div (D+KT)$

$A = 2{,}722.5 \text{ cubic feet} \div [4 \text{ feet} + [(7.5 \text{ inches/hour}/12 \text{ inches/foot})(2 \text{ hours})]]$

$A = 518.6 \text{ square feet}$

$V = A \cdot D$

$V = (518.6 \text{ square feet})\cdot(4 \text{ feet})$

$V = 2{,}074.4 \text{ cubic feet}$

Assuming that the stored runoff will exfiltrate completely into the ground within 72 hours in accordance with **Equation 6-5**, the infiltration structure must have a storage volume of 2,074.4 cubic feet.

The "*Simple Dynamic Method*" provides a **24% decrease** in sizing relative to the "*Static Method*" for this example.

To size an infiltration SCM using the "*Simple Dynamic*" Method, Applicants may also use a computer model based on TR-20 and TR-55 as described below. As more fully set forth below, this computer model assumes that the *Required Recharge Volume* is entering the infiltration SCM during the peak two hours of the storm and that runoff is being discharged from the SCM during the same two hour period at the *in-situ saturated hydraulic conductivity* rate. This contemporaneous exfiltration allows an Applicant to reduce the size of the infiltration SCM.

a. **Step A.** Use **Equation 6-1** to determine the *Required Recharge Volume*

b. **Step B.** Select a 24-hour rainfall event that generates the *Required Recharge Volume* during the peak 2 hours. Use only the Site's impervious drainage area and the default NRCS Initial Abstraction of 0.2S and a rainfall distribution based on NOAA Atlas 14 data in accordance with **Section 6.2.2**. Set the storm duration for 24 hours, but use a start time of 11 hours and an end time of 13 hours. This creates a truncated hydrograph where most of the rainfall typical of a 24-hour storm occurs in just 2 hours. Selecting the correct precipitation depth is an iterative process. Various precipitation depths must be tested to determine which depth generates the *Required Recharge Volume* (1-inch for HSG A, B, and C soils), using the Win TR-20 method (or other software based on TR-20). Each precipitation depth evaluated generates a runoff hydrograph. The area under the hydrograph is a volume. The correct result is achieved when the volume under the inflow hydrograph equals the *Required Recharge Volume* (1-inch for HSG A, B, and C soils; 1-inch to the Maximum Extent Practicable for D soils).

c. **Step C.** Using the resulting inflow hydrograph, choose an appropriate exfiltration structure with an appropriate bottom area and storage volume.[72]

   i. Use recharge system bottom as maximum infiltrative surface area. Do not use sidewalls.[73]

   ii. Assume stormwater exfiltrates from the device over the peak 2-hour period of the rainfall event determined in step b above.

   iii. Set exfiltration rates no higher than the field measured in-situ saturated hydraulic conductivity for the corresponding soil at the specific location where infiltration is proposed.

   iv. Assume exfiltration rate is constant.

   v. Using the computer model, confirm adequate Storage Volume.

[72] An Applicant may have to select several different size infiltration structures before they identify a structure that is adequately sized.

[73] If the recharge system includes stone or other media, remember that the effective storage volume only includes the voids between the stone or other media. See **Equation 6-2**.

d. **Step D.** Go to **Step 3** to confirm that the bottom of the proposed infiltration SCM is large enough to ensure that the practice will drain completely in 72 hours or less. For purposes of the **Step 3** evaluation, assume the exfiltration rates are constant. The field measured *in-situ saturated hydraulic conductivity* must be calculated in accordance with the "*Soil Evaluation Procedures*" presented by **Section 6.3**.

Example Calculation Using the "Simple Dynamic" Method with <u>Computer Model</u> to Size the Storage Volume

Problem Statement: Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). The site is located in Hardwick, MA and therefore may use the regional NRCS NOAA Type D rainfall distribution in accordance with **Figure 6-3**. Based on results of field testing performed in accordance with **Section 6.3** "*Soil Evaluation Procedures*", the *in-situ saturated hydraulic conductivity* was measured to be 7.5 inches/hour at the actual location and soil layer where infiltration is proposed. An infiltration structure is proposed with a bottom that has a surface area of 525 square feet and a storage volume of 2,077 cubic feet. Use the "*Simple Dynamic*" Method to confirm that this storage volume is adequate.

Solution:

- **Step A.** Use **Equation 6-1** to calculate the required recharge volume.

  $$R_v = F \cdot IA$$

  $$R_v = [(1.0 \text{ inches}/12 \text{ inches/foot})][(0.75 \text{ acre})(43{,}560 \text{ square feet/acre})]$$

  $$R_v = 2{,}722.5 \text{ cubic feet}$$

- **Step B.** The amount of precipitation is determined iteratively by developing a hydrograph that generates the *Required Recharge Volume* of 2,722.5 cubic feet during the peak two hours of the storm. A hydrograph is generated for a storm that produces 2.50-inches of precipitation and indicates the runoff is entering the infiltration structure at a maximum rate of 1.81 cfs during the most intense two hours of the storm (**Figure 6-6**).
- **Step C**. An exfiltration system is sized to store the difference between the inflow volume and the outflow volume using an infiltration rate of 7.5 inches/hour over the 2-hour period. The outflow hydrograph reveals that runoff will leave the infiltration structure at a rate of approximately 0.09 cfs during the peak two hours of the storm. The results yield an infiltration structure with a surface ponding depth of 3.96 feet and a storage volume of 2,077 cubic feet (**Figure 6-7**).
- **Step D**. Confirm that the bottom of the proposed infiltration SCM is large enough to ensure that the practice will drain completely in 72 hours or less using **Equation 6-5**.

Keep in mind with an infiltration trench (or other recharge SCM with storage provided by stone, media, sand, or other medium) that the final sizing calculations should only count the volume of the voids as providing the storage (see **Equation 6-2** for example void storage calculation).

Summary for Subcatchment 1: S1

Runoff = 1.81 cfs @ 12.13 hrs, Volume= 2,731 cf, Depth> 1.00"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 11.00-13.00 hrs, dt= 0.05 hrs
NOAA 24-hr_NE_D D Rainfall=2.50"

	Area (ac)	CN	Description
*	0.750	98	Paved roads w/curbs
	0.750		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Urban Setting**

Subcatchment 1: S1

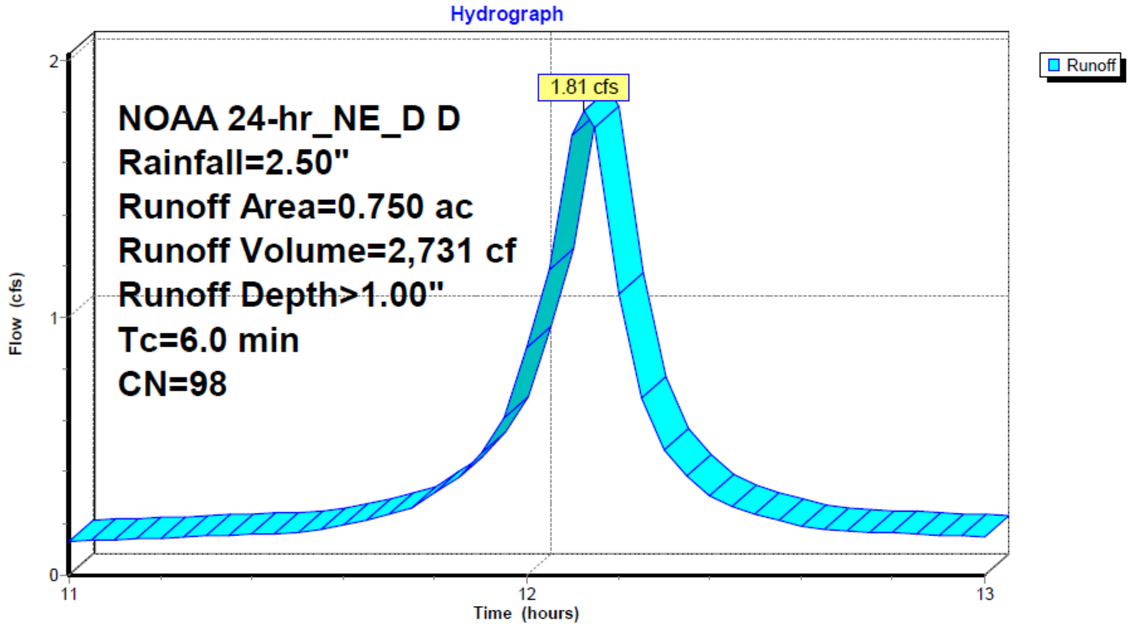

Figure 6-6. Hydrograph output from example site's upstream subcatchment (Simple Dynamic Method)

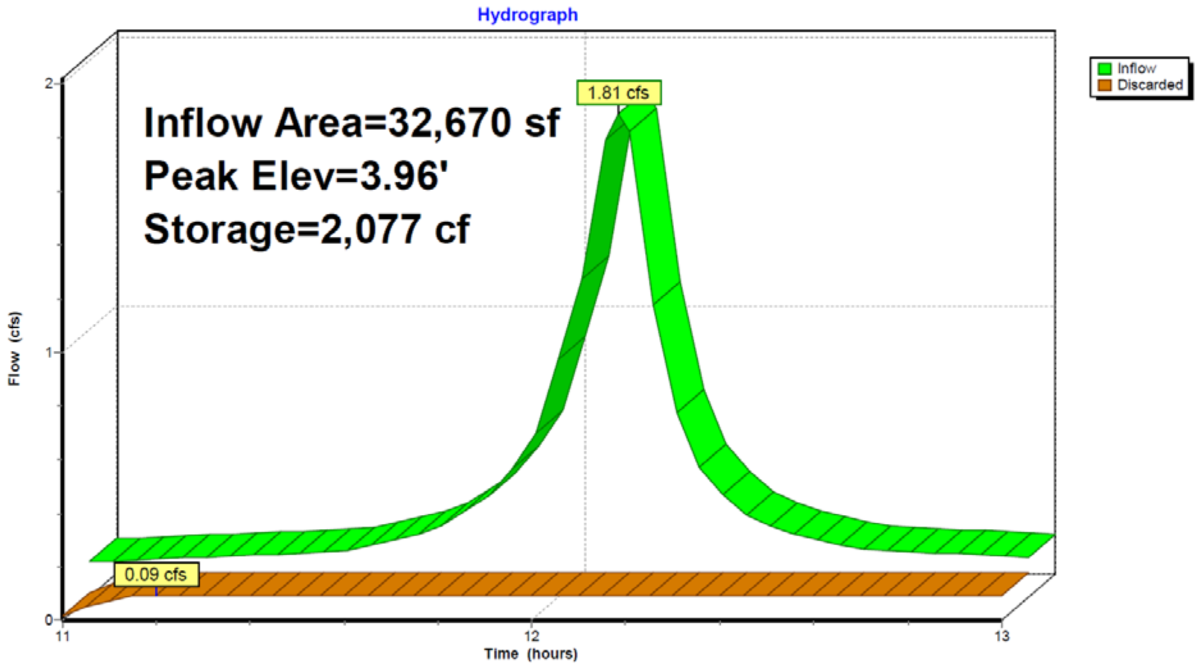

Figure 6-7. Hydrograph output from example site's infiltration SCM (Simple Dynamic Method)

"Dynamic Field" Method

The "*Dynamic Field*" Method requires *In-situ saturated hydraulic conductivity* testing at the actual location and soil layer where exfiltration is proposed in accordance with the "Soil Evaluation Procedures" presented by **Section 6.3**. TSS pretreatment must be provided.

b. **Step A.** Use **Equation 6-1** to determine *Required Recharge Volume.*

c. **Step B.** Select a 24-hour rainfall event that generates the *Required Recharge Volume* over 12 hours. Use only the Site's impervious drainage area and the default NRCS Initial Abstraction of 0.2S and a rainfall distribution based on NOAA Atlas 14 data in accordance with **Section 6.2.2**. Set the storm duration for 24 hours, but use a start time of 6 hours and an end time of 18 hours. This creates a truncated hydrograph where most of the rainfall typical of a 24-hour storm occurs in just 12 hours. Selecting the correct rainfall depth is an iterative process. Various precipitation depths must be tested to determine which depth generates the *Required Recharge Volume*, using the Win TR-20 method (or other software based on TR-20). Each precipitation depth evaluated generates a runoff hydrograph. The area under the hydrograph is a volume. The correct result is achieved when the volume under the inflow hydrograph equals the *Required Recharge Volume.*

d. **Step C.** Using the resulting inflow hydrograph, choose an appropriate infiltration structure with an appropriate bottom area and storage volume.[74]

   i. Use recharge system bottom as maximum infiltrative surface area. Do not use sidewalls.

   ii. Assume that exfiltration begins immediately at 6 hours and continues for 12 hours. Infiltration of the *Required Recharge Volume* may take more than 12 hours.

   iii. Set exfiltration rate used in the analysis to no higher than 50% of the *in-situ saturated hydraulic conductivity* rate in the soil layer where infiltration is proposed (*e.g.,* if the *in-situ* rate is 10 inches/hour, 50% · 10 in/hr = 5 inches/hour).

   iv. Assume exfiltration rate is constant.

   v. Using the WinTR20/WinTR55 computer model confirm adequate *Storage Volume*.

e. **Step D.** Go to **Step 3** to ensure that the bottom of the infiltration SCM is large enough to ensure that the system will completely drain in 72 hours using 50% of the *in-situ saturated hydraulic conductivity* rate determined using field-testing in accordance with **Section 6.3**.

Example Calculation Using the "Dynamic Field" Method with Computer Model to Size the Storage Volume

Problem Statement: Assume a one (1) acre undeveloped site. Assume 75% of the site is proposed to be impervious area (0.75 acre). The site is located in Hardwick, MA and therefore may use the regional NRCS NOAA Type D rainfall distribution in accordance with **Figure 6-3**. Based on results of field testing performed in accordance with **Section 6.3** "*Soil Evaluation Procedures*", the in-situ saturated hydraulic conductivity was measured to be 7.5 inches/hour at the actual location and soil layer where infiltration is proposed. An infiltration structure is proposed with a maximum surface ponding depth of 4 feet to be used for recharge purposes, exclusive of the freeboard required for peak rate control. Use the *"Dynamic Field"* method to determine the storage volume and bottom area of the infiltration basin.

Solution:

[74] An Applicant may have to try different size infiltration structures before an infiltration structure that is adequately sized is identified.

- **Step A.** Use **Equation 6-1** to calculate the required recharge volume.

  $R_v = F \cdot IA$

  R_v = [(1.0 inches/12 inches/foot)][(0.75 acre)(43,560 square feet/acre)]

  R_v = 2,722.5 cubic feet or 100.8 cubic yards

- **Step B.** The amount of precipitation is determined iteratively by developing a hydrograph that generates the *Required Recharge Volume* of 2,722.5 cubic feet during the peak 12 hours of the storm. A hydrograph is generated for a storm that produces 1.45-inches of precipitation and indicates the runoff is entering the infiltration structure at a maximum rate of 1.02 cfs during the most intense 12 hours of the storm (**Figure 6-8**).
- **Step C.** An exfiltration system is then sized to store the difference between the inflow volume and the outflow volume using an infiltration rate of 4.5 inches/hour over the 12-hour period (*i.e.,* 50% of the in-situ *saturated hydraulic conductivity* of 7.5 inches/hour determined by field-testing). The bottom area is iteratively sized the smallest possible bottom area, 390 square feet, that can be achieved while maintaining a maximum surface ponding depth of 4 feet. The outflow hydrograph reveals that runoff will leave the infiltration structure at a rate of approximately 0.03 cfs during the peak 12 hours of the storm. The results yield an infiltration structure with a surface ponding depth of 3.92 feet and a storage volume of 1,529 cubic feet (**Figure 6-9**).
- **Step D**. Confirm that the bottom of the proposed infiltration SCM is large enough to ensure that the practice will drain completely in 72 hours or less using **Equation 6-5**.

Note: the storage volume of 1,529 cubic feet and bottom area of 390 square feet is over **<u>25% smaller</u>** than the storage volume of 2,077 cubic feet and the bottom area of 525 square feet produced by the "*Simple Dynamic*" Method in the previous example. The smaller storage volume and bottom area arises because infiltration is assumed to occur over a longer period in the "*Dynamic Field*" Method than the "*Simple Dynamic*" Method, *i.e.,* 12 hours instead of two hours.

Summary for Subcatchment 1: S1

Runoff = 1.02 cfs @ 12.13 hrs, Volume= 2,797 cf, Depth> 1.03"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 6.00-18.00 hrs, dt= 0.05 hrs
NOAA 24-hr_NE_D D Rainfall=1.45"

	Area (ac)	CN	Description
*	0.750	98	Paved roads w/curbs
	0.750		100.00% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry, Urban Setting**

Subcatchment 1: S1

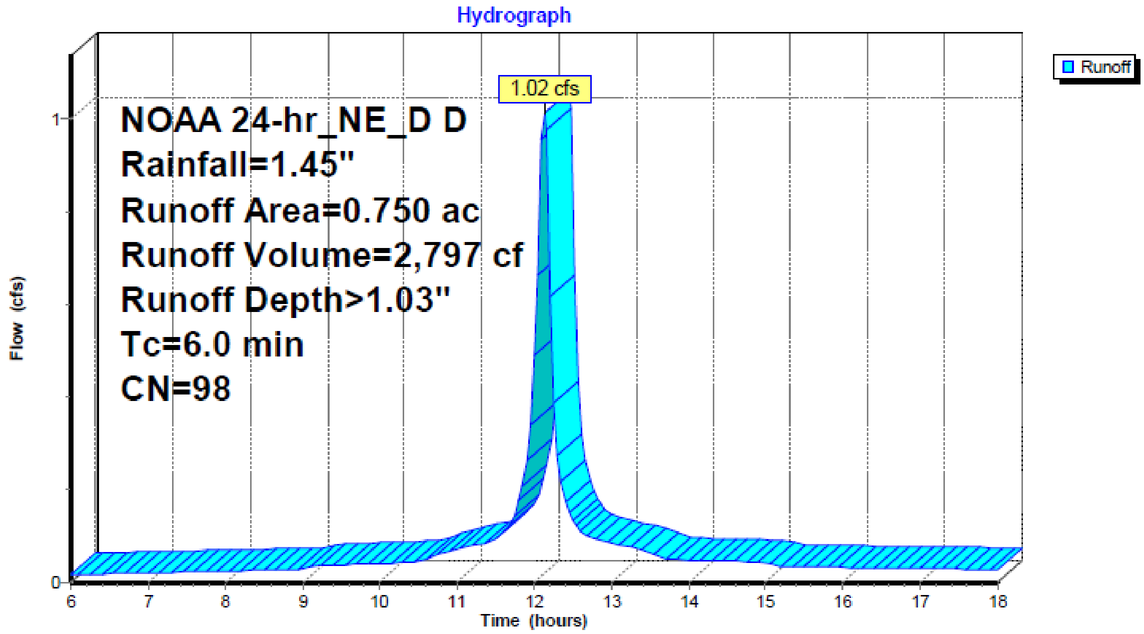

Figure 6-8. Hydrograph output from example site's upstream subcatchment (Dynamic Field Method)

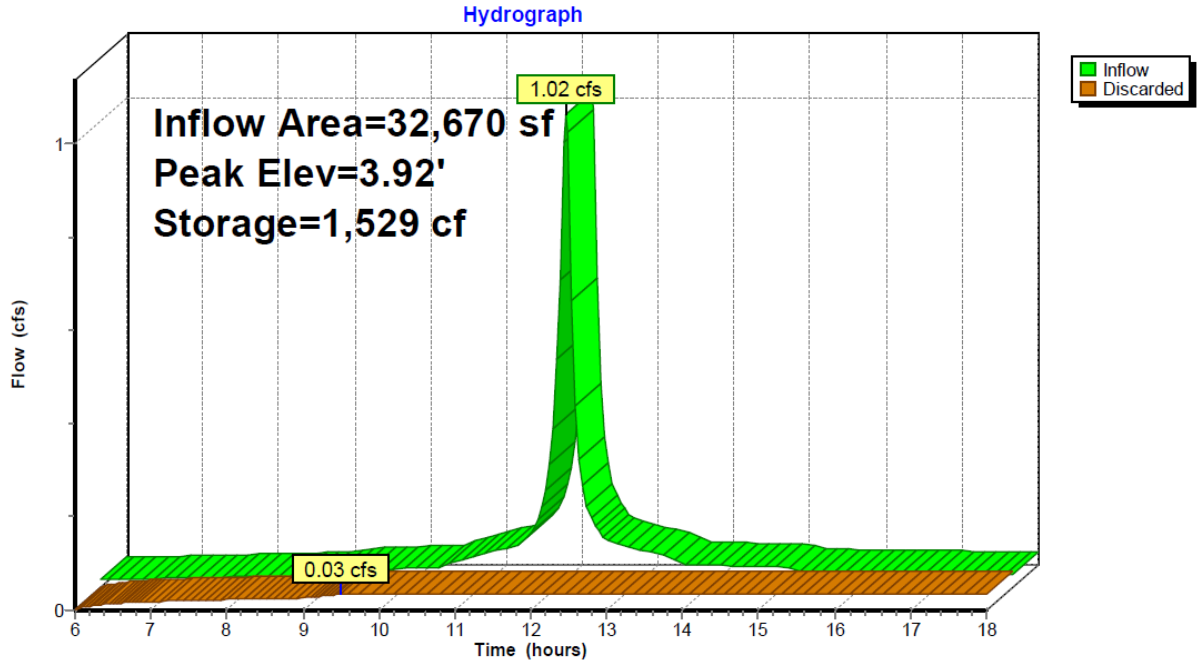

Figure 6-9. Hydrograph output from example site's infiltration SCM (Dynamic Field Method)

"Continuous Simulation" Method

The "*Continuous Simulation"* Method requires *In-situ saturated hydraulic conductivity* testing at the actual location and soil layer where exfiltration is proposed in accordance with the "Soil Evaluation Procedures" presented by **Section 6.3**. TSS pretreatment must be provided. MassDEP has developed a spreadsheet-based tool to implement the "*Continuous Simulation Method*" accessible at: https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards.

The steps to implement this method are listed below.

- Determine the 3 closest weather stations geographically located within the same Major River Basin or within 25 miles of the project site, for which precipitation and temperature daily data is available through the NOAA National Centers for Environmental Information (formerly the National Climatic Data Center). Data sources other than the NOAA National Centers for Environmental Information are not acceptable.
    a. The data must be available during the 1991 to 2020 climate normal 30-year period.
    b. The daily data at each station that is utilized must be at least 80% complete during the climate normal period. If the daily data is not at least 80% complete, another weather station must be selected.
- Determine a daily weighted daily precipitation average of the three stations based on distance from the project site. See calculation spreadsheet for how to "censor" missing data from a given station on a given day.
- The target recharge is 70% of the overall weighted annual precipitation average over the 30-year climate normal period. For example, if the overall weighted annual precipitation average is 54.09-inches, the annual recharge target is 70% x 54.09-inches = 37.87-inches/year. Areas with less precipitation will have a lower recharge target and areas with greater precipitation will have a higher recharge target.

- Use the MassDEP calculation spreadsheet to convert the annual recharge target into a “Target Depth Factor” (F) which can be applied to Stormwater Control Measure (SCM) design for computation of the *Required Recharge Volume* (Rv). Use **Equation 6-1** to size the SCM to hold the Rv, including voids for applicable SCMs, see “*Calculating Recharge Volume for Infiltration SCMs*.”
- At the maximum storage volume, conduct drawdown analysis to ensure the design volume from impervious area will infiltrate over 3-days based on **Step 3** “*Drawdown within 72 Hours*”.
- For infiltration SCMs sized using the *Continuous Simulation Method,* the drawdown analysis must use 50% of the lowest field measured *in-situ saturated hydraulic conductivity* rate at the location and specific soil layer where exfiltration is proposed. If the volume is not able to fully infiltrate within 3-days, increase the bottom area of the practice, to iteratively size the practice.

Step 3: Drawdown Within 72 Hours

This analysis serves to size the bottom area of the recharge practice, and assumes no groundwater mound develops under the practice which would impede stormwater infiltration. Computations must reflect drawdown within the 72-hour period for whatever volume is directed to the recharge practice. For example, if a recharge practice is proposed to exfiltrate the entire runoff volume associated with the 100-year 24-hour storm, the drawdown analysis needs to demonstrate it is accomplished within 72-hours (on a design basis).

The Drawdown Analysis required herein is not conservative in that it does not take in account mounding that occurs under stormwater recharge practices. However, mounding analysis must be conducted as part of the Drawdown analysis for recharge practices with 4-feet or less of separation to seasonal high groundwater *AND* where the recharge practice is proposed to exfiltrate the runoff volume from the 10-year or higher storm. See the *Mounding Analysis* section below. In other situations, mounding analysis is recommended to provide a margin of safety to ensure a drawdown within 72-hours, but not required.

When performing drawdown calculations, use in-situ *saturated hydraulic conductivity* rates obtained during field testing in accordance with the “Soil Evaluation Procedures” presented by **Section 6.3**.

a. For infiltration SCMs sized using the "*Static"* Method, use field data to classify the Hydrologic Soil Group (HSG) at the location and specific soil layer where exfiltration is proposed, then select the corresponding *saturated hydraulic conductivity* value from **Table 6-4**.
b. For infiltration SCMs sized using the "Simple *Dynamic"* Method*,* the drawdown analysis must be based on the *Required Recharge Volume* infiltrating at the lowest field measured *in-situ saturated hydraulic conductivity* rate at the location and specific soil layer where exfiltration is proposed.
c. For infiltration SCMs sized using the "*Dynamic Field"* Method*,* the drawdown analysis must be based on the *Required Recharge Volume* infiltrating at 50% of the lowest field measured *in-situ saturated hydraulic conductivity* rate at the location and specific soil layer where exfiltration is proposed.
d. For infiltration SCMs sized using Continuous Simulation*,* the drawdown analysis must be based on the *Required Recharge Volume* infiltrating at 50% of the lowest field measured *in-situ saturated hydraulic conductivity* rate at the location and specific soil layer where exfiltration is proposed.
e. The saturated hydraulic conductivity rate shall be assumed to be constant for purposes of the drawdown analysis. [75]
f. Only the bottom surface shall be considered. No credit shall be afforded to sidewall exfiltration.

[75] The drawdown analysis also assumes that the water table does not fluctuate during the draw down period.

g. If the drawdown analysis indicates the entire volume cannot be drawn down within 72 hours, the bottom area of the infiltration SCM must be increased or the *Required Recharge Volume* must be reduced. The *Required Recharge Volume* may be reduced by reducing the amount of Impervious Surfaces on the site or by taking advantage of the ESSD Credits (See **Appendix A**).

To determine whether an infiltration SCM will drain within 72 hours, **Equation 6-5** must be used[76]:

$$\mathbf{Time_{drawdown}} = \frac{\boldsymbol{V_{SCM}}}{(\mathbf{K})(\mathbf{Bottom\ Area})} \qquad \textbf{Equation (6-5)}$$

Where,

V_{SCM} is the infiltration SCM's storage volume (computed using the Static or Dynamic Methods)

K is the *Saturated Hydraulic Conductivity* determined in accordance with the "Soil Evaluation Procedures" presented by **Section 6.3**.

Bottom Area is the infiltration SCM's bottom area.

[76] In some cases, the infiltration structure may be designed to treat the *Required Water Quality Volume* and/or to attenuate peak discharges in addition to infiltrating the *Required Recharge Volume*. In that event, the storage volume of the structure must be used in the formula for determining drawdown time in place of the *Required Recharge Volume*.

Example Drawdown Calculation

Problem Statement. Assume a one-acre site. An area that is 0.75 acres is proposed to be developed as impervious area. An infiltration structure is proposed to meet Standard 3. Using **Equation 6-1** and the required runoff depth of 1-inch, the *Required Recharge Volume* is determined to be 2722.5 cubic feet. The infiltration structure is sized using the “Static Method” to have a storage volume of 2722.5 cubic feet.

Field testing performed in accordance with the “Soil Evaluation Procedures” presented by **Section 6.3** classified the soils at the proposed location and specific soil layer where infiltration is proposed as Hydrologic Soil Group “A”. The design saturated hydraulic conductivity is therefore 1.42 in/hr in accordance with **Table 6-3**.

The bottom area of the proposed basin is 303 square feet. Determine whether the proposed infiltration structure will draw down the 2722.5 cubic feet of water within 72 hours. The drawdown time is calculated from **Equation 6-5** as follows.

$$Time_{drawdown} = \frac{2722.5\ cubic\ feet}{(1.42\ inches/hour)(1ft/12\ inches)(303\ square\ feet)} = 76\ hours$$

76 hours < 72 hours so result is not satisfactory for design purposes

The infiltration structure as designed is estimated to drawdown in 75.9 hours, which is not within the 72-hour requirement. Consequently, the bottom area of the infiltrative surface would need to be increased (*e.g.,* instead of an infiltration structure with 303 square foot bottom area, evaluate a structure with a bottom area of 350 square feet, etc.) or the *Required Recharge Volume* would have to be reduced. The *Required Recharge Volume* could be reduced by reducing the amount of Impervious Surfaces or by taking advantage of the ESSD Credits (see **Appendix A**).

Other Considerations for Standard 3

Water Budgeting Analysis: Evaluating if the Recharge Location Could Change the Hydrologic Regime of a Wetland Resource Area

If runoff from an existing Wetland Resource Area is redirected to a proposed infiltration SCM, the infiltration SCM should be evaluated to determine if the proposed recharge location could alter the Wetland Resource Area by causing changes to the hydrologic regime (i.e., by lowering the water level or water table). For example, if Watershed “A” contains a vernal pool within a Bordering Vegetated Wetland, and the vernal pool is fed by groundwater, and runoff from Watershed “A” is proposed to be directed to Watershed “B” for infiltration, an evaluation is necessary to determine if redirecting the runoff will cause an alteration to the vernal pool. In such instances, Water Budgeting using the Thornthwaite method or equivalent must be employed. TR-20/TR-55 methods are not sufficient for water budgeting purposes. Water budgeting analysis is not required if the recharge is directed to the same subwatershed where the impervious surfaces are proposed.

Capture Area Adjustment: Determining if Adequate Runoff is Directed to the Recharge Practice[77]

[77] A similar adjustment must be made if runoff from all Impervious Surfaces is not directed to treatment SCMs.

Sufficient runoff must be directed to infiltration SCMs to ensure infiltration of the *Required Recharge Volume*. In some cases, designers size exfiltration practices based on the *Required Recharge Volume*, but then direct only a portion of the site's impervious area to the practice. Infiltration SCMs may therefore not be able to capture sufficient rainfall on an average annual basis to meet the *Required Recharge Volume*. In this case, designers and reviewers have two options:

1) Redesign the site so that runoff from a majority of the impervious areas located on the site is directed to the infiltration SCMs, or
2) Increase the storage capacity of the infiltration SCMs so that they may capture more of the runoff from the Impervious Surfaces located within the contributing drainage area.

Capture Area Impervious Cover Threshold

In no case shall runoff from **less than 65%** of the site's impervious cover be directed to the SCMs intended to infiltrate the *Required Recharge Volume.* When **less than 65%** of Impervious Surfaces on a site are directed to infiltration SCMs, the system cannot capture sufficient runoff to infiltrate the *Required Recharge Volume.*

Use the following calculation method when where runoff from only a portion of the impervious area on a site is directed to one or more infiltration SCMs. This method is intended to ensure that infiltration SCMs are able to capture sufficient runoff from the Impervious Surfaces within the contributing drainage area to infiltrate the *Required Recharge Volume*. This procedure is not needed for those sites where all Impervious Surfaces drain to an infiltration SCM. The steps of this procedure are as follows:

1) Calculate the *Required Recharge Volume* based on total site impervious cover and size the infiltration SCMs using the "*Static*" Method, one of the "*Dynamic*" Methods, or the "*Continuous Simulation*" Method.
2) Calculate the site's impervious area that drains to proposed recharge facilities.
3) Divide the total site impervious area by the impervious area draining to the proposed recharge facilities.
4) Multiply the resulting quotient from Step 3 by the original *Required Recharge Volume* calculated under Step 1 to determine the adjusted minimum storage volume needed to meet the recharge volume requirement.

Example Capture Area Adjustment Calculation

Problem Statement. A 1.5-acre site with 1 acre of impervious cover overlays Hydrologic Soil Group "A" soils. Based on site and topographic constraints, runoff from only 0.7 acres of the impervious cover will be discharged to one or more recharge facilities. Find the minimum recharge storage volume needed for the site, assuming the *"Static"* Method.

Solution.

1) Rv = F · IA
2) Rv = [(1.0 inches/12 inches/foot)(1.0 acre)(43,560 sq. ft./acre)]
   Rv = 3,630 cubic feet
3) Site area draining to recharge facilities = 0.70 (1.0 acre) = 0.7 acres
4) Ratio of total site area to site area draining to recharge facilities = 1.0 acre / 0.7 acre = 1.43
5) Adjusted minimum required recharge volume = [(1.43)(3,630 cubic feet)] = 5,191 cu. ft.

Assuming that the analysis indicates that the stored runoff will exfiltrate completely into the ground within 72 hours, the recharge facilities need to be sized, at a minimum, to hold 5,191 cubic feet of runoff.

Mounding Analysis

Mounding analysis is required when the vertical separation from the bottom of an exfiltration system to seasonal high groundwater is less than four (4) feet and the recharge system is proposed to attenuate the peak discharge from a 10-year or higher 24-hour storm (*e.g.,* 10-year, 25-year, 50-year, or 100-year 24-hour storm). [78] In such cases, the mounding analysis must demonstrate that the *Required Recharge Volume* (*e.g.,* infiltration basin storage) is fully dewatered within 72 hours (so the next storm can be stored for exfiltration). The mounding analysis must also show that the groundwater mound that forms under the recharge system will not break out above the land or water surface of a wetland (*e.g.,* it doesn't increase the water sheet elevation in a Bordering Vegetated Wetland, Salt Marsh, or Land Under Water within the 72-hour evaluation period).

The Hantush[79], USGS MODFLOW, or other equivalent method may be used to conduct the mounding analysis depending on the SCM type. The Hantush method predicts the maximum height of the groundwater mound beneath a rectangular or circular recharge area. As such, Hantush is not an acceptable method for linear features (i.e., infiltration trenches, subsurface infiltrators). Use MODFLOW to perform the mounding analysis for linear features. The Hantush method is available in proprietary software and free automated online calculators.[80] If the analysis indicates the mound will prevent the infiltration SCM from fully draining within the 72-hour period, an iterative process must be employed to determine an alternative design that drains within the 72-hour period.

Mounding analysis is also needed when recharge is proposed at or adjacent to a site classified as contaminated, was capped in place, or has an Activity and Use Limitation (AUL) that precludes inducing runoff to the groundwater, pursuant to MGL Chapter 21E and the Massachusetts Contingency Plan 310 CMR 40.0000; or is a solid waste landfill pursuant to 310 CMR 19.000; or groundwater from the recharge location flows directly toward a solid waste landfill or 21E site. In this case, the mounding analysis must determine whether infiltration of the Required Recharge Volume will cause or contribute to groundwater contamination.

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[78] In other situations, mounding analysis is advisable, although not required. For example, conditions such as tight soils, high groundwater, or a thin saturated zone could cause a mound to form under the recharge practice preventing the practice from draining within the required 72-hours.

[79] Hantush 1967 – See Reference for Standard 3

[80] USGS Scientific Investigations Report 2010-5102 includes a spreadsheet that solves the Hantush Equation to simulate groundwater mounding beneath a hypothetical infiltration basin (Carleton, 2010): https://pubs.usgs.gov/sir/2010/5102/.

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6.2.4 Standard 4: Pollutant Removal

Required Computations or Demonstrations

- ❑ Source Control and Pollution Prevention Measures must be identified in the Long-Term Pollution Prevention Plan (LTPPP) (See **Section 4.3.2** for requirements).
- ❑ SCMs are sized to remove TSS and TP in accordance with requirements from **Section 2.3.4**.

Computations and demonstrations covered by this section include:

- ❑ Calculate pollutant removals for SCMs <u>with</u> a EPA Performance Removal Curve or MassDEP Crosswalk.
- ❑ If applicable, calculate pollutant removals for SCMs <u>without</u> an EPA Performance Removal Curve.
- ❑ Calculate TSS pretreatment.
- ❑ If applicable, size proprietary SCMs.
- ❑ If applicable, perform *de minimis* stormwater discharges and weighted average method calculations.
- ❑ If applicable, size one SCM to meet multiple stormwater standards.

Additional required computations and demonstrations covered by other sections include:

- ❑ If applicable, perform soil evaluation to determine which infiltration rates will be used for SCM sizing (see **Section 6.3**)
- ❑ Calculate contributing drainage area (see **Section 6.4**) and impervious area (see **Section 6.5**).

What Tools are Available to Assist with Calculations?

The following tools are available for preparing pollutant removal calculations. Refer to the following pages of this section for example calculations using each of these tools.

1. For SCMs <u>with</u> an EPA PRC or MassDEP Crosswalk:

   - Version 2.1 of the EPA Best Management Practice Accounting and Tracking Tool (BMP-BATT), available at: https://www.epa.gov/npdes-permits/stormwater-tools-new-england#swbmp.
   - Graphical and tabular versions of the EPA PRCs used by version 2.1 of EPA-BATT (see **Appendix B**).

2. For SCMs <u>without</u> an EPA PRC, including pretreatment SCMs:

   - MassDEP Excel based worksheets, available at: https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards.

Summary of Water Quality Treatment Requirements

- ❑ SCMs must be sized to remove TSS and TP in accordance with requirements from **Section 2.3.4**.

- For new development, Stormwater Management Systems shall be designed to remove 90% of Total Suspended Solids (TSS) AND 60% of Total Phosphorus (TP) from the total average annual post-construction load generated from impervious surface area on the site. When a WQv of at least 1.0 inch is recharged on site, full credit is provided for Standard 3 and 4.
- For stormwater discharges from certain areas as summarized by **Section 2.3.4** (*e.g.,* within areas with *rapid infiltration rates*, Zone IIs, Interim Wellhead Protection Areas, or near or to other Critical Areas), the treated WQv must be at least 1.0 inch.
- When there is no applicable EPA Performance Removal Curve, the treated WQv must be at least 1.0 inch. See **Table 2-2** for a list of SCMs that have applicable EPA Performance Removal Curves.

❑ To meet the TSS/TP removal standard, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis to be submitted with the Notice of Intent. Other SCMs and related stormwater Best Management Practices shall only be used to meet those portions of this TSS/TP removal Standard that cannot be fully met by ESSD and LID. See **Section 6.1.4** for more information on the written alternatives analysis.

❑ TSS Pretreatment must be provided before discharge to most SCMs. See **Table 2-2** for a list of SCMs that require pretreatment.

❑ TSS Pretreatment of at least 25% must be provided before discharge to most SCMs (see **Table 2-2** for a list of SCMs that require pretreatment). At least 44% TSS pretreatment is required for stormwater discharges to certain areas as summarized by **Table 2-1**.

❑ Separate calculations shall be completed for each stormwater outlet to demonstrate compliance with TSS and TP removal requirements.

How is Pretreatment Addressed by these Methods?

Pretreatment credits are already incorporated into the EPA Performance Removal Curves and the MassDEP pollutant removal credits – *i.e.,* the EPA-PRCs and MassDEP pollutant removal credits assume that the SCM has been designed with proper pretreatment in accordance with the **Appendix A** Structural SCM Specifications and the Massachusetts Stormwater Handbook. Applicants must therefore demonstrate that the required 25% or 44% TSS pretreatment is provided when performing calculations.

*For example, assume that an infiltration basin is being designed to receive runoff from a Land Use with a Higher Pollutant Load (LUHHPL) for a new development project. As indicated by **Table 2-1**, at least 44% TSS pretreatment and a treated Water Quality Volume of at least 1 inch is required for this instance. The Applicant would take the following steps to claim pollutant removal credit:*

1. *Calculate pretreatment credits.*
   a. *Use the **Appendix A** Structural SCM Specifications to identify which pretreatment measures are appropriate for infiltration basins and **Table 2-3** to identify which pretreatment measures are appropriate for LUHPPLs – e.g., sediment forebay, oil grit separator.*
   b. *Use **Table 2-2** to identify the TSS pretreatment credit that is assigned to each pretreatment SCM. For example, sediment forebays and oil grit separators are both assigned a TSS pretreatment credit of 25%.*
   c. *Use the MassDEP Pollutant Removal Worksheet to calculate the pretreatment credit.[1] See **Figure 6-13** for an example calculation where a treatment train of two pretreatment SCMs are used to achieve a TSS pretreatment credit of 44%.*
2. *Calculate pollutant removal credits exclusive of the pretreatment credits.*
   a. *Use the EPA Performance Removal Curves (EPA PRCs) to size the infiltration basin to treat a WQv of at least 1 inch and remove at least 90% TSS and 60% TP <u>exclusive</u> of the 44% TSS pretreatment credit.*
   b. *For example, assume that EPA PRCs are used to size the infiltration basin to remove 96% TSS and 65% TP. A 96% TSS removal credit would be assigned to the sediment forebay, oil grit separator, and infiltration basin combination – no additional TSS removal credit is given for the pretreatment SCMs.*

Calculating Pollutant Removals for SCMs <u>with</u> an EPA Performance Removal Curve

The EPA Performance Removal Curves (EPA-PRCs) must be used to determine pollutant removal credits for SCMs with an established curve. Refer to the SCM Convention Crosswalk for a list of SCMs with an available EPA-PRC (**Table 2-2**). The EPA-PRCs are available in graphical and tabular form in **Appendix B**, or can be accessed from the most recent version of the EPA Best Management Practice Accounting and Tracking Tool (BMP-BATT).[81] The following procedure can be used to calculate pollutant removal credits for TP and TSS using the EPA-PRCs.

- **Step 1:** Determine the required TP and TSS percent removal for the site by reviewing requirements for Standard 4 (see **Section 2.3.4** and "*Summary of Water Quality Requirements*" above).

[81] EPA BMP-BATT (version 2.1): https://www.epa.gov/npdes-permits/stormwater-tools-new-england#swbmp.

- **Step 2:** Determine the impervious drainage area to be treated by the SCM (see **Section 6.5** for definition of impervious area and **Section 6.4** for a procedure for calculating contributing drainage area).
- **Step 3**: Select the SCM(s) that will be used to meet Standard 4 pollutant removal requirements, then access the EPA-PRCs. If the SCM uses infiltration for treatment, perform field testing in accordance with the "*Soil Evaluation Procedures*" presented in **Section 6.3** to determine the *in-situ saturated hydraulic conductivity*. Select the appropriate EPA-PRC to use for the SCM based on the determined *in-situ saturated hydraulic conductivity*. The EPA-PRCs were developed based on the 1983 Rawls Rates. If the selected in-situ saturated *hydraulic conductivity* does not match those provided by the EPA-PRC, use the EPA-PRC for the infiltration rate that is nearest to, but less than, the determined infiltration rate – for example, if the field measured *in-situ saturated hydraulic conductivity* at the SCM's location and soil layer depth is determined to be 0.35 inches per hour, use the EPA-PRC for 0.27 inches per hour (see below for an example).
- **Step 4:** Use the EPA-PRC to calculate the minimum depth of runoff (RD) from the upstream impervious area (IA) that the SCM must treat to meet pollutant removal requirements (see below for example).
- **Step 5:** Calculate the minimum required design storage volume (DSV) that the SCM must hold to meet pollutant removal requirements (**Equation 6-6**). The DSV includes permanent system treatment volume and does not include volume associated with peak rate or flood control (i.e., volume above the primary outlet control).

$$DSV = RD \cdot IA \qquad \textbf{Equation (6-6)}$$

Where,

DSV is the SCM design storage volume.

RD is the runoff depth from upstream impervious area.

IA is the impervious area that drains to the SCM.

- **Step 6:** Size specific SCM dimensions based on the minimum required DSV. Each SCM will have a different method of calculating this volume. The 2016 MA Small MS4 Permit, Attachment 3 to Appendix F, Table 3-5 provides equations to calculate the DSV for each SCM that has a performance curve (https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/appendix-f-attach-3-2016-ma-sms4-gp-mod.pdf). Refer to **Table 2-2** for a crosswalk that relates SCMs from the 2016 Small MA Permit to the Stormwater Handbook.

Example Calculation using the EPA Performance Removal Curves

Problem Statement. On a two (2) acre site, one (1) acre is proposed to be developed for a retail store and parking lot. The proposed parking lot will have 50 parking spaces, and generate less than 1,000 vehicle trips/day. An infiltration basin is proposed to meet Stormwater Standards 2, 3, and 4. Based on a soil evaluation performed on site in accordance with Standard 3 (see **Section 6.3**), the field measured *in-situ saturated hydraulic conductivity* of the soils at the proposed location of the infiltration basin was determined to be 0.80 inches per hour. Determine the minimum required *SCM Storage Volume* to meet TSS and TP pollutant removal requirements.

Solution using EPA PRC's from Appendix B. The minimum required *SCM Storage Volume* is determined as follows.

- **Step 1:** As a new development, the project is required to remove 90% TSS and 60% TP.
- **Step 2:** The impervious drainage area (IA) to be treated is 1 acre.

- **Step 3**: The selected SCM is an Infiltration Basin.
  - Obtain the Infiltration Basin EPA-PRCs.
  - There are six performance curves available for Infiltration Basins based on the design infiltration rate of the underlying soils. The curves include the following infiltration rates: 0.17 in/hr, 0.27 in/hr, 0.52 in/hr, 1.02 in/hr, 2.41 in/hr, and 8.27 in/hr
  - The measured in-situ *saturated hydraulic conductivity* was 0.80 in/hr. The rate that is closest to, but less than 0.80 in/hr is 0.52 inches per hour. Use the curve for 0.52 in/hr.
- **Step 4**: The minimum depth of runoff from the impervious area, RD, that the Infiltration Basin must treat is obtained from the selected EPA-PRC with a design infiltration rate of 0.52 inches per hour (see **Figure 6-10**).
  - Per **Figure 6-10**, the minimum RD to meet the 90% TSS removal requirement is approximately 0.32 inches. The minimum RD to meet the 60% TP removal requirement is approximately 0.25 inches. Therefore, the SCM should be sized for a RD of at least 0.32 inches using TSS as the limiting factor to meet pollutant removal targets.
- **Step 5**: The minimum required design storage volume (DSV) for the Infiltration Basin to meet pollutant removal requirements is calculated using **Equation 6-6**.
  - DSV = RD · IA
  - DSV = (RD/12 inches/ft)·(IA · 43,560 square feet / acre)
  - DSV = (0.32 inches /12 inches/ft)·(1 acre · 43,560 square feet / acre)
  - DSV = 1,162 cf.
- **Step 6:** Configure SCM dimensions that can hold the minimum DSV.

Because the treatment system is proposed to be used to recharge the first 1-inch of runoff and a peak runoff rate attenuation volume for the 100-year 24-hour storm, the volume of the infiltration basin must be designed to be larger than 0.32-inches (see "When One Practice is Sized to Meet Multiple Stormwater Standards" for more information).

Solution Using EPA BMP-BATT. The calculation procedure is slightly different if the EPA-PRCs from the BMP-BATT Tool are used. By default, the BMP-BATT tool provides estimates of annual pollutant removals (i.e., lb/yr) based on specific treated impervious land use types. MassDEP does not differentiate between specific treated impervious land use types and only requires that a percentage of the total average annual post-construction TP and TSS load generated from impervious site area be removed. The required *SCM Storage Volume* is therefore determined as follows.

- **Step 1, 2, and 3**: These steps are the same as above. All required information is input into the BMP-BATT in accordance with the user guide.[82] See **Figure 6-11a** for an example screenshot of land use inputs and **Figure 6-11b** for an example screenshot of Infiltration Basin inputs.
- **Step 4**: Pollutant removal efficiency can then be calculated by clicking on "Edit BMP Efficiencies". See **Figure-10c** for an example screenshot of the output. If the pollutant

[82] EPA-BMP BATT User Guide: https://www3.epa.gov/region1/npdes/stormwater/tools/batt-users-guide-v2-1.pdf.

removal efficiency is too low, the user has the option to iteratively adjust (increase) the Storage Volume until pollutant requirements are met.

Important: If the EPA-BMP BATT is used to perform pollutant removal calculations, the Applicant must provide a printout or screenshots of all inputs and outputs to enable review of results. There is an option in the BMP-BATT to export a project report. The exported project report provides information on treated impervious runoff depth and calculated pollutant removal efficiencies.

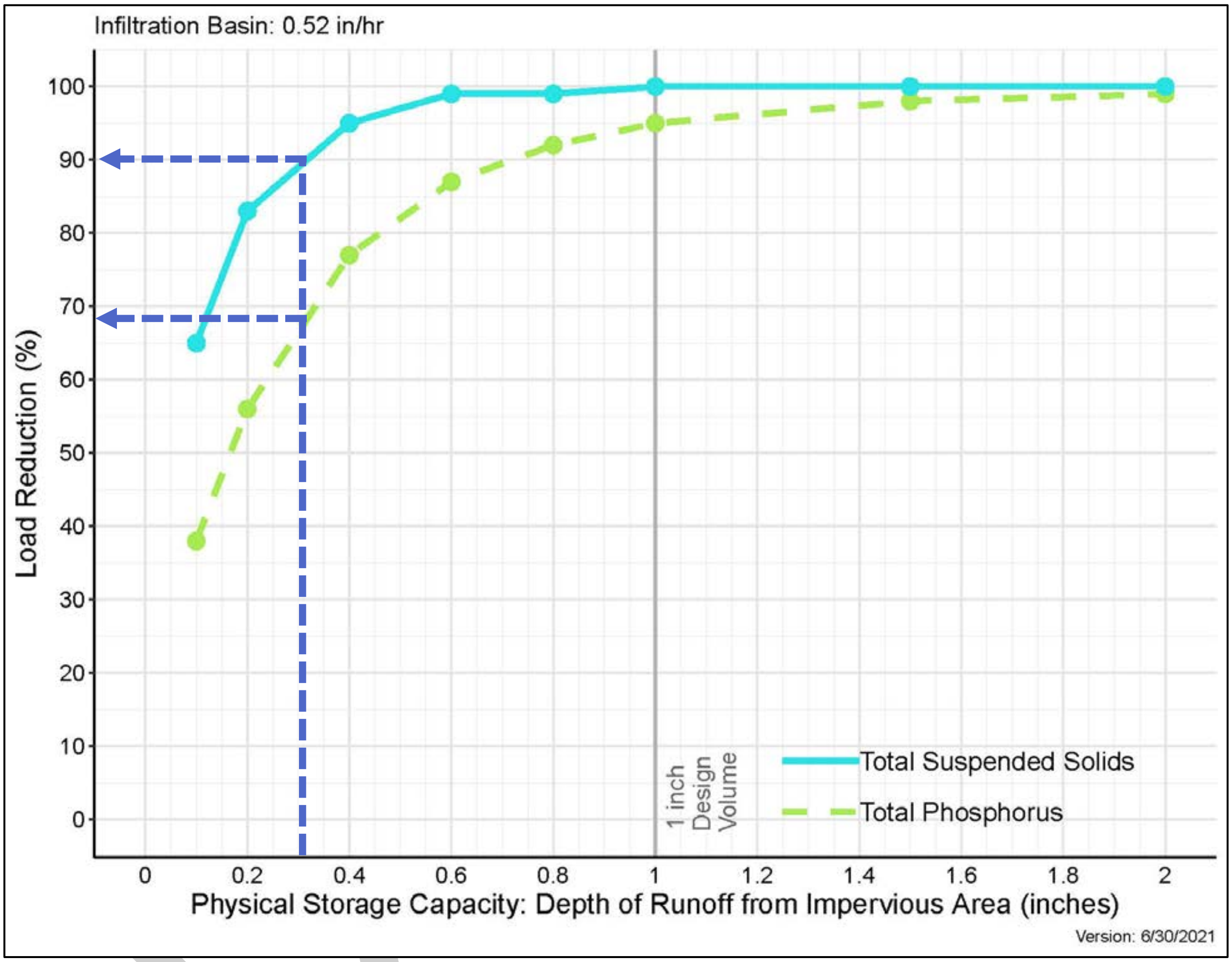

Figure 6-10. Example EPA Performance Removal Curve from **Appendix B** for an Infiltration Basin with a Design Infiltration Rate of 0.52 inches/hour

(Purple dashed line depicts pollutant load reduction % for TSS and TP for a treated RD of 0.32 inches from previous example.)

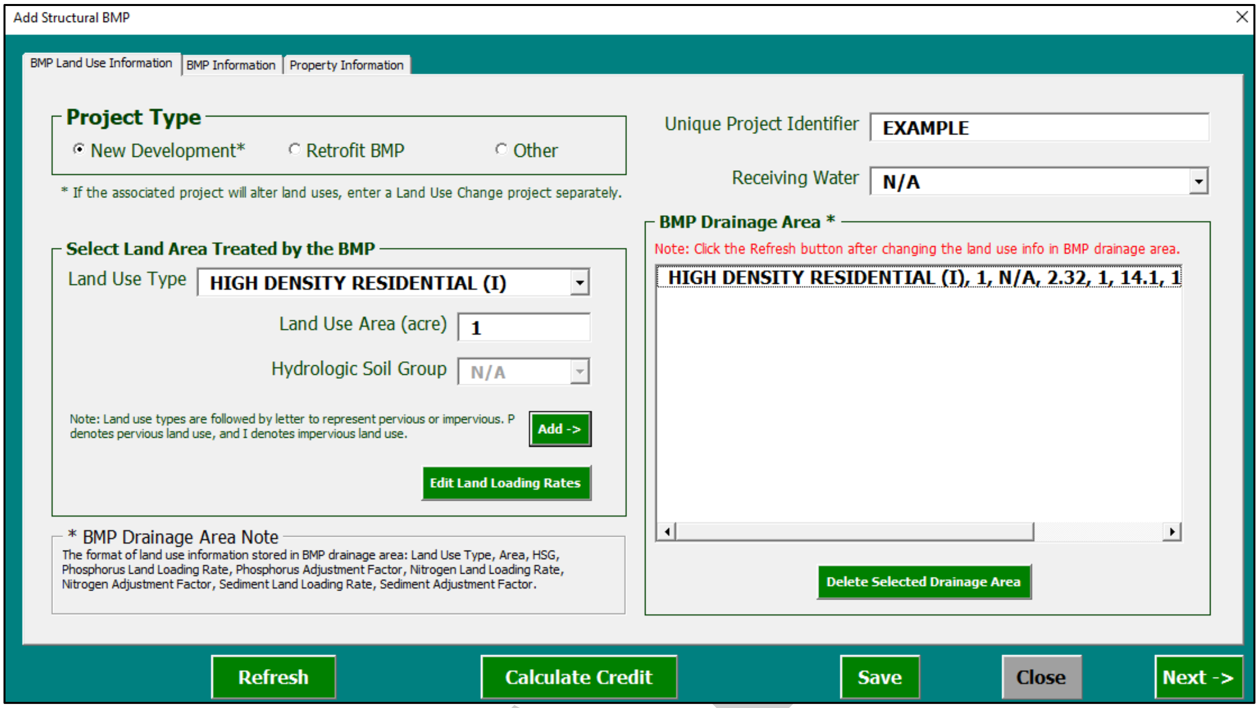

Figure 6-11a. Example screenshot from Version 2.1 of the EPA BMP-BATT depicting land use inputs

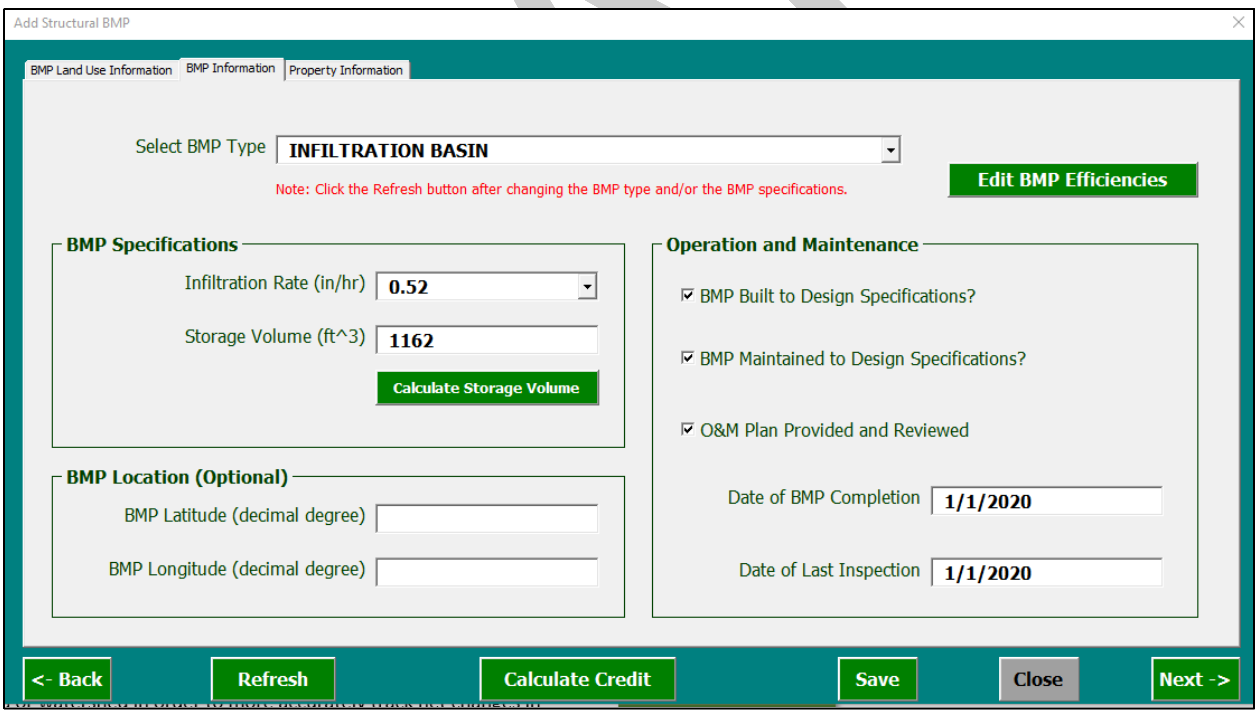

Figure 6-11b. Example Screenshot from Version 2.1 of the EPA BMP-BATT depicting Infiltration Basin inputs

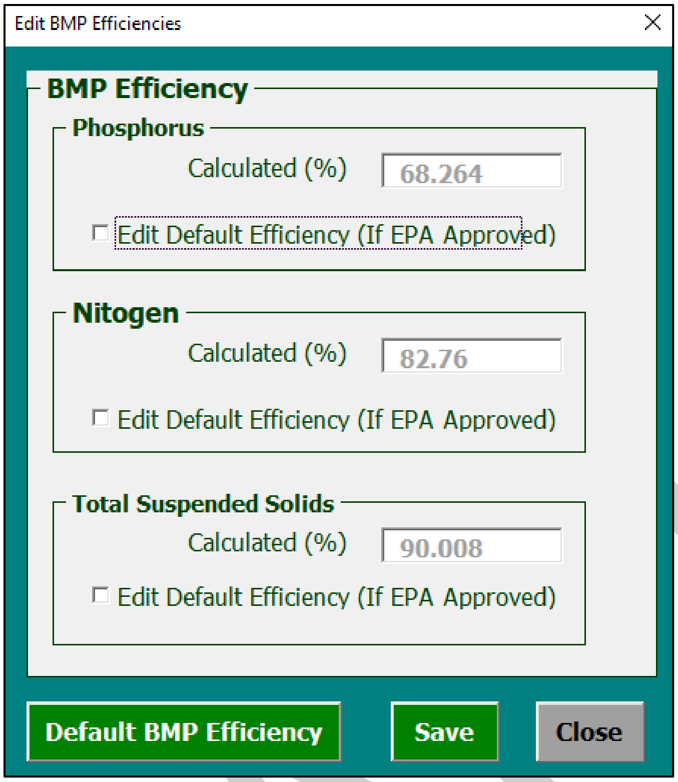

Figure 6-11c. Example screenshot from Version 2.1 of the EPA BMP-BATT depicting calculated pollutant removal efficiency

Pollutant Removal Calculations for Certain Stormwater Discharges

As summarized in **Section 2.3.4**, a treated WQv of at least 1.0 inch of impervious area must be provided for certain stormwater discharges (*e.g.,* Critical Areas, LUHPPLs), or when the SCM is proposed to provide the 1-inch required recharge volume. For these instances, all steps of the EPA Performance Removal Curve Procedure are the same with the exception of using a RD of at least 1.0 inch for Step 4 and Step 5.

In the aforementioned example, a RD of 1.0 inch results in a TP removal rate of approximately 95% and a TSS removal rate of approximately 99%. The resulting minimum required storage volume (i.e., DSV) of the Infiltration Basin would be 3,630 cubic feet as calculated by **Equation 6-8** (see below).

Calculating Pollutant Removals for SCMs without an EPA Performance Removal Curve

Refer to the SCM Convention Crosswalk for a list of SCMs that do not have an EPA Performance Removal Curve or MassDEP Crosswalk (**Table 2-2**). The following procedure must be used to calculate pollutant removal credits for TP and TSS for SCMs without an established EPA Performance Removal Curve. Step 5 of this procedure must also be used to demonstrate that the required 25% or 44% TSS pretreatment has been achieved.

- **Step 1:** Determine the contributing impervious drainage area to be treated by the SCM (See **Section 6.2.3**).

- **Step 2**: Calculate the required *Water Quality Volume* (WQv). The required WQv is the runoff volume requiring treatment – it is calculated as the required runoff depth (RD) multiplied by the total post-construction impervious site area (IA) (**Equation 6-7**).

$$WQv = RD \cdot IA \qquad \textbf{Equation (6-7)}$$

  Where,

  WQv is the *Required Water Quality Volume*

  RD is the runoff depth from upstream impervious area

  IA is the impervious area that drains to the SCM

- **Step 3:** Determine the required TP and TSS percent removal for the site by reviewing Standard 4 requirements (see **Section 2.3.4**).
- **Step 4**: Select the SCM(s) that will be used to meet Standard 4 pollutant removal requirements <u>without</u> an EPA Performance Removal Curve. See **Table 2-2** for MassDEP pollutant removal credits for SCMs <u>without</u> an EPA Performance Removal Curve.
- **Step 5:** Use MassDEP worksheets to prepare TSS and TP removal computations. MassDEP has two worksheets available to prepare pollutant removal computations for SCMs without an EPA Performance Removal Curve; one is an automated spreadsheet and the other is a manual version.[83] See **Figure 6-12** for an example blank worksheet. A completed version of either worksheet must be submitted as part of the Stormwater Report to demonstrate that the proposed treatment options will achieve the required pollutant removals.

  When proposing proprietary structural treatment practices in accordance with **Section 5.3**, Applicants must use the manual worksheet, since the proprietary treatment practices are not listed in the dropdown menu in the automated spreadsheet. An example that demonstrates how to use the manual form is set forth below.

[83] MassDEP TSS and TP removal worksheets: https://www.mass.gov/guides/massachusetts-stormwater-handbook-and-stormwater-standards.

INSTRUCTIONS:

Non-automated: Mar. 4, 2008

1. Sheet is nonautomated. Print sheet and complete using hand calculations. Column A and B: See MassDEP Structural BMP Table
2. The calculations must be completed using the Column Headings specified in Chart and Not the Excel Column Headings
3. To complete Chart Column D, multiple Column B value within Row x Column C value within Row
4. To complete Chart Column E value, subtract Column D value within Row from Column C within Row
5. Total TSS Removal = Sum All Values in Column D

Location:

TSS Removal Calculation Worksheet

A BMP[1]	B TSS Removal Rate[1]	C Starting TSS Load*	D Amount Removed (B*C)	E Remaining Load (C-D)
		1.00		

Total TSS Removal =

Separate Form Needs to be Completed for Each Outlet or BMP Train

Project:

Prepared By:

Date:

*Equals remaining load from previous BMP (E) which enters the BMP

Figure 6-12. Example blank pollutant removal form for manual calculations

Example Calculation to Calculate 44% Pretreatment using MassDEP Worksheet

Problem Statement. Sheet runoff from a high-intensity parking lot with greater than 1,000 vehicle trips per day is directed to a series of off-line Deep Sump Catch Basins. The runoff from the deep sump catch basins is directed to an Oil/Grit Separator for further pretreatment, and then to an infiltration basin. There is a single stormwater outlet from the infiltration basin directed to a stream. MassDEP assigns a TSS annual removal rate for a properly designed Deep Sump Catch Basin of 25% and a properly designed and offline Oil/Grit Separator of 25% as indicated by **Table 2-2**. *Use the pollutant removal worksheet to determine whether the 44% pretreatment requirement is met.*[84]

Solution: Complete the pollutant removal worksheet and present it with the Stormwater Report accompanying the Wetlands NOI. Refer to **Figure 6-7** for a completed version of the worksheet for this example. Step-by-step instructions are provided below.

- **Deep Sump Catch Basin Calculations**. Manually, write in the name “Deep Sump Catch Basin” into Cell B1. In Cell C2, manually write in the assigned 25% TSS removal rate for Deep Sump Catch Basins. Only 25% TSS credit is provided, even though multiple Deep Sump Catch Basins capture runoff and direct it to the Oil/Grit Separator. Write 1.00 in Cell D1 (100% of the TSS load is presumed to be directed to the Deep Sump Catch Basin inlets). Multiply the 25% TSS removal rate for the Deep Sump Catch Basin by the starting TSS load of 1. Fill the result of 0.25 or 25% in Cell E1. Next determine the remaining TSS load, after stormwater leaves the device. The remaining load is the Starting TSS Load minus the TSS removed by the device. In this case, the remaining load is 1 – 0.25 = 0.75 or 100% - 25% = 75%. Write 75% in Cell F1.
- **Oil/Grit Separator Calculations**. Next, manually write in the name of the second structural SCM, the Oil/Grit Separator, into Cell B2. In Cell C2, manually write in 0.25 or 25%, the assigned TSS removal rate for the Oil/Grit Separator properly designed in accordance with the **Appendix A** specifications. In Cell D2, manually write in 0.75 or 75%, which is the remaining load listed in Cell F1 that is being directed to the Oil/Grit Separator. Multiply Cells C2 by D2, which would be 0.25 x 0.75. The result is 0.1875 or 0.19, rounded. Write this result in Cell E2. The remaining load is then determined by subtracting Cell E2 from D2, or 0.75 – 0.19 = 0.56. The result of 0.56 or 56% is manually written into Cell F2.
- **Final Result**. Since the stormwater is not routed through any other devices for pretreatment, the final result is determined by adding 25% and 19% to obtain 44% (the required pretreatment values). Manually write this result in Cell E6.

  TSS removal rates for each device as set forth in the pollutant removal table, **Table 2-2**, must not be added. If the TSS removal rates set forth in the table for each device were added, it would appear that the Deep Sump Catch Basins and Oil/Grit Separator would remove 50% of the presumed annual TSS load (25% +25% = 50%). This is not the case. Adding the removal rates for the Deep Sump Catch Basins and Oil/Grit Separator does not take into account the fact that the influent TSS load is reduced when stormwater is routed from the first structural SCM to the second structural SCM. In this example, the influent load to the Oil/Grit Separator is only 75%, not 100%, because the Deep Sump Catch Basin is presumed to have removed 25% of the initial TSS load for runoff enters the Oil/Grit Separator.

  Refer to **Figure 6-13** for a completed solution for this example depicting the resulting 44% TSS removal from the pretreatment devices.

[84] If runoff is directed to a SCM like an extended dry detention basin that is required to include a sediment forebay, no additional credit is given to the sediment forebay when determining whether TSS or TP removal is achieved. However, the 25% removal credit given to the sediment forebay can be used to satisfy the 44% pretreatment requirement prior to discharge to an infiltration structure for runoff from LUHPPLs, within an area with a *rapid infiltration rate*, within a Zone II or Interim Wellhead Protection Area, or near to other Critical Areas.

INSTRUCTIONS:
1. In BMP Column, click on Blue Cell to Activate Drop Down Menu
2. Select BMP from Drop Down Menu
3. After BMP is selected, TSS Removal and other Columns are automatically completed.

Version 1, Automated: Mar. 4, 2008

Location: Example

TSS Removal Calculation Worksheet

B BMP[1]	C TSS Removal Rate[1]	D Starting TSS Load*	E Amount Removed (C*D)	F Remaining Load (D-E)
Deep Sump and Hooded Catch Basin	0.25	1.00	0.25	0.75
Oil Grit Separator	0.25	0.75	0.19	0.56
	0.00	0.56	0.00	0.56
	0.00	0.56	0.00	0.56
	0.00	0.56	0.00	0.56

Total TSS Removal = 44%

Separate Form Needs to be Completed for Each Outlet or BMP Train

Project: Example
Prepared By:
Date:

*Equals remaining load from previous BMP (E) which enters the BMP

Figure 6-13. Solution of pretreatment example, completed using the automated spreadsheet

Sizing Proprietary Manufactured SCMs for Purposes of Standard 4

MassDEP's "Standard Method to Convert Required Water Quality Volume to a Discharge Rate" shall be used for sizing flow based on proprietary manufactured SCMs (see **Appendix D**). This computational method primarily affects the sizing of proprietary manufactured stormwater treatment separators, and does not affect other types of stormwater treatment practices that are volume based. Proprietary Manufactured SCMs may only be used to meet TSS pretreatment provisions contained in Stormwater Standards 3 - 7 and Standard 11 (see **Section 5.3** for more information).

De Minimis Stormwater Discharges for Purposes of Standard 4

The required pollutant removal rates shall be achieved at each outlet discharging to a receiving wetland or water body. The only exception to this is when the discharge is considered to be *de minimis*. The stormwater discharge from an individual outlet is considered *de minimis* when all the following conditions are satisfied:

- ❑ Physical site conditions preclude installation of a pollutant treatment practices prior to discharge (*e.g.,* lack of space between a wetland and a road, lack of head differential).
- ❑ The discharge is less than or equal to 1 cfs for the runoff associated with the 2-year, 24-hour storm.
- ❑ Required TSS and TP removal is achieved on an average weighted basis from the site as a whole using the weighted average method described below. This will require more than the required TSS and TP removal at some stormwater outlets to compensate for the outlets that achieve less than the required TSS and TP removal.

- ❑ The stormwater outlets where additional controls are used to achieve more than the required TSS and TP removal must discharge to the same reach of the same wetland or water body as the outlets that achieve less than the required TSS and TP removal.
- ❑ Controls are placed at the outlet to prevent erosion or scour of the wetland/water body and bank.
- ❑ Standard 2 (peak rate attenuation) and Standard 3 (recharge) must be achieved on a site-wide basis.
- ❑ Source control and pollution prevention measures that mitigate the impact of the untreated or partially treated discharges are identified in the Pollution Prevention Plan required by Standard 4 and fully implemented (*e.g.,* street sweeping).
- ❑ The size of the drainage area contributing runoff to the untreated outlet has been reduced to the maximum extent practicable.

If all these conditions are met, the discharge is considered *de minimus*. In that event, the Weighted Average Method described by **Equation 6-8** shall be used to determine if the required TSS and TP removal rates are achieved on a site-wide basis for purposes of design.

$$\mathbf{Weighted\ Average}\ \% = \frac{(\mathbf{A_1} \cdot \mathbf{P_1}\%) + (\mathbf{A_2} \cdot \mathbf{P_2}\%) + \cdots\ (\mathbf{A_n} \cdot \mathbf{P_n}\%)}{\mathbf{A_1} +\ \mathbf{A_2} + \cdots \mathbf{A_n}} \qquad \textbf{Equation (6-8)}$$

Where,

A_n is the upstream impervious area, from Area 1 to Area "n"

P% is the assigned percent pollutant removal rate from Area 1 to Area "n"

Equation 6-8 must be completed twice when performing *de minimus discharge* calculations – once for TSS and once for TP.

Example Calculation – Discharge is Considered De Minimus

Problem Statement. A new development with 10 acres of Impervious Surfaces proposes two outlet points discharging to the same reach of a Wetland Resource Area. The proposed project is required to provide 90% TSS removal is 90% and 60%TP removal.

Solution.

- Runoff from 9.995 impervious acres is to be directed to one outlet, after receiving 92% TSS and 65% TP removal.
- Drainage from a low point in the entry road from the remaining 0.005 acres (218 square feet) is to be directed to another outlet to the same Wetland Resource Area, with no TSS or TP treatment.
- Measures such as source reduction of winter sanding and quarterly street sweeping with vacuum sweepers are incorporated into the Pollution Prevention Plan required by Standard 4 to reduce TSS and TP loading from the outlet point.
- In-pipe storage is proposed to reduce the peak rate of the discharge. Erosion controls such as riprap are proposed at the outlet to reduce the velocity of the discharge so it does not scour the wetland (Standard 1).
- The discharge from a 2-year 24-hour storm is calculated to be less than 1 CFS.
- The size of the drainage area where treatment is not feasible has been reduced to the maximum extent practicable.
- No TSS and TP treatment is possible, because there is insufficient head between the road sag point and the surface elevation of the Wetland Resource Area.
- Using **Equation 3-9**, the overall weighted average for TSS removal is determined to be 91.9%, while the overall weighted average for TP is determined to be 64.9%.

The impact to the Wetland Resource Area from stormwater is considered *de minimis,* because the calculated discharge is less than 1 CFS and all the other conditions set forth above are met.

Example Calculation – Discharge is <u>Not</u> Considered De Minimus

Problem Statement. A proposed new development with 10 acres of Impervious Surfaces with two outlet points discharging to the same reach of a Wetland Resource Area. The proposed project is required to provide 90% TSS removal is 90% and 60% TP removal.

- Runoff from 9 acres of Impervious Surfaces is to be directed to one outlet, after receiving 92% TSS and 65% TP removal.
- Runoff from the remaining one acre is to be directed to another outlet, with no TSS treatment.
- The discharge rate from the one acre is determined to be 10 CFS.
- Using **Equation 6-8**, the overall weighted average for TSS removal is determined to be 82.9%, while the overall weighted average for TP is determined to be 58.5%.

Solution. The discharge is not *de minimis,* because the 1 CFS threshold is exceeded. In addition, the required TSS and TP removal percentages are not met. The discharge would result in a violation of Standard 1, because an untreated discharge is being made to Waters of the Commonwealth.

When One Practice Is Sized to Meet Multiple Stormwater Standards

A single SCM can be designed to meet multiple Stormwater Standards – *e.g.,* peak rate attenuation (Standard 2), recharge (Standard 3), and water quality treatment (Standard 4). Computations must demonstrate that the volumes required by each Standard are provided by the single practice. Any assumptions used in conducting the computations must be consistent for each Standard.

Example Calculation – Sizing One Practice to Meet Multiple Stormwater Standards

Problem Statement. An Infiltration Basin is proposed for a new development project to provide recharge (Standard 3), and water quality treatment (Standard 4). Assume that the minimum depth of runoff from the contributing impervious area required to meet the *Required Recharge Volume* is 1.0 inch (Standard 3). Also assumed that the minimum depth of runoff from impervious area required to meet required TSS and TP removal requirements is approximately 0.3 inches (Standard 4).

Solution. The Infiltration Basin must therefore be sized, at minimum, for the Required Recharge Volume because it is larger than the required Water Quality Volume to meet TSS and TP removal requirements. If the Infiltration Basin were to also be sized for Standard 2 (peak rate attenuation), additional evaluation would be required to verify that peak rate attenuation is achieved with the proposed sizing. If peak rate attenuation is not achieved, the storage volume would need to be iteratively increased and/or the configuration of the outlet control structure would need to be iteratively modified until peak rate attenuation is achieved.

Standard 4 References

Claytor, R.A., and Schueler, T.R., 1996, Design of Stormwater Filtering Systems. Center for Watershed Protection, Silver Spring, MD.

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6.2.5 Standard 5: Land Uses with Higher Potential Pollutant Loads

Required Computations or Demonstrations

Standard 5 applies to Land Uses with Higher Potential Pollutant Loads (LUHPPLs) as defined in **Section 2.3.5**. Demonstrations include:

- ❑ Source controls and pollution prevention measures must be identified in the Long-Term Pollution Prevention Plan to be submitted with the NOI or WQC Application (see **Section 4.3.2** for requirements) and thereafter implemented after completion of the Project.[85] If the Project is subject to the EPA Multi-Sector General Permit (MSGP), the Long-Term Pollution Prevention Plan must be consistent with the Industrial Stormwater Pollution Prevention Plan (SWPPP) required to be prepared as part of the MSGP.
- ❑ Use SCMs approved by MassDEP to be suitable for treating runoff from LUHPPLs (see **Table 2-3**).
- ❑ Demonstrate that SCMs are sized to capture a Required *Water Quality Volume* of at least 1-inch (see **Section 6.2.4** for pollutant removal computations).
- ❑ Demonstrate that 44% TSS removal pretreatment requirement is achieved before discharge to an infiltration structure (see **Section 6.2.4** for pollutant removal computations).
- ❑ Demonstrate horizontal setbacks are met in accordance with **Section 2.5**.
- ❑ If there is a potential for runoff with high concentrations of oil and grease, demonstrate that an oil grit separator, sand filter, filtering bioretention area or equivalent will be used to provide pretreatment.

Standard 5 References

Massachusetts Department of Environmental Protection, Surface Water Quality Discharge Standards, 314 CMR 3.00, 4.00, and 5.00

U.S. EPA, 2021, Multi-Sector General Permit, https://www.epa.gov/npdes/stormwater-discharges-industrial-activities-epas-2021-msgp.

[85] Some land uses with higher potential pollutant loads may be covered under the Multi-Sector General Permit (MSGP). The MSGP requires that an Industrial-SWPPP be prepared. Applicants may use one document to fulfill the SWPPP requirements of the MSGP and the pollution prevention plan requirements of Standard 4. If there is a discharge from a site that holds an MSGP to an ORW, MassDEP WM15 must be submitted.

6.2.6 Standard 6: Critical Areas

Required Computations or Demonstrations

Standard 6 applies to discharges to Critical Areas as defined in **Section 2.3.6**. Demonstrations include:

- ❑ Source control and pollution prevention measures must be identified in the Long-Term Pollution Prevention Plan (LTPPP) (see **Section 4.3.2** for requirements).
- ❑ Use SCMs approved by MassDEP to be suitable for treatment of discharge near or to a particular Critical Area (see **Table 2-4a, b, c, and d** for suitability).
- ❑ Demonstrate that SCMs are sized to capture a *Required Water Quality Volume* of at least 1-inch (see **Section 6.2.4** for pollutant removal computations).
- ❑ Demonstrate that the 44% TSS removal pretreatment requirement is achieved before discharge to the infiltration structure (see **Section 6.2.4** for pollutant removal computations).
- ❑ Demonstrate horizontal setbacks are met in accordance with **Section 2.5**, including but not limited to: setback outside of Zone I and Zone A of public drinking waters.

Standard 6 References

Massachusetts Department of Environmental Protection Surface Water Quality Standards, 314 CMR 4.0, and associated Basin Classifications & Maps (314 CMR 4.06), https://www.mass.gov/doc/314-cmr-4-massachusetts-surface-water-quality-standards/download.

MassGIS Online Mapping Tool, https://www.mass.gov/orgs/massgis-bureau-of-geographic-information .

Coldwater Fisheries Resources, https://www.mass.gov/info-details/coldwater-fish-resources.

6.2.7 Standard 7: Redevelopment

Standard 7 applies only to those parts of the project that meet the definition of Redevelopment as described in **Section 2.3.7**

Required Computations or Demonstrations

- ❑ Complete the Redevelopment Checklist (see **Appendix E**).

- ❑ Prepare a written alternatives analysis for any Standards proposed to be met to the MEP (see **Section 6.1.4**). **Note:** The 80% TSS / 50% TP pollutant removal must be fully met. If pollutant removals cannot be fully met, the written alternatives analysis must identify Offsite Mitigation alternatives. See below for more information on Offsite mitigation.

- ❑ To meet the TSS/TP removal standard, Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques must be used unless demonstrated to be Impracticable based on a written alternatives analysis to be submitted with the Notice of Intent. Other SCMs and related stormwater Best Management Practices shall only be used to meet those portions of this TSS/TP removal Standard that cannot be fully met by ESSD and LID. See **Section 6.1.4** for more information on the written alternatives analysis.

Redevelopment Checklist and Written Alternatives Analysis

The Redevelopment Checklist must be completed and submitted with the WPA NOI or WQC Application for any project that includes Redevelopment (see **Appendix E**). The Redevelopment Checklist provides a detailed list of requirements that Redevelopment projects must meet for each Standard. If the Redevelopment checklist demonstrates that full compliance can't be achieved for any applicable standards, or if the required 80% TSS and 50% TP pollutant removals cannot be fully met, a written alternatives analysis must be completed as detailed by **Section 6.1.4**. The written alternatives analysis must identify Offsite Mitigation alternatives to meet the required pollutant removals as detailed below.

Offsite Mitigation

As defined by 310 CMR 10.04, Offsite Mitigation is a compliance approach for Redevelopment projects where Stormwater Control Measures (SCMs) are implemented at a location that is not within the Project Site to achieve compliance with Standard 3 (recharge), the pollutant removal requirements of Standard 7, and Standard 11 (TMDLs).

Eligibility

Offsite Mitigation must be implemented when the pollutant removal requirements of Standard 7 and the pollutant removal requirements of Standard 11 cannot be fully met onsite. Offsite Mitigation may be allowed for Standard 3 (recharge) and the recharge requirements of Standard 11 when the written alternatives analysis determines that the Standard cannot be met to the Maximum Extent Practicable onsite. Refer to **Table 2-5** for a summary of requirements for Redevelopment projects listed by Stormwater Standard. Offsite mitigation is not allowed for the following instances:

- The proposed project will discharge to a Resource Area from a Land Use with Higher Potential Pollutant Load (LUHPPL) (Standard 5).
- The proposed project will discharge to or near a Critical Area (Standard 6).

Offsite Mitigation is not intended to be a routine extension of a Project Site for purposes of wetland replacement, or for locating pollutant removal practices in place of designing Stormwater Management Systems for on-site compliance.

Required Documentation

Completion of the following steps will be presumed to meet the Offsite Mitigation requirements of Standard 7.

- **Step 1, Complete the Redevelopment Checklist.** Complete the Redevelopment Checklist and verify that full compliance with the pollutant removal requirements of Standard 7 and Standard 11 cannot be met on-site (see **Appendix E**). The Redevelopment Checklist must be completed and submitted with the WPA NOI or WQC Application for any project that includes Redevelopment as defined by **Section 2.3.7**.
- **Step 2, Prepare a Written Alternatives Analysis.** If the Redevelopment Checklist demonstrates that full compliance cannot be achieved for the pollutant removal requirements of Standard 7 and Standard 11, a written alternatives analysis must be submitted with the NOI or WQC Application in accordance with **Section 6.1.4**.[86] Offsite Mitigation alternatives must be completed in the following geographic order:
    - Same Project Site: The area within the Project Locus that comprises the limit of work for activities (310 CMR 10.04).
    - Same Project Locus: The lot on which an Applicant proposed to perform an activity (310 CMR 10.04).
    - Adjacent site: Any property that shares a border with the Project Locus.
    - Same Wetland Resource Area: Any Wetland Resource Area adjacent to each other within the same reach, including areas with a hydrologic connection. For example, Bordering Land Subject to Flooding adjacent to a Bordering Vegetated Wetland is part of the same wetland system.
    - Same municipality: Choosing a mitigation site within the same Town provides the Town and local Conservation Commissions oversight of construction, maintenance, and compliance monitoring activities at the mitigation area. Sites within adjacent municipalities may be considered if both municipalities provide written concurrence.
    - Same steam reach within the same HUC12 subwatershed: Hydrologic Unit Code 12 sub-watershed (HUC12) subwatershed boundaries shall be those defined as HUC12 or smaller (*e.g.,* HUC14, HUC16) by the National Watershed Boundary Dataset (WBD) distributed by the USGS/NRCS.[87]. Use of the HUC12 boundary data distributed by MassGIS is not acceptable, since it is not updated as often as the USGS/NRCS version.

  The written alternatives analysis must demonstrate that the highest practicable level of stormwater management is being implemented at the target location before moving to the next sequential item on the above list. For example, the written alternatives analysis must propose the highest practical level of stormwater management within the Project Locus before evaluating options at an adjacent site. The adjacent site would be required to meet the equivalent pollutant removal or recharge that cannot be provide within the Project Locus on an area weighted average – see calculations and example below.
- **Step 3, Submit Supporting Documentation.** The following supporting documentation must be submitted with the NOI or WQC Application:
    - Stormwater Report (See **Section 6.1**)
    - Accompanying Site Plans (see **Section 6.1.3**)
    - Redevelopment Checklist (see **Appendix E**)
    - Written alternatives analysis (see **Section 6.1.4**).

[86] **Note:** Offsite mitigation may also be allowed for Standard 3 and the recharge requirements of Standard 11 when the written alternatives analysis determines that MEP cannot be achieved on site (see **Step 4** below).

[87] WBD HUC12 data is available through the web at: https://hydro.nationalmap.gov/arcgis/rest/services/wbd/MapServer.

Step 4, Finalization. Following approval, record the alternative location for Offsite Mitigation and obtain an easement. The local Conservation Commission, or MassDEP on appeal, have discretion to determine if on-site compliance with Standard 3, Standard 7, or Standard 11 is infeasible based on the Stormwater Report submitted with the required NOI or WQC Application. If on-site compliance is determined to be infeasible, the Issuing Authority must require Offsite Mitigation for the pollutant removal requirements of Standard 7 and the pollutant removal requirements of Standard 11. The Issuing Authority may allow Offsite Mitigation to fulfill the requirements for Standard 3 and the recharge requirements of Standard 11 to the MEP.

Demonstrating that On-Site Compliance is Infeasible

Through the Redevelopment Checklist and written alternatives analysis, the Applicant must demonstrate that all feasible efforts have been made to address site constraints and to meet Standard 3 to the MEP and to fully meet the Standard 7 pollutant removal requirements on-site. The Applicant must provide a detailed explanation of site constraints. Examples of site constraints include but aren't limited to: HSG D soils that provide minimal infiltration, shallow depth to seasonal high groundwater or bedrock, steep slopes, or insufficient area to comply with setback requirements. The Applicant must also include a detailed evaluation of ESSD and LID techniques (**Section 4.2**) and accompanying ESSD Credits (**Appendix A**) that were considered, and why they could not be used to meet the Standards. Refer to **Section 6.1.4** for detailed information to include in the written alternatives analysis.

Calculations

- Calculations must clearly depict the impervious area proposed to be managed, treated, or recharged On-Site versus Off-site.
- The Off-Site location is expected to provide an equivalent pollutant removal or recharge on an area weighted basis. The impervious Off-Site area must also be equal to or greater than the untreated impervious On-Site area to provide sufficient runoff volume to equal the runoff volume from the onsite location.
- For pollutant removals, the area weighted average of On-Site vs. Off-site treatment must result in a removal of at least 80% TSS and 50% TP of the total average annual post-construction load generated from contributing Impervious Surfaces of the Project Site. For Standard 3 groundwater recharge, the area weighted average of On-Site vs. Offsite recharge must result in a Recharge Volume of 1.0 inch of the total post-construction impervious site area to the Maximum Extent Practicable (MEP).
- Use **Equation 6-9** to calculate area weighted averages for required pollutant removals. **Equation 6-9** must be used twice – once for TSS and once for TP.

$$\mathbf{P}_{AVG}\% = \frac{(\mathbf{A}_{ON} \cdot \mathbf{P}_{ON}\%) + (\mathbf{A}_{OFF} \cdot \mathbf{P}_{OFF}\%)}{\mathbf{A}_{ON} + \mathbf{A}_{OFF}} \qquad \textbf{Equation (6-9)}$$

Where,

P_{AVG}% is the area weighted average pollutant removal from on-site and off-site areas.

P_{ON}% and P_{OFF}% is the assigned percent pollutant removal rate from on-site (ON) and off-site (OFF) areas.

A_{ON} and A_{OFF} is the Contributing impervious area from on-site (ON) and off-site (OFF) areas.

- Use **Equation 6-10** and **Equation 6-11** to calculate area weighted averages for Standard 3 Recharge.

$$F_{ON} = \frac{R_{v,ON}}{A_{IMP,ON}}$$ **Equation (6-10a)**

$$F_{OFF} = \frac{R_{v,OFF}}{A_{IMP,OFF}}$$ **Equation (6-10b)**

$$F_{AVG} = \frac{(\mathbf{A}_{ON} \cdot F_{ON}) + (\mathbf{A}_{OFF} \cdot F_{ON}\%)}{\mathbf{A}_{ON} + \mathbf{A}_{OFF}}$$ **Equation (6-11)**

Where,

F_{ON} and F_{OFF} is the depth of recharged runoff from on-site (ON) and off-site (OFF) areas.

$R_{v,ON}$ and $R_{v,OFF}$ is the amount of on-site (ON) and off-site (OFF) Recharge Volume.

A_{ON} and A_{OFF} is the Contributing impervious area from on-site (ON) and off-site (OFF) areas.

F_{AVG} is the area weighted average depth of recharged runoff from on-site and off-site areas, 1-inch to the MEP.

Example Offsite Mitigation Calculation

Problem Statement. An existing 1.5 acre commercial lot with an impervious area of 1.3 acres is to be redeveloped into multi-family residential housing units. The Redevelopment project will result in a proposed impervious area of 1.1 acres. The Registered Professional Engineer (RPE) has completed the Redevelopment Checklist and has determined that Standard 7 pollutant removals (*i.e.,* 80% TSS and 50% TP) cannot be fully met on-site. *Perform an evaluation to determine the extent of required Offsite Mitigation to fully meet Standard 4.*

Step 1, ESSD / LID Evaluation. The Applicant has performed an evaluation of possible ESSD / LID techniques from **Table 4-1** and ESSD Credits from **Appendix A**. Given the constrained site footprint, many of the ESSD / LID techniques and credits are infeasible. To meet the requirement to implement ESSD / LID, the following ESSD / LID techniques will be included in the design as detailed in the written alternatives analysis:

- The site was designed to minimize impervious cover as feasible by adding a story to the building to decrease its footprint and to reduce the width and length of available parking stalls. Parking has been limited to just 15 temporary parking spaces. The remainder of parking has been arranged at an off-site location.
- Porous pavement sidewalks and an exfiltrating bioretention area will be used as described in Step 2.
- A 50-ft wide vegetated buffer consisting of forest and shrubs will be planted within the Buffer Zone to a Wetland Resource Area in accordance with criteria from ESSD Credit 7 (see **Appendix A**).

Step 2, Determine Ability to Meet Requirements On-Site. The Applicant must design the Stormwater Management System to remove 80% of Total Suspended Solids (TSS) AND 50% of Total Phosphorus (TP) from the total average annual post-construction load generated from impervious surface area on the site. The impervious surface area to be treated is 1.1 acres. Based on the aforementioned ESSD / LID evaluation, the maximum implementation extent for each SCM was determined to be as follows:

- 4,500 square feet of porous pavement sidewalks with an 18 inch filter course will be installed.
- 7,000 square feet of impervious area will discharge to a 350 cubic foot exfiltrating bioretention area. This will result in a treated depth of runoff from upstream impervious area of 0.60 inches.
- 3,000 square feet of impervious area will discharge to a 50 foot wide vegetated buffer via uniform sheet flow.

The total treated impervious area is therefore 14,500 square feet of the required 47,916 square feet (*i.e.,* 1.1 acres) – 33,416 square feet of impervious on-site area is therefore untreated.

Step 3, Determine Ability to Meet Requirements Off-Site. The Applicant has identified an off-site adjacent property that shares a border with the Project Locus that has ample space to accommodate implementation of a treatment SCM to provide pollutant removal. The contributing impervious drainage area of the off-site property is 35,000 square feet (*i.e.,* greater than the required minimum treatment area of 33,416 square feet). The Applicant therefore proposes to install an exfiltrating bioretention area with a storage capacity of 575 cubic feet. This will result in a treated depth of runoff from upstream impervious area of 0.20 inches.

Step 4, Calculate Area Weighted Average. Based on **Equation 6-9**, the area weighted pollutant removal for the combined on-site and off-site area is 84% TSS and 59% TSS which exceeds the required 80% TSS and 50% TP removal. See Table below for a summary of calculations and notes on how computations were performed.

Calculation Summary *(see below for notes)*

Location	SCM	Contributing Imp. Area, A_{IMP} (sf)	Treated Storage Volume (ft^3)	Treated Depth (in)	Pollutant Removals (%)	
					TSS	TP
On-Site	Exfiltrating Bioretention Area	7,000	350	0.60	98%	85%
	Porous Pavement (18-in filter course)	4,500	-	-	94%	70%
	50-ft Wide Buffer (ESSD Credit 7)	3,000	-	-	90%	60%
Off-Site	Forebay to Exfiltrating Bioretention Area	35,000	575	0.20	80%	52%
Total Imp. Area Treated:		**49,500**	**Area Weighted Average:**		**84%**	**59%**

Table Notes:

1. On-Site Exfiltrating Bioretention Area: The treated depth, storage volume, and pollutant removals are calculated in accordance with procedures described in **Section 6.2.4**. Assume that *in-situ saturated hydraulic conductivity* testing is performed in accordance with **Section 6.3.4** at the location and soil layer where recharge is expected to occur with a result of 0.43 inches per hour. Pollutant removals are calculated based on the EPA Performance Removal Curve for an "Infiltration Basin" as selected from **Table 2-2**. The "Infiltration Basin" curve with an infiltration rate of 0.27 inches per hour is selected because it is the curve that is nearest to, but less than the determined in-situ saturated hydraulic conductivity measurement of 0.43 inches per hour. Pollutant removals are selected from the curve based on a treated depth of runoff from upstream impervious area of 0.60 inches.
2. On-Site Porous Pavement: Pollutant removals are calculated in accordance with procedures from **Section 6.2.4** based on the EPA Performance Removal Curve for "Porous Pavement" as selected from **Table 2-2**. Pollutant removals are calculated from the curve based on the 18 inch filter course.
3. On-Site Buffer: The buffer is designed to meet or exceed all criteria presented by ESSD Credit 7 in **Appendix A**. Assume that a soils evaluation performed in accordance with **Section 6.3.4** verifies that the soils underlying the buffer area are HSG B and that the impervious area to pervious area ratio is 1:1. According the Table Buffer 1 of **Appendix A**, this results in pollutant removals of 90% TSS and 60% TP.
4. Off-Site Exfiltrating Bioretention Area: The calculations are performed using the same methods as described previously for the on-site exfiltrating bioretention area. Assume that *in-situ saturated hydraulic conductivity* testing is performed in accordance with **Section 6.3.4** at the location and soil

layer where recharge is expected to occur with a result of 0.35 inches per hour. The EPA Performance Removal Curve with an infiltration rate of 0.27 inches per hour is therefore used.

5. Area weighted average pollutant removals are computed from **Equation 6-9** for TSS and TP. The calculations clearly depict the impervious area to be treated on-site vs. off site and verify that the treated impervious off-site area (35,000 sf) is greater than the untreated on-site area (33,416).

Site Selection

The considerations for selecting a suitable mitigation site incorporate recommendations from collaborative efforts between EPA and outside entities such as the Center for Watershed Protection, ACOE and other states' agencies and organizations (see References). The recommendations listed below are evaluations that will help to identify a best fit for pollutant removal mitigation. They include the selected site's proximity to Redevelopment site, the landscape and soil features that make the site suitable for successful removal of TSS and TP according to Standard 4, and the ability to avoid impacts to wetland resources and changes to site hydrology and minimize flooding downstream properties. Other key considerations include site availability and the potential to establish legal arrangements that will ensure long term access for compliance monitoring and maintenance activities.

- **On-site and Downstream Flooding.** Loss of wetland resources, loss of recharge to groundwater, and changes to the Redevelopment site hydrology can lead to flooding on-site and impact neighboring properties by increasing the peak runoff rate and the volume of stormwater discharging from the site. It can also increase erosion, and reduce water quality by increasing water temperature and decreasing the amount of dissolved oxygen required to sustain chemical regimes of aquatic ecosystems such as cold water fisheries. For these reasons and others, the mitigation site should be situated upstream of the Redevelopment site within the HUC-12 sub-watershed.
- **Site Constraints.** Selection of an appropriate site should include access to the property to ensure that Conservation Commissions can enter the site for compliance monitoring and site inspections. Site access for operation and maintenance activities for post-construction stormwater management BMPs should be provided. An operation and maintenance plan with a map that identifies the SCM types and locations shall be provided in accordance with Standard 9. It is recommended that agreements be developed and signed by the Applicant and property owner and recorded in the chain of title with the Order of Conditions for the project. Refer to **Section 2.3.9** for more information on long-term operations and maintenance.

Offsite Mitigation References

Hruby, T., et al, (December 2009) Ecology Publication #09-06-032, Selecting Wetland Mitigation Sites Using a Watershed Approach, State of Washington Department of Ecology
https://fortress.wa.gov/ecy/publications/documents/0906032.pdf

Center for Watershed Protection (June 2018). Guidance for Developing an Off-Site Stormwater Compliance Program for Redevelopment Projects in Massachusetts.
https://www3.epa.gov/region1/npdes/stormwater/ma/ma-off-site-mitigation-guidance-manual.pdf.

USACOE (2016) New England District Compensatory Mitigation Guidance 2016
https://www.nae.usace.army.mil/portals/74/docs/regulatory/Mitigation/2016_New_England_Compensatory_Mitigation_Guidance.pdf

6.2.8 Standard 8: Construction Period Controls

Required Computations or Demonstrations

- ❑ Submit a Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan (CPPP) with the NOI or WQC Application[88]
- ❑ Calculate the entire area to be disturbed.
- ❑ Calculate the limit of disturbance at any one time. Specify this limit in the CPPP. [89]
- ❑ Demonstrate that all proposed control measures are properly sized.

Construction Period Pollution Prevention and Erosion and Sediment Control Plan

A Construction Period Erosion, Sedimentation and Pollution Prevention Plan (CPPP) is required to be prepared and submitted with the NOI or WQC Application. Refer to **Section 4.3.3** for CPPP requirements.

Properly Sized Control Practices

Erosion control and sedimentation control measures should not be confused. Erosion control measures include limiting land disturbance and stabilizing land fully before destabilizing additional land area. Sediment control measures are back up controls such as straw bales or sediment fences, in case the erosion controls fail.

Computations shall be provided in the CPPP demonstrating that all control measures are properly sized and meet design specifications in accordance with any relevant manufacturer specifications, good engineering practices, requirements specified in the *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas* (**Appendix C**), **Section 4.3.3**, and the EPA Construction General Permit (CGP), whichever is more stringent. Sizing is particularly important for construction period sediment traps.

- **Sediment Trap Sizing**: The EPA CGP and MassDEP currently have different sizing methods for sediment traps (also known as sediment basins).
    - The EPA CGP requires that sediment traps provide storage for a calculated volume of runoff from the 2-year, 24-hour storm or 3,600 cubic feet of storage per acre drained.
    - The **Appendix C** Massachusetts Erosion and Sedimentation Control Guidelines prepared by MassDEP indicate that the construction period control sediment trap must be sized, at a minimum, to hold at least 0.5-inches of runoff per acre drained (approximately 1,815 cubic feet per acre drained). The **Appendix C** guidance indicates that when computing the number of acres draining into a common location, it is not necessary to include flows from off-site areas and flows from on-site areas that are either undisturbed or have undergone final stabilization where such flows are diverted around both the disturbed area and the sediment trap.

[88] For projects subject to jurisdiction under the Wetlands Protection Act, the construction period pollution prevention erosion and sedimentation control plan must be included as part of the Stormwater Report submitted with the Notice of Intent to comply with 310 CMR 10.05(6)(k)8. And 314 CMR 9.06(6)(a)8. In rare instances, where a project is highly complex, a DRAFT CPPP may be submitted. In such a circumstance, a final CPPP must be submitted to the Issuing Authority for their review and written approval prior to the commencement of any land disturbance.

[89] Land disturbances greater or equal to 1 acre required to obtain coverage under EPA NPDES Construction General Permit. If a stormwater discharge is proposed to an ORW, MassDEP Application WM15 must be submitted.

When both the EPA CGP and a Wetlands or WQC permit are required, perform computations using both the EPA and MassDEP specifications, then size the practice using whichever runoff volume is the larger of the two.

- **Potential Soil Loss**: Where potential soil loss needs to be evaluated as part of sizing a control practice, the Revised Universal Soil Loss Equation2 (RUSLE2) may be used. RUSLE2 is an automated method, based on the Universal Soil Loss Equation (USLE). [90]

Standard 8 References

Fifield, J.S., 2002, Field Manual on Sediment and Erosion Control Best Management Practices for Contractors and Inspectors, Forester Press.

Fifield, J.S., 2004, Designing for Effective Sediment and Erosion Control on Construction Sites, Forester Press

Massachusetts Department of Environmental Protection, 2003, Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas, https://www.mass.gov/doc/complete-erosion-and-sedimentation-control-guidelines-a-guide-for-planners-designers-and/download.

Pitt, R., Clark, S., and Lake, D., 2007, Construction Site Erosion and Sediment Controls: Planning, Design and Performance, Forester Press

U.S. EPA, 2017, Construction General Permit for Small and Large Construction Activities, https://www.epa.gov/npdes/epas-2017-construction-general-permit-cgp-and-related-documents.

[90] RULSE2 may be downloaded from NRCS via the web at: http://fargo.nserl.purdue.edu/rusle2_dataweb/RUSLE2_Index.htm.

6.2.9 Standard 9: Operation and Maintenance Plan

- Submit an Operation and Maintenance Plan as required by Standard 9 with the NOI or WQC Application (see **Section 2.3.9** for Operation and Maintenance Plan requirements).
- All SCMs should be designed to be accessible for maintenance. Some SCMs require a full perimeter accessway such as Extended Detention Basins and Infiltration Basins in accordance with the setback requirements summarized by **Section 2-5**.

No computations are necessary.

6.2.10 Standard 10: Illicit Discharges to Drainage System

- Include measures to prevent Illicit Discharges in the Long-Term Pollution Prevention Plan (LTPPP) required by Standard 4 (see **Section 4.3.2** for other LTPPP requirements).[91]
- For Redevelopments or any interconnections proposed to an existing drainage system, conduct an inspection to identify whether there are any existing Illicit Discharges to Waters of the Commonwealth (includes wetlands and groundwaters), or to a storm drain system. Eliminate any Illicit Discharges discovered. In some circumstances, an Underground Injection Control (UIC) registration may need to be submitted to MassDEP before to properly close a groundwater well that is an Illicit Discharge (*e.g.,* automotive floor drain).
- Submit an Illicit Discharge Compliance Statement with the NOI or WQC Application.[92]

No computations are necessary.

Note: Boat wash water from marinas and boat yards directed to a storm drain is considered an Illicit Discharge under the Wetlands Protection Act and Water Quality Certification.

6.2.11 Standard 11: Total Maximum Daily Loads

Required Computations or Demonstrations

- Perform steps outlined in **Section 6.2.11** to: 1) identify whether the project is subject to a TMDL; 2) identify which pollutant(s) are applicable; 3) identify suitable SCMs to treat suitable pollutants; and 4) appropriately size SCMs in accordance with Standard 3 and Standard 4.
- A written summary shall be included in the Stormwater Report demonstrating that the steps were followed to address applicable TMDL pollutants. If the Project is not subject to a TMDL for the specific pollutants identified in Standard 4, provide a statement indicating that Standard 11 is not applicable.
- Use SCMs approved by MassDEP to be suitable for treatment of discharge near or to a water with a TMDL (see **Table 2-6** for suitability)

[91] Refer to **Section 2.3.10** for a summary of methods for identifying Illicit Discharges to stormwater drainage structures and wetlands.

[92] For projects subject to jurisdiction under the Wetlands Protection Act, the Illicit Discharge Compliance Statement may be included in the Stormwater Report submitted with the Notice of Intent. The Illicit Discharge Compliance Statement must be submitted before stormwater is discharged to the post-construction stormwater BMPs.

6.3 Soil Evaluation Procedures

A soil evaluation must be performed for use in peak runoff rate attenuation computations (Standard 2), recharge computations (Standard 3), and pollutant removal computations that rely on infiltration SCMs through use the EPA Performance Removal Curves (Standard 4). The purpose of this section is to provide soil evaluation procedures for these computations. All soil evaluations must be performed by a *Competent Soils Professional*.[93] The following procedures are covered by this section:

- Soil testing methods
- Field verification of Hydrologic Soil Groups for use in assigning Runoff Curve Numbers (RCNs) for peak runoff computations (Standard 2)
- Field verification of soils at the specific location for recharge will occur (Standard 3)
- Field verifying soils for use with the EPA Performance Removal Curves (Standard 4).
- Documenting Findings on Plans

6.3.1 Soil Testing Methods

The soil evaluation procedures presented herein rely on the testing methods described below. These methods include:

- Testing for saturated hydraulic conductivity;
- Determining seasonal high groundwater;
- Performing a soil textural analysis; and
- Determining the Hydrologic Soil Group (HSG).

Testing for Saturated Hydraulic Conductivity

Field test methods to assess *in-situ saturated hydraulic conductivity* (K_{sat}) must simulate the "field-saturated" condition. See ASTM D5126-16e1 (2016) Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone. Acceptable tests include:

- Constant Head Method with Guelph permeameter - ASTM D5126-16e1 Method;
- Falling head permeameter – ASTM D5126-16e1 Method;
- Falling Head Method with the Double ring permeameter or infiltrometer - ASTM D3385-18[94], D5093-15e1[95], D5126-16e1 Methods; and
- Constant Head Method using the Amoozemeter or Amoozegar permeameter – Amoozegar 1992.
- Falling Head method with the Mini-Disk Infiltrometer: NRCS Soil Survey Field and Laboratory Method Manual Version 2, 2014, page 165: https://www.nrcs.usda.gov/sites/default/files/2023-01/SSIR51.pdf

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[93] A Competent Soils Professional is an individual with demonstrated expertise in soil science, limited to the following: a Massachusetts Registered Professional Engineer in civil or environmental engineering, Engineer in Training (EIT certificate) with a concentration in civil or environmental engineering, or Bachelor of Arts or Sciences degree or more advanced degree in Soil Science, Geology, or Groundwater Hydrology from an accredited college or university, that for purposes of stormwater management, assesses the Seasonal High Groundwater Elevation, soil texture, Saturated Hydraulic Conductivity Test, and hydrologic soil group. A soil evaluator pursuant to 310 CMR 15.017 and 15.018 is not a Competent Soil Evaluator.

[94] ASTM D3385-18 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer.

[95] ASTM D5093-15e1 Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring.

Note:

- Care must be exercised in selecting an appropriate test in well sorted sandy soils that are difficult to fully saturate, such as those well sorted sandy soils that may be found on Cape Cod, the Islands, and Southeast Massachusetts.
- A Title 5 percolation test is not an acceptable test for *saturated hydraulic conductivity*. Title 5 percolation tests overestimate the *saturated hydraulic conductivity*. Although such tests are not acceptable for purposes of stormwater infiltration, they may provide valuable insight into infiltration conditions that exist at a site.

Determining Seasonal High Groundwater

Seasonal high groundwater represents the highest groundwater elevation. Depth to seasonal high groundwater must be identified based on redox features in the soil based on the Munsell Color System (see Fletcher and Veneman listed in References). When redox features are not available, installation of temporary push point wells or observation wells must be considered during the spring when groundwater is highest and results compared to nearby long term groundwater wells monitored by the United States Geological Survey (USGS) to estimate whether regional groundwater is below normal, normal or above normal.[96] Use of the Frimpter method is acceptable when redox is not observable.

Performing a Soil Textural Analysis based on Field Testing Results.

Soil texture represents the relative composition of sand, silt and clay in soil. Soil texture must be determined using procedures described in the USDA, 2007, National Soil Survey Handbook (NSSH), Section 618.67 (Texture Class, Texture Modifier, and Terms Used in Lieu of Texture), including grain-size sieve analysis and hydrometer tests[97]. Classification of soil texture shall be consistent with the USDA Textural Triangle (see **Figure 6-14**). The NRCS also has online tools to assist in soil texture analysis, once the relative proportions of sand, silt, and clay have been determined.[98]

Using Results from Field Testing to Determine Hydrologic Soil Groups.

The depth and saturated hydraulic conductivity of any water impermeable layer and the depth to any high water table are used to determine the correct Hydrologic Soil Group (HSG) for the soil. The property that is most limiting to water movement generally determines the HSG. The *Competent Soils Professional* shall use field testing results (*i.e.,* K_{sat}, depth to seasonal high groundwater and other impermeable layers, soil texture) to identify HSGs as applicable. HSGs must be identified in accordance with Chapter 7 of the Part 630 Hydrology National Engineering Handbook.[99] The chapter includes descriptions of each HSG, and a decision matrix to assist with identification.

[96] USGS groundwater monitoring data: http://ma.water.usgs.gov.

[97] National Soil Survey Handbookhttps://www.nrcs.usda.gov/resources/guides-and-instructions/national-soil-survey-handbook

[98] NRCS Online Tools for Soil Textural Analysis: https://www.nrcs.usda.gov/resources/education-and-teaching-materials/soil-texture-calculator.

[99] USDA NRCS, Chapter 7, Part 630 Hydrology National Engineering Handbook: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=22526.wba.

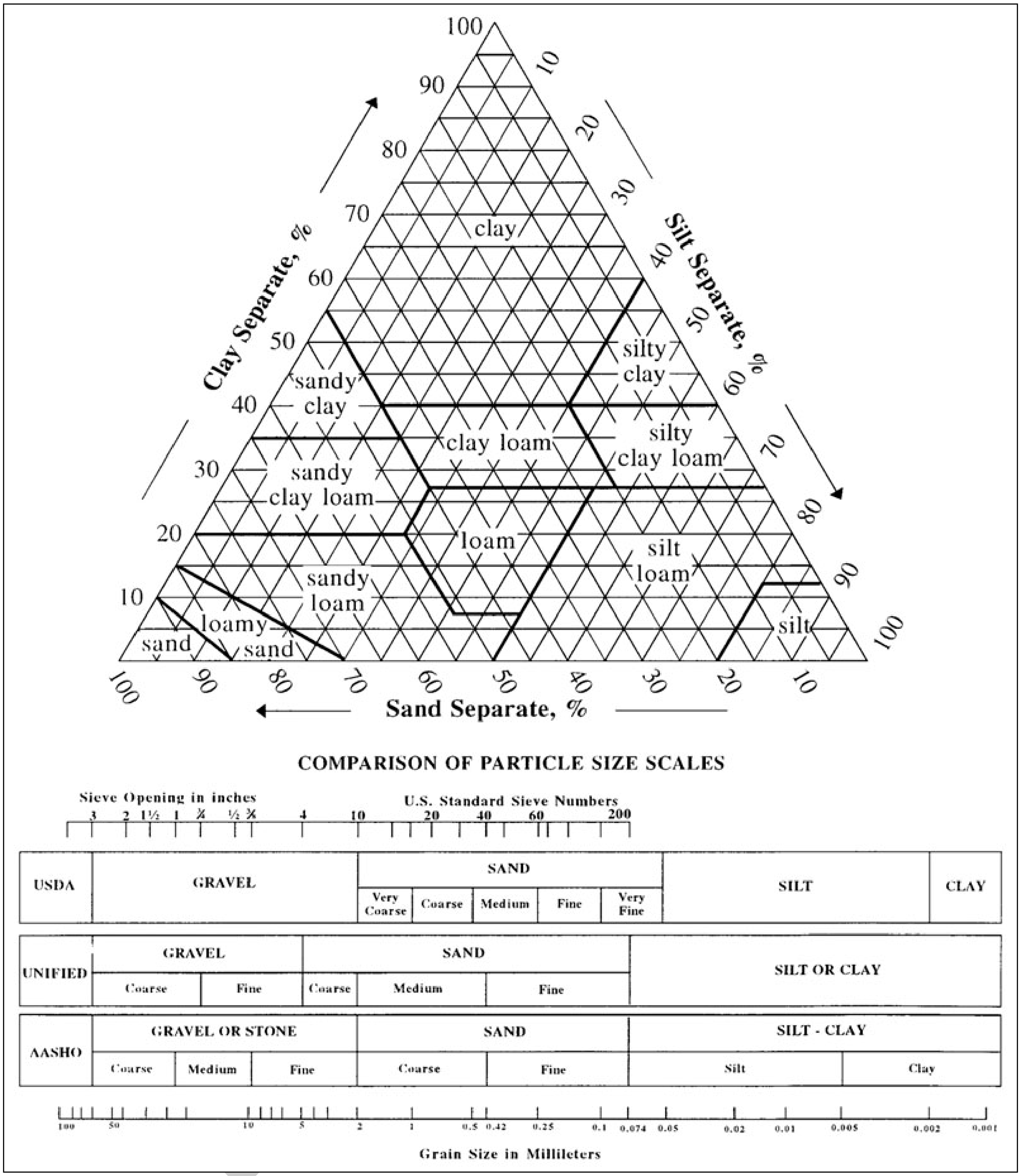

Figure 6-14. USDA, NRCS, 2007 National Soil Survey Handbook, Part 618, Exhibit 618.87,

(Texture Triangle and Particle-Size Limits of AASHTO, USDA and Unified Classification Systems

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_053386
http://www.basiccivilengineering.com/2017/05/classification-soil-usda-aashto-unified-classification-methods.html)

6.3.2 Field Verifying HSGs for Peak Runoff Computations

The following steps shall be performed to determine Hydrologic Soil Groups (HSGs) throughout the site for use in assigning Runoff Curve Numbers (RCNs) for peak runoff rate computations required by Standard 2.

Note: This procedure also applies to identification of HSGs for ESSD Credit 4 (Roof Disconnection), ESSD Credit 5 (Roadway Disconnection), and ESSD Credit 7 (Buffer Enhancement).

- **Step 1, Evaluate Existing NRCS Soil Surveys.** NRCS soil surveys are to be used as the first step in identifying soils and soil hydrologic groups present at the site. All counties in Massachusetts have been mapped by NRCS[100]. Locate the site using the electronic Soil Survey or on plans included in a hard copy of the Soil Survey. Identify the NRCS soil type and associated Hydrologic Soil Group by consulting the Soil Survey lists for the site.

- **Step 2, Perform Site Visit to Verify Soil Conditions.** After completion of **Step 1**, a site visit must be conducted to confirm the NRCS soil survey. The site visit will allow for observation of noticeable deviations in site conditions (*i.e.,* bedrock outcrops, open gravel/sand areas, recent filling). The site visit must establish whether the on-site soils have been disturbed, filled, or altered in a way that affects the natural drainage of the site.

  The following tasks shall be performed:

  a. Conduct site visit. Determine whether any noticeable deviations on site exist from the NRCS Soil Survey (*i.e.,* bedrock outcrops, open gravel/sand areas, recent filling). Determine whether the on-site soils have been disturbed, filled, or altered in any way.
  b. Review any existing field test pit data and available boring logs and compare with NRCS information published in the Soil Survey. Boring logs and test pit data often indicate the soil textural class and varying soil strata (*i.e.,* restrictive layers) and may assist in further refinements of soil delineations.
  c. Review any existing USGS geologic maps for general rock types and bedrock depths. The presence of bedrock, including rock outcrops, is a significant factor for site planning and the potential for groundwater recharge. Knowledge of the bedrock and rock type at the site will be beneficial in further characterizing existing recharge conditions.
  d. Review available aerial photographs. If a detailed site map is not available at the time of the initial investigation, an aerial photograph may provide additional information for delineating impervious and pervious areas.

  When the Soil Survey does not identify the HSG(s) at the site or when the site conditions are not consistent with the NRCS Soil Survey, **Step 3** must be completed. When the NRCS Soil Survey identifies the Hydrologic Soil Group(s) at the site, and the **Step 2** investigation indicates site conditions are consistent with the NRCS Soil Survey, proceed to **Section 6.3.5** "*Documenting Findings on Plans*".

- **Step 3. Perform Field Testing and Analysis**. Where the NRCS Soil Survey does not identify the Hydrologic Soil Group or when the site conditions are inconsistent with the NRCS Soil Survey, an analysis of the soils present throughout the entire site must be performed to determine the HSG(s).[101]

[100] NRCS Soil Survey information is available online at: https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=MA or http://nesoil.com/massachusetts_soil_survey.htm

[101] The NRCS Soil Surveys may not identify the Hydrologic Soil Group(s) at sites located in urban areas. Most counties in Massachusetts have areas that have been mapped by NRCS as urban land or complexes of urban land and a soil series. When soils are mapped as urban land or complexes of urban land, the NRCS does not assign the soils to a Hydrologic Soil Group.

The following testing is required in accordance with the methods described by **Section 6.3.1**: 1) in-situ saturated hydraulic conductivity; 2) depth to seasonal high groundwater; and 3) soil textural analysis. It is <u>not acceptable</u> to solely perform a textural analysis to determine the HSG.

A minimum of one test location must be completed per acre with a minimum of 4 test locations per site. Testing must be conducted in the surface soil horizons. Perform at least one test location per 5,000 square feet for ESSD Credit 3, ESSD Credit 4, and ESSD Credit 7. NRCS Soil Survey evaluations typically cover the first 60-inch soil depth. Soils must not be composited from one test pit or bore hole with soils from another test pit or bore hole for purposes of the textural analysis. A minimum of two borings (or test pits) are required for each test location. Use the first boring or test pit to evaluate seasonal high groundwater and soil texture. Use the second boring or test pit to perform in-situ *saturated hydraulic conductivity* testing.

- **Step 4. Use Results from Testing to Determine Hydrologic Soil Groups.** Use the information collected in **Step 3** to identify the Hydrologic Soil Group(s) from each test location in accordance with the methods described by Section **6.3.1** – *i.e.,* HSG must be identified as a function of measured hydraulic conductivity, soil texture, and depth to impermeable layers.

- **Step 5. Assign Runoff Curve Numbers**. Use the resulting HSGs to assign Runoff Curve Numbers (RCNs) to peak rate analysis required for Standard 2 in accordance with procedures described in the *Hydrology Handbook for Conservation Commissioners*. Refer to **Section 6.2.2** for more information on peak rate computations required by Standard 2.

- **Step 6. Prepare a Plan identifying Hydrologic Soil Groups for the Site.** See **Section 6.3.5** "Documenting Findings on Plans" section below.

6.3.3 Field Verifying Soils at Specific Location Where Recharge is Proposed

The following steps shall be performed to determine soil conditions at actual location(s) on the site where recharge is proposed as required by Standard 3.

- **Step 1. Perform Field Testing and Analysis.** Conduct field soil testing at the specific SCM location(s) where recharge is proposed. The following testing is required in accordance with the previously described methods: 1) in-situ saturated hydraulic conductivity; 2) depth to seasonally high groundwater; and 3) soil textural analysis. It is <u>not acceptable</u> to solely perform a textural analysis to determine the HSG or to use the Rawls Rates to determine saturated hydraulic conductivity.

  The number of test locations is dependent on the type and size of the infiltration SCM. The minimum number of test locations for specific infiltration SCMs are summarized below.

  i. Linear infiltration SCMs (*i.e.,* infiltration trenches, linear configured MassDOT infiltration practices): At least 2 test locations per proposed trench or linear configuration. Infiltration trenches and linear infiltration practices over 100 feet in length must include at least one additional test location for each 50 foot increment.
  ii. Exfiltrating Treebox filters, Dry Wells, and Leaching Catch Basins: At least 1 test location. Two borings per test location: one for the seasonal high groundwater and the other for in-situ saturated hydraulic conductivity testing.
  iii. All other infiltration SCMs: At a minimum, one test location for every 5,000 square feet with a minimum of three (3) test locations per infiltration practice Two borings per test location:

Further, the NRCS does not typically identify the Hydrologic Soil Group(s) for soils mapped as Udorthents, udipsamments, nomans land, pits, gravels and quarries. The total area of urban complex soils in Massachusetts is approximately 150,000 acres or 3 % of the mapped area in the state. Soils mapped as urban and other soils comprise approximately 255,000 acres or 5.5% of the total mapped area.

one for the seasonal high groundwater and the other for *in-situ saturated hydraulic conductivity* testing.

iv. Additional requirements apply when fill materials are determined to be present as described below.

A minimum of two borings (or test pits) are required for each test location. Use the first boring or test pit to evaluate seasonal high groundwater and soil texture. Use the second boring or test pit to perform *in-situ saturated hydraulic conductivity* testing.

i. Borings or test pits used to evaluate seasonal high water and soil texture must be advanced to a depth of at least 60 inches below the lowest engineering depth of the SCM. It will need to be deeper than 60-inches when there is an indication that there may be a confining layer deeper than 60-inches. For example, if the USGS Surficial Mapping indicates bedrock is near the surface, the borings should go until refusal or 20-feet, whichever is shallower.

ii. Borings or test pits used to perform *in-situ saturated hydraulic conductivity* testing must be taken at the actual location and soil layer where infiltration is proposed (*e.g.,* if the O, A and B soil horizons are proposed to be removed, the tests need to be conducted in the C soil layer below the bottom elevation of the proposed recharge system).

- **Step 2. Use Results from Testing to Determine the Design Saturated Hydraulic Conductivity for Recharge Computations.** Use the information collected in **Step 1** to identify the design *saturated hydraulic conductivity* (K_{sat}) for recharge computations and sizing of the recharge SCM at the soil layer where infiltration is proposed.

  i. <u>Static Method</u>. The design K_{sat} must be obtained by identifying the HSG, then selecting the appropriate K_{sat} from **Table 6-4**. Use the information collected in **Step 1** to identify the HSG(s) at each test location in accordance with the methods described by **Section 6.3.1** – *i.e.,* HSG must be identified as a function of measured hydraulic conductivity, soil texture, and depth to impermeable layers. The lowest of the test results measured in the field must be used for sizing the stormwater recharge SCMs (see example below). **Note:** As indicated in **Section 6.2.2**, Applicants may incorporate exfiltration into peak rate reduction calculations for applicable infiltration SCMs. The design K_{sat} for those calculations must be obtained from **Table 6-4**. Field measured in-situ saturated hydraulic conductivity values shall <u>not</u> be used.

  ii. <u>Simple Dynamic Method</u>. The design K_{sat} must be based on the <u>lowest</u> field measured in-situ K_{sat}, and not the average (see example below).

  iii. <u>Dynamic Field Method</u>. The design K_{sat} must selected based on the <u>lowest</u> field measured in-situ K_{sat}, and not the average. Once selected, a 50% Factor of Safety must be applied (see example below).

  iv. <u>Continuous Simulation Method</u>. The design K_{sat} must be based on the <u>lowest</u> field measured in-situ K_{sat}, and not the average (see example below). Once selected, a 50% Factor of Safety must be applied (see example below).

- **Step 3. Prepare a Plan Documenting Findings**. See **Section 6.3.5** "Documenting Findings on Plans".

Table 6-4. Design saturated hydrologic conductivity based on Hydrologic Soil Group for the *"Static" Method*

HSG	Design K_{sat} (in/hr)
A	1.42
B	0.57
C	0.10
D	0.02

Notes:

1. Table adapted from Table 7-1 of the NRCS 2009 Part 630 National Engineering Handbook.
2. Design K_{sat} values assume that the depth to any impermeable layer (*e.g.,* bedrock) or the water table is greater than 2 feet.
3. Values in this table must be used when sizing infiltration SCMs based on the *Static Method or when incorporating exfiltration into peak rate reduction calculations for applicable infiltration SCMs as described in **Section 6.2.2***.
4. The selected HSG must correspond to a field evaluation conducted in the actual location and soil layer where stormwater infiltration is proposed as described in the procedures above.

Example Calculations to Determine Design K_{sat} for Standard 3 Recharge Computations

Problem Statement. Assume three samples are taken at a proposed infiltration basin in the actual soil layer where recharge is proposed. Based on the results of the K_{sat} testing, a soil textural analysis, and evaluation of depth to seasonal high water and potential confining layers, the C*ompetent Soils Professional* has assigned Hydrologic Soil Groups (HSG) to each sample. The assigned HSG and field measured K_{sat} of the three samples are listed below.

- Sample 1: 1.75 in/hr. (HSG A)
- Sample 2: 2.25 in/hr. (HSG A)
- Sample 3: 1.32 in/hr. (HSG B)

Based on these soil testing results, determine which design K_{sat} should be used to size the proposed infiltration basin based on three potential sizing methods (*i.e., Static*, *Simple Dynamic*, and *Field Dynamic*).

Static Method. The design K_{sat} must be selected from **Table 6-4** based on the HSG that yields the lowest K_{sat}. The design K_{sat} must be based on HSG B soils and is therefore 0.57 in/hr.

Simple Dynamic Method. The design K_{sat} must be selected based on the lowest field test result. The design K_{sat} is therefore 1.32 in/hr.

Dynamic Field Method and the Continuous Simulation Method. The design K_{sat} must be selected based on the lowest field test result with a Factor of Safety of 50%. Therefore, the lowest rate of 1.32 in/hr corresponding to Sample 3 must be used, then multiplied by 0.50 to arrive at a design K_{sat} of 0.66 in/hr.

When Fill Materials are Determined to be Present

Recharge may be provided on fill provided the material is clean and relatively homogenous.

- When fill materials are present or are added prior to construction of the system, a soil textural analysis and field testing for saturated hydraulic conductivity must be conducted in both the fill material and the underlying parent materials. The Hydrologic Soil Group and saturated hydraulic conductivity of the more restrictive layer shall be used to size the infiltration SCM. The HSG and saturated hydraulic conductivity must be assigned based on the previously described methods.
- If fill is present that is composed of asphalt, brick, concrete, construction debris, or if materials classified as solid or hazardous waste are identified at the specific location where recharge is proposed, recharge elsewhere on site must be considered. Alternatively, the debris or waste may be removed in accordance with all applicable Solid and Hazardous Waste Regulations (see 310 CMR 19.000 and 40.0000) and replaced with clean material suitable for infiltration. Any solid or hazardous wastes present on the site must be managed in strict accordance with MassDEP Solid Waste Regulations, 310 CMR 19.000, Hazardous Waste Regulations, 310 CMR 30.00, and the Massachusetts Contingency Plan Regulations, 310 CMR 40.000.

6.3.4 Field Verifying Soils for use with the EPA Performance Removal Curves

Field derived saturated hydraulic conductivity (K_{sat}) values must be used for infiltration SCMs that are sized using the EPA Performance Removal Curves to obtain Standard 4 pollutant removal credit. [102] The following steps describe the procedure that must be followed to select the appropriate K_{sat} rate and EPA Performance Removal Curve for relevant infiltration SCMs. See **Section 6.2.4** for more information on calculating pollutant removals for SCMs with an EPA Performance Curve.

- **Step 1. Perform Field Testing and Analysis.** Conduct in-situ *saturated hydraulic conductivity* testing at the specific SCM location(s) where infiltration will occur in accordance with methods described by **Section 6.3.1**. The number of test locations is dependent on the type and size of the infiltration SCM. The minimum number of test locations for specific infiltration SCMs is summarized by Step 1 of **Section 6.3.3**.
- **Step 2. Use Results from Testing to Determine the Design Saturated Hydraulic Conductivity for Selection of the Appropriate EPA Performance Removal Curve.** Use the information collected in **Step 1** to identify the design *saturated hydraulic conductivity* (K_{sat}) for selection of the appropriate EPA Performance Removal Curve. The design K_{sat} must be based on the lowest field measured in-situ K_{sat}, and not the average (see example below).
- **Step 3. Select the Appropriate EPA Performance Removal Curve Based on the Selected Design Saturated Hydraulic Conductivity.** The EPA Performance Removal Curves were developed based on the 1983 Rawls Rates. If the field measured K_{sat} rate does not match those provided by the Performance Removal Curves, use the Performance Removal Curve for the infiltration rate that is nearest to, but less than, the determined infiltration rate (see example below).

[102] EPA Region Performance Removal Curves:

- Option 1, EPA BATT (version 2.1): https://www.epa.gov/npdes-permits/stormwater-tools-new-england#swbmp;
- Option 2, graphical and tabular MassDEP version (**Appendix B**).

- **Step 4. Prepare a Plan Documenting Findings**. See **Section 6.3.5** "*Documenting Findings on Plans*".

Example Calculation to Determine Design K_{sat} for Standard 4 Pollutant Removal Computations

Problem Statement. Assume three samples are taken at a proposed infiltration basin in the actual soil layer where recharge is proposed. The results of field in-situ K_{sat} testing for three samples are listed below.

- Sample 1: 1.75 in/hr.
- Sample 2: 2.25 in/hr.
- Sample 3: 1.32 in/hr.

Based on these soil testing results, determine which design K_{sat} and appropriate EPA Performance Removal Curve (PRC) should be used to size the proposed infiltration basin to obtain pollutant removal credit.

Select the Design K_{sat}. The design K_{sat} must be selected based on the lowest field test result. The design K_{sat} is therefore 1.32 in/hr.

Select the Appropriate EPA Performance Removal Curve. Access the Infiltration Basin EPA PRC using **Appendix B** or the EPA BMP-BATT. There are six performance curves available for Infiltration Basins based on the design infiltration rate of the underlying soils. The curves include the following infiltration rates: 0.17 in/hr, 0.27 in/hr, 0.52 inch/hr, 1.02 in/hr, 2.41 in/hr, and 8.27 in/hr. The field measured design K_{sat} was 1.32 in/hr. Use the curve for 1.02 in/hr.

6.3.5 Documenting Findings on Plans

After all relevant soil evaluation procedures have been performed, prepare site plans that summarize results. Site plans must accompany the Stormwater Report that is submitted with the Wetland NOI or WQC Application. Refer to **Section 6.1.3** for more information on Stormwater Report and Site Plan requirements. At minimum, the following information must be included on the soil summary plan.

- Prepare a plan of the site clearly delineating the Hydrologic Soil Groups throughout the entire site and the specific point(s) where recharge is proposed. Deviations from the NRCS Soil Surveys and special conditions discovered during additional investigations (relative to recharge potential) must be noted on the plan and described.
- The plan shall identify the location of all borings and test pits, including the location of any known prior test pits or borings. Test pit or boring logs shall be appended to the plan, identifying in cross section the soil types, seasonal high groundwater elevation, confining layers, and other appropriate information. The plan shall also clearly depict the location and result of any field measured saturated hydraulic conductivity measurements.

Soil Evaluation References

ASTM D3385-03 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer

ASTM D5093-02 Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring

ASTM D5126-90, 2004, Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone.

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6.4 Calculating Contributing Drainage Area

The contributing drainage area must be determined for purposes of determining compliance with Standards 2, 3, and 4.

The contributing drainage area for Standard 2 includes all areas contributing drainage to a site, including off-site locations. The contributing drainage area is determined by using topographic high points as the drainage area boundaries. USGS Topographic Mapping may not provide the resolution needed, particularly for smaller sites, or sites that are relatively flat. When a ground survey is conducted, contours should be created in at least 2-foot increments.

For purposes of Standards 3 and 4, only the impervious areas are used for purposes of calculating the *Required Recharge Volume* and the *Water Quality Volume.* Off-site impervious areas are only included in the drainage area for Standards 3 and 4 when off-site drainage flows through the Project Site. For example, on a 10-acre lot that is 100% impervious, a 1-acre portion is proposed to be redeveloped. The 10-acres is the Project Locus[103]. The 1-acre portion is the Project Site. Drainage from the other 9-acres of the Project Locus drains through the 1-acre Project Site to a wetland. Therefore, the entire Project Locus is considered the contributing drainage area for Standards 3 and 4, and may include adjacent impervious areas outside the Project Locus if they drain through the Project Site.

6.5 Calculating Impervious Area

Impervious area must be determined in order to calculate the *Required Recharge Volume* and the *Water Quality Volume.* The impervious area must also be determined for purposes of Standard 2 to assign appropriate Runoff Curve Numbers for peak rate analysis. The impervious area is a subset of the contributing drainage area. ESSD Credits can be used to reduce the *Required Recharge Volume* and the *Required Water Quality Volume,* for Standards 3 and 4 (See **Appendix A**). Impervious area is typically just on the Project Site. However, when run-on from offsite impervious area(s) occurs to the on-site impervious area, that off-site area must be included.

[103] Project Locus and Project Site are both defined terms at 310 CMR 10.04.

How are Impervious Areas Defined?

For purposes of stormwater management, Impervious Surfaces are defined by 310 CMR 10.04 to include any surface that prevents or significantly impedes the infiltration of water into the underlying soil, including, but not limited to:

- Artificial turf and compacted gravel or soil.
- Roads, building rooftops, solar arrays, parking lots, shared use paths, bicycle paths, and sidewalks paved with concrete or asphalt, or similar materials; and
- Buildings or structures created using non-porous material.

Compacted gravel or soil means gravel roads, gravel parking lots, dirt roads, dirt parking lots, and un-vegetated areas that have historically provided or have been designed to provide a compacted surface for use by vehicles, pedestrians, and bicycles. Compacted surfaces do not include lawns, roadway median strips, landscaped areas and natural turf athletic fields. This presumption that a soil is compacted can be overcome by showing that the soil strength is less than 10 bars of pressure (approximately 145 pounds per square inch or 10^6 pascals).

Porous pavement is considered to be an impervious surface for sizing purposes. Similarly, a green roof is considered to be an impervious surface for purposes of sizing the growing media that treats the *Required Water Quality Volume* and determining the total *Required Recharge Volume* for the site. A green roof is a treatment device and does not recharge the groundwater.

Appendix A

SCM Specifications for the Massachusetts Stormwater Handbook

Introduction

This Appendix lists the Stormwater Control Measure (SCMs) specifications and criteria that must be met in order for the practices to be deemed acceptable to meet the Stormwater Management Standards listed in MassDEP Wetland and WQC regulations at 310 CMR 10.05(6)(k) and 314 CMR 9.06(6)(a). If these specifications and criteria are not met, the practice is not acceptable to meet the MassDEP Wetlands and WQC regulations. These specifications are minimum criteria.

The SCM Specifications provided by this Appendix are split into four primary categories (see Table of Contents):

- Environmentally Sensitive Site Design (ESSD) Credits;
- Nonstructural Stormwater Control Measures;
- Structural Stormwater Control Measures (including Low Impact Development Practices); and
- Operating and Source Controls.

Refer to **Section 4** of the Stormwater Handbook "*Site Planning and Design*" for definitions of each SCM category and guidance on how to incorporate these SCMs into site designs. Also refer to **Section 6.2** of the Stormwater Handbook "*Required Documentation and Computations*" for detailed information on sizing SCMs to meet specific Stormwater Standards.[1] Finally, **Table 2-7** of the Stormwater Handbook includes a summary of each SCM's ability to meet specific Stormwater Standards.

ESSD Credits

A suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. ESSD and LID must be used unless demonstrated to be impracticable based on a written alternatives analysis submitted with the Notice of Intent. Other SCMs shall only be used to the meet those portions Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 6.1.4** for more information on the written alternatives analysis.

Each MassDEP recognized ESSD / LID technique listed by **Section 4.2** of the Stormwater Handbook has an applicable Fact Sheet that describes the practice in more detail – fact Sheets are available in this Appendix. Most recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID Implementation Requirement as summarized by **Table A-1**.

Table A-1. Summary of ESSD / LID Fact Sheets and associated ESSD Credits

Fact Sheet Name	ESSD Credit Name
Environmentally Sensitive Site Design (ESSD)	**Credit 1**: Environmentally Sensitive Site Design
	Credit 2: Environmentally Sensitive Site Design for Solar Arrays
Disconnection to Qualifying Pervious Areas	**Credit 3**: Rooftop Runoff Directed to Qualifying Pervious Areas
	Credit 4: Roadway, Driveway, or Parking Lot Rooftop Runoff Directed to Qualifying Pervious Areas
Tree Canopy Runoff Reduction	**Credit 5:** Tree Canopy Enhancement and Protection
Minimize Impervious Cover	**Credit 6:** Reduce Impervious Area at Redevelopment Sites
Protect or enhance Buffer Area	**Credit 7:** Protect or Enhance Buffer Areas
Preserve and Use Natural Drainage Systems	N/A – There is no numerical credit available for implementation of this MassDEP recognized ESSD / LID technique.
No Disturbance to Wetland Resource Area	N/A – There is no numerical credit available for implementation of this MassDEP recognized ESSD / LID technique.
Small Scale Controls	N/A – There is no numerical credit available for implementation of this MassDEP recognized ESSD / LID technique.

[1] MassDEP has endeavored to make sure that requirements in the regulations and other sections of the Massachusetts Stormwater Handbook are consistent. If there is a discrepancy between the information listed in this Appendix and elsewhere in this document, the most restrictive must be applied.

ESSD Credit Eligibility

An Applicant of a project that is eligible for ESSD Credits is required to comply with all Stormwater Management Standards as described in **Section 2.3** of the Stormwater Handbook. The application of these credits does not relieve the design engineer or reviewer from the standard of engineering practice associated with safe conveyance of stormwater runoff and good drainage design. Refer to the sections below for eligibility, implementation criteria, and the ability of each ESSD Credit to meet specific Stormwater Standards.

Calculating Pollutant Removals for Structural SCMs

The EPA Performance Removal Curves (EPA-PRCs) must be used to determine pollutant removal credits for SCMs with an established curve. Refer to the SCM Convention Crosswalk in the Massachusetts Stormwater Handbook for a list of SCMs with an available EPA-PRC (**Table 2-2**). The EPA-PRCs are available in graphical and tabular form in **Appendix B** of the Massachusetts Stormwater Handbook, or can be accessed from the most recent version of the EPA Best Management Practice Accounting and Tracking Tool (BMP-BATT).[2]

Some commonly used SCMs do not have an established EPA Performance Curve. MassDEP SCMs without an approved EPA Performance Curve or "Crosswalk" equivalent must use a 1.0 inch Water Quality Volume (WQv) to size the treatment practice. Pollutant removal credit may be calculated using MassDEP assigned values from **Table 2-2** for SCMs without an EPA Performance Curve or DEP Crosswalk equivalent.

Refer to the Massachusetts Stormwater Handbook for more information on pollutant removal calculation requirements (**Section 6.2.4**).

[2] EPA BMP-BATT (version 2.1): https://www.epa.gov/npdes-permits/stormwater-tools-new-england#swbmp.

Contents

Environmentally Sensitive Site Design Techniques (ESSD)

- **Environmentally Sensitive Site Design**
    - Credit 1: Environmentally Sensitive Site Design
    - Credit 2: Environmentally Sensitive Site Design for Solar Arrays
- **Disconnection to Qualifying Pervious Areas**
    - Credit 3: Rooftop Runoff Directed to a QPA
    - Credit 4: Roadway, Driveway, or Parking Lot Runoff Directed to a QPA
- **Tree Canopy Implementation for Runoff Reduction**
    - Credit 5: Tree Canopy Enhancement and Protection
- **Minimize Impervious Cover**
    - Credit 6: Reduce Impervious Area at Redevelopment Sites
- **Protect or Enhance Buffer Areas**
    - Credit 7: Protect or Enhance Buffer Areas
- **Natural Drainage Systems**
- **No Disturbance to Wetland Resource Areas**

General Environmentally Sensitive Site Design

Description and Purpose

Environmentally sensitive site design (ESSD) applies low impact development (LID) techniques to minimize stormwater runoff and nonpoint source pollution by reducing impervious surfaces, disconnecting flow paths, treating stormwater at its source, minimizing disturbance, maximizing open space, protecting natural features and processes, and/or enhancing wildlife habitat.

In general, these non-structural approaches to drainage improvements should be given preference and ESSD should be the first priority consideration to meet the Stormwater Management Standards. Some ESSD techniques that minimize the creation of new runoff, enhance groundwater recharge, and remove suspended solids include: minimizing impervious surfaces, fitting the development to the terrain, preserving and capitalizing on natural drainage systems, and reproducing pre-development hydrologic conditions. Refer to **Section 4.2** for more information on ESSD and LID techniques, including a list of MassDEP recognized techniques.

ESSD Credits

As indicated in the “Introduction” section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There are two ESSD Credits associated with this Fact Sheet.

- **Credit 1:** Environmentally Sensitive Site Design.
- **Credit 2**. Environmentally Sensitive Site Design for Solar Arrays.

See below for more information on these credits.

Components of ESSD

Conventional development strategies treat stormwater as a secondary aspect of site design, usually managed with “pipe-and-basin” systems that collect rainwater and discharge it off-site. In contrast, ESSD embraces hydrology as a critical factor for site design. Existing conditions influence the location of roadways, buildings, and parking areas, as well as design of the stormwater management system.

ESSD is a multi-step process that involves identifying important natural features, placing buildings and

Image Credit: Puget Sound Technical Guidance Manual

roadways in areas less sensitive to disturbance, and designing stormwater management systems that create relationships between development and natural hydrology. The attention to natural hydrology, stormwater “micromanagement,” nonstructural approaches, and vegetation results in a more attractive, multifunctional landscape with development and maintenance costs comparable to or less than conventional strategies that rely on pipe-and-basin approaches.

Landscaping is an important component of environmentally sensitive site design. Ecological landscaping strategies seek to minimize the amount of lawn area and enhance the property with native, drought-resistant species; as a result, property owners use less water, pesticides, and fertilizers. A creative landscape can be used for a smaller lawn or applied at a larger scale for subdivisions. The maintenance of vegetated buffers along waterways can also enhance the site and help protect water quality. Re-establishment of vegetated buffers through removal of impervious surfaces at Redevelopment sites is also ESSD.

Planning Considerations

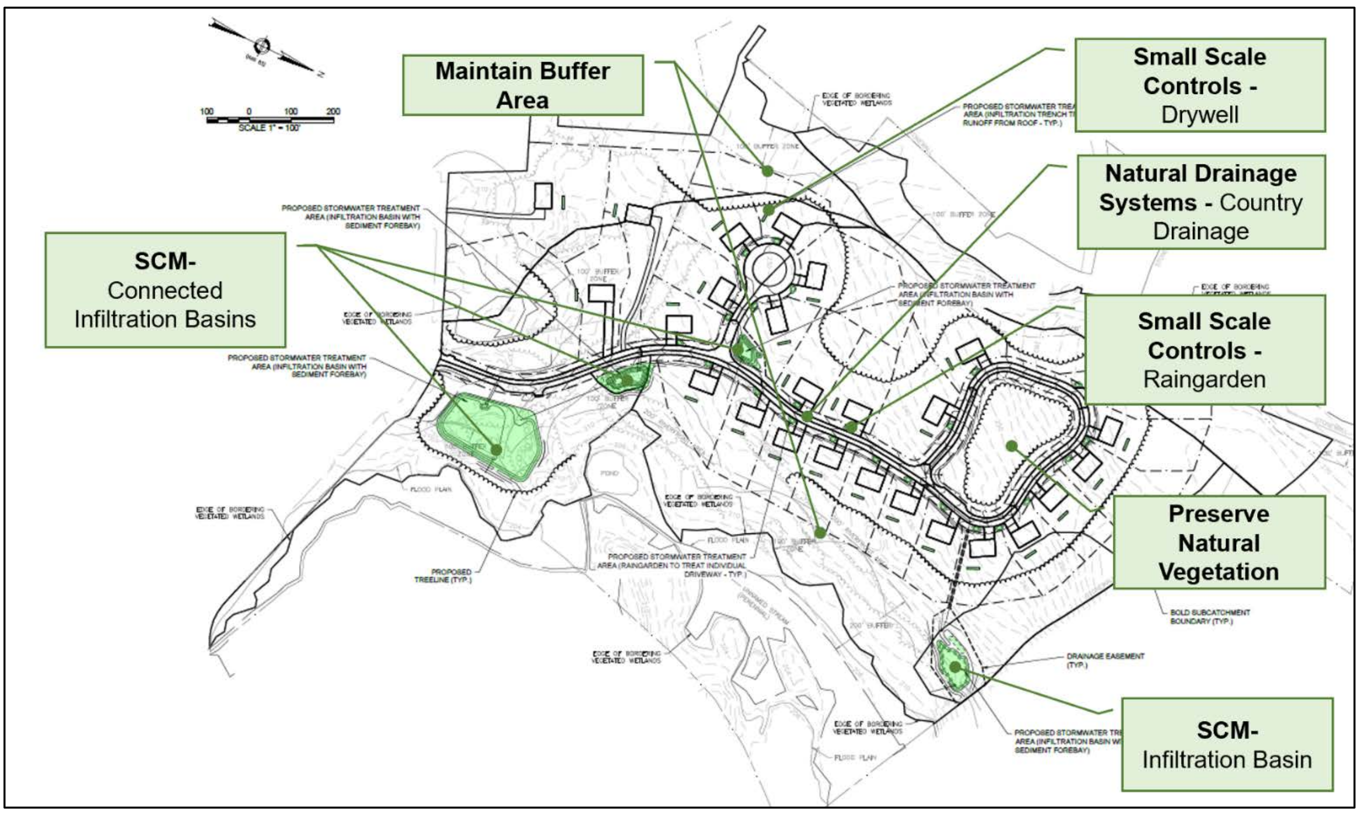
ESSD can be applied to both residential and non-residential developments as well as Redevelopment projects to limit land disturbance and preserve important natural features. ESSD begins with assessing the environmental and hydrologic conditions of a site and identifying important natural features such as streams and drainage ways, floodplains, wetlands, water supply protection areas, high-permeability soils, steep slopes, erosion-prone soils, woodland conservation areas, farmland, and meadows. This investigation helps to determine which “conservation areas” should be protected from development and construction impacts, and which site features (i.e., natural swales) should be incorporated into the stormwater management system.

The site analysis also identifies a “development envelope” where development can occur with minimal impact to hydrology and other ecologic, scenic, or historic features. In general, the development envelope includes upland areas, ridge lines and gently sloping hillsides, and soils prone to ponding and runoff production outside of wetlands, leaving the remainder of the site in a natural undisturbed condition. Clustering building lots to create a more compact development reduces the amount of clearing and grading required. It is important to protect mature trees and to limit clearing and grading to the minimum amount needed for buildings, access, and fire protection. Converting wooded areas to lawns increases the volume of runoff that must be managed. The design should confine construction activity, including stockpiles and storage areas, to those areas that will be permanently altered, and clearly delineate the construction fingerprint.

Some environmentally sensitive site designs that seek to cluster development and reduce lot coverage may conflict with local land use regulations or public perceptions about what type of development is desirable. For example, a compact multi-story building may be more visible than a single-story building with a larger footprint. To address this concern, developers, advocates and regulators who recognize the benefits of ESSD must educate the public about these benefits.

ESSD Examples

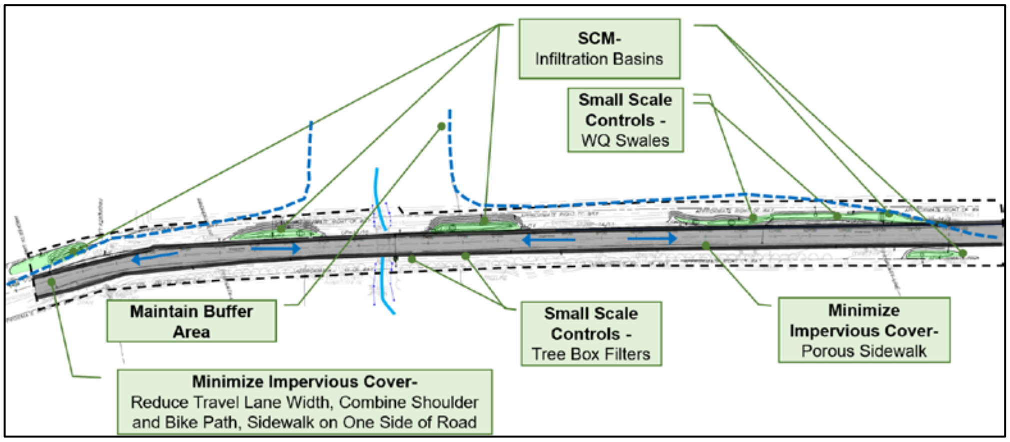
ESSD implementation can take many forms depending on the site type. Examples of three different development and Redevelopment projects are provided below. Most of the ESSD techniques shown on these examples are described in additional fact sheets provided in this Appendix.



Example new development site with ESSD techniques

This example site implements ESSD in the following ways:

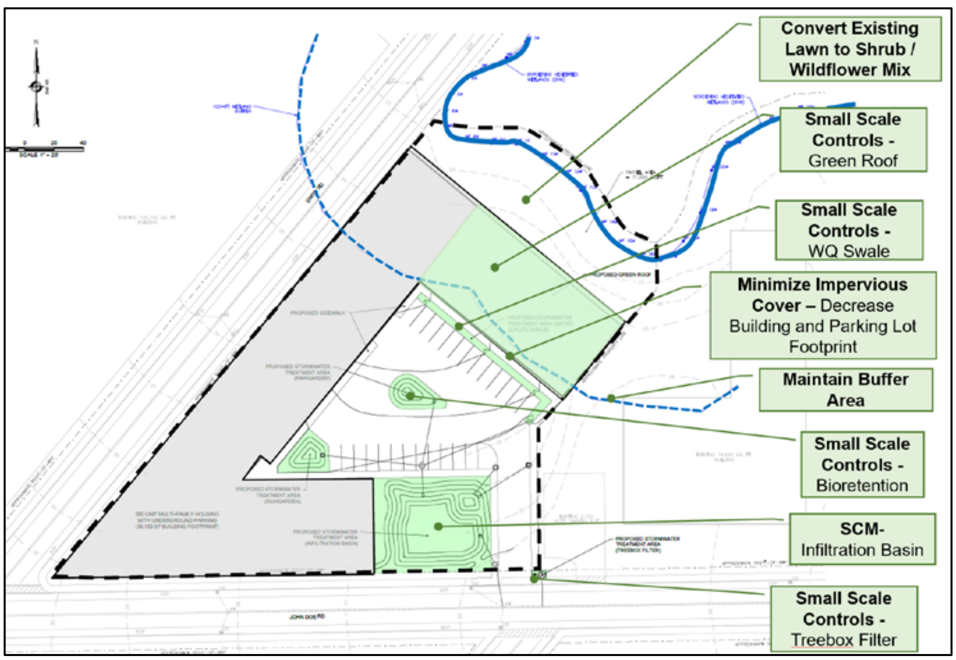
- Wetland Resource Area buffer is maintained and not disturbed throughout the site.
- Small scale controls (i.e., raingardens, drywells) capture runoff from each driveway and roof.
- Front yard setbacks and driveway lengths are minimized, which reduces impervious site cover.
- All roadside runoff is conveyed through country drainage rather than curb and gutters.
- The remaining runoff not captured by upgradient small scale controls is captured by infiltration basins.



Example road Redevelopment project with ESSD techniques

This example site implements ESSD in the following ways:

- The Wetland Resource Area is maintained and not disturbed throughout the site.
- Small scale controls (i.e., water quality swales, tree box filters, porous pavement) capture runoff.
- Impervious area is reduced by narrowing road width and using a combined shoulder / bike path.
- The remaining runoff not captured by upgradient small scale controls is captured by infiltration basins.



Example commercial Redevelopment project with ESSD techniques

This example site implements ESSD in the following ways:

- Wetland Resource Area is maintained and not disturbed throughout the site.
- Small scale controls (i.e., green roof, water quality swales, bioretention, tree box filters) capture runoff from the parking lot and roof.
- The building and parking lot footprint are reduced, which reduces impervious site cover.
- The remaining runoff not captured by upgradient small scale controls is captured by an infiltration basin.

ESSD Credit 1: Environmentally Sensitive Site Design

This ESSD Credit is given for ESSD techniques that "cluster" development or reduce development scale to leave a significant amount of the site undisturbed in its natural state. This credit is applicable to new development and Redevelopment projects. If a site is designed, constructed, operated, and maintained in accordance with the requirements of this credit, a project Applicant need not develop and implement additional structural stormwater SCMs to meet Standard 3, Standard 4, and the pollutant removal requirements of Standard 7.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation.
3 - Recharge	Provides 1-inch of groundwater recharge if minimum criteria are met.
4 - TSS/ TP Removal	Provides 90% TSS and 60% TP removal if minimum criteria are met.
5 - Higher Pollutant Loading	May not be used for runoff from land uses with Higher Potential Pollutant Loads (LUHPPLs).
6 - Discharges near or to Critical Areas	May be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	May be used to treat all TMDL pollutants specified in **Table 2-6** of the Stormwater Handbook if minimum criteria are met.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Minimum Required Criteria

This ESSD Credit is only available when the following criteria are met:

- ❑ The total impervious cover footprint must be less than 15% of the base lot area.
- ❑ The site does not have the following characteristics:
    - o Land Use with Higher Potential Pollutant Loads (LUHPPL);
    - o Urban fill, unless the fill is removed and soil replaced with clean topsoil or hydrogeological testing is conducted indicating the filled soils are relatively homogeneous horizontally and vertically with a vertical Ks equivalent to a Hydrologic Soil group A, B, or C soil in accordance with **Table 6-4** of the Stormwater Handbook;
    - o Soils classified as contaminated pursuant to the Massachusetts Contingency Plan (MCP);
    - o Soils with seasonal high groundwater-groundwater elevation within 2 feet of the land surface.
- ❑ The following Wetland Resource Areas (WRAs) may <u>not</u> be included in the base lot area used for purposes of determining compliance with ≤ 15% impervious cover footprint requirement:
    - o Any vegetated wetlands (Bordering Vegetated Wetland (BVW), Isolated Vegetated Wetland (IVW), Salt Marsh);
    - o Land Under Water and Waterways;
    - o Land Under Ocean;
    - o Bank;
    - o Coastal Bank; or
    - o 5,000 square feet or 10% of the Riverfront Area, whichever is greater.
- ❑ Alteration of base lot cannot occur in any coastal WRA other than Land Subject to Coastal Storm Flowage; or BVW or IVW.

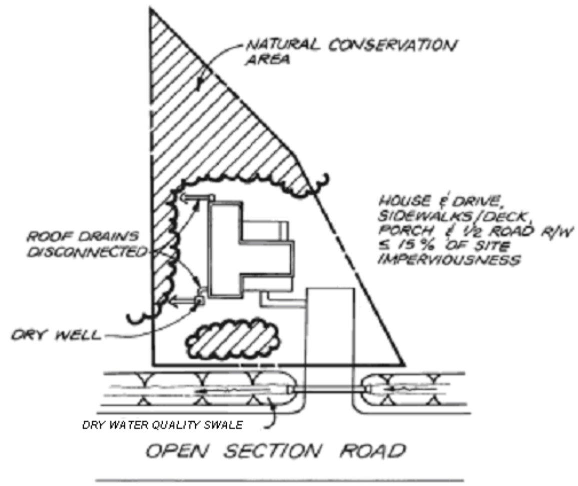
Example Calculation for ESSD Credit 1

Problem Statement: A single-family lot that is part of a low-density subdivision is located in a Critical Area.

- The base lot area is 2.5 acres.
- The post-development impervious area is determined to be 0.35 acres (14%).
- All other “minimum criteria” area met.

Solution:

- ❑ Determine eligibility based on “minimum required criteria.”
- ❑ Required Recharge Volume (Standard 3) and Pollutant Removal (Standard 4, Standard 7) are considered to be met by site design.
- ❑ Other applicable Standards must still be met, including peak rate attenuation (Standard 2).



Example of ESSD for Credit 1

ESSD Credit 2: ESSD for Solar Arrays

Photovoltaic System (PVS) solar projects within the Buffer Zone to a Wetland Resource Area may receive ESSD Credit as detailed below. If a PVC solar Project Site is designed, constructed, operated, and maintained in accordance with the requirements of this credit, a project Applicant need not develop and implement additional structural stormwater SCMs to meet Standard 3, Standard 4, and the pollutant removal requirements of Standard 7. This credit is applicable to new development and Redevelopment projects.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation.
3 - Recharge	Provides 1-inch of groundwater recharge if minimum criteria are met.
4 - TSS/ TP Removal	Provides 90% TSS and 60% TP removal if minimum criteria are met.
5 - Higher Pollutant Loading	May not be used for runoff from land uses with Higher Potential Pollutant Loads (LUHPPLs).
6 - Discharges near or to Critical Areas	May not be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	May be used to treat all TMDL pollutants specified in **Table 2-6** of the Stormwater Handbook if minimum criteria are met.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Minimum Required Criteria

This ESSD Credit is only available when the following criteria are met:

- ❑ Permanent slopes on which the PVS arrays are placed must be no greater than 5%, naturally or as graded.
- ❑ The final grading must not include direct discharges to WRAs, and must avoid or minimize channelized stormwater flow from the Buffer Zone directly into wetland Resource Areas.
- ❑ Native topsoil is preserved or supplemented sufficient to maintain vegetation cover. Soil must be of sufficient depth to maintain vegetation.
- ❑ Natural vegetative cover consisting solely of native grass and herbaceous plant species shall be planted or maintained at the site to meet NRCS TR55 “good condition” or better (>75%).
- ❑ Solar panel rows are spaced in a manner to allow sunlight penetration sufficient to support vegetation between the solar panel rows.
- ❑ Where panel rows follow the slope (i.e. the panel arrays are constructed down, rather than across, a slope) provide intermittent gaps between adjacent panels sufficient to accommodate anticipated runoff so that runoff occurs from individual panels rather than from the length of the entire array;
- ❑ Panel drip edges (or leading edge of panels) are no greater than 2-3 feet above the ground surface to minimize splash erosion.
- ❑ No point source discharges are allowable except for emergency overflows or flow from level spreaders.
- ❑ No work is proposed in a Buffer Zone of a Resource Areas that borders a Critical Area, as defined at 310 CMR 10.04 and 314 CMR 9.02, or in the estimated habitat identified on the most recent Estimated Habitat Map of State Listed Rare Species prepared by the Natural Heritage and Endangered Species Program.
- ❑ To qualify for the credit, no structural SCMs may be constructed, except for the following: infiltration trenches and water bar/log bars.
- ❑ For the peak runoff rate analysis, TR55 curve numbers for fully developed urban areas must be utilized to determine the post construction runoff conditions (e.g., curve numbers for open space - lawns, parks). Curve numbers intended for commercial agricultural areas such as the “meadow” curve numbers or “brush” curve numbers are not appropriate to characterize post construction runoff conditions.

Disconnection of Impervious Surfaces

Description and Purpose

An impervious area is considered “connected” if runoff from it flows directly into the drainage system. It is also considered “connected” if runoff occurs as shallow concentrated flow that runs over a pervious area and then into the drainage system (USDA, 1986). Disconnection of impervious surfaces is the practice of directing stormwater runoff from impervious surfaces to a Qualifying Pervious Area (QPA).

QPAs are natural or vegetated areas where discharge is directed via sheet flow and not as a point source discharge. They must be stabilized and have runoff characteristics at or lower than the NRCS Runoff Curve Numbers in **Table QPA 1**.

Disconnection directs runoff from rooftops and impervious roads, driveways, and parking lots to QPAs where it can either infiltrate into the soil or flow over it with sufficient time and reduced velocity to allow for filtering. This practice can reduce demand on system capacity and reduce pollutant loads to Surface Waters.

Table QPA 1. Maximum NRCS Runoff Curve Numbers for Qualifying Pervious Area

Cover Type	HSG A	HSG B	HSG C
Natural: Woods Good Condition	30	55	70
Natural: Brush Good Condition	30	48	65
Landscaped: Good Condition (grass cover > 75% or equivalent herbaceous plants)	39	61	74

Environmentally Sensitive Site Design (ESSD) Credits

As indicated in the “Introduction” section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There are two ESSD Credits associated with this Fact Sheet.

- **Credit 3:** Rooftop runoff directed to Qualifying Pervious Areas
- **Credit 4:** Parking lots, driveways, and roadways directed to Qualifying Pervious Areas.

See following pages for more information on these credits.

General Requirements and Design Considerations

There are multiple design considerations for QPAs and disconnection of impervious surfaces that must be implemented to obtain ESSD Credit. A list of general requirements is provided below. Refer to the below credits for more detailed eligibility requirements and design criteria.

- No work, including any alteration for stormwater management, may be proposed within any Wetland Resource Area except for Riverfront Area (RA), Bordering Land Subject to Flooding (BLSF), Isolated Land Subject to Flooding (ILSF), or Land Subject to Coastal Storm Flowage (SCSF). The underlying Performance Standards in these Resource Areas must be met.
- Where a portion of the Buffer Zone is proposed to serve as part of the QPA, the area shall **not** extend into the inner 50 feet of the Buffer Zone. Refer to ESSD Credit 7 for a credit for protecting or enhancing buffer areas.
- The QPA must be owned or controlled (e.g., drainage easement) by the property owner.
- The QPA must be a fully stabilized natural or landscaped area with runoff characteristics at or lower than the NRC Runoff Curve Numbers presented on **Table QPA 1**.
- The average contributing overland slope to and across the QPA must be less than or equal to **5%**.
- Runoff shall enter the QPA uniformly across its entire length as sheet flow and not a point discharge. The flow path to the QPA shall be no more than **75-feet** long. Use of practices such as level spreading may be needed to meet this requirement.

- Use a pea gravel diaphragm or grass / gravel combination for pretreatment (see Specification in this Appendix).
- A soil evaluation must be performed to verify Hydrologic Soil Group (HSG) of the underlying soils in accordance with **Section 6.3.2** of the Stormwater Handbook. Ponding of water directed to a QPA must be avoided. The receiving QPA must be comprised of HSG A, B, or C soils.
- The flow path through the QPA must comply with the setbacks in **Table 2-8** of the Stormwater Handbook (e.g., 50 feet away from any septic system components – such as a soil absorption system or leach field, 50 feet from vegetated wetlands and land under water).
- This ESSD Credit may not be used in locations where information is submitted during the public hearing or introduced by the Conservation Commission that there is a demonstrated history of groundwater flooding.
- To prevent compaction of the soil in the QPA, construction vehicles must not be allowed to drive over the area. If it becomes compacted, the soil must be amended, tilled, and revegetated to restore its infiltrative capacity once construction is complete.
- Must not receive runoff from upgradient areas that have sealcoats containing coal-tar emulsions.
- The Operation and Maintenance (O&M) Plan required by Stormwater Standard 9 must include measures to inspect the QPA at least yearly for evidence of ponding. The O&M Plan shall incorporate measures to address any ponding that is observed during the inspection. The O&M Plan shall also include measures to replace any soil eroded from the QPA and to replace any vegetation detrimentally impacted by the drainage.

Maintenance

QPAs require an Operation and Maintenance (O&M) Plan that should include:

- Measures to inspect the QPA at least yearly for evidence of ponding, sediment deposition, and vegetation dieback.
- Measures to remove deposited sediment (e.g., sand from winter sanding operations), address any ponding, and replant vegetation that has died (e.g., vegetation impacted by winter road salting).
- Measures to replace any eroded soil from the QPA.
- Methods for how future scarifying and repaving operations will be conducted to ensure that stormwater contaminated during repaving operations will not detrimentally impact regulatory wetland areas and Buffer Zones.

References

USDA, 1986. Urban Hydrology for Small Watershed (TR 55). Available at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf.

Photo credit: NCDENR Stormwater BMP Manual (4/1/2014)

ESSD Credit 3: Rooftop Runoff Directed to a QPA

This ESSD Credit is available when rooftop runoff is directed to a Qualifying Pervious Area (QPA). This credit is applicable to new development and Redevelopment projects. See below for the ability of this ESSD Credit to meet specific Stormwater Standards. The Applicant must meet all required criteria to be eligible for this credit.

Note: this credit is only applicable to the impervious area discharged to and treated by the QPA and not the entire site.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides peak flow attenuation for smaller storms by reducing the composite Runoff Curve Number that is used for TR-55 peak runoff calculations (see required criteria).
3 - Recharge	Use **Table QPA 2** to determine recharge credit. Provides 1-inch of groundwater recharge credit for the portion of the site that drains to the QPA if all minimum criteria herein are met.
4 - TSS/ TP Removal	Use **Table QPA 2** to determine pollutant removal credit. Provides 90% TSS removal and 60% TP removal for the portion of the site that drains to the QPA if all minimum criteria are met.
5 - Higher Pollutant Loading	May be used for runoff from LUHPPL if minimum criteria are met.
6 - Discharges near or to Critical Areas	May be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	May be used to treat all TMDL pollutants specified in **Table 2-6** of the Stormwater Handbook if minimum criteria are met.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Recharge and Pollutant Removal Credit

Recharge and pollutant removal credit for directing rooftop runoff to a QPA is based on the Hydrologic Soil Group Type of the receiving QPA and the ratio of impervious area to impervious area (**Table QPA 2)**.

If the ratio of impervious area to pervious area does not match those provided by the table, use the ratio that is nearest to, but more than, the determined ratio. For example, if the impervious area to pervious area ratio is 3:1, calculate pollutant removal credit based on a ratio of 4:1.

Note: Many QPAs will not be able to meet pollutant removal requirements for an entire subcatchment. See **ESSD Credit 4** for an example calculation which demonstrates how to use an area weighted average to evaluate subcatchment-wide pollutant removals for multiple SCMs in accordance with **Section 2.3.4** of the Stormwater Handbook.

Table QPA 2. Recharge and pollutant removal credits for directing rooftop runoff to a QPA

Impervious Area to Pervious Area Ratio	HSG A	HSG B	HSG C
8:1	NC	NC	NC
6:1	NC	NC	NC
4:1	NC	NC	NC
2:1	NC	NC	NC
1:1	✓	✓	NC
1:2	✓	✓	✓
1:4	✓	✓	✓
1:10	✓	✓	✓
1:30	✓	✓	✓
1:50	✓	✓	✓

Table Key:

- **Check Mark (✓) =** Credit is provided for 1-inch recharge, 90% TSS removal, and 60% TP removal.
- **NC =** No credit is provided for recharge or pollutant removal.
- Assumes that all minimum required criteria are met.

Minimum Required Criteria

This ESSD Credit is only available when the following criteria are met:

- ❑ General QPA requirements are met (see "**Disconnection of Impervious Surfaces**" Fact Sheet above).
- ❑ The lot is greater than 6,000 ft^2.
- ❑ The receiving QPA does not have the following characteristics:

- Urban fill, unless the fill is removed and soil replaced with clean topsoil or hydrogeological testing is conducted indicating the filled soils are relatively homogeneous horizontally and vertically with a vertical Ks equivalent to a Hydrologic Soil group A, B, or C soil in accordance with **Section 6.3.2** of the Stormwater Handbook. Also, see **Section 6.3.4** of the Stormwater Handbook, “When Fill Materials are Determined to be Present”, for additional requirements.

❑ The rooftop area meets the following criteria:
  - The rooftop area contributing runoff to any one downspout cannot exceed 1,000 ft^2.
  - The rooftop can only be a metal roof if the building is located outside a Zone II or Interim Wellhead Protection Area.
  - The building must not be used for industrial purposes.
  - The rooftop area contributing runoff is not a “Green Roof.”

❑ QPAs treating rooftop runoff must also meet the following criteria:
  - Calculate pollutant removal and recharge credit based on the receiving HSG and the ratio of impervious area to pervious area in accordance with **Table QPA 2**.
  - Downspouts must be at least 10 feet away from the nearest impervious surface to prevent reconnection to the stormwater management system. If a gutter/downspout system is not used, the rooftop runoff must be designed to sheet flow at low velocity away from the structure housing the roof.

❑ To take credit for rooftop disconnection associated with a Land Use with Higher Potential Pollutant Loads (LUHPPL), the rooftop runoff must not commingle with runoff from any paved surfaces or activities or areas on the site that may generate higher pollutant loads.

❑ In locations where information is submitted during the public hearing or introduced by the Conservation Commission that there is a demonstrated history of groundwater flooding, this ESSD credit may not be utilized.

❑ To take credit for peak flow attenuation, a composite Runoff Curve Number (RCN) must be calculated using procedures from TR-55 for subcatchments that include unconnected impervious area (i.e., for subcatchments where an impervious rooftop discharges to a QPA). Refer to Figure 2-2 of TR-55 for a flow chart depicting the required calculation methodology based on the impervious area percentage within the subcatchment.

❑ The site plans submitted with the NOI or WQC Application must include a tabulation and visual representation that all required dimensions from the “general requirements” and “minimum required criteria” area met (e.g., average slope, maximum contributing drainage area, ratio of impervious to pervious area).

❑ **Note:** Credit is not given for a Qualifying Pervious Area that discharges to a Buffer Area that is being credited as part of ESSD Credit 7 (i.e., credit cannot be double counted).

Example Calculation for ESSD Credit 3

Problem Statement: 25 single-family residential lots (~1/2 acre lots) are part of a new development. The site has just one drainage subcatchment. The roof area of each house will be 2,000 ft^2. Each roof will be connected to two downspouts, each with a contributing area of 1,000 ft^2. Discharge from each roof is to be directed to a Qualifying Pervious Area (QPA). The QPAs are located in HSG B Soils*. Determine the minimum required area of each QPA to obtain a credited recharge volume of 1 inch, credited TSS removal of 90%, and credited TP removal of 60%.*

Note: See **ESSD Credit 4** for an example calculation which demonstrates how to use an area weighted average to evaluate subcatchment-wide pollutant removals for multiple SCMs in accordance with **Section 2.3.4** of the Stormwater Handbook.

- ❑ **Step 1, Determine the required number of QPAs.** The rooftop area contributing runoff to any one downspout cannot exceed 1,000 ft^2. Therefore, discharge from each roof will be directed to two (2) QPAs.
- ❑ **Step 2, Determine required sizing of each QPA**. As indicated by **Table QPA 2**, the ratio of impervious area to the area of the QPA must be at least 1:1 to obtain a credited recharge volume of 1 inch, credited TSS removal of 90%, and credited TP removal of 60%. Therefore, the area of each QPA must be at least 1,000 ft^2.
- ❑ **Step 3, Verify eligibility.** Verify that all "Minimum Required Criteria" are met. For example, the QPA must be designed such that runoff enters the QPA uniformly across its entire length as sheet flow and not a point discharge.
- ❑ **Step 4, Calculate credits.** The disconnection to QPA results in 1 inch of groundwater recharge (Standard 3), 90% TSS / 60% TP removal (Standard 4) for each roof's contributing impervious area – i.e., 25 roofs x 2,000 ft^2 / roof = 50,000 sf. Runoff from all other impervious areas on site must be managed in accordance with the Stormwater Standards.

ESSD Credit 4: Roadway, Driveway, or Parking Lot Runoff Directed to a QPA

This ESSD Credit is available for practices that direct runoff from impervious roads, driveways, and parking lots to Qualifying Pervious Areas (QPAs). This credit is applicable to new development and Redevelopment projects. See below for the ability of this ESSD Credit to meet specific Stormwater Standards. The Applicant must meet all required criteria to be eligible for this credit.

Note: This credit is only applicable to the impervious area discharged to and treated by the QPA and not the entire site.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides peak flow attenuation for smaller storms by reducing the composite Runoff Curve Number that is used for TR-55 peak runoff calculations (see required criteria).
3 - Recharge	Use **Table QPA 3** to determine recharge credit. Provides 1-inch of groundwater recharge credit for the portion of the site that drains to the QPA if all minimum criteria herein are met.
4 - TSS/ TP Removal	Use **Table QPA 3** to determine pollutant removal credit. Provides 90% TSS removal and 60% TP removal for the portion of the site that drains to the QPA if all minimum criteria are met.
5 - Higher Pollutant Loading	May not be used for runoff from LUHPPL.
6 - Discharges near or to Critical Areas	May be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	May be used to treat all TMDL pollutants specified in **Table 2-6** of the Stormwater Handbook if minimum criteria are met.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Recharge and Pollutant Removal Credit

Recharge and pollutant removal credit for directing roadway, driveway, or parking lot runoff to a QPA is based on the Hydrologic Soil Group Type of the receiving QPA and the ratio of impervious area to impervious area (**Table QPA 3)**.

If the ratio of impervious area to pervious area does not match those provided by the table, use the ratio that is <u>nearest to, but more than</u>, the determined ratio. For example, if the impervious area to pervious area ratio is 3:1, calculate pollutant removal credit based on a ratio of 4:1.

Note: Many QPAs will not be able to meet pollutant removal requirements for an entire subcatchment. See **ESSD Credit 4** for an example calculation which demonstrates how to use an area weighted average to evaluate subcatchment-wide pollutant removals for multiple SCMs in accordance with **Section 2.3.4** of the Stormwater Handbook.

Table QPA 3. Recharge and pollutant removal credits for directing rooftop runoff to a QPA

Impervious Area to Pervious Area Ratio	HSG A	HSG B	HSG C
8:1	NC	NC	NC
6:1	NC	NC	NC
4:1	NC	NC	NC
2:1	NC	NC	NC
1:1	✓	✓	NC
1:2	✓	✓	✓
1:4	✓	✓	✓
1:10	✓	✓	✓
1:30	✓	✓	✓
1:50	✓	✓	✓

Table Key:

- **Check Mark (✓) =** Credit is provided for 1-inch recharge, 90% TSS removal, and 60% TP removal.
- **NC =** No credit is provided for recharge or pollutant removal.
- Assumes that all minimum required criteria are met.

Minimum Required Criteria

This ESSD Credit is only available when the following criteria are met:

- ❑ General QPA requirements are met (see "**Disconnection of Impervious Surfaces**" Fact Sheet above).
- ❑ This credit is available for paved driveways, roads, and parking lots associated with all land uses, except for high-intensity parking lots that

generate 1,000 or more vehicle trips per day or runoff not segregated from LUHPPL.

- ❑ The receiving QPA does not have the following characteristics:
  - o Urban fill, unless the fill is removed and soil replaced with clean topsoil or hydrogeological testing is conducted indicating the filled soils are relatively homogeneous horizontally and vertically with a vertical Ks equivalent to a Hydrologic Soil group A, B, or C soil in accordance with with **Section 6.3.2** of the Stormwater Handbook. Also, see **Section 6.3.4** of the Stormwater Handbook, "When Fill Materials are Determined to be Present", for additional requirements.
- ❑ Driveways, roadways, and parking lots, or the contributing impervious area must meet the following criteria:
  - o The contributing impervious area draining to any one discharge cannot exceed 1,000 ft^2.
  - o The flow path from the contributing impervious area must be less than 75 feet in length.
- ❑ Runoff from driveways, roadways and parking lots may be directed over soft shoulders, through curb cuts, or level spreaders to QPAs. Measures must be employed at the discharge point to the QPAs to prevent erosion and ensure uniform sheet flow.
- ❑ QPAs treating runoff from driveways, roadways and parking lots must also meet the following criteria:
  - o Calculate pollutant removal and recharge credit based on the receiving HSG and the ratio of impervious area to pervious area in accordance with **Table QPA 3**.
- ❑ This ESSD credit may <u>not</u> be utilized in locations where information is submitted during the public hearing or introduced by the Conservation Commission that there is a demonstrated history of groundwater flooding.
  - ❑ To take credit for peak flow attenuation, a composite Runoff Curve Number (RCN) must be calculated using procedures from TR-55 for subcatchments that include unconnected impervious area (i.e., for subcatchments where an impervious roadway, driveway, or parking lot discharges to a QPA). Refer to Figure 2-2 of TR-55 for a flow chart depicting the required calculation methodology based on the impervious area percentage within the subcatchment.
  - ❑ The site plans submitted with the NOI or WQC Application must include a tabulation and visual representation that all required dimensions from the "general requirements" and "minimum required criteria" area met (e.g., average slope, maximum contributing drainage area, ratio of impervious to pervious area).
- ❑ **Note:** Credit is not given for a Qualifying Pervious Area that discharges to a Buffer Area that is being credited as part of ESSD Credit 7 (i.e., credit cannot be double counted).

Example Calculation for ESSD Credit 4

Problem Statement: A new development will include a building and a parking lot with a resulting impervious area of 0.60 acres. The site has just one drainage subcatchment. The Applicant has proposed to sheet runoff from three (3) portions of the parking lot to three (3) separate QPAs. The remaining impervious area will be treated by other SCMs. The underlying soils of the entire site have been determined to be HSG A in accordance with procedures described by **Section 6.3** of the Stormwater Handbook. *Determine the required sizing of each QPA and other SCMs to meet the Required 1 inch Recharge Volume (Standard 3), and the required 90% TSS / 60% TP removal (Standard 4).*

- ❑ **Step 1, Determine QPA Sizing**. The Applicant has calculated the maximum contributing impervious area and available area for each QPA as listed by **Table QPA 4** (below). The ratio of impervious area to pervious area must be rounded up to the nearest value based on **Table QPA 3**. For example, the ratio of impervious area to pervious area is 1.80 for QPA No. 1; therefore, the ratio to be used for crediting is 2:1.

- ❑ **Step 2, Verify eligibility.** Verify that all "Minimum Required Criteria" are met for all three proposed QPAs. For example, the upstream flow path must be less than 75 feet long.

- ❑ **Step 3, Calculate the credited recharge volume (Standard 3) and pollutant removal (Standard 4).**
  - Recharge volume. As indicated by the **Table QP 4**, the ratio of impervious area to pervious area for each QPA is at most 2:1. Each QPA is therefore eligible to receive credit to recharge 1 inch of upstream impervious area per **Table QPA 3**.
  - Pollutant removals. As indicated by the **Table QP 4**, the ratio of impervious area to pervious area for each QPA is at most 2:1. Each QPA is therefore eligible to receive credit for 90% TSS and 60% TP removal from upstream impervious area per **Table QPA 3**

- ❑ **Step 4, Calculate the required sizing of other SCMs to meet Standard 3 and Standard 4 requirements.** As indicated by **Table QP 4**, the three (3) QPAs treat and recharge 2,750 sf upstream impervious area (appx. one tenth of the site's impervious area). Additional SCMs are required to meet subcatchment-wide pollutant removals on an area weighted basis. Area weighted averages can be calculated based on **Equation 6-9** of the Stormwater Handbook.
  - Other SCMs on the 0.60 acre site (26,136 sf) would be required to recharge a depth of at least 1.0 inch of the remaining contributing upstream area of 23,386 square feet to meet the 1.0 inch recharge requirement (Standard 3).
  - Other SCMS on the 0.60 acre site (26,136 sf) would be required to remove at least 90% TSS and 60% TP of the remaining contributing upstream area of 23,386 square feet to meet the 90% TSS and 60% TP removal requirement (Standard 4).
  - For example, an infiltration basin or other infiltrating SCM could be designed to meet these criteria in HSG B soils.

Table QP 4. Example solution for ESSD Credit 4

SCM ID	Contributing Imp. Area, A_{IMP} (sf)	QPA Area, A_{QPA} (sf)	Ratio A_{IMP} to A_{QPA} (actual)	Ratio A_{IMP} to A_{QPA} (rounded)	Recharge Depth, F (in)	Pollutant Removals (%)	
						TSS	TP
QPA No. 1	900	500	1.80	2:1	1.0	90.0%	60.0%
QPA No. 2	850	910	0.93	1:1	1.0	90.0%	60.0%
QPA No. 3	1,000	1,350	0.74	1:1	1.0	90.0%	60.0%
Other SCMs	23,386	N/A	N/A	N/A	1.0	90.0%	60.0%

Imp. Area Total:	26,136	**Area Weighted Averages:**	1.0	**90.0%**	**60.0%**

Tree Canopy Implementation for Runoff Reduction

Description and Purpose

A leafy tree canopy can help intercept and retain precipitation and transfer water back to the atmosphere through evapotranspiration reducing the overall volume of stormwater. Additionally, the shade, tree litter, and roots beneath the canopy can help promote infiltration reducing runoff volume, slow the travel of runoff lowering peak runoff rates, and stabilize the soil surface preventing erosion and associated impacts. Trees and their roots capture and use water to sustain the tree and help it grow. Trees can infiltrate and filter pollutants carried by stormwater, helping to maintain good water quality at nearby Surface Waters. There are many potential configurations that can implement tree canopy for a parking lot, subdivision road, urban street, and more.

ESSD Credits

As indicated in the "Introduction" section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There is one ESSD Credit associated with this Fact Sheet:

- **Credit 5:** Tree Canopy Enhancement and Protection

See below for more information on this credit.

Selecting Trees

The selection of tree species for street plantings and the landscaping of development projects should be based on site-specific assessment of environmental conditions and on the desired tree functions. Preferably, trees selected for urban plantings should comprise native species because they are adapted to local conditions and are likely to require less maintenance. However, given the space constraints and the environmental conditions associated with urban environments, selection of appropriate trees may require consideration of hardy, non-invasive, non-native species, consistent with regional horticultural practices. The table below outlines environmental conditions affecting the selection of tree species for planting in the urban environment (CEI June 2017).

Environmental Condition	Species Selection Guidance
USDA plant hardiness zone	Select species appropriate to hardiness zone. However, consider tolerance of species to potential shift in temperature regime associated with climate change.
Sunlight exposure	Select species tolerant of sun exposure at site.
Microclimate features	Select drought tolerant species for areas subject to high wind exposure or high heat reflection.
Topography	Consider landscape position in assessing tree exposure to excessive drainage or flooding.
Regional forest association	Where feasible, select native species from regional forest association in preference to other species.
Soil texture	Select species based on tolerance to site conditions. In urban settings and Redevelopment sites, sites for tree plantings may need to be modified or existing soils be replaced to provide conditions supportive of healthy tree growth.
Soil drainage	
Soil compaction	
Soil pH	Select species tolerant of existing pH conditions. If trees will be planted where concrete pavement surfaces or prepared soil mixtures may alter soil pH, select species with a tolerance to alkaline soil conditions.
Soil chemistry	Consider salt content of existing soils, and select salt tolerant species as warranted.
Stormwater runoff to planting site	Assess whether the planting site will likely receive runoff from adjacent areas, in determining whether species should be flood tolerant and drought tolerant.
Floodplain connection	Consider position relative to floodplain in assessing whether species should be flood tolerant.
Space limitations	Consider location of surface features, subsurface features, and above surface features in selecting species and mature tree size.
Other limiting factors	Consider other limiting factors that may be specific to the site or its local context, including disease and pest resistance, cultural factors, potential exposure to animal and human impacts, and other factors.

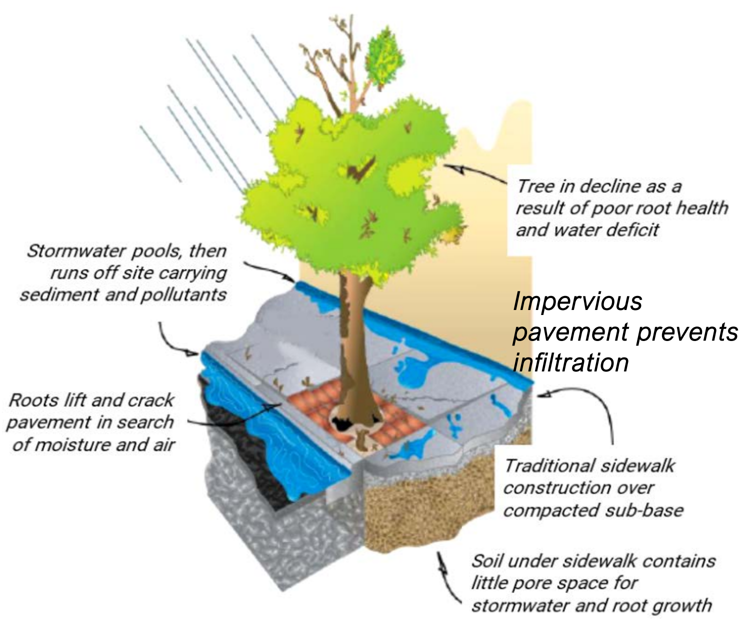
The table below presents tree height, mature spread, and area of average mature spread for a limited selection of native and non-native street trees recommended by Massachusetts Department of Transportation (MassDOT) and Department of Conservation and Recreation (DCR) (https://masstreewardens.org/wp-content/uploads/Tree-Selection-1.pdf).

Scientific Name	Common Name	Tree Height	Mature Spread	Area of Avg. Mature Spread
		ft	ft	sq ft
Large Trees				
Acer rubrum	Red Maple	40-75	25-35	707
Celtis occidentalis	Northern Hackberry	40-60	40-50	1,590
Fraxinus pennsylvanica	Green Ash	50-60	45-50	1,771
Ginkgo biloba	Ginkgo	50-80	50-60	2,375
Gleditsia triacanthos	Honeylocust	30-70	35-50	1,418
*Platanus hybrida**	London Planetree	70-100	50-70	2,826
Quercus palustris	Pin Oak	60-70	35-40	1,104
Quercus robur	English Oak	40-50	40-60	1,963
Quercus rubra	Northern Red Oak	60-80	50-60	2,375
Tilia cordata	Littleleaf Linden	60-70	35-50	1,418
Ulmus americana	American Elm	60-80	50-70	2,826
Ulmus parvifolia	Chinese Elm	40-50	35-50	1,418
Zelkova serrata	Japanese Zelkova	50-80	50-75	3,066
Medium Trees				
Acer campestre	Hedge Maple	25-35	30-35	829
Koelreuteria paniculata	Goldenraintree	30-40	30-40	962
Pyrus calleryana	Callery Pear	30-35	30-40	962
Small Trees				
Amelanchier sp.	Common Serviceberry	15-25	15-20	240
Crataegus phaenopyrum	Washington Hawthorn	25-30	20-25	397
Cornus kousa	Kousa Dogwood	30	15-20	240
Malus sp.	Crabapple (Indian Summer)	15-30	10-25	240
Malus sp.	Crabapple (Harvest Gold)	15-30	10-25	240
Ostrya virginiana	Eastern Hophornbeam	30	25-30	594

Installing Trees

In addition to selecting the correct tree species for the environmental conditions on a site, provisions for its initial planting and care are essential to the long-term viability of the tree. The designer should provide either for adequate landscape islands or tree lawns to support the required soil volume, or explore the use of structural measures to provide for root growth beneath adjacent impervious surfaces.

Trees are often installed near pavements without providing sufficient soil volume to support development of a healthy, mature canopy. As a general rule, for optimal growth, the volume of useable soil for a tree should be approximately 2 cubic feet of soil for each square foot of crown projection orthe area of the tree within the "drip line" of the overhanging leaf canopy.



Maintenance

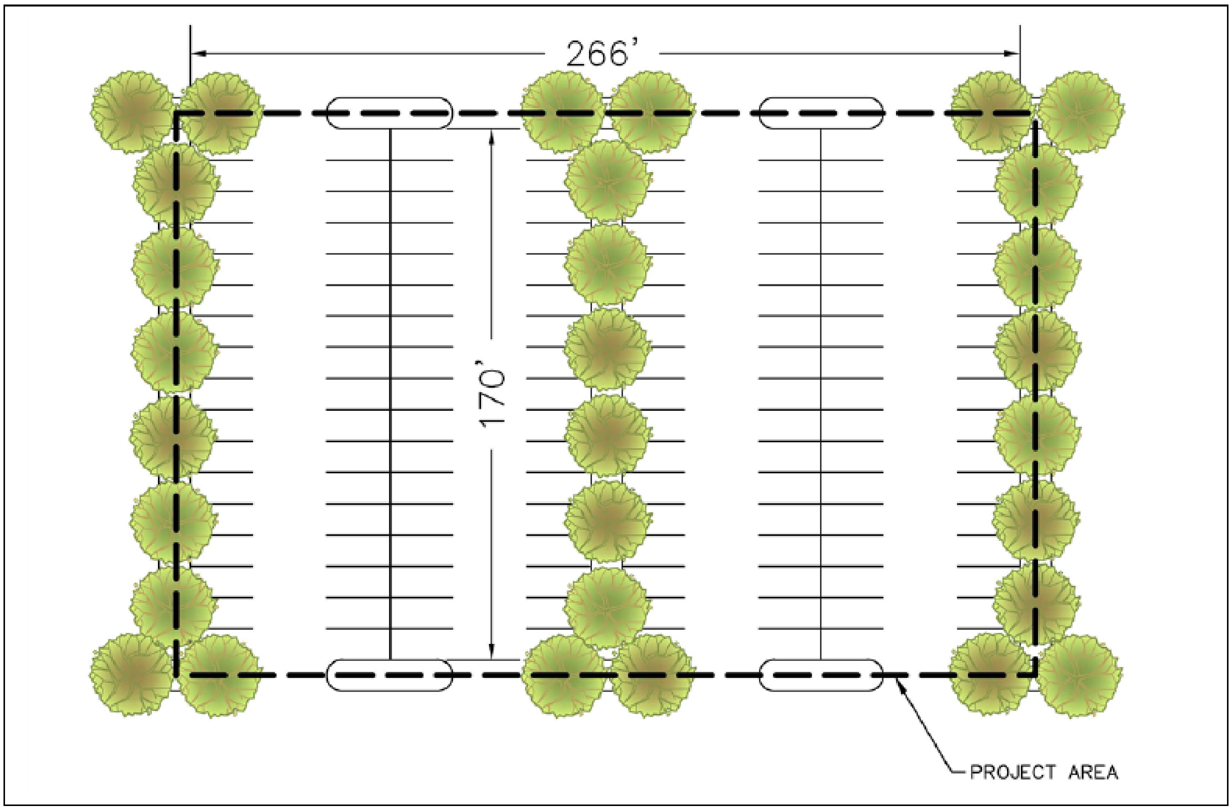
Local maintenance programs are required when tree canopies are used for stormwater management for trees located within public property or within approved projects. Recommended maintenance practices include:

- Routine care of the trees for the life of the project or until Redevelopment occurs to maintain healthy, vigorous trees. Instructions should be prepared by a qualified professional.
- Frequent irrigation to initiate root establishment for young trees.
- Timely care for damaged and diseased trees.
- Replacement of dead or severely damaged trees within six months.
- Annual sweeping following leaf-drop in the fall to remove leaf litter that can contribute nutrients to stormwater runoff.

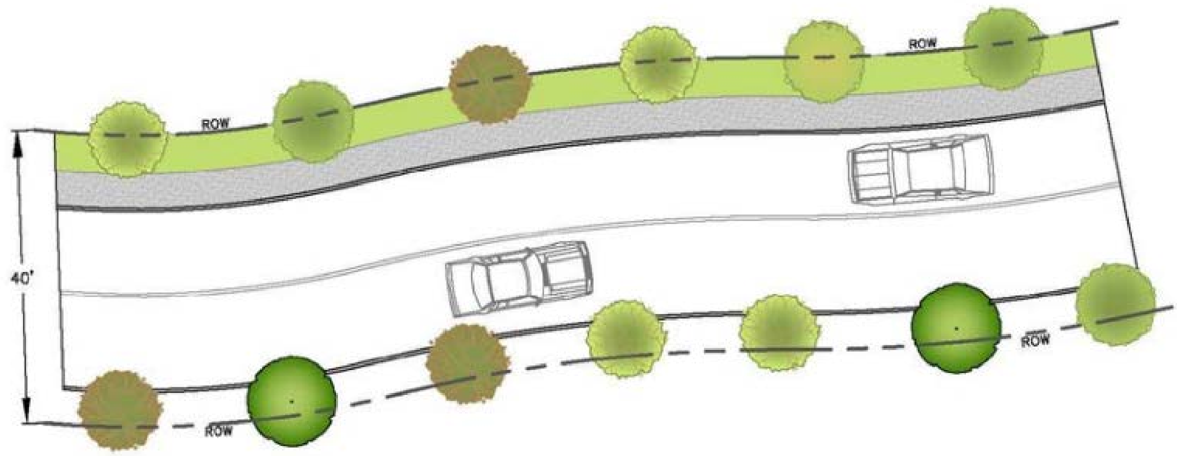
More information on the use of tree canopies as SCMs is provided in the Tree Canopy Stormwater Implementation and Outreach Report.

Tree Canopy Implementation Examples

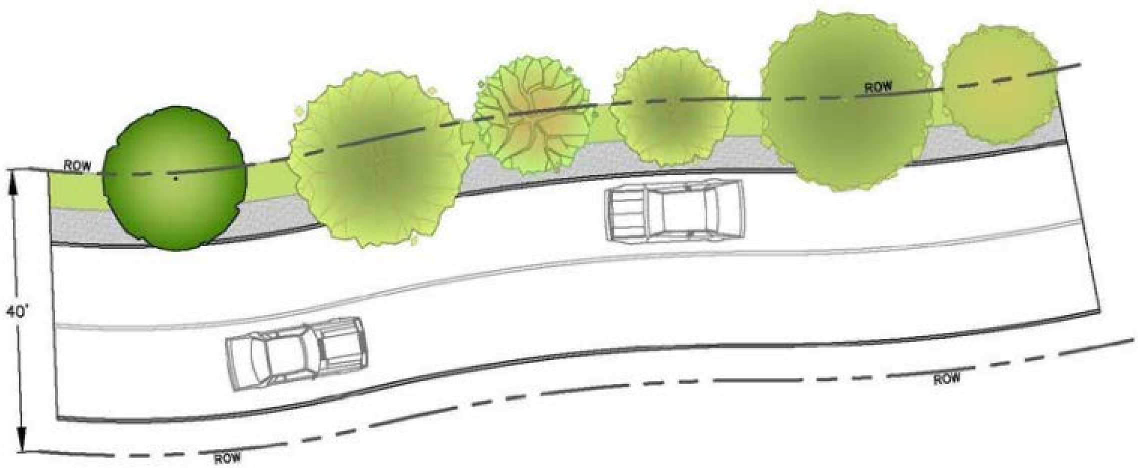
Some examples of potential tree canopy implementation are provided below. There are many more potential configurations that can used to implement tree canopy.



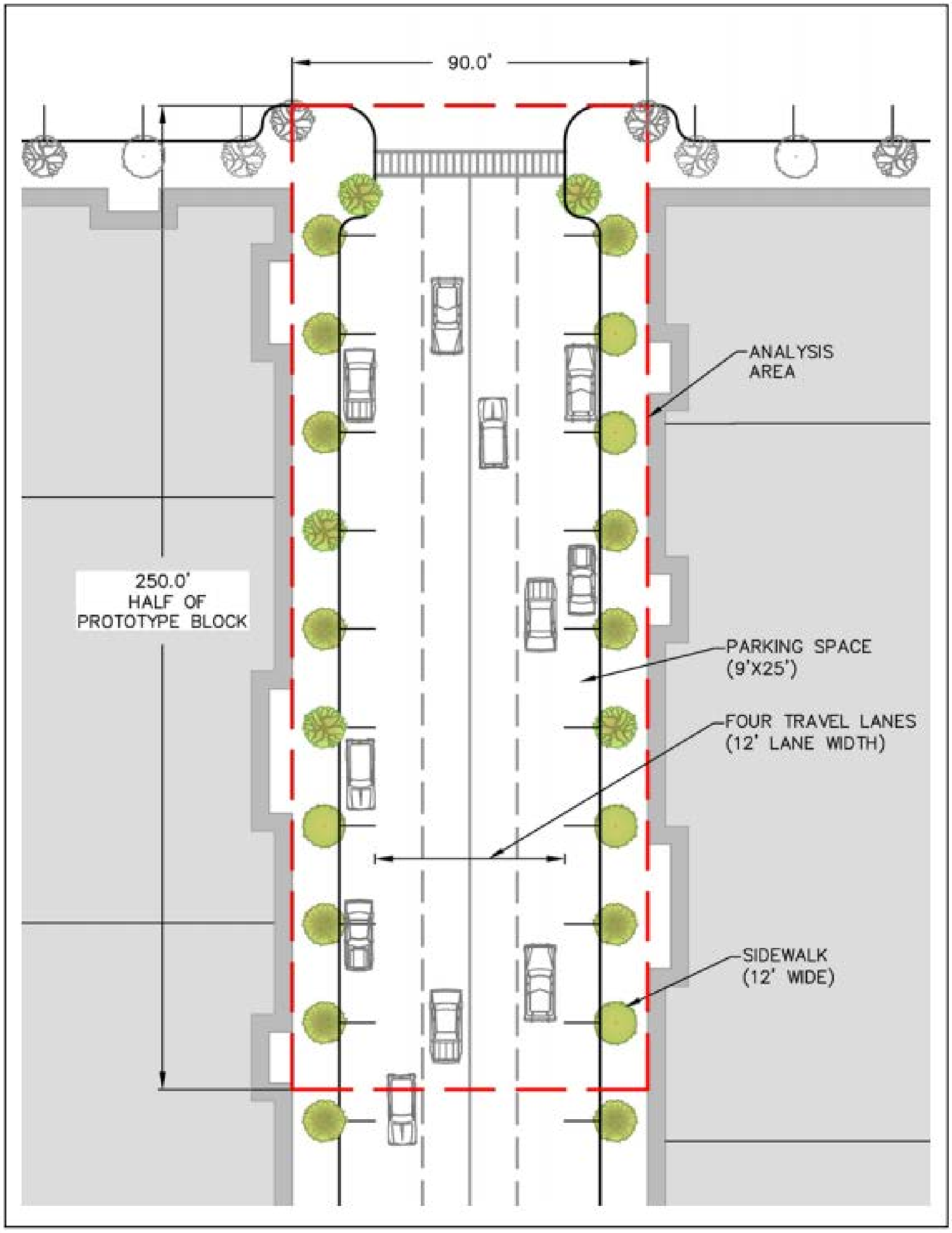
Tree canopy implementation example for a parking lot.



Tree canopy implementation example for subdivision road (small trees on both sides of road).



Tree canopy implementation example for subdivision road (large trees on one side of road).



Tree canopy implementation example for urban street (small trees on both sides of street).

References

Comprehensive Environmental Inc (CEI). June 2017. Tree Canopy Stormwater Implementation & Outreach Program. http://treecanopybmp.org/uploads/files/CEI%20Tree%20Canopy%20Stormwater%20Technical%20Report%202017.pdf

Photo credit: https://www.epa.gov/sites/production/files/2015-11/documents/stormwater2streettrees.pdf

ESSD Credit 5: Tree Canopy Enhancement and Protection

This ESSD Credit is available when new or existing tree canopy extends over ground level impervious cover. The credit consists of a reduction in **Effective Impervious Cover (EIC)** which may be deducted from the total area of impervious surface that must be managed as required by Standard 3, Standard 4, and the pollutant removal requirements of Standard 7.

This EIC Reduction credit is available for new development and Redevelopment projects; and applies to all ground level impervious cover and all land use types. The tree canopy credit shall not be used to reduce the area of impervious surface for the analysis of peak runoff rates or volumes. **Note:** All calculations must be performed based on drainage subcatchment and not the entire site.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation.
3 - Recharge	Results in a reduction in Effective Impervious Cover which may be deducted from the total area of impervious surface that must be managed as required by Standard 3.
4 - TSS/ TP Removal	Results in a reduction in Effective Impervious Cover which may be deducted from the total area of impervious surface that must be managed as required by Standard 4 and the pollutant removal requirements of Standard 7.
5 - Higher Pollutant Loading	May be used for runoff from land uses with Higher Potential Pollutant Loads (LUHPPLs).
6 - Discharges near or to Critical Areas	May be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	May be used to treat all TMDL pollutants specified in **Table 2-6** of the Stormwater Handbook if minimum criteria are met.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Minimum Required Criteria

This ESSD Credit is only available when the following criteria are met:

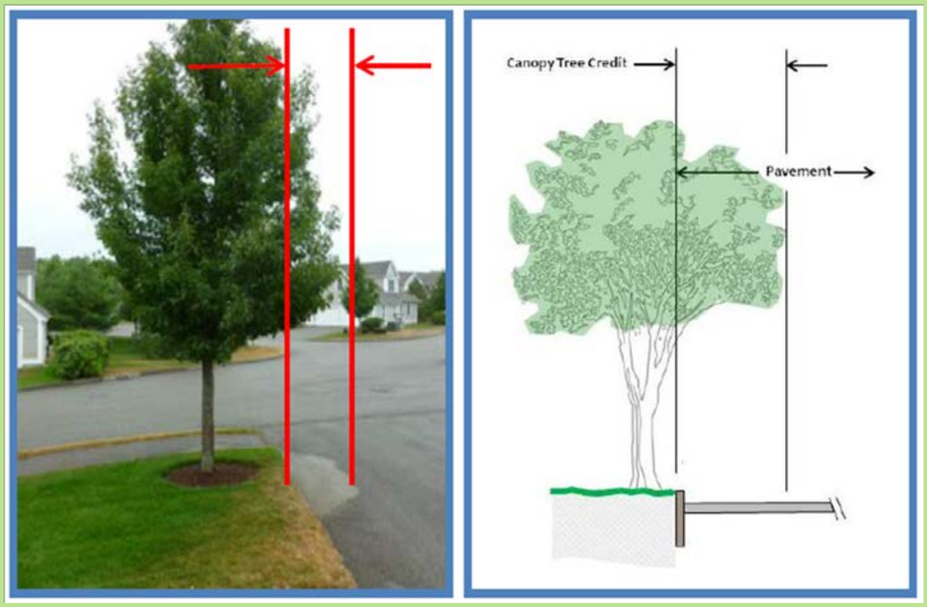
- ❑ The tree canopy must extend over ground level impervious cover. Ground level impervious cover includes paved streets, parking areas, sidewalks, and other impervious surfaces at grade. Ground level impervious cover does not include the roofs of structures.
- ❑ New trees:
  - o Must be a non-invasive species suitable for use in an urban environment.
  - o Must be species included on the MassDEP approved tree list for this credit (See Fact Sheet above).
  - o Must be deciduous trees at least 2-inch diameter at breast height (dbh). (Coniferous trees are not typically installed to overhang impervious surfaces, and are not included as qualifying trees for the purposes of this credit.)
  - o Must be installed in a planting bed or trench with a soil volume available for rooting to sustain a tree at maturity (use 40 years) (**see below calculations**).
  - o Soils must consist of native natural soil materials or installed planting media meeting standard horticultural practices, designed to promote normal, healthy root penetration and tree growth. The required soil volume shall not extend under pavement or other compacted surfaces, unless the Applicant provides for specialized structural soils systems specifically designed for tree plantings.
  - o The soil shall have a depth of at least 3 feet.
- ❑ Existing trees:
  - o Must be a non-invasive species suitable for use in an urban environment.
  - o Must be protected during construction.
  - o Shall be at least 4-inch diameter at breast height (dbh) to be eligible for the reduction.
  - o A qualified professional (Massachusetts Registered Landscape Architect or Massachusetts Certified Arborist, or other professional such as a tree warden) must document the following:
    - Suitability of location of each existing tree proposed for credit for continued growth health of the tree (including but not limited to consideration of proximity to power lines, overshadowing by larger trees, proximity to buildings and pavements, etc.);

- Condition of the tree, based on visual examination of factors including but not necessarily limited to evidence of disease, pest infestation, foliage dieback, and structural deficiencies.

- ❑ NOI/WQC Application Requirements:
  - o Project Narrative describes:
    - How the credit will be achieved.
    - Where and how the project provides for preservation of existing trees or the installation of new trees for which runoff reduction credits will be claimed.
    - How existing trees will be preserved.
    - How new trees will be installed.
    - Who is responsible for maintenance and replanting.
    - How the tree canopy will be permanently maintained for the life of the project (40 years) or until Redevelopment occurs.
  - o Site Plan includes:
    - Indicate existing trees to be preserved and for which ESSD Credit is claimed.
    - Document the size, species, and dimensions of existing tree crown for each tree qualifying for runoff reduction credit.
    - Provide a tabulation of the total area of ground-level impervious surface that will be located beneath existing tree canopy.
    - Indicate proposed (i.e., new) trees to be installed for which ESSD Credit is claimed.
    - Indicate size, species, and projected dimensions of mature tree crown (use an age of 40 years for estimating mature crown diameter).
    - Provide a tabulation of the total area of ground level impervious surface that will be located beneath proposed canopy at maturity.
  - o Required Calculations Include (**see below for example**):
    - Qualifying Canopy Area (CA)
    - Required Soil Volume (Sv) (new trees)
    - Effective Impervious Cover Reduction credit for preservation of existing trees and/or provision of new trees. (EIC_R).
    - Total Impervious Cover (IC) within the design subcatchment.
    - Effective impervious cover (EIC) to be used for Standard 3 and Standard 4.
- ❑ The Operation and Maintenance Plan includes:
  - o Long term tree care and replacement provisions.
  - o Pavement sweeping each fall following leaf-drop.
- ❑ The project design ensures the existing trees will be viable following project completion.
  - o Except as otherwise provided by a qualified professional, the trees shall be protected during construction according to the practices outlined in the publication Protecting Trees from Construction Damage (Nancy Miller, David Rathke, and Gary Johnson, 1993, rev. 1999, Saint Paul, MN: Minnesota Extension Service).
  - o New earth disturbance within the essential root zone, defined as the area located on the ground between the tree trunk and 10 feet beyond the drip line of an existing tree, is prohibited unless the following provisions are followed.
    - The disturbance is conducted in strict accordance with written tree preservation/protection instructions prepared by a qualified professional (Massachusetts Registered Landscape Architect, Massachusetts Certified Arborist, or other professional approved by the municipality).
    - Finished grade shall be no higher than the trunk flare of each tree to be retained. If a grade change of six inches or more at the base of a tree is proposed, a retaining wall or tree well shall be required, unless alternative measure is specified by a qualified professional.
    - The Applicant shall provide performance surety approved by the local Conservation Commission, providing for the replacement with a qualifying new tree in the case that the existing tree dies within five years of the date of issuance of a certificate of compliance under these regulations.

What Variables are Considered for Calculation of this Credit?

This credit is provided only for impervious surfaces that are within the drip line of the tree canopy as illustrated by the figure below**.** The qualifying **Canopy Area** (CA) is the area of ground level impervious surface beneath the **Canopy Projection Area** (CP) at maturity (i.e., within the drip line) of new and existing trees for which credit is claimed. Pervious surfaces beneath the canopy are not included in this tabulation.



Runoff reduction credit based on the area of pavement beneath tree canopy

The reduction is dependent on the **provision of sufficient soil volume** (S_V) to sustain a mature tree. Each new tree must be installed in a **planting bed or trench** with a soil volume available for rooting equal to two (2) times the CP of the tree at maturity (use 40 years as the age at maturity). This volume must be adjusted for the soil volume actually provided for each tree.

These variables are used to calculate the **Effective Impervious Cover Reduction** (EIC_R) from implementation of tree canopies. The **EIC_R** may be deducted from the total area of impervious surface within the design subcatchment that must be managed as required by Standard and Standard 4.

Calculations for ESSD Credit 6

Calculating the Effective Impervious Cover Reduction (EIC_R) for New Trees:

- **Step 1:** Tabulate the qualifying Canopy Area (CA) consisting of the area of ground level impervious surface beneath the canopy projection area (i.e., within the drip line) of new trees for which this credit is claimed (**Equation A-1**). The area shall assume the tree Canopy Projection (CP) at maturity (40 years) (**Equation A-2**). Pervious surfaces beneath the canopy shall not be included in this tabulation.

$$\mathbf{CA} = \mathbf{CP} - \boldsymbol{A_{Perv}} \qquad \textbf{Equation (A-1)}$$

$$\mathbf{CP} = (\boldsymbol{\pi}) \cdot (\boldsymbol{D_{Crown}})^2 \qquad \textbf{Equation (A-2)}$$

Where,

CA is the Qualifying Canopy Area for each tree

CP is the Canopy Projection Area for each tree (**Equation A-2**)

A_{Perv} is the Pervious Area beneath the CP (e.g., area of planter)

D_{Crown} is the crown diameter of the tree at maturity (see Fact Sheet)

- **Step 2:** Calculate the Maximum Potential EIC_R for New Trees using **Equation A-3**. This formula accounts for the average interception benefit of a tree from the time it is installed (2-inch caliper) until the time it reaches its mature size.

$$\boldsymbol{EIC_{R(Max,New)}} = (\mathbf{0.075}) \cdot (\mathbf{CA}) \qquad \textbf{Equation (A-3)}$$

- **Step 3**: Verify that there is sufficient soil volume to sustain a mature tree. For full credit, each new tree shall be installed in a planting bed or trench with a soil volume (Sv) available for rooting equal to two (2) times the total canopy projection area (CP) of the tree at maturity (use 40 years as the age at maturity) (**Equation A-4**). For example, a tree with a mature crown diameter of 30 feet has an area at the drip line equal to 707 square feet. The required soil volume for this tree would be 2 x 707 = 1414 cubic feet. At four feet of soil depth, the required planting area for this tree would be 354 square feet of suitable planting material.

  If the <u>actual</u> provided Sv is less than the <u>required</u> Sv, the tree may receive partial credit, prorated based on soil volume according **Equation A-5**.

$$\boldsymbol{Sv_{Required}} = (\mathbf{2}) \cdot (\mathbf{CP}) \qquad \textbf{Equation (A-4)}$$

$$\mathbf{F} = \frac{(\boldsymbol{Sv_{Actual}})}{(\mathbf{2}) \cdot (\mathbf{CP})} \qquad \textbf{Equation (A-5)}$$

  Where F is an adjustment factor trees without adequate Sv for rooting.

- **Step 4:** Calculate the Credited EIC_R for New Trees using **Equation A-6**. For example, in the above case, if the designed planting bed has only 400 cubic feet of soil volume (e.g., 10 ft. x 10 ft. x 4 ft. depth), then the tree credit shall be multiplied by the adjustment factor (F) = 400/1414 = 0.28. That is, only 28% of the maximum allowable credit shall be allowed for that tree.

$$\boldsymbol{EIC_{R(Credited,new)}} = \mathbf{F} \cdot \boldsymbol{EIC_{R(Max)}} \qquad \textbf{Equation (A-6)}$$

Calculating the Effective Impervious Cover Reduction (EIC_R) for <u>Existing Trees</u>:

- **Step 1:** Tabulate the qualifying Canopy Area (CA) consisting of the area of ground level impervious surface beneath the canopy projection area (i.e., within the drip line) of existing trees for which credit is claimed. Project plans should document the extent of existing canopy.
- **Step 2:** Calculate the Credited EIC_R for Existing Trees using **Equation A-7**. This formula accounts for the interception benefit of the tree at the time of permit issuance, and assumes no increase in benefit over time.

$$\boldsymbol{EIC_{R(Credited,Existing)}} = (\mathbf{0.15}) \cdot (\mathbf{CA}) \qquad \textbf{Equation (A-7)}$$

Calculating the resulting Effective Impervious Cover (EIC):

- **Step 1:** Tabulate the total area of the design subcatchment's Impervious Cover (IC).
- **Step 2**: Tabulate the total Credited EIC_R for new and existing tree canopy (see previous calculations).
- **Step 3**: Compute the Effective Impervious Cover (EIC) for use in calculations for Standard 3 and Standard 4 using **Equation A-8**.

$$\mathbf{EIC} = (\mathbf{IC}) - \boldsymbol{EIC_{R(Credited)}} \qquad \textbf{Equation (A-8)}$$

Example Calculation for ESSD Credit 5

Problem Statement: A project will result in the development of 60,000 square feet of impervious surface. The site has just one drainage subcatchment. The site plans document the preservation of existing trees to provide 6,000 square feet of canopy extending over parking areas, walks, and drives. The site plans also provide for 36 new trees whose estimated crown diameter at maturity will be 40 feet (20-foot radius), if the trees are planted with sufficient space for root growth. Assume that the remainder of the site within the subcatchment will be treated by an infiltration basin (i.e., all new trees and preserved existing trees are installed over impervious cover that drains to the infiltration basin).

- 12 of the new trees will each be planted in a 10-foot by 20-foot landscaped island located in a parking area, with suitable soils extending to at least 4 feet of depth.
- The remaining 24 new trees will be planted in lawn areas and spaced so that available soil for root penetration exceeds 2600 cubic feet for each tree. The drawings document that the canopy overhanging pavement at full maturity would be 8,000 square feet.

Calculate the allowable reduction in effective impervious cover (EIC_R).

Solution:

- ❑ **Step 1:** Determine eligibility using Checklist above.
- ❑ **Step 2:** Calculate the EIC for existing trees:
  - o EIC_R existing trees = 0.15 x 6,000 sq. ft. = 900 sq. ft. (**Eq. A-7**)
- ❑ **Step 3:** Calculate the EIC for new trees planted in islands:
  - o Canopy Projection Area, each tree: CP = (π) x (20 ft.)^2 = 1,257 sq. ft. (**Eq. A-2**)
  - o Pervious area of each planter: A = 10 ft. x 20 ft. = 200 sq. ft.
  - o Impervious area beneath crown: CA_{each} = 1,257 ft. - 200 ft.= 1,057 sq. ft. (**Eq. A-1**)
  - o Total area of impervious under canopy: CA = 12 trees x 1,057 sq. ft. = 12,684 sq. ft.
  - o Maximum credit: EIC_R max. = 0.075 x CA = 0.075 x 12,684 sq. ft. = 951 sq. ft. (**Eq. A-3**)
  - o Required soil volume each tree: S_v = 2 x CP = 2 x 1,257 sq. ft. = 2,514 cu. ft. (use **Eq. A-4**)
  - o Soil volume provided each tree: S_v actual = 10 ft. x 20 ft. x 4 ft. = 800 cu. ft.
  - o Adjustment soil volume: Adj. Factor = 800 cu. ft. / 2,514 sq. ft. = 0.32 (use **Eq. A-5**)
  - o Final credit for trees in planters:
  - o EIC_R trees in islands = 0.32 x EIC_R max = 0.32 x 951 sq. ft. = 304 sq. ft. (use **Eq. A-6**)
- ❑ **Step 4:** Calculate the EIC for new trees in lawn areas, with tree canopy overhanging pavement:
  - o EIC_R trees in lawns = 0.075 x 8,000 sq. ft. = 600 square feet. (use **Eq. A-3**)
- ❑ **Step 5:** Calculate the total credit for all qualifying trees:
  - o EIC_R = 900 + 304 + 600 = 1,804 sq. ft.
  - o The credited EIC_R can be deducted from the total impervious area used for Standard 3, Standard 4, and Standard 7 pollutant removal computations – i.e., 60,000 sq. ft. minus 1,804 sq. ft. = 58,196 sq. ft.
- ❑ **Step 6**: Apply the credited EIC_R to Standard 3. Assume that the "Static Method" is used to compute the Required Recharge Volume (Rv) based on **Equation 6-1** of the Stormwater Handbook. The Rv is based on a target runoff depth of at least 1 in ($0.08\overline{33}$ ft.) times the total impervious area the post-development site of 60,000 sq. ft.
  - o The Rv without the Tree Canopy EIC reduction is therefore $0.08\overline{33}$ ft. x 60,000 sq. ft. = 5,000 cu. ft.
  - o The Rv with the Tree Canopy Credit and a 1,804 sq. ft. reduction in impervious area is therefore $0.08\overline{33}$ ft. x (60,000 sq. ft. – 1,804 sq. ft) = 4,850 cu. ft.

- [ ] **Step 7**: Apply the credited reduction in EIC to Standard 4 (or the pollutant removal requirements of Standard 7). Assume that the EPA Performance Curve presented by **Figure 6-10** of the Stormwater Handbook is used for an Infiltration Basin. According to **Figure 6-10**, a depth of runoff from upstream impervious area (D_{WQ}) of at least 0.3 in (i.e., 0.025 ft) would be required to meet the 90% TSS / 60% TP removal requirement. The required volume of the infiltration basin would therefore be computed using **Equation 6-7** of the Stormwater Handbook as the D_{WQ} times the upstream impervious area.

    - The required basin sizing to meet Standard 4 <u>without</u> the Tree Canopy EIC reduction is therefore 0.025 ft x 60,000 sq. ft. = 1,500 cu. ft.
    - The required basin sizing to meet Standard 4 <u>with</u> the Tree Canopy EIC reduction is therefore 0.025 ft x (60,000 sq. ft. – 1804 sq. ft.) = 1,455 cu. ft.

Minimize Impervious Cover

Description and Purpose

Impervious surfaces include streets, parking lots, driveways, roofs, and other areas where water cannot infiltrate naturally into soil. Replacing natural vegetation and soils with impervious surfaces leads to increased runoff volume and velocity, larger pollutant loads, and may adversely affect long-term hydrology and natural systems through flooding and channel erosion. Research demonstrates a decrease in fish, amphibian, and insect species when the percent imperviousness within a watershed exceeds 15%.

By minimizing impervious cover, a Applicant can decrease stormwater runoff, increase infiltration and evapotranspiration, and minimize the collection, concentration, and conveyance of runoff. In urban development, streets usually account most of the impervious area, while parking lots and rooftops are the largest contributors on commercial sites. The techniques incorporated into overall road design will depend on the soils, development density, zoning, and use of the receiving water.

ESSD Credits

As indicated in the “Introduction” section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There is one ESSD Credit associated with this Fact Sheet:

- **Credit 6:** Reduce Impervious Area at Redevelopment Sites

See below for more information on this credit.

Planning Considerations

Careful site planning can reduce the impervious area created by pavement and roofs and the volume of runoff and pollutant loading requiring control. As the impervious surface area of a development increases, the size and expense of the stormwater control facilities also increase. Minimizing impervious surfaces mitigates this problem and provides more space for conservation of natural features and design of more functional SCMs. Local zoning and development standards, such as those addressing road widths or cluster zoning, affect the amount of runoff generated by projects.

Applicable Regulations

To ensure a reliable source of safe drinking water, it is essential that impervious areas be minimized in certain recharge areas. To further that goal, the Massachusetts Drinking Water Regulations (310 CMR 22.00) require that municipalities proposing new groundwater sources for a public water system enact land use controls to prohibit land uses within the Zone II that create impervious cover exceeding 2,500 square feet or 15% of a lot, whichever is greater. These standards can only be exceeded if a system for artificial recharge of precipitation is provided which ensures that there is no degradation of groundwater quality. The Drinking Water Regulations impose a similar requirement on municipalities proposing new Surface Water sources.

Common Approaches

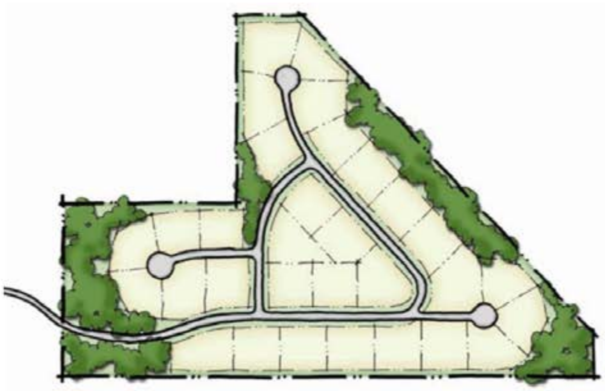
- **Maintain as much of the pre-development vegetation as possible**, especially larger trees that may be on site. Vegetation absorbs water and reduces the amount of stormwater runoff.
- **Reduce frontage and other setbacks** to reduce driveway length.
- **Modify zoning** to allow *planned unit developments* that limit the density while maximizing the amount of undisturbed open space and *cluster developments* that cluster or group buildings closer together to maximize undisturbed open space.
- **Reduce the horizontal footprint of buildings**. Footprint size can be reduced by constructing a taller building, including parking facilities within the building itself, while maintaining the same floor to area (FAR) ratio.
- **Reduce the size of parking areas***:* Parking areas can be reduced by shrinking the parking lot stalls, reducing the circulation area, using a diagonal parking stall configuration, or building structured

parking garages. Parking areas with adjacent or nearby facilities can be shared.

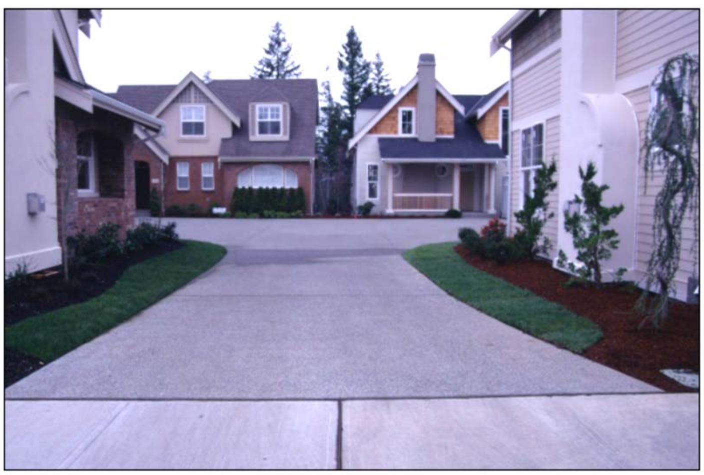
- **Reduce to one lane***,* or eliminate if practical, on-street parking lanes on local access roads.
- **Limit sidewalks to one side**, or eliminate if practical, on local low-traffic roads.
- **Implement shared driveways** to provide access to several homes.
- **Reduce driveway length or width**.

Examples of Common Approaches

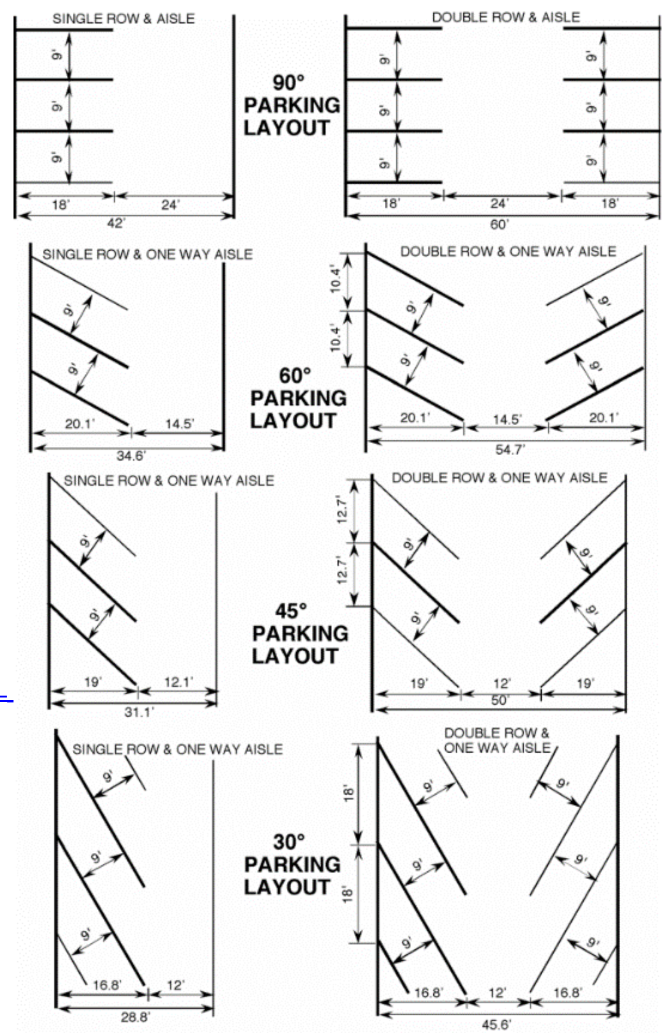
1. Cluster Development (Puget Sound Action Team 2005)



2. Shared Driveways (Puget Sound Action Team 2005)



3. Parking Angle (Virginia Asphalt Association



References

Puget Sound Action Team, Office of the Governor, Olympia, Washington. 2005. Low Impact Development Technical Guidance Manual for Puget Sound https://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf

Virginia Asphalt Association, Parking Lot Design - https://vaasphalt.org/pavement-guide/pavement-design-by-use/parking-lot-design/

ESSD Credit 6: Reduce Impervious Area at Redevelopment Sites

This ESSD Credit is available for the reduction of total impervious area (TIA) at Redevelopment sites. If all requirements of this credit are met, a project Applicant need not implement any additional ESSD / LID techniques to satisfy the ESSD / LID implementation requirement summarized by **Section 4.2** of the Stormwater Handbook. This credit also consists of a reduction in TIA which, by definition, is deducted from the total area of impervious surface that must be managed as required by Standard 2, Standard 3, Standard 4, and the pollutant removal requirements of Standard 7

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Consists of a reduction in Total Impervious Area (TIA) which, by definition, is deducted from the total area of impervious surface that must be managed as required by Standard 2.
3 - Recharge	Consists of a reduction in Total Impervious Area (TIA) which, by definition, is deducted from the total area of impervious surface that must be managed as required by Standard 3.
4 - TSS/ TP Removal	Consists of a reduction in Total Impervious Area (TIA) which, by definition, is deducted from the total area of impervious surface that must be managed as required by Standard 4 or the pollutant removal requirements of Standard 7.
5 - Higher Pollutant Loading	May be used for runoff from land uses with Higher Potential Pollutant Loads (LUHPPLs).
6 - Discharges near or to Critical Areas	May be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	May be used to treat all TMDL pollutants specified in **Table 2-6** of the Stormwater Handbook if minimum criteria are met.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Minimum Required Criteria

This ESSD Credit is only available when the following criteria are met:

- ❑ The project is a Redevelopment.
- ❑ Total Impervious Area (TIA) of the site must be reduced by at least **15%** from existing conditions.
- ❑ The resulting TIA of the site must be less than **75%** of the base lot area.
- ❑ The Site Plan must clearly demonstrate the existing TIA, the proposed TIA, and the resulting percent reduction.

Example Calculation for ESSD Credit 6

Problem Statement: Assume a 10.0-acre site to be redeveloped for a retail use. The existing impervious area is 2.0 acres, including a parking lot. The developer proposes to reduce the impervious area by 0.5 acres by reducing the size of the parking lot and reducing the size of the proposed building's footprint.

Solution:

- ❑ **Step 1:** Determine the change Total Impervious Area using **Equation A-9**.

$$\Delta \text{TIA} = \frac{A_{\text{IMP (proposed)}} - A_{\text{IMP (initial)}}}{A_{\text{IMP (initial)}}}$$

Where,

ΔTIA is the precent change in TIA Impervious Area

$A_{IMP(initial)}$ is the Initial Impervious Area

$A_{IMP(proposed)}$ is the Proposed Impervious Area

ΔTIA = (1.5 acres – 2 acres) / 2 acres = 25% reduction in TIA

- ❑ **Step 2:** Use the resulting TIA to design SCMs to meet all Stormwater Standards.

Protecting and Enhancing Buffer Areas

Description and Purpose

A Buffer Zone is an area of land extending outward from the boundary of any area specified in 310 CMR 10.02(1)(a) (e.g., Bordering Vegetated Wetland). Buffers can be used to protect water quality and to prevent erosion and sedimentation along wetlands, streams and other Surface Waters. Buffers can also be incorporated into natural landscaping of an area.

Buffers provide a living filter to reduce erosion and runoff velocities, especially on unstable steep slopes. Through protecting or enhancing buffer areas, a project Applicant can partially or completely prevent discharge of nonpoint source pollutants such as sediment, organic material, nutrients, and pesticides. Buffers can also provide benefits beyond those related to water and drainage, including protection of critical habitat adjacent to streams and wetlands, corridors for wildlife movement, aesthetic benefits, and a visibility and noise screening.

ESSD Credits

As indicated in the “Introduction” section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There is one ESSD Credit associated with this Fact Sheet:

- **Credit 7:** Protect or Enhancing Buffer Areas

See below for more information on this credit.

Common Applications

The following approaches are commonly used to enhance or protect buffer areas:

- **Acquisition and Protection:** Involves obtaining easements or full fee acquisition rights for wetlands and riparian areas along inland and coastal Surface Waters and wetland resources areas. May also rely on regulation to restrict activities that have negative impacts on wetlands and riparian areas through special area zoning and transferable development rights.
- **Restoration:** Restoration is the return of an area to conditions similar to those present prior to disturbance, by re-establishing the characteristics of buffer areas that promote vegetative composition and cover, flow characteristics of Surface Water and groundwater, hydrology and geochemical characteristics of substrate, and species composition.

Effectiveness

The ability of a buffer to remove pollutants is dependent on the width of the buffer, the type of vegetation, the manner in which runoff traverses the vegetated areas, the slope, and the soil composition within the buffer area (Cohen 1997). Effectiveness increases with increased detention time, and is reduced significantly in the absence of sheet flow. If the buffer is intended to function as a stormwater control measure (SCM), it may be used in conjunction with other SCMs, such as grass filter strips on the outer edge of the buffer to help diffuse runoff.

Planning Considerations

The following impact a buffer’s capacity to remove pollutants from runoff:

- **Soil type** influences infiltration and pollutant removal. Hydrologic Soil Group (HSG) A soils have desirable high infiltration rates and are optimal for removal of Total Suspended Solids (TSS) and Total Phosphorus (TP).
- **Historically forested soils** are beneficial to a buffer’s pollutant removal capacity because they have high organic content, can closely mimic hydric soils, and typically have limited compaction.
- **Hydrologic flow path** is determined by topography and soil. Wetlands and areas with a high-water table increase hydraulic residence time, which allows for greater pollutant removal from runoff.
- **Slope** impacts the sediment removal, with buffer slopes less than 5% being good for removal. Slopes above 5% may be less effective.

- **Land use intensity** (e.g., amount and type of developed land and impervious surfaces) of the area draining into the buffer and the buffer itself will affect pollutant removal performance.
- **The pollutant removal effectiveness** is typically optimal in diverse buffers that are densely vegetated with woody species (e.g., forested buffers with dense growth of canopy trees and under-canopy tree and shrub species). Buffers that become forested or more diverse over time are expected to become more effective.

Healthy, intact buffers protect water quality by reducing pollutants from entering water bodies. The following should be considered when protecting or enhancing existing Buffer Areas:

- **Preserving existing natural vegetation** is generally the easiest and most successful method.
- Establishing **new buffer areas** requires an appropriate soil planting layer – typically a loamy topsoil 12-18 inches in depth. Depending on the site, the existing soils may need to be amended to ensure success of tree and shrub plantings. Careful maintenance is important to ensure establishment of healthy vegetation, particularly in the first growing season.
- Leave all **unstable steep slopes** in natural vegetation.
- Fence or flag **clearing limits** and keep all equipment and construction debris out of the natural areas.
- Keep all excavations outside the **dripline of trees** and shrubs.
- Do not push **debris or extra soil** into the Buffer Zone area because it will cause damage from burying and smothering.

Maintenance

Potential maintenance activities include watering for the first year of replanting or in drought conditions, selective cutting, replanting and weed control (hand weeding or careful spraying). Existing buffer areas need little or no maintenance. Fertilization should be avoided. It is important that maintenance activities do not cause soil compaction, excessive disturbance or impact close to the river (CH2MHILL 1998). Fallen or decaying vegetation in established areas should not be removed. Excessive raking, brush clearing or plant removal can reduce water detention time and breakdown of pollutants by plants and microorganisms (Cohen 1997).

References

CH2MHILL. 1998. Pennsylvania Handbook of Best Management Practices for Developing Areas.

Cohen, R. 1997. Fact Sheet # 8: Functions of Riparian Areas for Pollution Prevention. Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement, Massachusetts Riverways Program.

MassDEP Massachusetts Clean Water Toolkit, Buffer Zones, Stream Corridors and Riparian Areas - https://megamanual.geosyntec.com/npsmanual/bufferzones.aspx

MassDEP Massachusetts Clean Water Toolkit, Riparian Forest Buffers - https://megamanual.geosyntec.com/npsmanual/riparianforestbuffers.aspx

Roca Communications, June 2019, Pollutant Removal Credits for Buffer Restoration in MS4 Permits Final Panel Report, http://nerrssciencecollaborative.org/media/files/CGG/Green_Credit_%20Report_June2019.pdf

ESSD Credit 7: Protect or Enhance Buffer Areas

This ESSD Credit is available when runoff from upgradient impervious surfaces is directed to a vegetated buffer via sheet flow. This credit is applicable to new development and Redevelopment projects that plant a **new** buffer, **expand** (enhance) an existing buffer, or **protect** an existing buffer. See below for the ability of this ESSD Credit to meet specific Stormwater Standards. The Applicant must meet all required criteria to be eligible for this credit.

Note: This credit is only applicable to the impervious area discharged to the vegetated buffer and not the entire site. All calculations must be performed based on drainage subcatchment and not the entire site. Run-on from any offsite areas must be included in any subcatchment calculations.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Peak rate attenuation requirement is assumed to be met for the portion of the site that drains to the buffer area if all minimum criteria are met. The peak rate attenuation requirement for this credit does not need to be demonstrated by modeling.
3 - Recharge	Use **Table Buffer 1** to determine recharge credit. Provides 1-inch of groundwater recharge credit for the portion of the site that drains to the buffer area if all minimum criteria herein are met.
4 - TSS/ TP Removal	Use **Table Buffer 1** to determine pollutant removal credit. Provides 90% TSS removal and 60% TP removal for the portion of the site that drains to the buffer if all minimum criteria are met.
5 - Higher Pollutant Loading	May not be used for runoff from land uses with Higher Potential Pollutant Loads (LUHPPLs) <u>except</u> for parking lots with high-intensity uses that generate more than 1,000 vehicle trips per day or more.
6 - Discharges near or to Critical Areas	May be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	May be used to treat all TMDL pollutants specified in **Table 2-6** of the Stormwater Handbook if minimum criteria are met.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Recharge and Pollutant Removal Credit

Recharge and pollutant removal credit for protecting and enhancing buffer areas is based on the Hydrologic Soil Group Type of the buffer area and the ratio of impervious area to impervious area (**Table Buffer 1)**.

If the ratio of impervious area to pervious area does not match those provided by the table, use the ratio that is <u>nearest to, but more than</u>, the determined ratio. For example, if the impervious area to pervious area ratio is 3 to 1, calculate pollutant removal credit based on a ratio of 4 to 1.

Table Buffer 1. Recharge and pollutant removal credits for protecting and enhancing buffers.

Impervious Area to Pervious Area Ratio	HSG A	HSG B	HSG C
8:1	NC	NC	NC
6:1	NC	NC	NC
4:1	NC	NC	NC
2:1	NC	NC	NC
1:1	✓	✓	NC
1:2	✓	✓	✓
1:4	✓	✓	✓
1:10	✓	✓	✓
1:30	✓	✓	✓
1:50	✓	✓	✓

Table Key:

- **Check Mark (✓) =** Credit is provided for 1-inch recharge, 90% TSS removal, and 60% TP removal.
- **NC =** No credit is provided for recharge or pollutant removal.
- Assumes that all minimum required criteria are met.

Minimum Required Criteria

This ESSD Credit is only available when the following criteria are met.

- ❑ No work, including any alteration for stormwater management, may be proposed within any Wetland Resource Area except for Riverfront Area (RA), Bordering Land Subject to Flooding (BLSF), Isolated Land Subject to Flooding (ILSF), or Land Subject to Coastal Storm Flowage (SCSF). The underlying Performance Standards in these Resource Areas must be met.
- ❑ The buffer width shall be measured horizontally outwards (i.e., upgradient) from the boundary of the Wetland Resource Area.
- ❑ The minimum buffer width shall be **50 feet** for Redevelopment Projects and **75 feet** for New

Development Projects except for projects within Riverfront Area. The minimum buffer width shall be at least **100 feet** for all projects within the Riverfront Area.

- ❑ Buffer improvements must protect or enhance the entire length of any Buffer Zone within the design subcatchment.
- ❑ The flow path to the buffer shall be no more than **75-feet** long on impervious surfaces, and no more than **300-feet long** on landscaped areas, so flow won't concentrate.
- ❑ The average contributing overland slope to and across the buffer shall be less than or equal to **5%**.
- ❑ Recharge and pollutant removal credit must be calculated based on **Table Buffer 1**.
- ❑ Runoff shall enter the buffer uniformly across its entire length as sheet flow. If needed, use a level spreader to accomplish this. No closed drainage is allowed. Curb cuts that direct flow, swales, pipes, or other conveyances would be considered point sources and are not allowed.
- ❑ The elevation at the interface between the impervious surface and landscaped / vegetated areas needs to be equal. There can be no drop in slope at the interface for at least **20-feet**. A gravel strip may also be established at the interface to induce interflow (see "Pea Gravel Diaphragm with Filter Strip").
- ❑ For flow from parking lots to buffer area, establish a hard edge with no reveal at the interface of impervious surface and landscaped / vegetated areas (see **Figure Buffer 1** for example schematic).
- ❑ The underlying soils must be classified as Hydrologic Soils Group A, B, or C in accordance with procedures outlined in **Section 6.3.2** of the Stormwater Handbook.
    - o Urban Fill is not acceptable at locations where a **new buffer** is being planted or an **existing buffer** is being **expanded** unless the Urban Fill is removed and replaced with clean topsoil or hydrogeological testing is conducted indicating the filled soils are relatively homogeneous horizontally and vertically with a vertical saturated hydraulic conductivity (K_{sat}) equivalent to a Hydrologic Soil group A, B, or C in accordance with **Section 6.3.2** of the Stormwater Handbook. Also, see **Section 6.3.4** of the Stormwater Handbook, "When Fill Materials are Determined to be Present", for additional requirements.
- ❑ This credit may not be used for runoff from a LUHPPL except for for high-intensity parking lots that generate 1,000 or more vehicle trips per day.
- ❑ This credit may <u>not</u> be used for runoff from a metal roof unless the building is located outside a Zone II or Interim Wellhead Protection Area and the building must not be used for industrial purposes.
- ❑ All buffer improvements shall include a deed restriction with a restrictive covenant indicating that the **new**, **expanded,** or **protected** buffer must not be disturbed and must be unmanaged with the exception of routine debris and litter removal. The provisions contained within the deed restriction shall bind the landowners and their heirs, devisees, legal representatives, successors and assigns.
- ❑ Once planted, the boundary of the **new, expanded,** or **protected** buffer must be demarcated with permanent stone or concrete markers. Each marker must be at least 4 inches wide by 4 inches long by 30 inches tall. Each marker shall include a weatherproof permanent plaque or engraving with clearly visible writing that reads: "*Protected Buffer Area, Do not Disturb*". Markers must be placed in coordination with the Conservation Commission. It Is recommended that permanent markers be placed along the entire perimeter of the **new**, **expanded,** or **protected** buffer with at least one marker being placed every 200 feet. Markers must also be installed at all prominent angles (e.g., corners).
- ❑ The buffer must be unmanaged with the exception of routine debris and litter removal. The Operation and Maintenance Plan (O&M Plan) required by Standard 9 must specify how the buffer area will be managed. If used, the O&M Plan must also include provision to maintain level spreaders and gravel strips.
- ❑ This ESSD Credit may not be used in locations where information is submitted during the public hearing or introduced by the Conservation Commission that there is a demonstrated history of groundwater flooding.
- ❑ All planting requirements must be met as listed directly below.

Planting Requirements

- ❑ All **new**, **expanded**, or **protected** buffers must be comprised predominantly by woody species (trees or shrubs). Grassed or predominantly herbaceous buffers are not allowable.

For existing buffers to be protected:

- ❑ The Applicant must document that the areal coverage of canopy from tree and shrub species is at least 75% of the buffer area. Documentation can be provided based on a field assessment from a forester, wetland scientist, or other qualified botanist with experience in estimating the areal coverage of vegetation, and may be supported by the use of recent aerial imagery that represents conditions which are similar to those at the time of application submittal (i.e., no tree cutting or land clearing has occurred after the date of the imagery).

For new or expanded buffers:

- ❑ All plantings shall be native to New England.
- ❑ Shrubs and trees must be planted with uniform density throughout the buffer.
- ❑ At least 200 trees shall be planted per acre (minimum spacing between plantings of 15-feet on center).
- ❑ At least 450 shrubs shall be planted per acre (minimum spacing between plantings of 10-feet on center).
- ❑ If planting a mixture of trees and shrubs, the planting densities and spacing listed above must be maintained. If a shrub is planted directly adjacent to a tree, the on center spacing between the shrub and the tree must be a maximum of 10 feet.
- ❑ Planted shrubs shall be at least 18-24 inches tall. Planted trees shall be at least 24-26 inches tall. Larger plantings will generally have a higher survival rate than smaller plantings.
- ❑ Upon planting, stabilize areas between woody species with a New England native seed mix that is appropriate for the planted location based on moisture, sun, shade, and other factors such as proximity to roads.
- ❑ The buffer will be considered established when 75% of the planted trees and shrubs are alive after 2 growing seasons. If there are less than 75% live planted trees or seasons and natural regeneration (i.e., growth of volunteer woody species) has not made up the loss, re-planting must be performed.

Site Plans

In addition to requirements described in **Section 6.1.3** of the Stormwater Handbook, the site plans submitted with the NOI or WQC Application must include the following:

For all new, expanded, or protected buffers:

- ❑ Provide a tabulation and visual representation that all required dimensions from the "minimum required criteria" area met (e.g., width, length, average slope, maximum upland flow path, ratio of impervious to pervious area).

For existing buffers to be protected:

- ❑ The planting plan must visually depict the areal coverage of canopy from woody species described previously. Woody species must comprise at least 75% of the buffer area.
- ❑ The planting plan must include a summary table that indicates that proposed buffer area and dimensions.

For new or expanded buffers:

- ❑ The planting plan must visually depict proposed planting locations, proposed planting type (i.e., shrub vs. tree), proposed New England native species type, and proposed spacing.
- ❑ The planting plan must include summary tables that provide a list of each species type, whether the species is a tree or a shrub, what the proposed minimum spacing is, and how many are proposed to be planted.
- ❑ The summary tables must clearly indicate the proposed buffer area, the total number of proposed shrubs and trees, and the total number of proposed shrubs and trees to be planted per acre.

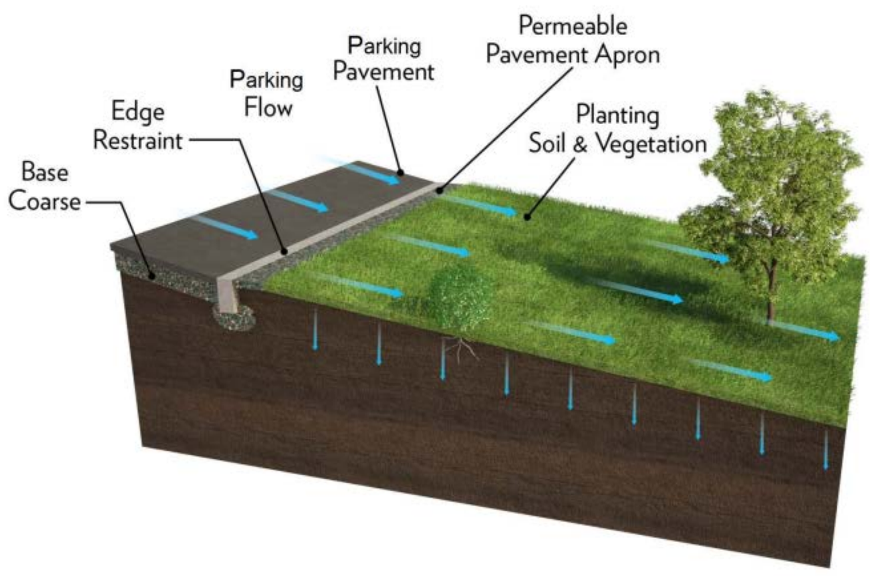


Figure Buffer 1. Example schematic of interface between impervious and pervious surface with a zero reveal edge restraint. *(Image source: 2019 RIDOT Linear Stormwater Manual)*

Example Calculation for ESSD Credit 7

Problem Statement: Assume a 3.0 ac site to be redeveloped for a retail use. The resulting impervious area of the proposed Redevelopment will be 1.6 ac. The existing site is comprised of a strip mall surrounded by impervious pavement. The impervious pavement along the northern portion of the site is located in the Buffer Zone of a Bordering Vegetated Wetland (BVW) with an approximate length of 250 ft. The Redevelopment proposes to remove the pavement located within the Buffer Zone and plant a new vegetated buffer. *Determine the physical criteria that would be required to implement a new buffer at this location, then calculate the credited reduction in Required Recharge Volume (Standard 3) and TSS / TP removal (Standard 4 or Standard 7) that will result from implementation of the buffer.*

- ❑ **Step 1,** Design the physical characteristics of the proposed buffer.
  - The **new** vegetated buffer will be planted along the entire 250 ft length of Buffer Zone that borders on the BWV. The new buffer will have a <u>minimum</u> width of 50 ft. The buffer will <u>not</u> be planted within the Wetland Resource Area. The overall area of the proposed buffer will be 14,000 sf.
  - The new buffer will receive uniform sheet flow from an upgradient parking lot with an average contributing overland slope to the buffer of 2% and a <u>maximum</u> contributing upland distance of 65 ft. The average slope across the buffer will also be 2%. The overall area of the contributing upgradient parking lot will be 15,000 sf.
  - The ratio of impervious area to buffer area will be 15,00 sf / 14,000 sf = 1.1). This number must be rounded <u>up</u> to select the nearest ratio of 2:1 for use in calculating pollutant removals and recharge (**Table Buffer 1**).
  - Based on a soil evaluation performed in accordance with **Section 6.3.2**, the subgrade (i.e., native material) that underlies the existing pavement and aggregate subbase is classified as Hydrologic Soil Group B. The existing pavement and aggregate sub-base will be removed prior to planting and replaced with clean topsoil prior to planting.
  - The buffer will be comprised entirely of New England native tree species planted with a uniform density of at least 200 trees per acre with a spacing of at least 15-feet on center. The area of the proposed buffer is 14,000 sf (0.32 ac). The minimum number of tree plantings is therefore 0.32 x 200 = 64 trees.
- ❑ **Step 2,** Verify that the buffer meets all other minimum required criteria and requirements as listed previously (e.g., site plan preparation, zero percent drop at impervious/pervious interface, preparation for permanent markers, etc.).
- ❑ **Step 3,** Calculate the credited reduction in recharge volume.
  - Assume that the "Static Method" is used to compute the Required Recharge Volume (Rv) based on **Equation 6-1** of the Stormwater Handbook. The Rv is based on a target runoff depth of at least 1 in ($0.08\overline{33}$ ft) times the total impervious area of the post-development condition of 1.6 ac (69,696 sf). The Rv for the entire site is therefore $0.08\overline{33}$ ft x 69,696 sf = 5,808 cf.
  - The buffer will capture 15,000 sf of upgradient impervious area from the contributing parking lot. Implementation of the buffer is credited with 1 in of groundwater recharge from the impervious area directed to the buffer via uniform sheet flow. The site's Rv will therefore be reduced by $0.08\overline{33}$ ft x 15,000 = 1,249.5 cf. Additional ESSD / LID techniques will be required to recharge the remaining Rv (i.e., 5,808 – 1249.5 = 4558.5 cf).
- ❑ **Step 4,** Calculate the credited pollutant TSS and TP removal.
  - Implementation of the buffer is credited with a removal of 90% TSS and 60% TP from 15,000 sf of impervious area directed to the buffer via uniform sheet flow from the contributing parking lot (i.e., based on a ratio of impervious area to pervious area of 2:1 in accordance with **Table Buffer 1**)
  - The remaining impervious area of the site must be treated with additional ESSD / LID techniques to meet the overall 80% TSS and 50% TP removal requirement of Standard 7.

Preserve and Use Natural Drainage Systems

Description and Purpose

Instead of replacing natural drainage features with engineered systems that rapidly convey runoff downstream, existing natural drainage features such as “country drainage” can be incorporated into the design. Natural drainage systems can help to reduce or eliminate the need for structural drainage systems by helping to maintain flood volumes, peak discharges, and base flows at pre-development levels. Trace metals, hydrocarbons, and other pollutants will also bind to the underlying soils and organic matter. The infiltration process allows for separation of the nutrients and other contaminants from stormwater as it percolates through the subsurface soils.

ESSD Credits

As indicated in the “Introduction” section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There are no numerical ESSD Credits associated with this Fact Sheet; however, practices that preserve that use natural drainage systems are recognized to be ESSD / LID by MassDEP as defined by **Section 4.2.1** of the Stormwater Handbook.

Applicability

Natural drainage systems are best used in residential development, particularly lower density single-family areas. Protecting and conserving natural drainage features or designing a road with country drainage becomes more difficult in higher density developments with more impervious cover, such as commercial and industrial developments.

Standard Approach

The standard approach of using curbing on streets and parking areas impairs natural drainage systems. Curbs are widely held to be the signature of quality development; they provide a neat, “improved” appearance and also help delineate roadway edges. Because curb-and-gutter streets trap runoff in the roadbed, storm inlets and drains are logical solutions to providing good drainage for the roadbed. Unfortunately, a requirement for curb-and-gutter streets can create significant stormwater management problems. Because storm drains operate on gravity flow, their efficiency is maximized if they are located in the lowest areas of the site.

Storm drain pipes are usually located in valleys and low areas, destroying natural drainage ways. Natural filtration and infiltration capacities are lost in the most strategic locations.

Further, in most instances, storm drains are designed for short-duration, high-frequency storms and not for flood flows, which are handled by street and gutter flows after the storm drain capacity is exceeded. The result is that the natural drainage ways are converted from slow-moving, permeable, absorptive, vegetated waterways to fast-moving, impervious, self-cleaning, paved waterways, thereby increasing hydraulic efficiency, peak discharges and flood volumes.

When natural waterways are paved and designed to quickly drain to the culverted stormwater management system, this will minimize channel storage times as well as reduce base flows and groundwater recharge. When examined in the context of environmentally sensitive site design, the net effect of the seemingly beneficial decision to use curbs can initiate a snowball effect that amplifies the extremes in the hydrologic cycle, increasing flood flows and reducing base flows.

Curb-and-gutter developments also affect water quality. Trace metals from automobile emissions and hydrocarbons from automobile crankcase oil and fuel spillage are directly deposited on paved surfaces. For the most frequent rainfalls, the first flush of stormwater runoff washes these deposits into the storm drain system, which is designed to keep in suspension the particles to which the pollutants adhere. The particles, together with their attached pollutants, are delivered via the runoff water to receiving waters where reductions in velocity permit them to settle out. Nutrient-rich runoff from surrounding lawns quickly moves through the paved system with no opportunity to come into contact with plant roots and soil surfaces. The result is rapid delivery of contaminants to lakes, streams, estuaries, and wetlands.

Design Considerations

Preserving or incorporating natural drainage pathways into site designs can reduce or eliminate the need for stormwater pipe networks, which can reduce costs, maintenance burdens, and site disturbance related to pipe installation. Natural drainage features should be identified during the site analysis and used to guide site design. Natural drainage features may include, but aren't limited to:

- swales;
- drainage pathways;
- natural depressions;
- wetlands;
- perennial and intermittent streams; and
- water bodies.

These existing features should be protected during construction with any disturbance minimized. When incorporating natural drainage features into site design, they should be planted with native vegetation. Upstream conditions need to be considered when preserving or incorporating natural drainage, since runoff volumes and rates can be significantly increased by development. Stormwater control measures (SCMs) may be necessary in the design to prevent the erosion and degradation of the natural drainage features.

References

Photo credit: https://megamanual.geosyntec.com/npsmanual/waterqualityswales.aspx
https://megamanual.geosyntec.com/npsmanual/checkdams.aspx

No Disturbance to Wetland Resource Areas

Description and Purpose

Protection of Wetland Resource Areas (WRAs) is one of the most important considerations when designing a stormwater management system. WRAs provide a variety of ecological functions, including water quality improvement for receiving waters, flood storage, groundwater recharge, wildlife habitat, etc. WRA and their Buffer Zone are protected under the Massachusetts Wetlands Protection Act (WPA).

A primary objective of the site planning and design process should be to **avoid direct wetland impacts**. Where impacts are unavoidable, they must be minimized and mitigation (e.g., constructed wetlands, wildlife habitat improvements) must be provided. Proper design of stormwater systems is necessary to prevent excess sediment and other pollutants from discharging to wetlands, which can lead to impairment of the important functions that they provide.

ESSD Credits

As indicated in the “Introduction” section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There are no numerical ESSD Credits associated with this Fact Sheet; however, practices that preserve that use natural drainage systems are recognized to be ESSD / LID by MassDEP as defined by **Section 4.2.1** of the Stormwater Handbook.

Applicability

The WPA regulations, at 310 CMR 10.02(1)(a) through (f), define WRAs as the following “Areas Subject to Protection under the Act”:

Inland wetlands, e.g., bordering vegetated wetlands (wet meadows, marsh, swamp or bog bordering any creek, river, stream, pond or lake), bank, land under water, land subject to flooding, and the riverfront area.

Coastal wetlands, e.g., coastal banks, coastal beaches, coastal dunes, land under the ocean, designated port areas, barrier beaches, rocky intertidal shores, land under salt ponds, land containing shellfish, land subject to coastal storm flowage, and salt marsh; and

Maintenance

The Operations and Maintenance Plan required by Standard 9must provide that best practical measures be implemented to conduct maintenance activities in a manner that avoids, minimizes and mitigates adverse impacts to WRAs.

Additional Information

Refer to **Section 2.3** for more information on stormwater management and wetland protection regulations, including:

- Point source and non-point source discharges
- Erosion and Sedimentation control
- Stormwater discharges outside WRAs
- Regulatory requirements after the fact
- Conversion of impervious surfaces to pervious surfaces
- Operation and maintenance
- Jurisdiction over stormwater management systems

References

MassDEP Massachusetts Clean Water Toolkit, Wetlands, Vernal Pools, and Forestry Operations in Massachusetts. https://megamanual.geosyntec.com/npsmanual/wetlandsvernalpoolsandforestry.aspx

Photo credit: https://megamanual.geosyntec.com/npsmanual/wetlandsvernalpoolsandforestry.aspx

Small Scale Controls

Description and Purpose

Small scale controls, including some Low Impact Development (LID) techniques, are small-footprint stormwater control measures that can be variably sized to treat storms that generate less than 1-inch of runoff and, in aggregate, can account for the total pollutant removal required on-site. Small-scale control measures are designed to reduce, treat, and infiltrate stormwater at its source and are meant to provide stormwater management options on sites that have limited space for traditional sized Stormwater Control Measures (SCMs), or within rights-of-ways.

ESSD Credits

As indicated in the “Introduction” section of this Appendix, a suite of ESSD Credits is available to encourage project Applicants to implement MassDEP recognized Environmentally Sensitive Site Design (ESSD) and Low Impact Development (LID) techniques. There are no numerical ESSD Credits associated with this Fact Sheet; however, practices that preserve that use natural drainage systems are recognized to be ESSD / LID by MassDEP as defined by **Section 4.2.1** of the Stormwater Handbook.

Types of Small Scale Controls

Small scale controls are intended to capture the first flush of stormwater runoff. The Stormwater Standards define the first flush as the first inch of stormwater runoff from the beginning of a storm, which carries concentrated pollutants including suspended sediments. Pollutant concentrations are typically higher at the beginning of a storm than at the middle or end of the storm.

Small scale controls are often possible using existing or proposed site features and can be replicated over an entire site. Implementation of small scale controls can conserve natural drainage pathways and open space and significantly reduce the impact from development. Small scale controls can also provide additional benefits beyond those related to water quality and drainage, such as increased property values, reduced energy costs, noise control, and habitat for wildlife.

Example rain garden

Example green roof

Example tree box filter

Examples of small scale LID practices include the following:

- Bioretention and rain gardens, tree box filters, stormwater planters
- Dry wells and infiltration trenches
- Roadside water quality swales
- Vegetated filter strips
- Porous pavement
- Green roofs

Small scale controls must be designed, installed, and maintained in accordance with the Stormwater Standards. Refer to the Structural SCM Specifications in this appendix.

Planning Considerations

- During the planning process, an Applicant should identify small scale source controls that could reduce the requirements for structural stormwater SCMs and prevent the discharge of pollutants to receiving waters.
- When planning to use small scale controls that include vegetation, Applicants should develop a planting plan with drought-tolerant native species that typically require less maintenance.

References

MassDEP Massachusetts Clean Water Toolkit, Low Impact Development Site Design: https://megamanual.geosyntec.com/npsmanual/lowimpactdevelopmentsitedesign.aspx

Nonstructural SCMs

- **Street Cleaning**

Street and Parking Lot Cleaning

Description and Purpose

Street and parking lot cleaning is a nonstructural method of controlling pollutants in storm water. It involves the use of mechanical, vacuum, or regenerative air pavement cleaning equipment (and sometimes manual labor), to remove particulates from the pavement surface prior to wash-off by storm water runoff. Many municipalities and some private entities have street cleaning programs.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	Provides TSS and TP removal if minimum criteria are met in accordance with **Table SC.1**.
5 - Higher Pollutant Loading	May be used for runoff from LUHPPL if minimum criteria are met.
6 - Discharges near or to Critical Areas	May be used for discharges near or to Critical Areas.
7 - Redevelopment	May be used for Redevelopment.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
11 - Total Maximum Daily Loads	Does not meet any TMDL treatment requirements
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Minimum Required Criteria

Street cleaning can qualify for pollutant removal credit at the discretion of the Issuing Authority as listed by **Table SC.1**. To obtain pollutant removal credit, street cleaning must be performed on a monthly basis for at least 10 months of the year (excluding January and February).

Credit is contingent on a signed agreement by the Owner that specifies sweeping frequency, type of technology, the impervious area or road miles cleaned, and the general land use type(s) of the impervious area cleaned. Street and parking lot cleaning are applicable to new development and Redevelopment projects.

Pollutant Removal Credit

TSS and TP removal credit for street and parking lot cleaning is based on the following table.

Table SC.1 Pollutant removal credits for street and parking lot cleaning

Sweeper Equipment	TSS (%)	TP (%)
Mechanical Broom	3	2
Vacuum Assisted	5	3
Regenerative Air	16	7

Effectiveness

Although intended to provide nonpoint source pollution control, many street cleaning programs are not effective at capturing peak sediment loads. There are many reasons that some street cleaning programs are not effective, including:

- The period immediately following winter snowmelt, when road sand and other accumulated sediment and debris is washed off, is frequently missed by street cleaning programs.
- Larger particles of street dirt may prevent smaller particles from being collected.
- The entire width of roadway may not be swept.
- Sweepers may be driven too quickly to achieve maximum efficiency.
- Land surfaces along the paved surfaces may not be entirely stabilized.

Studies have also shown that street cleaning can be highly effective if conducted properly (Breault 2005, Zarriello 2002). As described below, there are three primary factors that can have a major influence on the effectiveness of a street cleaning program: access, sweeper type, and frequency of cleaning.

Access

Parked cars impede street cleaning. Studies have shown that up to 95% of the solids on a paved surface accumulate within 9 feet of the curb, regardless of land use (Sorenson, 2013). It is essential that entities responsible for stormwater maintenance have the authority to impose parking regulations to facilitate proper cleaning, particularly in densely populated or heavily traveled areas, to allow sweepers to get as close to curbs as possible.

Equipment

There are three types of street cleaners: mechanical broom, vacuum assisted, and regenerative air. Each has a different ability to remove TSS and TP (see **Table SC.1**).

- **Mechanical Broom:** Mechanical sweepers use brooms or rotary brushes to scour the pavement. Although most sweepers currently in use in Massachusetts are mechanical sweepers, they are not as effective as other methods and are especially ineffective at picking up fine particles.
- **Vacuum Assisted:** These cleaners use gutter brooms to remove particles from the street and the refuse is then placed in the path of a vacuum intake that transports the dirt to the hopper. The transported dirt is often saturated with water. The overall efficiency of vacuum-assisted cleaners is generally higher than that of mechanical cleaners, especially for particles larger than the dust and dirt range (USDOT).
- **Regenerative Air:** These cleaners blow air onto the road or parking lot surface, causing fines to rise where they are vacuumed. Regenerative air cleaners may blow fines off the vacuumed portion of the surface. Regenerative air cleaners are generally more effective than mechanical and vacuum sweepers.

Regardless of the type chosen, the efficiency of street cleaning is increased when cleaners are operated in tandem.

Frequency

Unlike other stormwater treatment practices that function whenever it rains, street cleaning picks up dirt only when streets and parking lots are swept. Pollutant removal efficiency is based on annual loading rates. If a road were swept only once a year with a sweeper that is 100% efficient, it would remove only a small fraction of the annual pollutant load. The efficiency of all sweeper types increases with increased frequency.

Planning Considerations

In deciding whether street cleaning is an effective option, consider factors such as whether road and parking lot shoulders are stabilized, the speed at which the sweepers will need to be driven (safety factor for busy roads and highways), whether access is available to the curb (i.e., if vehicles parked along the curb line will preclude cleaning to edge of curb), the type of sweepers, and if sweepers will be operated in tandem.

Maintenance

Street cleaning materials must be handled and disposed of properly. MassDEP's Bureau of Waste Prevention has issued a written policy regarding the reuse and disposal of street cleanings. These materials are regulated as a solid waste, and can be used in three ways:

- In one of the ways already approved by MassDEP (e.g., daily cover in a landfill, additive to compost, fill in a public way)
- If approved under a Beneficial Use Determination
- Disposed in a landfill

MassDEP provides guidance and standards for handling, reusing, and disposing of materials collected by street cleanings.

References

Breault, Robert F., Smith, Kirk P. and Sorenson, Jason R., 2005, Residential Street-Dirt Accumulation Rates and Chemical Composition, and Removal Efficiencies by Mechanical-and Vacuum-Type Sweepers, New Bedford, Massachusetts, 2003–04 - https://pubs.er.usgs.gov/publication/sir20055184

Donner, Sebastian., et al., May 2016, Recommendations of the Expert Panel to Define Removal Rates for Street and Storm Drain Cleaning Practices - https://www.chesapeakebay.net/documents/FINAL_APPROVED_Street_and_Storm_Drain_Cleaning_Expert_Panel_Report_--_Complete2.pdf

Smith, Kirk P., 2002, Effectiveness of Three Best Management Practices for High-Runoff Quality along the Southeast Expressway, Boston, Massachusetts, USGS, Water-Resources Investigations Report 02-4059, http://water.usgs.gov/pubs/wri/wri024059/

Sorenson, Jason R., 2013, Potential Reductions of Street Solids and Phosphorus in Urban Watersheds from Street Cleaning, Cambridge, Massachusetts - https://pubs.usgs.gov/sir/2012/5292/pdf/sir2012-5292_rev030613.pdf

U.S Department of Transportation (USDOT) Federal Highway Administration. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Fact Sheet – Street Sweepers. https://www.environment.fhwa.dot.gov/env_topics/water/ultraurban_bmp_rpt/3fs16.aspx

United States Environmental Protection Agency (US EPA). 1983. *Results of the Nationwide Urban Runoff Program*. Vol. 1. Final Report. Office of Water, US EPA. Washington, DC. https://www3.epa.gov/npdes/pubs/sw_nurp_vol_1_finalreport.pdf

Zarriello, Phillip J., Robert F. Breault, and Peter K. Weiskel, 2002, Potential Effects of Structural Controls and Street Sweeping on Stormwater Loads to the Lower Charles River, Massachusetts, USGS, Water Resources Investigation Report 02-4220, http://water.usgs.gov/pubs/wri/wri024220/

Structural Pretreatment

- Deep Sump Catch Basin
- Oil and Grit Separators
- Proprietary Separators
- Sediment Forebays
- Vegetated Filter Strips
- Pea Gravel Diaphragm with Filter Strip

Deep Sump Catch Basin

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation
3 - Recharge	Provides no groundwater recharge. May be used as a pretreatment practice.
4 - TSS/ TP Removal	**No EPA Curve.** **TSS**: MassDEP 25% pretreatment removal credit **TP**: MassDEP 0% TP removal credit. Because of their limited effectiveness and storage capacity, deep sump catch basins receive TSS removal credit only if they are used for pretreatment, have hoods, have an inlet grate that screens out gross solids, have no curb inlet, and are designed as off-line systems.
5 - Higher Pollutant Loading	Suitable for TSS pretreatment. Although provides some spill control capability, a deep sump catch basin may not be used in place of an oil/grit separator or sand filter for land uses that have the potential to generate runoff with high concentrations of oil and grease such as: high-intensity-use parking lots, gas stations, fleet storage areas, vehicle and/or equipment maintenance and service areas.
6 - Discharges near or to Critical Areas	May be used as pretreatment SCM. Not an adequate spill control device for discharges near or to critical areas.
7 - Redevelopment	Suitable for pretreatment only
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required. See maintenance section.
11 - Total Maximum Daily Loads	Suitable for TSS pretreatment. Does not meet any TMDL treatment requirements as a stand-alone treatment practice.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Deep sump catch basins with a hood are underground retention systems designed to remove trash, debris, and coarse sediment from stormwater runoff trough gravity separation, and may serve as temporary spill containment devices for floatables such as oils and greases.

Advantages/Benefits

- Located underground, so limited lot size is not a deterrent.
- Compatible with subsurface storm drain systems.
- Can be used to provide TSS pretreatment when retrofitting small urban lots where larger pretreatment SCMs may not feasible.
- Provide TSS pretreatment of runoff before it is delivered to other SCMs.
- Easily accessed for maintenance.
- Longevity is high with proper maintenance.

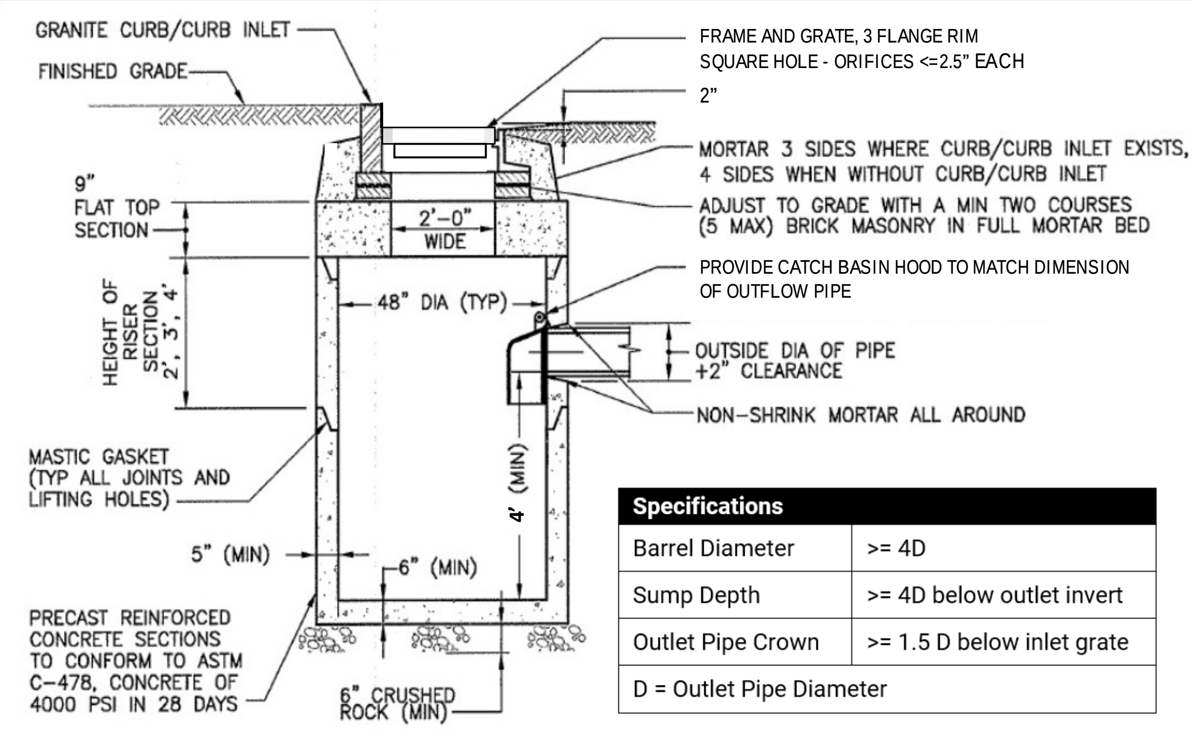
Disadvantages/Limitations

- Limited pollutant removal.
- Expensive to install and maintain, resulting in high cost per unit area treated.
- No ability to control volume of stormwater
- No ability to reduce peak runoff rate
- Frequent maintenance is essential
- Requires proper disposal of trapped sediment and oil and grease
- Entrapment hazard for amphibians and other small animals

Suitability to Treat TMDL Pollutants

- While some pretreatment SCMs are capable of removing certain TMDL pollutants, they cannot be used as a standalone practice.
- Pretreatment SCMs are encouraged to be implemented as part of a larger treatment train.

Example Deep Sump Catch Basin *(Adapted from University of New Hampshire)*



Specifications	
Barrel Diameter	>= 4D
Sump Depth	>= 4D below outlet invert
Outlet Pipe Crown	>= 1.5 D below inlet grate
D = Outlet Pipe Diameter	

Unit Treatment Process

Gravity separation

Special Features

All deep sump catch basins must include hoods and be placed offline to receive the TSS pretreatment credit. If the deep sump catch basin contains a curb inlet, a vertical curb inlet grate must be installed to receive TSS pretreatment credit. See Design Considerations (directly below) and the "**Vertical Curb Inlet Grates**" Specification of this Appendix for more information. For MassDOT Highway projects, see Highway Specific Considerations in **Section 5.7**.

ESSD / LID Alternatives

Not applicable. This is a pretreatment practice.

Suitable Applications

- Pretreatment
- Residential subdivisions
- Office
- Retail

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

- Design and construct deep sump catch basins as off-line systems.
- Space the inlets so that the contributing drainage area to any deep sump catch basin does not exceed ¼ acre of impervious cover
- Flow rate does not exceed the maximum capacity of the inlet grate. The inlet grate flow rate shall not exceed 3 cubic feet per second during any design storm.
- Divert excess flows to another SCM intended to meet the water quantity requirements (peak rate attenuation) or to a storm drain system. An off-line design enhances pollutant removal efficiency, because it reduces the resuspension of sediments in large storms.

Sump Depth: Make the sump depth (distance from the bottom invert of the outlet pipe to the inside bottom of the basin) at least four feet times the diameter of the outlet pipe and more if the contributing drainage area has a high sediment load. The minimum sump depth is 4 feet below the outlet pipe invert. Double catch basins, those with 2 inlet grates, may require deeper sumps. Install the invert of the outlet pipe at least 4 feet from the bottom of the catch basin grate.

Inlets: Inlets provide primary treatment, by preventing gross solids, including trash, from entering the catch basin and contaminating the runoff. Inlets serve to prevent larger debris from entering the sump.

The Federal Highway Administration (FHWA) HEC12 identifies 4 types of inlets: **grate inlets, curb-opening inlets, slotted inlets, and combination inlets**. Of the four inlet types, grate inlets are the preferred method to receive 25% TSS pretreatment removal credit since they do not allow gross solids such as trash to bypass primary treatment by the grate. However, curb opening inlets or combination inlets are eligible to receive 25% TSS pretreatment removal credit provided that a curb guard (i.e., vertical curb inlet grate) be installed in the curb opening. The curb-guard is a vertical grate that fits into the curb opening. See the "**Vertical Curb Inlet Grates**" Specification of this Appendix for more information. Slotted inlets are not eligible to receive 25% TSS pretreatment removal credit.

- Inlet Grate Sizing: To be effective, the orifices in the grate inlet must be ≤ 2.5-square inches and grate openings must not allow flows greater than 3 cfs to enter the deep sump catch basin.

- Curb Opening Sizing: If the grate inlet is designed with a curb opening, the grate must reach to the back of the curb opening to prevent bypass. See "**Vertical Inlet Grates**" section of this Specification for sizing criteria.

All inlets must be constructed of a durable material and fit tightly into the frame so it won't be dislodged by automobile traffic. The grate inlet must not be welded to the frame so that sediments may be easily removed and must be placed flush with the curb to prevent trash, leaves, and sediment from bypassing the coarse screening provided by the inlet grates. To facilitate maintenance, the grate inlet must be placed along the road shoulder or curb line rather than a traffic lane. For MassDOT projects, see **Section 5.7** for Highway Specific Considerations related to inlets.

Hoods: May be fabricated from cast iron, high-density polyethylene (HDPE), or similar materials. To receive the 25% removal credit, hoods must be used in deep sump catch basins. Hoods also help contain oil spills. For MassDOT Highway projects, see **Section 5.7** for Highway Specific Considerations related to hoods.

Inserts: Proprietary baskets and filters are marketed that install under the grate to enhance pollutant removal efficiency. See "*Catch Basin Insert*" Specification in this Appendix. Inserts should be considered an option for retrofits and Redevelopments, especially to improve the performance of any existing catch basin that does not contain a deep sump. Silt sacks used to provide construction period sediment control are not a post construction Catch Basin Insert. Some designs of Catch Basin Inserts contain hydrocarbon-absorbing polymers, so may be capable of removing oils and greases contained in runoff. The inserts, depending on their design, may also be capable of removing gross solids such a trash. When a Catch Basin Insert is proposed, to determine if additional pollutant removal credit for TSS and/or TP is warranted, follow the process specified in **Section 5.3** of the Stormwater Handbook. Remember deep sump catch basins are only a pretreatment practice, so insets should never be relied upon as stand-alone treatment practices. When proposed as part of a NOI or WQC application, the O&M plan for any inserts that may be proposed must follow the manufacturer's recommendations.

The catch basin must be designed and installed to be watertight. Risers need to be grouted, mortared, or gasketed. Similarly, the outlet pipe junction with the catch basin must be watertight.

Note that within parking garages, the State Plumbing Code regulates inlet grates and other stormwater management controls.

Inlet grates inside parking garages are currently required to have much smaller openings than those described herein. Drainage within parking garages is considered wastewater, not stormwater, and must be directed to a Sanitary Sewer, following the provisions in the State Plumbing Code. Parking garage drainage must not be directed to wetland Resource Areas, to groundwater, or to the stormwater drainage system. Further parking garage drainage is not allowed to be directed to an Underground Floor Drain or Title 5 subsurface treatment system

Any weep holes must be above the outlet pipe crown. Never install the weep hole below the outlet pipe invert or in the bottom of the catch basin barrel. The contributing catchment is typically a street with curb and gutter flow or paved parking area. If the catchment has soft road shoulders (i.e., no curb/gutter) higher than the paved surface, no TSS or TP removal credit is appropriate.

Site Constraints

Deep sump catch basins must not be installed in the following situations

- When seasonal high groundwater would be within 2-feet of the bottom of the sump.

An Applicant may not be able to install a deep sump catch basin because of:

- Depth to bedrock;
- Presence of utilities; or
- Other site conditions that limit depth of excavation because of stability.

Maintenance

Activity	Frequency
Inspect Units	Four times per year
Remove sediment and debris buildup from units	Four times per year minimum or when depth of deposits is greater than or equal to one half the depth from bottom of the invert of the outlet pipe in catch basin.

Regular maintenance is essential. Deep sump catch basins remain effective at removing pollutants only if they are cleaned out frequently. Pitt 1985 found that once 50% of the sump volume is filled, the catch basin is not able to retain additional sediments. Woodward-Clyde Consultants on behalf of the Alameda County Urban Runoff Clean Water Program found that more frequent cleanings improved the removal efficiencies of catch basins.

Inspect deep sump basins at least four times per year and at the end of the foliage and snow-removal seasons. Sediments must also be removed four times per year or whenever the depth of deposits is greater than or equal to one half the depth from the bottom of the invert of the lowest pipe in the basin. If handling runoff from land uses with higher potential pollutant loads or discharging runoff near or to a critical area, more frequent cleaning may be necessary.

Clamshell buckets are typically used to remove sediment in Massachusetts. However, vacuum trucks are preferable, because they remove more trapped sediment and supernatant than clamshells. Vacuuming is also a speedier process and is less likely to snap a cast iron or HDPE hood within the deep sump catch basin.

Always consider the safety of the staff cleaning deep sump catch basins. Cleaning a deep sump catch basin within a road with active traffic or even within a parking lot is dangerous, and a police detail may be necessary to safeguard workers.

MassDEP classifies solids retained in catch basins as solid waste. Unless there is evidence that they have been contaminated by a spill or other means, MassDEP does not routinely require catch basin cleanings to be tested before disposal. Contaminated catch basin cleanings must be evaluated in accordance with the Hazardous Waste Regulations, 310 CMR 30.000, and handled as hazardous waste.

In the absence of evidence of contamination, catch basin cleanings may be taken to a sanitary landfill or other facility permitted by MassDEP to accept solid waste, without any prior approval by MassDEP. However, some sanitary landfills may require catch basin cleanings to be tested before they are accepted. With prior MassDEP approval, catch basin cleanings may be used as grading and shaping materials at landfills undergoing closure (see Revised Guidelines for Determining Closure Activities at Inactive Unlined Landfill Sites) or as daily cover at active landfills. MassDEP also encourages the beneficial reuse of catch basin cleanings whenever possible. A Beneficial Reuse Determination must be sought and obtained in such instances (see 310 CMR 19.060).

MassDEP regulations prohibit landfills from accepting materials that contain free- draining liquids. One way to remove liquids is to use a hydraulic lift truck during cleaning operations so that the material can be decanted at the site. After loading material from several catch basins into a truck, elevate the truck so that any free- draining liquid can flow back into a catch basin. If there is no free water in the truck, the material may be deemed to be sufficiently dry. Otherwise, the catch basin cleanings must undergo a Paint Filter Liquids Test before they can be disposed of at a sanitary landfill.

Go to https://www.mass.gov/doc/catch-basin-cleanings-management-guidelines/download for information on all of the MassDEP requirements pertaining to the disposal of catch basin cleanings.

References

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Oil/Grit Separators

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation
3 - Recharge	Provides no groundwater recharge. May be used as a TSS pretreatment practice.
4 - TSS/TP Removal	**No EPA Curve,** **TSS:** MassDEP 25% pretreatment removal credit when placed off-line **TP:** MassDEP 0% TP removal credit.
5 - Higher Pollutant Loading	MassDEP requires a pretreatment, such as an oil/grit separator that is capable of removing oil and grease, for land uses with higher potential pollutant loads where there is a risk of petroleum spills such as: high intensity use parking lots, gas stations, fleet storage areas, vehicle and/or equipment maintenance and service areas.
6 - Discharges near or to Critical Areas	May be a TSS pretreatment SCM when combined with other practices. May serve as a spill control device.
7 - Redevelopment	Highly suitable.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required. See maintenance section.
11 - Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice. May be used for TSS pretreatment.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Oil/grit separators are underground storage tanks. There are several types: baffle boxes, API separators, and Coalescing Plate Separators. Baffle boxes have three chambers designed to remove heavy particulates, floating debris and hydrocarbons from stormwater. API separators are used where significant quantities of oil may be encountered. The liquid is considered industrial wastewater and must not be directed to a wetland Resource Area or stormwater drainage system, so the API type separator is not discussed further in this section. Coalescing Plate Separators contain plates to separate oil from water.

Baffle boxes are the Oil/Grit Separator type most commonly used with non-industrial land uses. The three chambers consist of a forebay, oil-separation bay, and afterbay. Note that the forebay is not considered a sediment forebay for purposes of the Stormwater Handbook Specifications. Stormwater enters the first chamber, or forebay, where heavy sediments and solids drop out. The flow moves into the oil-separation bay, or second chamber, where oils and greases are designed to be trapped and further settling of suspended solids takes place. Trapped oil and grease are stored in this second chamber for future removal. After moving into the third outlet chamber, the clarified stormwater runoff is then discharged to a pipe and another SCM.

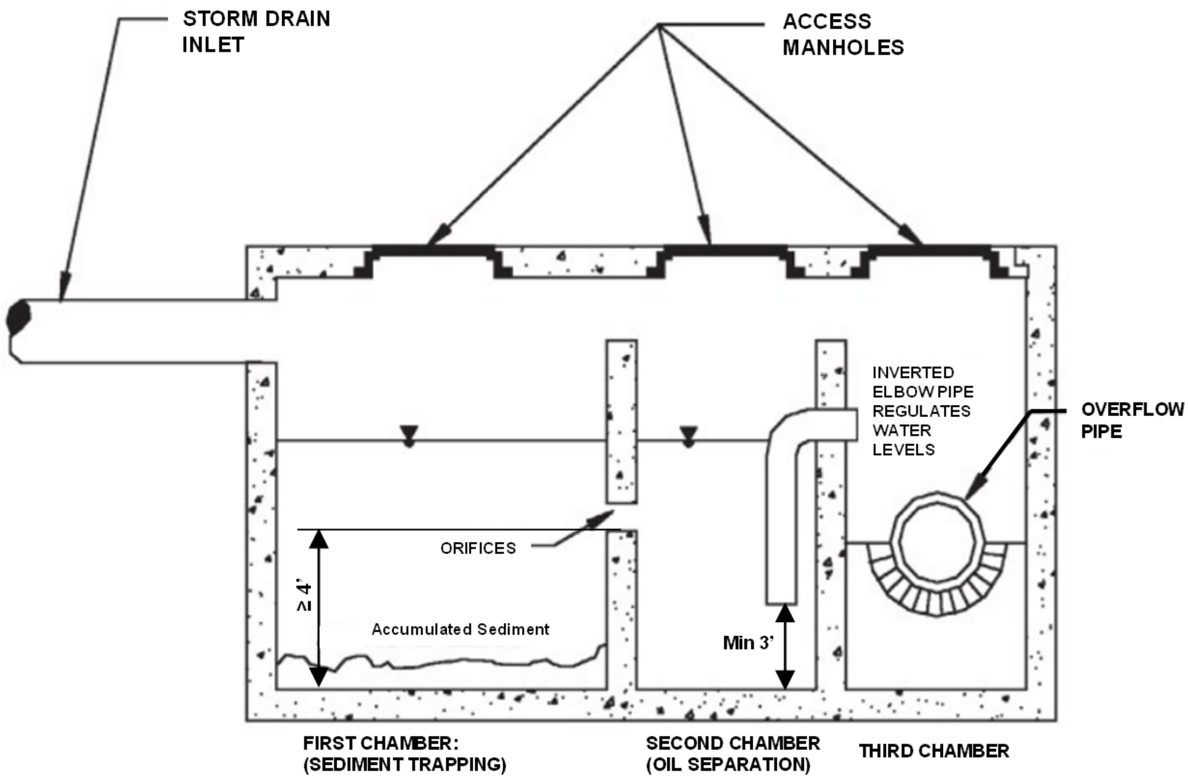
Advantages/Benefits

- Located underground so limited lot size not a deterrent in urban areas with small lots
- Can be used for retrofits
- Can be installed in any soil or terrain.
- Public safety risks are low.

Disadvantages/Limitations

- Limited pollutant removal; cannot effectively remove soluble pollutants, fine particles, or bacteria
- Can become a source of pollutants due to resuspension of sediment unless properly maintained
- Susceptible to flushing during large storms
- Limited to relatively small drainage areas
- Requires proper disposal of trapped sediments/oils
- May be expensive to construct and maintain
- Entrapment hazard for amphibians, other small animals

Example Baffle Box-type Oil/Grit Separator
(Typical Cross Section, Adapted from Schueler, 1987)



Suitability to Treat TMDL Pollutants

- While some pretreatment SCMs are capable of removing certain TMDL pollutants, they cannot be used as a standalone practice.
- TSS Pretreatment SCMs are required to be implemented as part of a larger treatment train.

Unit Treatment Process

- Gravity Separation.

ESSD / LID Alternatives

Not applicable. This is a pretreatment practice.

Applicability

Oil/grit separators must be used to manage runoff from those particular land uses with higher potential pollutant loads where there is a risk that the stormwater may be contaminated with oil or grease. Such industrial land uses require source control practices to minimize or prevent oil and greases from co-mingling with stormwater (see **Section 4.4.2**). These uses include the following:

- High-Intensity-Use Parking Lots (1,000+ uses/day)
- Gas Fueling Stations
- Fuel Storage Depots
- Vehicles (including boats, buses, cars, and trucks) and Equipment Service and Maintenance Areas
- Fleet Storage Areas

The term “grit” originated from its use in wastewater treatment. For Stormwater purposes, “grit” refers to sand, gravel, and other solids material “heavier” (higher specific gravity) than organic biodegradable solids present in stormwater (EPA 2003) Grit is defined differently for wastewater purposes.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

- Dovetail design practices, source controls and pollution prevention measures with separator design.
- Place separators before all other structural stormwater treatment practices (except for structures associated with source control/ pollution prevention such as drip pans and structural treatment practices such as deep sump catch basins that double as inlets).The bottom of the separator and any associated manholes necessary to install the separator offline must be set in elevation to be at least 2-feet above seasonal high groundwater.
- Limit the contributing drainage area to the oil/grit separator to one acre or less of impervious cover.
- Use oil/grit separators only in off-line configurations to treat the required water quality volume.
- Provide pool storage in first chamber of no less than 400 cubic feet per acre of impervious surface. The first two chambers must be able to collectively store at least the 1-inch Water Quality Volume (3,630 cubic feet/acre)
- Make the permanent pool in the first two chambers at least 4 feet deep.
- The O/G separator must be designed to be offline. This requires at least two manholes, one at the inlet and one at the outlet, with a diversion pipe connecting the two manholes.
- Runoff greater than the 1-inch Water Quality Volume must be designed to bypass the separator to prevent resuspension and discharge of previously trapped solids. The diversion pipe, or bypass, must be designed to bypass storms greater than the first 1-inch of runoff.
- Make oil/grit separator units watertight to prevent possible groundwater contamination.
- Use a trash rack or screen to cover the discharge outlet and orifices between chambers.
- Provide each chamber with manholes and access stepladders to facilitate maintenance and allow cleaning without confined space entry.
- Seal potential mosquito entry points.
- Install any pump mechanism downstream of the separator to prevent oil emulsification.
- Locate an inverted elbow pipe (hood) between the second and third chambers and with the bottom of the elbow pipe at least 3 feet below the second chamber's permanent pool. The inverted elbow may be constructed from cast iron, high-density polyethylene (HDPE), or similar materials.
- Provide appropriate removal covers that allow access for observation and maintenance.
- Where the structure is located below the seasonal high groundwater table, design the structure to prevent flotation.

For gas stations, automobile maintenance and service areas, and other areas where large volumes of petroleum and oil are handled, consider adding coalescing plates to increase the effectiveness of the device and reduce the size of the units. A series of coalescing plates constructed of oil-attracting materials such as polypropylene typically spaced one inch apart attracts small droplets of oil, which begin to concentrate until they are large enough to float to the surface.

Maintenance

Activity	Frequency
Inspect units	After every storm of at least 1-inch/day or greater but at least monthly
Remove accumulated sediment and liquid	Twice a year

Sediments and associated pollutants and trash are removed only when inlets or sumps are cleaned out, so regular maintenance is essential. Most studies have linked the failure of oil/grit separators to the lack of regular maintenance. The more frequent the cleaning, the less likely sediments will be re-suspended and subsequently discharged. In addition, frequent cleaning also makes more volume available for future storms and enhances overall performance. Cleaning includes removal of accumulated oil and grease and sediment using a vacuum truck. In areas of high sediment loading, inspect and clean inlets after every 1 inch/day or greater storm event. At a minimum, inspect oil/grit separators monthly, and clean them out at least twice per year. Polluted water or sediments removed from a oil/grit separator should be disposed of in accordance with all applicable local, state and federal laws and regulations including M.G.L.c. 21C and 310 CMR 30.00.

Note: Maintenance requirements for coalescing plate separators are different from those described for the baffle box types.

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Houston, City of, Harris County, Harris County Flood Control District, 2001, Storm Water Quality Management Guidance Manual, Section 4.4.2, p. 4-84 to 4-89, http://www.cleanwaterclearchoice.org/downloads/professional/guidance_manual_full.pdf

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New Zealand Water Environment Research Foundation, 2004, On-Site Stormwater Management Guideline, Section 5.10, pp. 23 to 24, On-Site Stormwater Management Guideline

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U.S. EPA, 2003, Wastewater Technology Fact Sheet, Screening and Grit Removal, EPA 832-F-03-011.

Proprietary Manufactured Separators

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	No EPA Curve. **TSS**: MassDEP Variable pretreatment removal credit, up to 44% **TP**: MassDEP 0% TP removal credit. TSS removal varies by unit. Must be used for pretreatment, be placed first in the treatment, and configured offline to receive removal credit(s) Follow procedures described in **Section 5.3** to determine removal credit(s).
5 – Higher Pollutant Loading	Suitable as pretreatment device.
6 – Discharges near or to Critical Areas	Suitable as pretreatment device or potentially a spill control device.
7 - Redevelopment	Suitable for pretreatment. Must be placed first in the treatment train to receive removal credit(s).
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required. See maintenance section.
11 - Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

A proprietary manufactured separator is a flow-through structure with a settling or separation chamber/sump to remove sediments and other pollutants. They rely upon gravity separation and swirling to separate floatables and coarser sediments. They are typically designed and manufactured by private businesses, and come in different sizes to accommodate different runoff volumes and flow conditions. Some rely solely on gravity separation and contain no swirl chamber. Since proprietary separators can be placed in almost any location on a site, they are particularly useful when either site constraints prevent the use of other stormwater techniques or as part of a larger treatment train. The effectiveness of proprietary manufactured separators varies greatly by size and design, so make sure that the units are sized correctly for the site's soil conditions and flow profiles, otherwise the unit will not work as designed. See the Design section.

Advantages/Benefits

- Removes coarser sediment.
- Useful on constrained sites.
- Can be custom-designed to fit specific needs of a specific site.

Disadvantages/Limitations

- Removes only coarse sediment fractions
- Provides no recharge to groundwater
- No control of the volume of runoff
- No peak rate runoff attenuation
- Frequent maintenance is essential
- For pretreatment only for both new development and Redevelopment.

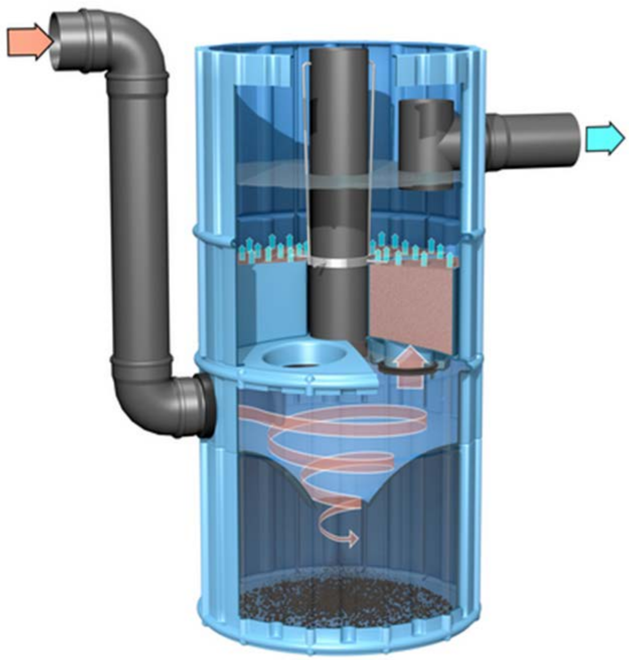
Suitability to Treat TMDL Pollutants

- While some pretreatment SCMs are capable of removing certain TMDL pollutants, they cannot be used as a standalone practice.
- Pretreatment SCMs are encouraged to be implemented as part of a larger treatment train.

Unit Treatment Process

- Physical settling

Example Proprietary Separator *(adapted from the Massachusetts Clean Water Toolkit)*



Special Features

Useful in highly urban areas as part of Redevelopment or retrofit due to small footprint, where larger traditional practices may be site constrained

ESSD / LID Alternatives

Not applicable. This is a pretreatment practice.

Applicability

Because they have limited pollutant removal and storage capacity, proprietary separators must be used for pretreatment only. Because they are placed underground, proprietary separators may be the only structural pretreatment SCMs feasible on certain constrained Redevelopment sites where space or storage is not available for more effective SCMs. They may be especially useful in ultra-urban settings such as Boston or Worcester. Some proprietary separators may be used for spill control.

Effectiveness

Proprietary separators have a wide range of TSS removal efficiencies. To assess the ability of proprietary separators to remove TSS and other pollutants, an Applicant should follow the procedures set forth in **Section 5.3**. The specific units proposed for a particular project cannot be effective unless they are sized correctly. Proprietary separators are usually sized based on flow rate. A proprietary separator must be sized to treat the 1-inch required water quality volume, using the MassDEP WQV to Peak Flow conversion method. To be effective at removing TSS and other pollutants the system must be designed, constructed, and maintained in accordance with the manufacturer's specifications and the specifications in this Handbook.

Planning Considerations

To receive TSS removal credit, proprietary separators must be used for pretreatment, placed at the beginning of a stormwater treatment train, and be configured to operate offline. They must be configured off-line to reduce scouring and re-entrainment of previously trapped sediment. They must be sized to treat the 1-inch WQV in accordance with the manufacturer's specifications and the specifications in this Handbook. Proprietary separators used as spill control devices may have to be sized differently than those used for TSS removal. They may only be used for pretreatment for new development or Redevelopment

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

The design of proprietary separators varies by manufacturer. Units are typically precast concrete, but larger systems may be cast in place. Units may have baffles or other devices to direct incoming water into and through a series of chambers, slowing the water down to allow sediment to drop out into internal storage areas, then directing this pre -treated water to exit to other treatment or infiltration devices. In some cases, flow will be introduced tangentially, to induce swirl or vortex. Units may include skirts or weirs, to keep trapped sediments from becoming re-entrained.

Generally, they are placed below ground on a gravel or stone base. The bottom of the separator must be placed at least 2-feet in elevation above seasonal high groundwater. Make sure all units contain inspection and access ports so that they may be inspected and cleaned. During design, take care to place the inspection and access ports where they will be accessible. Do not place the ports in locations such as travel lanes of roadways/highways and parking stalls.

Manufactured separators are typically available in different sizes. Larger sizes accommodate runoff from larger areas. The treatment chamber/sump must be sized to hold the 1-inch water quality volume. What this means is that the separator treatment chamber/sump must be able to hold a volume of 1-inch of runoff times the contributing impervious drainage area, without surcharging or bypass. If the separators are sized using the peak flow rate, they must be sized using the MassDEP 1-inch Water Quality Volume to Peak Flow Rate conversion method. Other methods to convert the 1-inch Water Quality Volume to Peak Flow Rate are not acceptable. The method to convert the 1-inch Water Quality Volume to Peak Flow Rate is listed in **Appendix D**.

All proprietary manufactured separators must be designed to ensure the first 1-inch Water Quality Volume is treated without any bypass. Some proprietary manufactured separators may contain an internal weir to prevent bypass. If the proprietary manufactured separator does not contain an internal weir to prevent bypass of the 1-inch Water Quality Volume, external manholes must be included in the design to route flows in excess of 1-inch around the proprietary manufactured separator.

Additionally, the proprietary manufactured separator must be designed to operate offline, and must be placed first in the treatment train.

Construction

Install construction barriers around the excavation area to prevent access by pedestrians. Use diversions and other soil erosion practices up-slope of the proprietary separator to prevent runoff from entering the site before construction of the units is complete. Implement practices to prevent construction period runoff from being discharged to the units until construction is complete and the soil is stabilized. Stabilize all surrounding area and any established outlets. Remove temporary structures after vegetation is established.

Maintenance

Activity	Frequency
Inspect in accordance with manufacturer requirements, but no less than twice a year following installation, and no less than once a year thereafter.	See activity
Remove sediment and other trapped pollutants at frequency or level specified by manufacturer.	See manufacturer information

Inspect and clean these units in strict accordance with manufacturers' recommendations and requirements. Clean the units using the method specified by the manufacturer. Vactor trucks are typically used to clean these units. Clamshell buckets typically used for cleaning catch basins are almost never allowed by manufacturers. Sometimes it will be necessary to remove sediment manually.

References

Example image on first page was sourced from Tahoe Regional Planning Agency Best Management Practices Handbook, May 2014, Chapter 4.4, https://tahoebmp.org/Documents/BMPHandbook/Chapter%204/4.4/g_HydDySep.pdf.

Sediment Forebays

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	**No EPA Curve.** **TSS**: MassDEP 25% pretreatment removal credit. **TP**: MassDEP 0% TP removal credit. MassDEP requires a sediment forebay as pretreatment before stormwater is discharged to an extended dry detention basin, wet basin, constructed stormwater wetland or infiltration basin. No separate credit is given for the sediment forebay. When they provide pretreatment for other SCMs, sediment forebays receive a 25% TSS removal credit.
5 – Higher Pollutant Loading	Suitable for TSS pretreatment.
6 – Discharges near or to Critical Areas	Suitable for TSS pretreatment.
7 - Redevelopment	Usually not suitable due to land use constraints.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required. See maintenance section.
11 - Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

A sediment forebay is a post-construction practice consisting of an excavated pit, bermed area, or cast structure combined with a weir, designed to slow incoming stormwater runoff and facilitate the gravity separation of suspended solids. This practice is different from a sediment trap used as a construction period SCM.

Advantages/Benefits

- Provides pretreatment of runoff before delivery to other SCMs.
- Slows velocities of incoming stormwater
- Easily accessed for sediment removal
- Longevity is high with proper maintenance
- Relatively inexpensive compared to other SCMs
- Greater detention time than proprietary separators

Disadvantages/Limitations

- Removes only coarse sediment fractions
- No removal of soluble pollutants
- Provides no recharge to groundwater
- No control of the volume of runoff
- Frequent maintenance is essential

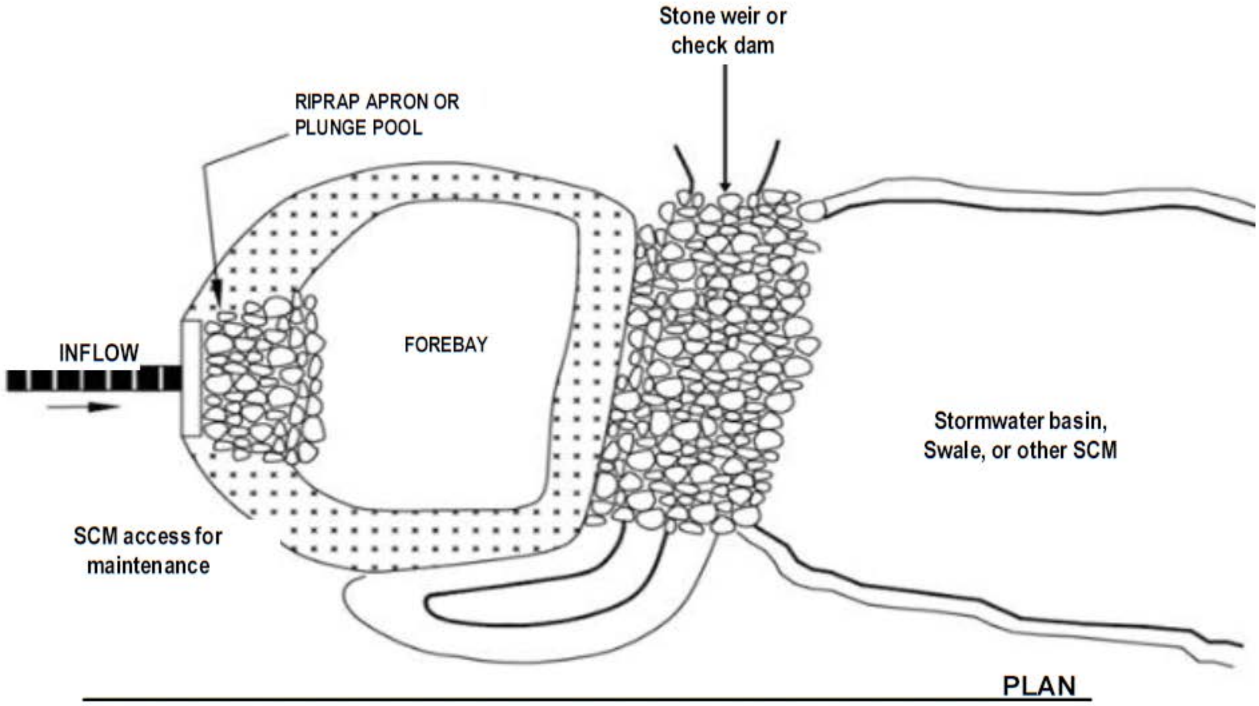
Suitability to Treat TMDL Pollutants

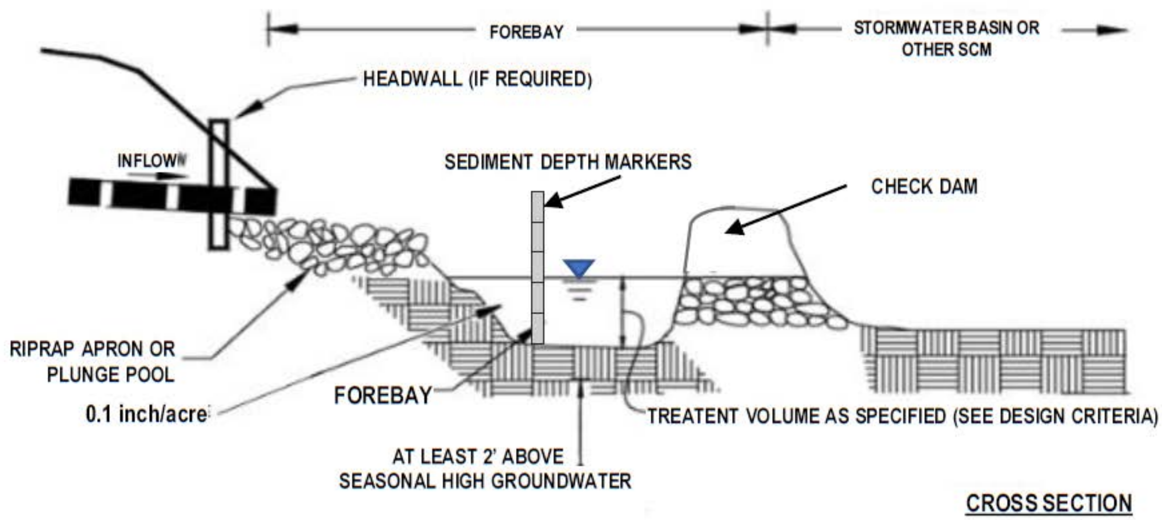
- While some pretreatment SCMs are capable of removing certain TMDL pollutants, they cannot be used as a standalone practice.
- Pretreatment SCMs are encouraged to be implemented as part of a larger treatment train.

Unit Treatment Process

- Gravity separation

Example Post-Construction Sediment Forebay
(*Adapted from the 2006 Vermont Stormwater Handbook*)





Special Features

MassDEP requires a sediment forebay as pretreatment before discharging to a dry extended detention basin, wet basin, constructed stormwater wetland, or infiltration basin.

MassDEP uses the term "sediment forebay" for permanent SCMs used to pretreat stormwater after construction is complete and the site is stabilized. MassDEP uses the term "sediment trap" to refer to temporary SCMs used for erosion and sedimentation control during construction. For information on the design and construction of sediment traps used during construction, consult the Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers and Municipal Officials (see **Appendix C**).

ESSD / LID Alternatives

Not applicable. This is a pretreatment practice.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Sediment forebays are typically on-line units, designed to slow stormwater runoff and settle out sediment.

The bottom of the sediment forebay must be placed at least 2-feet in elevation above seasonal high groundwater. It must be designed to fully dewater within 72-hours of a storm.

At a minimum, size the volume of the sediment forebay to hold 0.1-inch of runoff for each impervious acre to pretreat the water quality volume.

When routing the 2-year and 10-year storms through the sediment forebay, design the forebay to withstand anticipated velocities without scouring.

A typical forebay is excavated below grade with earthen sides and a stone check dam.

Design elevated embankments to meet applicable safety standards.

Stabilize earth slopes and bottoms using grass seed mixes recommended by the NRCS and capable of resisting the anticipated shearing forces associated with velocities to be routed through the forebay. Use only grasses. Using other vegetation will reduce the storage volume in the forebay. Make sure that the selected grasses can withstand periodic inundation under water, and drought- tolerant during the summer. MassDEP recommends using a mix of grasses rather than relying upon a single grass species.

Alternatively, the bottom floor may be designed with concrete or stone to aid maintenance. Concrete floors or pads, greatly facilitate the removal of accumulated sediment.

Design sediment forebays to make maintenance accessible and easy. Incorporate equipment access around the forebay perimeter as part of the design to facilitate maintenance. Provide an access way for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, by public or private right-of-way Sediment forebays may require excavation so concrete flooring may not always be appropriate. Sediment forebays with concrete flooring require notched weirs in order to fully drain within 72-hours of a storm.

Include sediment depth markers to simplify inspections. Sediment markers make it easy to determine when the sediment depth is between 3 and 6 feet and needs to be removed. Make the side slopes of sediment forebays no steeper than 3:1. Design the sediment forebay so that the discharge or outflow velocity can control the 2-year peak discharge without scour. Design the channel geometry to prevent erosion from the 2-year peak discharge.

Do not confuse post-construction sediment forebays with the sediment traps used as a construction-period control. Construction-period sediment control traps are sized larger than forebays, because there is a greater amount of suspended solids in construction period runoff. Construction-period sediment traps are sized based on drainage area and not impervious acre (see **Appendix C**). Never use a construction-period sediment trap for post-construction drainage purposes unless it is first brought off-line, thoroughly cleaned (including check dam), and stabilized before being made re-operational.

Refer to the Check Dam section of this Appendix for information on the design of the check dam component of the sediment forebay. Set the minimum elevation of the check dam crown to hold a volume of 0.1-inch of runoff/ impervious acre. In no case shall the upper crown of the check dam be less than 1-foot in height above the forebay floor. Check dam crown elevations are generally uniform..

Unless part of a wet basin, post construction sediment forebays must be designed to completely dewater between storms. Set the bottom of the forebay at a minimum of 2 feet above seasonal high groundwater, and place pervious material on the bottom floor to facilitate dewatering between storms. When using a concrete floor, the outlet invert must be set flush with the concrete floor, to allow for dewatering. For design purposes, when using a pervious bottom, use 72 hours to evaluate dewatering in the vertical direction through infiltration, assuming a volume of at least 0.1 inch of runoff times the impervious contributing drainage area is in the forebay, using half of the in-situ saturated hydraulic conductivity of the underlying soil. A stone check dam can act as a filter berm, allowing water to percolate through the check dam. Depending on the head differential, a stone check dam may allow greater dewatering than an earthen berm. For a sediment forebay with a concrete floor, the notch in the weir needs to be sized to release the captured 0.1-inch times impervious area volume over a period ≥ 24-hours, to provide for gravity separation of solids suspended in the runoff. The Weir Equation $\mathbf{Q = CLH^{3/2}}$ should be used to evaluate whether the runoff is retained for at least 24-

hours, where Q is the discharge in cubic feet per second, C is the discharge coefficient, L is the effective length of the weir crest in feet, H is the depth of flow in feet above the crest. Q is divided by the brimfull volume in the sediment forebay (0.1-inch times the impervious area), to obtain the retention time in seconds. Seconds is converted to hours (3600 seconds = 1 hour).

Maintenance

Sediments and associated pollutants are removed only when sediment forebays are cleaned out, so regular maintenance is essential. Frequently removing accumulated sediments will make it less likely that sediments will be resuspended. At a minimum, inspect sediment forebays monthly and clean them out at least four times per year. Stabilize the floor and sidewalls of the sediment forebay before making it operational, otherwise the practice will discharge excess amounts of suspended sediments.

When mowing grasses, keep the grass height no greater than 6-inches. Set mower blades no lower than 3 to 4 inches. Check for signs of rilling and gullying and repair as needed. After removing the sediment, replace any vegetation damaged during the clean-out by either reseeding or re-sodding. When reseeding, incorporate practices such as hydroseeding with a tackifier, blanket, or similar practice to ensure that no scour occurs in the forebay, while the seeds germinate and develop roots.

When the bottom floor is vegetated, during maintenance operations, it may be necessary to remove accumulated sediment by hand, along with re-seeding or re-sodding grasses removed during maintenance.

Activity	Frequency
Inspect sediment forebays	Monthly
Remove sediment, debris, and other trapped pollutants from sediment forebays	Four times per year and when sediment depth reaches 40% of the depth capacity

Vegetated Filter Strips

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Does not provide peak flow attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	**No EPA Curve.** **TSS**: MassDEP Variable pretreatment removal credit, 25% when greater than or equal to 25' and less than 50' wide; 45% when greater than or equal to 50' wide **TP**: MassDEP 0% TP removal credit.
5 - Higher Pollutant Loading	May be used to provide pretreatment as part of a pretreatment train if lined.
6 - Discharges near or to Critical Areas	May be used as part of a pretreatment train if lined. May be used near Cold-Water Fisheries.
7 - Redevelopment	Suitable for pretreatment
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required. See maintenance section.
11 - Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique. It is a pretreatment practice. Refer to ESSD Credits 4 and 5 for information on how a Qualifying Pervious Area can be used for treatment and recharge.

Description

Vegetated filter strips, also known as filter strips, grass buffer strips and grass filters, are uniformly graded vegetated surfaces (i.e., grass or close-growing native vegetation) that receive runoff from adjacent impervious areas. Vegetated filter strips typically treat sheet flow or small concentrated flows that can be distributed along the width of the strip using a level spreader. Vegetated filter strips are designed to slow runoff velocities, trap sediment, and promote infiltration, thereby reducing runoff volumes.

Advantages/Benefits

- Reduces runoff volumes and peak flows.
- Slows runoff velocities and removes sediment.
- Low maintenance requirements.
- Serves as an effective pretreatment for bioretention cells
- Can mimic natural hydrology
- Small filter strips may be used in certain urban settings.
- Ideal for residential settings and to treat runoff from small parking lots and roads.
- Can be used as part of runoff conveyance system in combination with other SCMs
- Little or no entrapment hazard for amphibians or other small creatures

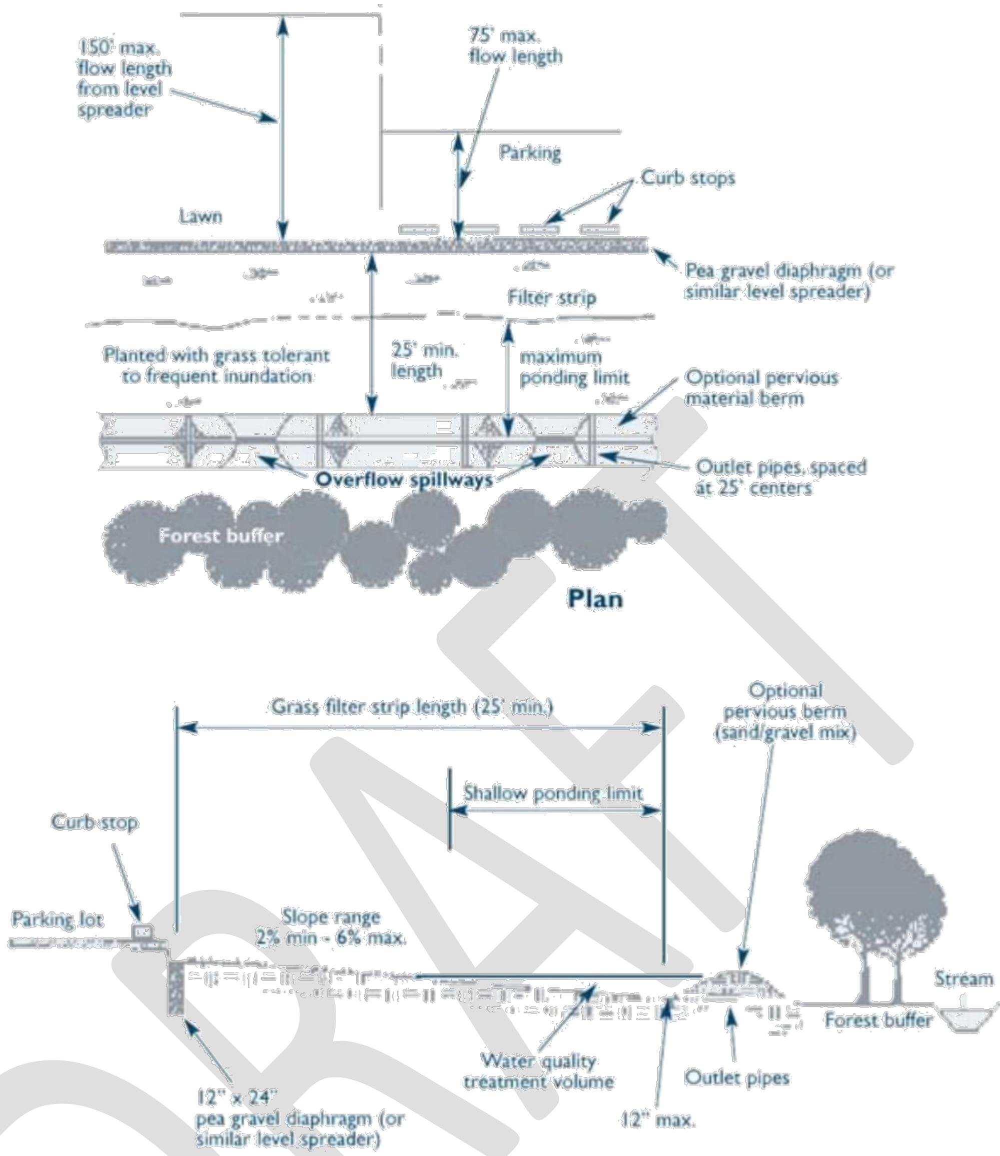
Disadvantages/Limitations

- Variability in removal efficiencies, depending on design
- Little or no treatment is provided if the filter strip is short-circuited by concentrated flows.
- Often a poor retrofit option due to large land requirements.
- Effective only on drainage areas with gentle slopes (less than 6 percent).
- Improper grading can greatly diminish pollutant removal.

Suitability to Treat TMDL Pollutants

- While some pretreatment SCMs are capable of removing certain TMDL pollutants, they cannot be used as a standalone practice.
- Pretreatment SCMs are encouraged to be implemented as part of a larger treatment train.

Example Vegetated Filter Strip - Adapted from Claytor and Schueler 1996



Unit Treatment Process

- Physical settling
- Biological uptake
- Possible filtration and chemical treatment (sorption to soil)

Special Features

Deconcentrates runoff. Appropriate to use when disconnecting runoff, provided slope is no greater than 2%.

ESSD / LID Alternatives

Not applicable. This is a pretreatment practice. Refer to ESSD Credits 4 and 5 for information on how a Qualifying Pervious Area can be used for treatment and recharge.

Applicability

Vegetated filter strips are used to pretreat sheet flow from roads, highways, and small parking lots. In residential settings, they are useful in pretreating sheet flow from driveways. They provide effective pretreatment, especially when combined with bioretention areas and stream buffers. Urban areas can sometimes accommodate small filter strips depending on available land area, making them potential retrofit options in certain urban settings. Vegetated filter strips can also be used as side slopes of grass channels or water quality swales to enhance infiltration and remove sediment.

Effectiveness

Variable TSS and TP removal efficiencies have been reported for filter strips, depending on the size of the contributing drainage area, the width of the filter strip, the underlying parent soil, the land slope, the type of vegetation, how well the vegetation is established, and maintenance practices. Vegetated filter strips may remove nutrients and metals depending on the length and slope of the filter, soil permeability, size and characteristics of the drainage area, type of vegetative cover, and runoff velocity.

Planning Considerations

Vegetated filter strips may be used as a stand-alone practice for Redevelopments, only where other practices are not feasible. Vegetated filter strips can be designed to fit within the open space and rights of way that are available along roads and highways. Do not design vegetated filter strips to accept runoff from land uses with higher potential pollutant loads (LUHPPL) without a liner. Vegetated filter strips function best for drainage areas of one acre or less with gentle slopes.

Cold Climate Considerations

In cold climates such as Massachusetts, the depth of soil media that serves as the planting bed must extend below the frost line to minimize the effects of freezing. Avoid using peat and compost media, which retain water and freeze during the winter, and become impermeable and ineffective.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Do not locate vegetated filter strips in soils with high clay content that have limited infiltration or in soils that cannot sustain grass cover.

The filter strip cannot extend more than 50 feet into a Buffer Zone to a wetland Resource Area.

The contributing drainage area to a vegetated filter strip is limited to one acre of less.

Design vegetated filter strips with slopes between 2 and 6 percent. Steeper slopes tend to create concentrated flows. Flatter slopes may cause ponding and create mosquito-breeding habitat.

Design the top and toe of the slope to be as flat as possible. Use a level spreader at the top of the slope to evenly distribute overland flows or concentrated runoff across the entire length of the filter strip. Many variations of level spreader designs may be used including level trenches, curbing and concrete weirs. The key to any level spreader design is creating a continuous overflow elevation along the entire width of the filter strip.

Include an impermeable liner and underdrain for discharges from Land Use with Higher Potential Pollutant Loads and for discharges within Zone IIs and Interim Wellhead Protection Areas; for discharges near or to other critical areas or in soils with rapid infiltration rates greater than 2.4 inches per hour.

Velocity dissipation (e.g., by using riprap) may be required for concentrated flows.

Design the filter strip to drain within 24 hours after a storm. The design flow depth must not exceed 0.5 inches.

To receive TSS removal credit, make the filter strip at least 25 feet long and generally as wide as the area draining to the strip. To prevent high-velocity concentrated flows, the length of the flow path must be limited to 75 feet if the filter strip handles runoff from impervious surfaces, and 150 feet if the filter strip handles runoff from pervious surfaces. The minimum width of the filter strip must be 20% of the length of the flow path or 8 feet, whichever is greater.

To minimize groundwater contamination and optimize hydraulic performance, the filter strip must be constructed at least 2 feet above seasonal high groundwater and 2 to 4 feet above bedrock. The filter strip must be planted with grasses that are relatively salt-tolerant. Select grasses to withstand high flow velocities under wet weather conditions.

A vegetated filter strip may be used as a qualifying pervious area for the LID Site Design Credits for disconnecting rooftop and non-roof top runoff. If designing the vegetated filter strip for pretreatment to a bioretention area/rain garden, see the "*Bioretention Areas*" section of this Appendix.

Construction

- Proper grading is essential to establish sheet flow from the level spreader and throughout filter strip.
- Implement soil stabilization measures until permanent vegetation is established.
- Protect the area to be used for the filter strip by using upstream sediment traps.
- Use as much of the existing topsoil on the site as possible to enhance plant growth.

Maintenance

Activity	Frequency
Inspect the level spreader for sediment buildup and the vegetation for signs of erosion, bare spots, and overall health.	Every six months during the first year. Annually thereafter.
Regularly mow the grass.	As needed
Remove sediment from toe of slope or level spreader and reseed bare spots.	As needed

Maintaining full turf coverage is essential to ensure TSS removal. If the turf is not properly established, filter strips will export sediment, resulting in no TSS removal. On-going regular maintenance is therefore critical for filter strips to be effective and to ensure that flow does not short-circuit the system. Conduct semi-annual inspections during the first year (and annually thereafter). Inspect the level spreader for sediment buildup and the vegetation for signs of erosion, bare spots, and overall health. Regular, frequent mowing of the grass is required. Remove sediment from the toe of slope or level spreader, and reseed bare spots as necessary. Periodically, remove sediment that accumulates near the top of the strip to maintain the appropriate slope and prevent formation of a "berm" that could impede the distribution of runoff as sheet flow.

Fertilize only when necessary. Use fertilizers that do not contain phosphorus. In nitrogen impaired waters where a TMDL has been established, use low nitrogen fertilizers (for example 5-0-5). Remove and compost grass clippings at an appropriate facility.

When the filter strip is located in the Buffer Zone to a wetland Resource Area, the operation and maintenance plan must include strict measures to ensure that maintenance operations do not alter the wetland Resource Areas. Please note, filter strips are restricted to the outer 50 feet of the Buffer Zone.

References

Center for Watershed Protection, Stormwater Management Fact Sheet: Grassed Filter Strip, http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Filtering%20Practice/Grassed%20Filter%20Strip.htm

Claytor, R.A. and T.R. Schueler. 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection. Silver Spring, Maryland.

Connecticut Department of Environmental Protection. 2004. Connecticut Stormwater Quality Manual.

International Stormwater SCM Database, Biofilter – Grass Strip, http://www.SCMdatabase.org

Knox County, Stormwater Management Manual, Volume 2, Section 4.3.9, Filter Strip, Pp. 4-155 to 4-164, Knox County Stormwater Management Manual 4.3.9 Filter Strip

Knoxville, City of, 2003, Knoxville SCM Manual Stormwater Treatment, Filter Strips and Swales, Practice No. ST – 05, City of Knoxville Filter Strips and Swales

Maine Department of Environmental Protection. 2006, Maine Stormwater Best Management Practices Manual, Chapter 5, Pp. 5-1 to 5-18, https://www.maine.gov/dep/land/stormwater/stormwaterSCMs/vol3/chapter5.pdf

Maryland Department of the Environment, 2000, Maryland Stormwater Design Manual, Volume I, Chapter 2, Unified Sizing Criteria, P. 2.39, http://www.mde.state.md.us/assets/document/chapter2.pdf

Massachusetts Highway Department. 2004. Storm Water Handbook for Highways and Bridges.

Metropolitan Council. 2001. Minnesota Urban Small Sites SCM Manual: Stormwater Best Management Practices for Cold Climates. Prepared by Barr Engineering Company. St. Paul, Minnesota.

New Jersey Department of Environmental Protection, 2004, Best Management Practice Manual, Chapter 9.10, Standard for Vegetated Filter Strip, Pp. 9.10-1 to 9.11-10,https://dep.nj.gov/stormwater/bmp-manual/

New York State Department of Environmental Conservation (NYDEC). 2001. New York State Stormwater Management Design Manual. Prepared by Center for Watershed Protection. Albany, New York.

United States Environmental Protection Agency (EPA). 1999. Preliminary Data Summary of Urban Storm Water Best Management Practices. EPA 821-R99-012.

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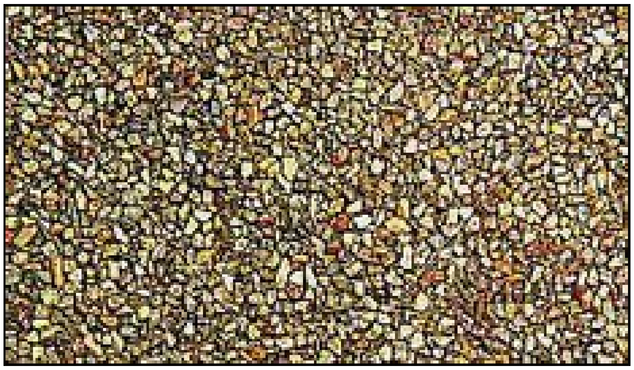
Virginia Department of Conservation and Recreation, Chapter 3, Minimum Standard 3.14, Vegetated Filter Strip, Pp. 3.14-1 to 3.14.-14, http://dcr.state.va.us/soil_&_water/documents/Chapter_3-14.pdf

Yu, S.L., S.L. Barnes, and V.W. Gerde, 993. Testing of Best Management Practices for Controlling Highway Runoff. Virginia Transportation Research Council, Charlottesville, VA.

Pea Gravel Diaphragm with Filter Strip



Important: Can only be used for the following SCMs: bioretention areas, infiltration trenches, ESSD Credit 3, ESSD Credit 4, ESSD Credit 7. May only be used when sheet flow is directed to these SCMs.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	No EPA Curve. **TSS**: MassDEP 45% pretreatment credit when properly designed. **TP**: MassDEP 0% TP removal credit.
5 - Higher Pollutant Loading	Not suitable as a pretreatment device
6 - Discharges near or to Critical Areas	May be used as a pretreatment device for certain SCMs except for those with discharges to/near bathing beaches and Shellfish Growing Areas
7 - Redevelopment	Suitable for pretreatment for certain SCMs
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required. See maintenance section.
11 - Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

A combination of two pretreatment practices for runoff sheeted to certain SCMs. The pea gravel diaphragm, also known as a stone diaphragm, is a stone trench filled with small river-run gravel, used as pretreatment device for sheet flow dosed to bioretention areas. The “filter strip” component is smaller than the “Vegetated Filter Strip.”

A gravel / grass combination is also suitable in lieu of the pea gravel diaphragm with filter strip. This should consist of a gravel strip at least 8 inches wide and at least 12-inches deep, followed by a sod strip that is at least 3 to 5 feet wide. The grass/gravel combination must encircle the entire bioretention area (Source: North Carolina Stormwater Manual, 2007.)

Advantages/Benefits

- Allows pretreatment of sheet flow dosed to certain SCMs.
- Smaller footprint than vegetated filter strips

Disadvantages/Limitations

- Limited pollutant removal.
- Gravel must be protected from traffic by curbs or other stops. Otherwise, the gravel will spread onto paved surfaces and into the bioretention area.

Suitability to treat TMDL Pollutants

- While some pretreatment SCMs are capable of removing certain TMDL pollutants, they cannot be used as a standalone practice.
- Pretreatment SCMs are encouraged to be implemented as part of a larger treatment train.

Unit Treatment Process

- Dispersion

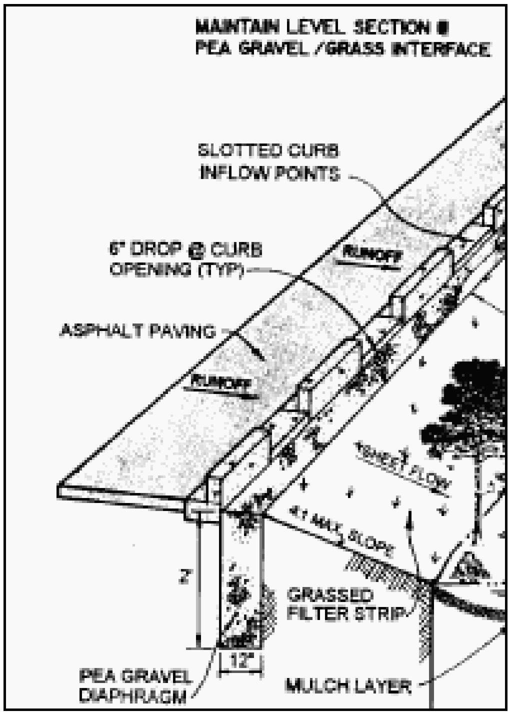
ESSD / LID Alternatives

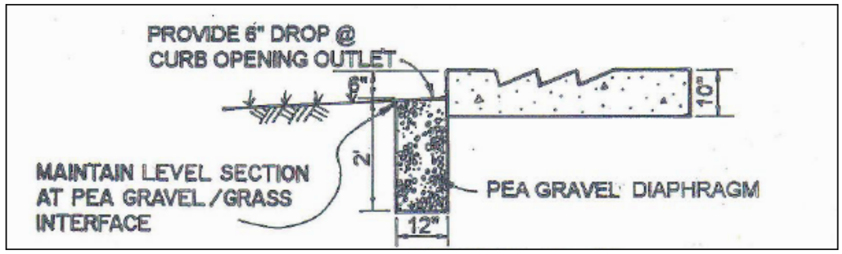
Not applicable. This is a pretreatment practice.

Suitable Applications

- Pretreatment for bioretention areas, infiltration trenches, ESSD Credit 3, ESSD Credit 4, and ESSD Credit 7.

Example Pea Gravel Diaphragm (from Claytor and Schueller, 1996)





Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

The pea gravel diaphragm with filter strip serves several purposes . First, it reduces the velocity of runoff from small storms. Second, it settles out coarser fractions of suspended sediment before they reach the bioretention area or rain garden. Third, it acts as a spreader, converting concentrated flow from impervious areas to sheet flow. The coarse fractions of sediment present in runoff as suspended sediment settle into the voids between the gravel. The filter strip component further lags incoming runoff from smaller storms and may provide some filtration of coarser sediments in the runoff.

Design Specifications

Pea Gravel Diaphragm component: A trench must be excavated. The trench must be a minimum of at least 12 inches wide. The depth of the trench must be a minimum of at least 24 inches. The trench must be located in the runoff flow path. The trench must be long enough to allow capture of runoff with bypass around the ends of the trench. Where bioretention areas or other applicable SCMs are located within landscaped areas and are not located immediately adjacent to paved areas such as parking lots, driveways, or roads, the pea gravel diaphragm must be located around the entire perimeter of the bioretention area in order to pretreat all sheet flow.

Pea gravel for the diaphragm must be ASTM D 448 size No. 6 (1/8” to ¼”). Use clean bank-run gravel only. The pea gravel must be back filled into the trench. The gravel should be hand shoveled into the trench when feasible to minimize disturbance of the trench by machinery. The gravel needs to be graded to provide a 6-inch drop below the curb openings from the adjacent paved surfaces to direct flow to the bioretention area.

When stormwater is first directed across lawns, landscaped areas, vegetated filter strips, and then to the pea gravel diaphragm, curbs or stops are not needed to protect the gravel or induce sheet flow.

Filter Strip component:

- The filter strip component must be located to pick up the runoff after it has flowed across the pea gravel diaphragm.
- The filter strip must be a minimum of 10 feet wide. Note this is less than the stand-alone “Vegetated Filter Strip” described in this Appendix.
- The filter strip slope must be no more than 2%. It must be planted with grasses to stabilize the surface, lag flow, and provide some further physical separation of suspended solids.
- For filter strips where road or parking lot runoff is directed, grasses selected to be planted in the filter strip should be salt tolerant.
- The filter strip component may be part of the bioretention area or rain garden. The bottom of rain garden or filtering bioretention area the pea gravel diaphragm with filter strip drains to must be at least 2-feet in elevation above seasonal high groundwater.

- Pea gravel diaphragm combined with a vegetated filter strip specially designed to provide pretreatment for a bioretention area as set forth in the following table.

Dimensions for Filter Strip Designed Specially to Provide Pretreatment for Bioretention Area

(Table source: Georgia Stormwater Manual and Claytor and Schuler 1996)

Parameter	Impervious Area				Pervious Areas (lawns, etc.)			
Max. inflow approach length (ft)	35		75		75		100	
Filter strip slope (max=6%)	<2%	>2%	<2%	>2%	<2%	>2%	<2%	>2%
Filter strip min. length (ft)	10	15	20	25	10	12	15	18

Maintenance

Activity	Frequency
Replace pea gravel as needed	Every 2 to 3 years
Maintain filter strip, including seasonally reseeding as necessary	Mowing as needed. Seasonally reseeding each spring and/or fall as needed

References

Georgia, 2001, Georgia Stormwater Management Manual, Bioretention, pages 3.23-43 to 3.23-58.

Claytor, Richard A. and Schueler, Thomas R., 1996. Design of Stormwater Filtering Systems. The Center for Watershed Protection. Silver Springs, MD.

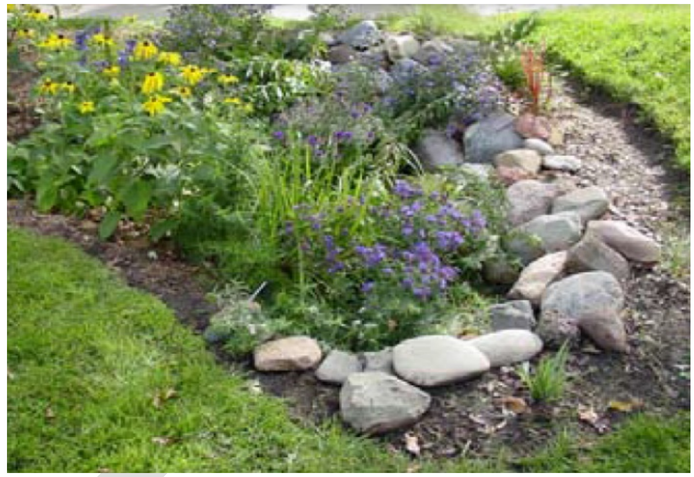
Structural Treatment

- **Bioretention Areas**
- **Constructed Stormwater Wetlands**
- **Extended Dry Detention Basin**
- **Proprietary Media Filters**
- **Sand and Organic Filters**
- **Wet Basins**
  (formerly wet retention ponds)

Bioretention Areas

Ability to meet specific standards

Standard	Description
2 - Peak Flow	**Bioretention (filtering and exfiltrating)** can both be designed to provide peak flow attenuation. See below for more information
3 - Recharge	**Bioretention (filtering)** does not provide groundwater recharge. **Bioretention (exfiltrating)** provides groundwater recharge.
4 - TSS/TP Removal	**Bioretention (filtering)** • Use EPA Performance Curve for Biofiltration. **Bioretention (exfiltrating)** • Use EPA Performance Curve for Infiltration Basin. Adequate pretreatment must be provided per Specification. See "Introduction" Section of this Appendix for more information the EPA Performance Curves.
5 - Higher Pollutant Loading	Can be used for certain land uses with higher potential pollutant loads if lined and sealed and adequate pretreatment is provided. Adequate pretreatment must include 44% TSS removal prior to infiltration. For land uses that have the potential to generate runoff with high concentrations of oil and grease such as high intensity use parking lots and gas stations, adequate pretreatment may also include an oil/grit separator, sand filter or equivalent. In lieu of a separator or sand filter, a filtering bioretention area also may be used as a pretreatment device for infiltration practices exfiltrating runoff from land uses with a potential to generate runoff with high concentrations of oil and grease.
6 - Discharges near or to Critical Areas	Suitable for discharges near Cold-Water Fisheries, bathing beaches and Shellfish Growing Areas, with adequate pretreatment and liners (if necessary).
7 - Redevelopment	Suitable with appropriate pretreatment
8 - Construction Phase	Construction phase runoff is not to be diverted to these areas; divert stormwater runoff to these areas only once the site has been stabilized.
11 - Total Maximum Daily Loads	See suitability to treat TMDL pollutant Tables (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.



Description

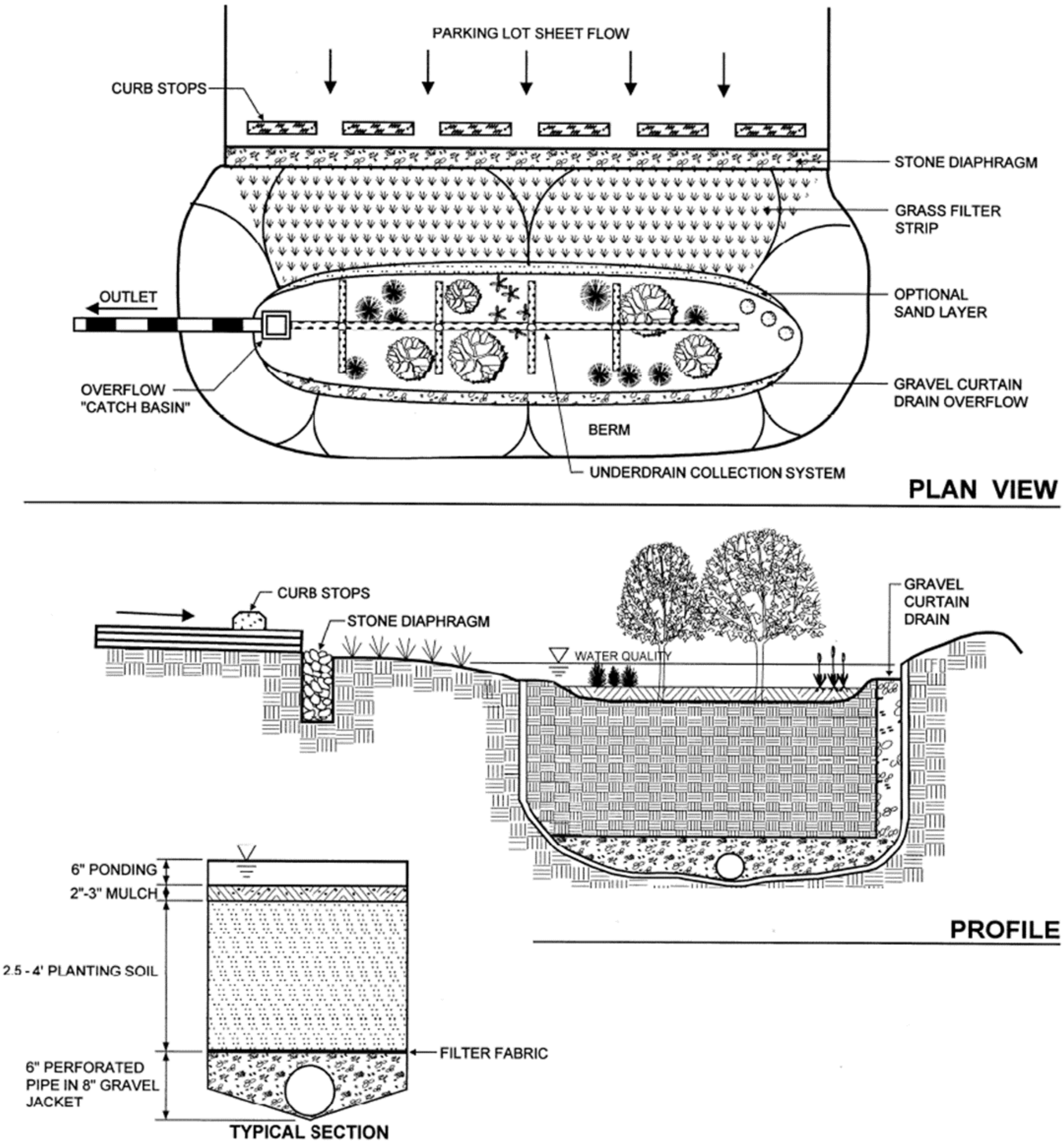
Bioretention is a technique that uses soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Bioretention cells are shallow depressions filled with sandy soil topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter. Bioretention areas may be designed to act as a filtering practice or an infiltration practice. Filtering bioretention areas do not infiltrate and cannot be used receive recharge credit towards Standard 3 – they have an underdrain that captures and conveys runoff downstream. Filtering bioretention areas may be lined. Exfiltrating bioretention areas are designed to provide infiltration.

There are two types of bioretention areas:

1. **Filtering Bioretention Areas** (designed solely as an organic filter): These areas contain an underdrain and do not infiltrate. A filtering bioretention area includes an impermeable liner, an overflow drain set to the maximum ponding depth, and an underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed to a discharge outlet, other best management practices, or the municipal storm drain system

2. **Exfiltrating Bioretention Areas**: exfiltrating bioretention areas (i.e., raingardens) configured to recharge groundwater in addition to acting as a filter. These areas may be configured as cells in series to provide additional recharge/overflow. This type does not contain an underdrain that connects to a stormwater treatment system outlet.

Example Filtering Bioretention Area
(Source: *2006 Vermont Stormwater Handbook*)



Filtering Bioretention Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	N
Total Phosphorous	N
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Exfiltrating Bioretention Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Special Features

- Adequate pretreatment is essential.
- Not recommended in areas with steep slopes.
- Depth of soil media depends on type of vegetation that is proposed.
- Soil media must be at least 30 inches deep to promote anoxic removal of nitrogen
- Not all bioretention cells are designed to exfiltrate. Infiltration requirements are applicable only to bioretention cells intended to exfiltrate.

Advantages/Benefits

- Bioretention Areas are Low Impact Development practices.
- Exfiltrating Bioretention Areas provide groundwater recharge and preserve the natural water balance of the site.
- Filtering Bioretention Areas filter pollutants
- Depending on mix of vegetation community, may provide shade, absorb noise, and provide windbreak.
- Removes other pollutants besides TSS and TP, including nitrogen, pathogens, and metals (dependent on filtering/exfiltrating design).
- Can be lined and sealed to prevent recharge where appropriate (filtering Bioretention).
- Can be used as a stormwater retrofit by modifying existing landscape or if a parking lot is being resurfaced.
- Can be used on small lots with space constraints.
- Exfiltrating Bioretention Areas minimize mosquito breeding compared to other SCMs.
- Little or no hazard for amphibians or other small animals

Disadvantages/Limitations

- Requires careful landscaping and maintenance
- Not suitable for large drainage areas

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Unit Process for Treatment

Physical settling, infiltration, chemical (sorption) and biological.

Applicability

Bioretention areas can provide excellent pollutant removal for the “first flush” of stormwater runoff. Properly designed and maintained cells remove suspended solids, metals, and nutrients, and can infiltrate an inch or more of rainfall. Distributed around a property, vegetated bioretention areas can enhance site aesthetics. In residential developments they are often described as “rain gardens” and marketed as property amenities. Routine maintenance is simple and can be handled by homeowners or conventional landscaping companies, with proper direction.

Bioretention systems can be applied to a wide range of commercial, residential, and industrial developments in many geologic conditions; they work well on small sites and on large sites divided into multiple small drainage areas. Bioretention systems are often well suited for ultra-urban settings where little pervious area exists. Although they require significant space (approximately 5% to 7% of the area that drains to them), they can be integrated into parking lots, parking lot islands, median strips, and traffic islands. Sites can be retrofitted with bioretention areas by replacing existing parking lot islands or by re- configuring a parking lot during resurfacing. On residential sites, they are commonly used for rooftop and driveway runoff.

Effectiveness

Bioretention areas remove pollutants through filtration, microbe activity, and uptake by plants; contact with soil and roots provides water quality treatment better than conventional infiltration structures. Studies indicate that bioretention areas can remove from 80% to 90% of TSS. If properly designed and installed, bioretention areas remove phosphorus, nitrogen, metals, organics, and bacteria to varying degrees.

Bioretention areas help reduce stress in watersheds that experience severe low flows due to excessive impervious cover. Low-tech, decentralized bioretention areas are also less costly to design, install, and maintain than conventional stormwater technologies that treat runoff at the end of the pipe.

Decentralized bioretention cells can also reduce the size of storm drainpipes, a major component of stormwater treatment costs. Bioretention areas enhance the landscape in a variety of ways: they improve the appearance of developed sites, provide windbreaks, absorb noise, provide wildlife habitat, and reduce the urban heat island effect.

Planning Considerations

Filtering bioretention areas are designed with an impermeable liner and underdrain so that the stormwater may be transported to additional SCMs for treatment and/or discharge. Exfiltrating bioretention areas are designed so that following treatment by the bioretention area the stormwater may recharge the groundwater.

Filtering bioretention areas are suitable to treat runoff from land uses with higher potential pollutant loads. Exfiltrating bioretention areas (rain gardens) may be used to treat runoff from high intensity parking areas, when source control is implemented and when pretreatment has been provided to achieve TSS removal of at least 44%. If the land use with higher potential pollutant load has the potential to generate runoff with high concentrations of oil and grease, other types of pretreatment, i.e., a deep sump catch basin and oil/grit separator or a sand filter, is required prior to discharge of runoff to an exfiltrating bioretention area.

A filtering bioretention area may also be used as a pretreatment device for an exfiltrating bioretention area or other infiltration practice that exfiltrates runoff from land uses with a potential to generate runoff with high concentrations of oil and grease.

Bioretention areas must not be located immediately adjacent to steep slopes. When the bioretention area is designed to infiltrate, the design must ensure vertical separation of at least 2 feet from the seasonal high groundwater table to the bottom of the bioretention cell.

For residential rain gardens, pick a low spot on the property, and route water from a downspout or sump pump into it. It is best to choose a location with full sun, but if that is not possible, make sure it gets at least half-day of sunlight.

Do not excavate an extensive rain garden or bioretention area under large trees. Digging up shallow feeder roots can weaken or kill a tree. If the tree is not a species that prefers hydric soil, the additional groundwater could damage it. The horizontal footprint of Rain gardens (exfiltrating type) must be sized using the same iterative process for infiltration practices (the 72-hour drawdown analysis – see **Section 6.2.3**).

Pre-treatment

To receive TSS and TP removal credit utilizing the EPA curves, pretreatment with at least 25% TSS removal must be provided. The following methods are credited to meet the pretreatment requirement.

If the flow is piped to the bioretention area:

- a deep sump catch basin combined with a sediment forebay will provide the 44% TSS removal.

For flow directed through an open channel:

- a grass channel; or
- water quality swale

For sheet flow, there are a number of pretreatment options to receive the 44% TSS removal credit. These options are:

- A vegetated filter strip that must be at least 25-feet wide, designed in accordance with the "*Vegetated Filter Strip*" specifications presented in this Appendix.
- A grass and gravel combination. This should consist of a gravel strip at least 8 inches wide and at least 12-inches deep, followed by a sod strip that is at least 3 to 5 feet wide. The grass/gravel combination must encircle the entire bioretention area (Source: North Carolina Stormwater Manual, 2007.)
- Pea gravel diaphragm combined with a vegetated filter strip specially designed to provide pretreatment for a bioretention area as set forth in the "*Pea Gravel Diaphragm with Filter Strip*" Specification included in this Appendix.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Size the bioretention area to be 5% to 7% of the area draining to it. Determine the vertical saturated hydraulic conductivity of the underlying native soil in accordance with the methods specified in **Section 6.3** of the Stormwater Handbook. Do not use a percolation test (i.e., Title 5) to determine the saturated hydraulic conductivity.

For exfiltrating bioretention, the bottom of the underlying gravel layer must be set in elevation at least 2-feet above seasonal high groundwater. For filtering bioretention, the bottom of the PVC membrane, geotextile fabric, clay liner, or media of filtering bioretention must be placed at least 2-feet in elevation above seasonal high groundwater.

The depth of the soil media must be between 2 to 4 feet. This range reflects the fact that most of the pollutant removal occurs within the first 2 feet of soil and that excavations deeper than 4 feet become expensive. The depth selected should accommodate the vegetation. If the minimum depth is used, only shallow rooted plants and grasses may be used.

If there is a Total Maximum Daily Load that requires nitrogen to be removed from the stormwater discharges, the bioretention area must have a soil media with a depth of at least 30 inches to create anoxic conditions. If trees and shrubs are to be planted within the bioretention area or rain garden, the soil media must be at least 3 feet deep

Size the cells (based on void spacing and ponding area) at a minimum to capture and treat:

- The **runoff volume** associated with the MassDEP Crosswalk Curves for TSS and TP removal (for new development, Stormwater Standard 4 90% TSS Removal/60% TP Removal and for Redevelopment, Stormwater Standard 7: 80% TSS removal and 50% TP removal);
- The **required recharge volume** when used only for recharge (Stormwater Standard 3); or the larger of the two when used to achieve compliance with Standards 3 and 4.

For exfiltrating bioretention, cover the bottom of the excavation with coarse gravel, over pea gravel, over sand. Earlier designs used geotextile fabric as a bottom blanket, but more recent experiences show that filter fabric is prone to clogging. Consequently, do not use geotextile fabrics or sand curtains. Use the Engineered Soil Mix below. Geotextile or PVC liners may be used for filtering bioretention.

Engineered Soil Mix for Both Infiltrating and Filtering Bioretention

The soil mix for bioretention areas must be a mixture of sand, triple shredded wood chips, and soil, blended together.

- 60% sand;
- 20 topsoil, (Clay content must not exceed 5%.); and
- 20% triple shredded wood chips blended into the sand and topsoil mix. The mix must not include any compost.
- The soil mix must be uniform, free of stones, stumps, roots or similar objects larger than 2 inches.

- Soil pH should generally be between 5.5-6
- 5, a range that is optimal for microbial activity and adsorption of nitrogen, phosphorus, and other pollutants.
- Use soils with 1.5% -3% organic content and maximum 500 ppm soluble salts.
- The sand component should be gravelly sand that meets ASTM D 422.

Sieve Size	Percent Passing
2-inch	100
¾ inch	70-100
¼ inch	50-80
U.S. No. 40	15-40
U.S. No. 200	0-3

- The topsoil component shall be a sandy loam, loamy sand, or loam texture.

On-site soil mixing or placement is not allowed if soil is saturated or subject to water within 48 hours. Cover and store soil to prevent wetting or saturation. Test soil for fertility and micro-nutrients and, only if necessary, amend mixture to create optimum conditions for plant establishment and early growth.

Grade the area to create a maximum ponding depth of 6-inches for infiltrating bioretention and 12-inches for filtering bioretention. Excessive ponding depth will cause vegetation mortality and scouring of the bioretention media.

Peak Reduction Modeling: For peak runoff reduction modeling, the depth of the "ponds" in the runoff model shall never exceed 12-inches. For exfiltrating bioretention areas, it is acceptable to discard loss to infiltration as detailed in **Section 6.3.3** of the Stormwater Handbook. Loss to infiltration may not be discarded for filtering bioretention areas. No storage shall be assumed to be provided by the bioretention media. The excess runoff in the peak runoff model shall be directed to a properly sized overflow. To receive peak credit, overflow must not be directed to an underdrain for exfiltrating bioretention areas.

Planting Plan: The planting plan shall include a mix of herbaceous perennials, shrubs, and (if conditions permit) understory trees that can tolerate intermittent ponding, occasional saline conditions due to road salt, and extended dry periods. A list of plants that are suitable for bioretention areas can be found at the end of this section. To avoid a monoculture, it is a good practice to include one tree per 175 square feet, and one per 50 square feet of bioretention area, with at least 3 species each of herbaceous perennials and shrubs. Invasive and exotic species are prohibited. The planting plan should also meet any applicable local landscaping requirements.

Drawdown: All exfiltrating bioretention areas must be designed to drain within 72 hours. However, rain gardens are typically designed to drain water within a day and are thus unlikely to breed mosquitoes.

For both bioretention types, the infiltration rate for design purposes for Stormwater Standard 3 must be based on the underlying parent material. (Generally, the underlying soil may have lower saturated hydraulic conductivity rate.) See **Section 6.2.3**.

Maximum Ponding Depth: The maximum ponding depth shall be set to 12-inches for both infiltrating and exfiltrating bioretention types.

Overflow: Must have an overflow to safely convey runoff during major storm events. Most filtering types include an overflow drain to direct ponded water to the underdrain.

Underdrains: Rain gardens (exfiltrating bioretention) shall not contain an underdrain.

Filtering bioretention area shall include an underdrain. The underdrain must be connected to an outlet to discharge or a conveyance directed to additional stormwater control measures.

Construction

Construction: During construction, avoid excessively compacting soils around the bioretention areas and accumulating salt around the drain field. To minimize sediment loading in the treatment area, direct runoff to the bioretention area only from the areas that are stabilized; always divert construction runoff elsewhere.

To avoid compaction of the parent material, work from the edge of the area proposed as the location of the cell until the cell and the contributing drainage areas are fully stabilized.

Place planting soils in 1-foot to 2-foot lifts and compact them with minimal pressure until the desired elevation is reached. Some engineers suggest flooding the cell between each lift placement in lieu of compaction.

Maintenance

Activity	Time of Year	Frequency
Inspect / remove trash	Year round	Monthly
Mow	Growing season	2 -12 times / year
Mulch	Spring	Annually
Fertilize	Growing season	Annually
Replace dead vegetation	Spring	Annually
Prune	Spring or fall	Annually
Replace entire media and all vegetation	Late spring / early summer	As needed*

* *"As needed" in this context for rain gardens means when runoff is observed to be ponding for greater than 3-days. Additionally, for filtering bioretention, when the runoff is observed to be ponding for greater than 3-days, the overflow drain and underdrain must be first checked for blockage. If the overflow drain and underdrain are not blocked, only then shall the media and vegetation be replaced.*

Premature failure of bioretention areas is a significant issue caused by lack of regular maintenance. Ensuring long-term maintenance involves sustained public education and deed restrictions or covenants for privately owned cells. Bioretention areas require careful attention while plants are being established and seasonal landscaping maintenance thereafter.

In many cases, a landscaping contractor working elsewhere on the site can complete maintenance tasks. Inspect pretreatment devices and bioretention cells regularly for sediment build-up, structural damage, and standing water.

Inspect soil and repair eroded areas monthly. Remove litter and debris monthly. Treat diseased vegetation as needed. Remove and replace dead vegetation twice per year (spring and fall).

Proper selection of plant species and support during establishment of vegetation should minimize—if not eliminate—the need for fertilizers and pesticides.

Remove invasive species as needed to prevent these species from spreading into the bioretention area. When runoff ponds in a rain garden for greater than three days, it indicates the media is becoming clogged and failure is occurring. When this occurs, excavate the bioretention area, scarify bottom and sides, replace gravel, sand, triple shredded woodchips, and soil, and replant.

Soil media should also be replaced if the soil media becomes disturbed, over-compacted, or contaminated with foreign or deleterious materials or liquids. For filtering bioretention, replace geotextile fabric or PVC liner. For rain gardens, there shall be no geotextile fabric or PVC liner, as it inhibits exfiltration. Disposal of used bioretention media shall be disposed of in accordance with MassDEP's Catch Basin Cleaning Policy (WEB: https://www.mass.gov/doc/catch-basin-cleanings-management-guidelines/download)

A summary of maintenance activities can be found on the previous page.

Because the soil medium filters contaminants from runoff, the cation exchange capacity of the soil media will eventually be exhausted. When the cation exchange capacity of the soil media decreases, change the soil media to prevent contaminants from migrating to the groundwater, or from being discharged via an underdrain outlet. Using small shrubs and plants instead of larger trees will make it easier to replace the media with clean material when needed.

Plant maintenance is critical. Concentrated salts in roadway runoff may kill plants, necessitating removal of dead vegetation each spring and replanting. The operation and maintenance plan must include measures to make sure the plants are maintained. This is particularly true in residential subdivisions, where the operation and maintenance plan may assign each homeowner the legal responsibility to maintain a bioretention cell or rain garden on his or her property. Including the requirement in the property deed for new subdivisions may alert residential property owners to their legal responsibilities regarding the bioretention cells constructed on their lot.

Cold Climate Considerations

Never store snow in bioretention areas. The Operation and Maintenance plan must specify where on-site snow will be stored. All snow dumps must comply with MassDEP's Snow Disposal guidance (As of 2020, WEB: https://www.mass.gov/doc/2020-snow-disposal-policy-and-guidance/download). When bioretention areas are located along roads, care must be taken during plowing operations to prevent snow from being plowed into rain gardens and bioretention areas.

If snow is plowed into the rain gardens and filtering bioretention area, runoff may bypass the rain garden/bioretention area and drain into downgradient wetlands without first receiving the required water quality treatment, and without recharging the groundwater comply with MassDEP's Snow Removal guidance. When bioretention areas are located along roads, care must be taken during plowing operations to prevent snow from being plowed into the bioretention areas. If snow is plowed into the cells, runoff may bypass the cell and drain into downgradient wetlands without first receiving the required water quality treatment, and without recharging the groundwater.

References

Low Impact Development Center, 2003, Drainage – Bioretention Specification, http://www.lowimpactdevelopment.org/epa03/biospec.htm

Prince Georges County, 2002, Bioretention Manual, http://www.goprincegeorgescounty.com/der/bioretention.asp

Puget Sound Action Team, 2005, Low Impact Development, Pp. 174 - 184 pdf http://www.psat.wa.gov/Publications/LID_tech_manual05/LID_manual2005.pdf

U.S. Environmental Protection Agency, 1999, Stormwater Technology Fact Sheet, Bioretention, EPA 832-F-99-012, http://www.epa.gov/owm/mtb/biortn.pdf

U.S. Environmental Protection Agency, 2005, National Management Measures to Control Nonpoint Source Pollution from Urban Areas, Publication Number EPA 841-B-05-004, Pp. 5-29, http://www.epa.gov/nps/urbanmm/

University of North Carolina,
www.bae.ncsu.edu/topic/bioretention
www.bae.ncsu.edu/stormwater/PublicationFiles/DesigningRainGardens2001.pdf

University of New Hampshire Stormwater Center, Specifications and Fact Sheets, https://www.unh.edu/unhsc/specs-and-fact-sheets-0.

Plantings for Bioretention Areas

When selecting species for bioretention areas (and other SCMs that include plantings such as raingardens, buffer zones, etc.), general considerations include the following:

- It is important to select **species that are well-suited to the expected hydrology** of the site. For example, species planted in center of a bioretention area should be able to withstand periodic inundation, while those planted on the upper margins should be drought-tolerant.

- To **select native species** that are appropriate for the regional climate, check the [USDA Plant Hardiness Zone Map](#) to see what planting zone the site is in. The hardiness zones in Massachusetts range from 5a in the Berkshire mountains to 7a on Cape Cod.

- Consider using a **mix of species** with varied height, texture, and color to add visual interest.

- What is the desired **plant size at maturity**? Although some shrub and small tree species can be easily pruned to maintain a desired size, consider how frequently such maintenance will be performed, or if there are other aesthetic considerations (such as maintaining views).

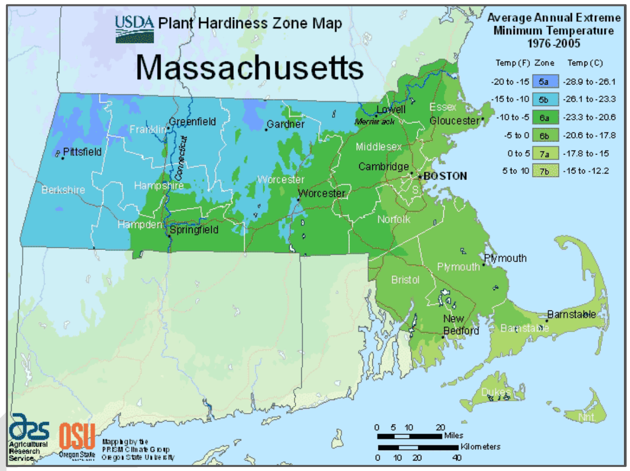
  Although larger trees may be suitable for some settings, make sure the site design (soil depth) can accommodate the full depth of the root zone at maturity, and that trees would not pose a potential risk to nearby structures, parking areas, etc.

- **Salt tolerance**: For bioretention areas that receive runoff from areas where salt is used for winter de-icing, special attention should be given to selecting salt-tolerant species. Look for the "salt-tolerant" icon in the table below.

- **Wildlife considerations**: In addition to their function within a bioretention area, plantings can benefit wildlife by providing food sources and habitat. However, it is also important to select species that will not be destroyed by wildlife and require replacement. For example, if deer are common in site vicinity, select [deer-resistant species](#). For shoreline plantings in areas where beavers are present, avoid woody species that are preferred by beavers, such as birch, aspen, alder, and willows.

- To help **ensure plant survival**, water immediately after planting, and then water weekly (if there is no significant rainfall) or as needed based on weather conditions during the first growing season. More frequent watering may be needed during hot weather.

A list of recommended New England native species for bioretention areas is provided on the following pages.



USDA Plant Hardiness Zone Map

Links to additional resources with planting lists and other guidance are provided below:

[Rain Gardens: A Way to Improve Water Quality](#)

[Native Plants for New England Rain Gardens](#)

[StormSmart Coasts - Coastal Landscaping in Massachusetts](#)

[The Vermont Rain Garden Manual](#)

[The Native Plant Trust](#)

[USDA Plants Database](#)

Bioretention Planting List

The species list below is adapted primarily from Rain Gardens: A Way to Improve Water Quality (University of Massachusetts Extension) and Native Plants for New England Rain Gardens (University of New Hampshire Extension), with additional information from the USDA Plants Database and The Native Plant Trust - Go Botany. This list includes examples of native species that are recommended for use in bioretention areas in Massachusetts, but is not intended to be a comprehensive list of all suitable species.

Symbol Key

Full Sun | Partial Sun | Shade | S Salt Tolerant

Type	***Scientific Name*** Common Name	Sun Exposure	Soil Moisture	Mature Height	USDA Hardiness Zone	Comments
Trees	***Acer negundo*** box elder maple	Full Sun, Partial Sun, Shade	dry to moist	30'-50'	3-8	Medium height, fast-growing tree; tolerates wide range of soil conditions; song birds and squirrels eat the seeds
	Acer rubrum red maple	Full Sun, Partial Sun, Shade	dry to wet	40'-60'	3-9	Shallow root system; attractive red flowers and fruit; tolerates moist or dry sites; red/yellow/orange fall color
	Betula populifolia gray birch (S)	Full Sun	dry to moist	20'-40'	3-6	Fast-growing smaller tree; a pioneer species; tolerates wide range of soil conditions
	Betula nigra river birch (S)	Full Sun, Partial Sun	dry to wet	40'-70'	4-9	Adaptable to wide range of moisture conditions; beautiful peeling bark; yellow fall color
	Carpinus caroliniana American hornbeam	Full Sun, Partial Sun	moist	20'-30'	3-9	Tolerates sun if soil is moist; tolerates periodic flooding; unique fluted silver-gray bark; yellow, red, or orange fall color
	Fraxinus pennsylvanica green ash (S)	Full Sun, Partial Sun, Shade	moist to wet	50'-70'	3-9	Fast-growing tall tree; tolerates a wide range of soil conditions and sun exposure; provides food and cover for various birds
	Nyssa sylvatica tupelo/black gum (S)	Full Sun, Partial Sun, Shade	dry to wet	40'-70'	3-9	Tolerates seasonal flooding or dry, rocky uplands; blue-black berries eaten by birds; brilliant scarlet fall foliage
Shrubs	***Amelanchier canadensis*** Canada serviceberry (S)	Full Sun, Partial Sun, Shade	dry to moist	15'-25'	4-7	Tall shrub (or small tree) with white flowers and reddish fruit in early summer; adaptable to many soil types and moisture conditions
	Aronia arbutifolia red chokeberry (S)	Full Sun, Partial Sun	dry to wet	6'-10'	4-9	White flowers in spring/summer; red fall foliage and bright red, edible berries in fall that persist into winter
	Arctostaphylos uva-ursi bearberry (S)	Full Sun, Partial Sun, Shade	dry to moist	1'-2'	2-6	Low-growing evergreen, highly tolerant of variable moisture conditions; requires acidic soil; small, shiny leaves and red berries
	Aronia melanocarpa black chokeberry (S)	Full Sun, Partial Sun	dry to wet	3'-6'	3-8	White flowers with red stamens; black berries persist in winter; dark purple-red fall color
	Clethra alnifolia sweet pepperbush (S)	Full Sun, Partial Sun, Shade	dry to moist	6'-8'	4-9	Fragrant white flower spikes; yellow fall color; butterfly nectar plant; well-suited to lower planting zone for bioretention areas

Type	*Scientific Name* Common Name	Sun Exposure	Soil Moisture	Mature Height	USDA Hardiness Zone	Comments
Shrubs	***Comptonia peregrina*** sweet fern		dry	2'-4'	2-6	Low-growing, deciduous shrub with sweet-scented, fern-like leaves; prefers acidic, sandy soil; best suited for upper margins/berms of bioretention areas
	Hamamelis virginiana common witch hazel		dry to moist	15'-20'	3-8	Spice-scented yellow flowers begin blooming in fall; tolerates irregular flooding or dry sites; yellow fall color
	Hydrangea arborescens smooth hydrangea		dry to moist	3'-5'	3-9	Creamy white flowers on new wood
	Ilex glabra inkberry		dry to wet	6'-12'	5-9	Slow-growing evergreen; greenish-white flowers and black-blue fruits; tolerates wet soils; periodic pruning recommended
	Ilex verticillata winterberry holly		moist to wet	6'-10'	3-9	White flowers; yellow fall color; both male and female needed for scarlet berries; tolerates wet soil; best suited for lowest/wettest portions of a bioretention area
	Leucothoe racemosa fetterbush		moist to wet	4'-6'	5-9	White drooping flowers; evergreen leaves turn red/purple after frost
	Rhododendron viscosum swamp azalea		moist to wet	6'-8'	4-9	Intensely fragrant white flowers; bronze fall color
	Salix discolor pussy willow		moist to wet	20'-40'	3-8	White flowers; silky gray catkins; provide a critical source of pollen for native bees that emerge early in the season
	Salix humilis small pussy willow		dry to moist	4'-8'	3-8	Vibrant green shrub with green catkins; deer resistant; attracts bees
	Salix purpurea purple osier willow		moist to wet	8'-10'	3-7	Fast-growing; low-maintenance; deer resistant; red catkins
	Sambucus canadensis elderberry		dry to wet	4'-12'	3-9	Large white flower clusters; purple berries eaten by a wide range of birds and mammals; fast-growing
	Swida amomum silky dogwood		moist to wet	6'-12'	4-8	Clusters of blue berries in summer
	Swida racemosa gray dogwood		moist to wet	10'-15'	4-8	Creamy, white flowers and berries in late summer
	Swida sericea red osier dogwood		moist to wet	6'-10'	3-8	White flowers; blue or white berries; red/maroon fall color; scarlet twigs in winter; highly adaptable
	Vaccinium angustifolium lowbush blueberry		dry to wet	6'-12'	2-5	Does well in acidic, poor soil; small edible blueberries; attractive bronze/red fall foliage

Type	***Scientific Name*** Common Name	Sun Exposure	Soil Moisture	Mature Height	USDA Hardiness Zone	Comments
Shrubs	***Viburnum dentatum*** arrowwood		dry to moist	5'-10'	3-8	Creamy white flowers; blue berries; crimson fall color
	Viburnum lentago nannyberry		dry to moist	14'-20'	2-8	Tall shrub with arching branches; white flowers in spring and black berries in late summer/ fall; attractive fall color
	Viburnum trilobum American cranberrybush		moist to wet	6'-10'	2-7	Densely branched shrub with creamy white flowers; edible red berries in fall that persist in winter; scarlet fall foliage
Perennials	***Actaea racemosa*** black cohosh/bugbane		moist	3'-6'	3-9	Flowers in large, white spikes; attracts pollinators
	Ageratina altissima white snakeroot		moist to wet	2'-3'	4-9	Summer blooms of long lasting, fuzzy white flower clusters; attracts pollinators
	Andropogon gerardii big bluestem		dry to moist	3'-5'	3-8	Clumping perennial grass with purplish, tassel-like flowers; tolerant of acid soil, sandy soil, flooding and drought.
	Aquilegia canadensis red columbine		moist	1'-2'	3-9	Flowers attract bees, hummingbirds, and butterflies; red flowers in late spring/early summer
	Asclepias incarnata swamp milkweed		moist to wet	2'-4'	3-9	Pink blooms in midsummer; butterfly nectar plant; monarch butterfly larval host plant
	Asclepias tuberosa butterfly milkweed		moist to wet	2'-4'	3-9	Orange summer blooms; monarch butterfly larval host; plant on a dry berm or upper margins of bioretention area
	Chelone glabra white turtlehead		moist to wet	2'-3'	3-9	White snapdragon type flowers; good fall bloomer; attracts butterflies and hummingbirds; best suited for lowest/wettest portions of a bioretention area
	Dennstaedtia punctilobula hay-scented fern		dry to moist	1'-3'	3-8	Spreads rapidly; fragrant, light-green foliage turns yellow in fall
	Dryopteris marginalis marginal wood fern		dry to moist	1'-3'	3-8	Fern with a leathery blue-green frond; spring fiddleheads are golden brown and furry
	Eupatorium perfoliatum common boneset		moist to wet	2'-5'	3-8	Prefers soil with relatively high organic matter content; excellent for attracting pollinators; deer and rabbit resistant
	Eurybia divaricata white wood aster		dry to moist	1'-3'	3-8	Good for dry shade or moist woods; white flowers attract butterflies
	Eutrochium purpureum sweet Joe Pye weed		moist to wet	5'-8'	3-9	Huge, dusty-pink flowers attract bees, birds, and butterflies; good fall color

Type	***Scientific Name*** Common Name	Sun Exposure	Soil Moisture	Mature Height	USDA Hardiness Zone	Comments
Perennials	***Gentiana clausa*** meadow bottle gentian		moist to wet	1'-3'	3-8	Bottle-shaped blue-purple flowers that never truly open; attracts bees and butterflies
	Geranium maculatum wild geranium, cranesbill		dry to moist	1'-2'	4-8	Showy pink flowers; very adaptable; important pollinator for native bees
	Hibiscus moscheutos swamp rose mallow		moist to wet	3'-6'	5-8	Shrub-like plant with large pink or white flowers; hummingbird nectar plant; best suited for lowest/wettest portions of a bioretention area
	Iris versicolor blue flag S		moist to wet	2'-3'	2-7	Deep blue blooms on attractive grass-like foliage; can grow with roots in water; best suited for placing at bioretention low spots or near inlet/outlet
	Lobelia cardinalis cardinal flower S		moist to wet	2'-3'	3-9	Will grows in full sun if kept moist; red flowers attract hummingbirds; best suited for placing at bioretention low spots or near inlet/outlet
	Lobelia siphilitica great blue lobelia		moist	2'-3'	4-9	Bell-shaped blue flowers remain in bloom for 3 to 4 weeks (*Note: This species in endangered in Massachusetts)*
	Matteuccia struthiopteris fiddlehead fern, ostrich fern		moist to wet	4'-5'	2-8	Plants form colonies by underground rhizomes; tall arching fronds; best suited for placing at bioretention low spots or near inlet/outlet
	Osmunda cinnamomea cinnamon fern		moist to wet	2'-4'	3-10	Grows in clumps with cinnamon-colored fronds; needs constant moisture if in sun; best suited for placing at bioretention low spots or near inlet/outlet
	Osmunda regalis royal fern		moist to wet	3'-6'	3-10	A tall, clump-forming fern producing a large rosette of bright green fronds; best planted in partial shade, but will grow in sun with ample moisture
	Panicum virgatum switch grass S		dry to moist	3'-6'	3-9	Attractive and adaptable grass; tolerates flooding; airy seed heads in summer
	Schizachyrium scoparium little bluestem S		dry to moist	3'-4'	3-9	Attractive native grass, blooms in August; dense root system; tolerant of poor soils
	Solidago spp. goldenrod S		dry to moist	18" – 6'	*Varies by species*	Over 20 *Solidago* species native to New England; yellow/golden late season color
	Symphyotrichum laeve smooth aster		dry to moist	2'-4'	3-9	Pale blue flowers attract birds, bees, and butterflies
	Symphyotrichum novae-angliae New England aster S		moist to wet	2'-3'	4-8	Nectar source for butterflies; important pollinator plant in late fall
	Symphyotrichum novi-belgii New York aster		moist to wet	3'	4-8	Purple flower with orange centers; attracts bees

Type	***Scientific Name*** Common Name	Sun Exposure	Soil Moisture	Mature Height	USDA Hardiness Zone	Comments
Perennials	***Tiarella cordifolia*** foam flower		moist	1'	3-8	Attractive groundcover with spikes of foamy white flowers in spring
	Verbena hastata blue vervain		moist to wet	3'-5'	3-9	Tall blue/purple flower spikes which bloom from summer through fall; attract birds, bees, and butterflies
	Vernonia noveboracensis New York ironweed		moist to wet	4'-6'	5-8	Good nectar source for monarch butterflies; best suited for placing at bioretention low spots or near inlet/outlet

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Constructed Stormwater Wetlands

Description

Constructed stormwater wetlands are stormwater wetland systems that maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling. Constructed stormwater wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Like extended dry detention basins and wet basins, constructed stormwater wetlands must be used with other SCMs, such as sediment forebays. There are five basic types of constructed stormwater wetlands: shallow marsh systems, basin/wetland systems, extended detention wetlands, pocket wetlands, and gravel wetlands. Information on gravel wetlands is presented at the end of this section.

Ability to meet specific standards

Standard	Description
2 - Peak Flow	If properly designed, can provide peak flow attenuation. Only volume in elevation above the permanent "pond" may be claimed for peak runoff rate reduction.
3 - Recharge	Provides no groundwater recharge
4 - TSS/TP Removal	Use EPA Performance Curve for Gravel Wetland to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves. Sediment forebay required for pretreatment.
5 - Higher Pollutant Loading	May be used as treatment SCM provided basin bottom is lined and sealed. When used for LUHPL drainage, the bottom must be placed at least 2-feet above the Seasonal High Groundwater elevation
6 - Discharges near or to Critical Areas	Do not use near Coldwater Fisheries or vernal pools. Suitable for use near other critical areas.
7 - Redevelopment	Suitable if sufficient space is available.
8 - Construction Phase	Construction phase runoff is not to be diverted to these areas; divert stormwater runoff to these areas only once the site has been stabilized.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Advantages/Benefits

- High pollutant removal efficiencies for soluble pollutants and particulates.
- Removes nitrogen, phosphorus, oil and grease
- Enhances the aesthetics of a site and provides recreational benefits.
- Provides wildlife habitat.

Disadvantages/Limitations

- Depending upon design, more land requirements than other SCMs.
- Until vegetation is well established, pollutant removal efficiencies may be lower than anticipated.
- Relatively high construction costs compared to other SCMs.
- May be difficult to maintain during extended dry periods.
- Does not provide recharge
- Creates potential breeding habitat for mosquitoes
- May present a safety issue for nearby pedestrians
- Can serve as decoy wetlands, intercepting breeding amphibians moving toward vernal pools. Any fencing must be designed and constructed so as not to create a barrier to wildlife movement. Generally, this means the bottom of any fencing must be at least 6-inches above the ground.

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Unit Process for Treatment

- Physical settling
- Biological uptake

Special Features

Like other stormwater SCMs, constructed stormwater wetlands may not be located within wetland Resource Areas regulated under the Massachusetts Wetlands Protection Act other than Riverfront Area, Land Subject to Coastal Storm Flowage, Isolated Land Subject to Flooding or Bordering Land Subject to Flooding.

The Operation and Maintenance Plan for constructed stormwater wetlands must include measures for monitoring and preventing the spread of invasive species

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

The Five Basic Types of Constructed Stormwater Wetlands

Like wet basins, most constructed stormwater wetlands require relatively large contributing drainage areas and dry weather base flows. Ten acres is the minimum contributing drainage area, although pocket type wetlands may be appropriate for smaller sites, if sufficient groundwater flow is available.

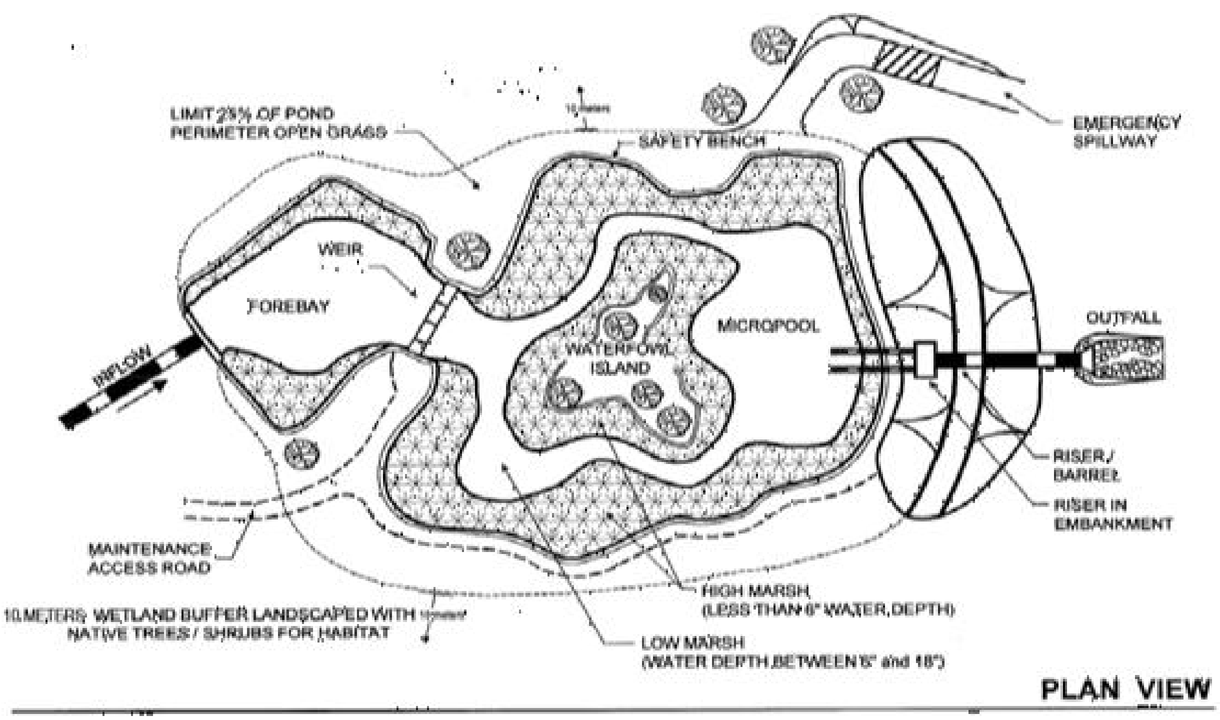
As described on the following pages, there are five basic constructed wetland designs:

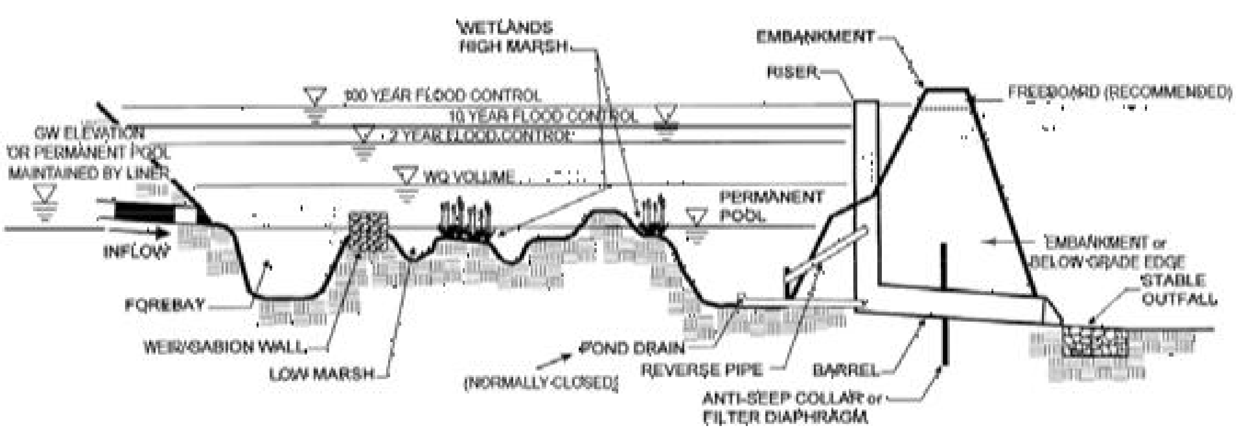
1. Shallow Marsh
2. Basin/Wetland (formerly Pond/Wetland)
3. Extended Detention (ED) Wetland,
4. Pocket Wetland
5. Gravel Wetlands (also known as Subsurface Gravel Wetlands)

Shallow Marsh Systems

Most shallow marsh systems consist of pools ranging from 6 to 18 inches deep during normal conditions. Shallow marshes may be configured with different low marsh and high marsh areas, which are referred to as cells. Shallow marshes are designed with sinuous pathways to increase retention time and contact area. Shallow marshes may require larger contributing drainage areas than other systems, as runoff volumes are stored primarily within the marshes, not in deeper pools where flow may be regulated and controlled over longer periods of time.

Example Shallow Marsh Wetland - Adapted from Schueler 1992

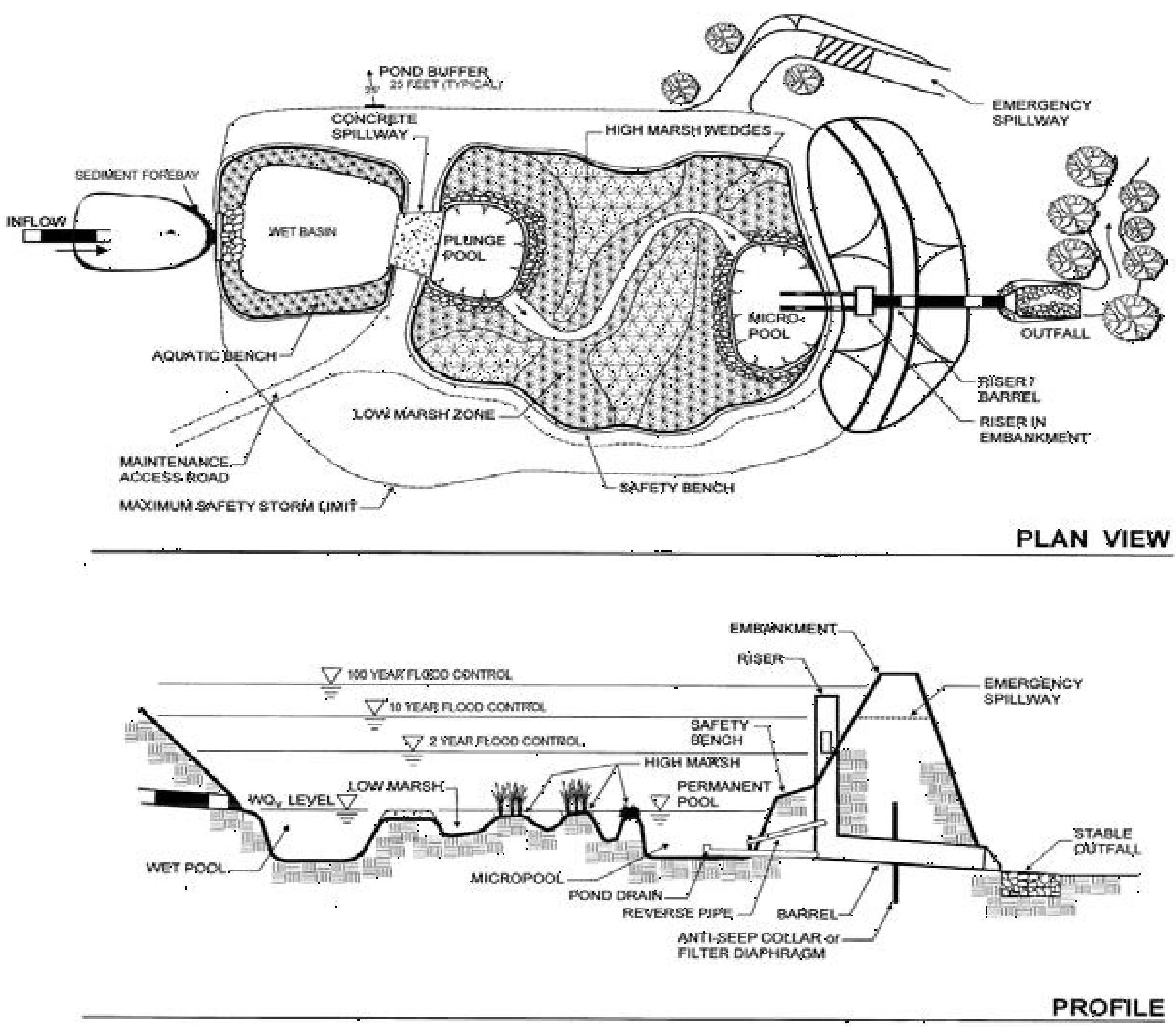




Basin/Wetland Systems
(formerly pond/wetland system)

Multiple cell systems, such as basin/wetland systems, use at least one wet basin along with a shallow marsh component. The first cell is a sediment forebay that outlets to a wet basin, which removes particulate pollutants. The wet basin also reduces the velocity of the runoff entering the system. Stormwater then travels to the next cell, which contains a plunge pool. The plunge pool acts as an energy dissipator. Shallow marshes provide additional treatment of runoff, particularly for dissolved pollutants. These systems require less space than the shallow marsh systems and generally achieve a higher pollutant removal rate than other stormwater wetland systems.

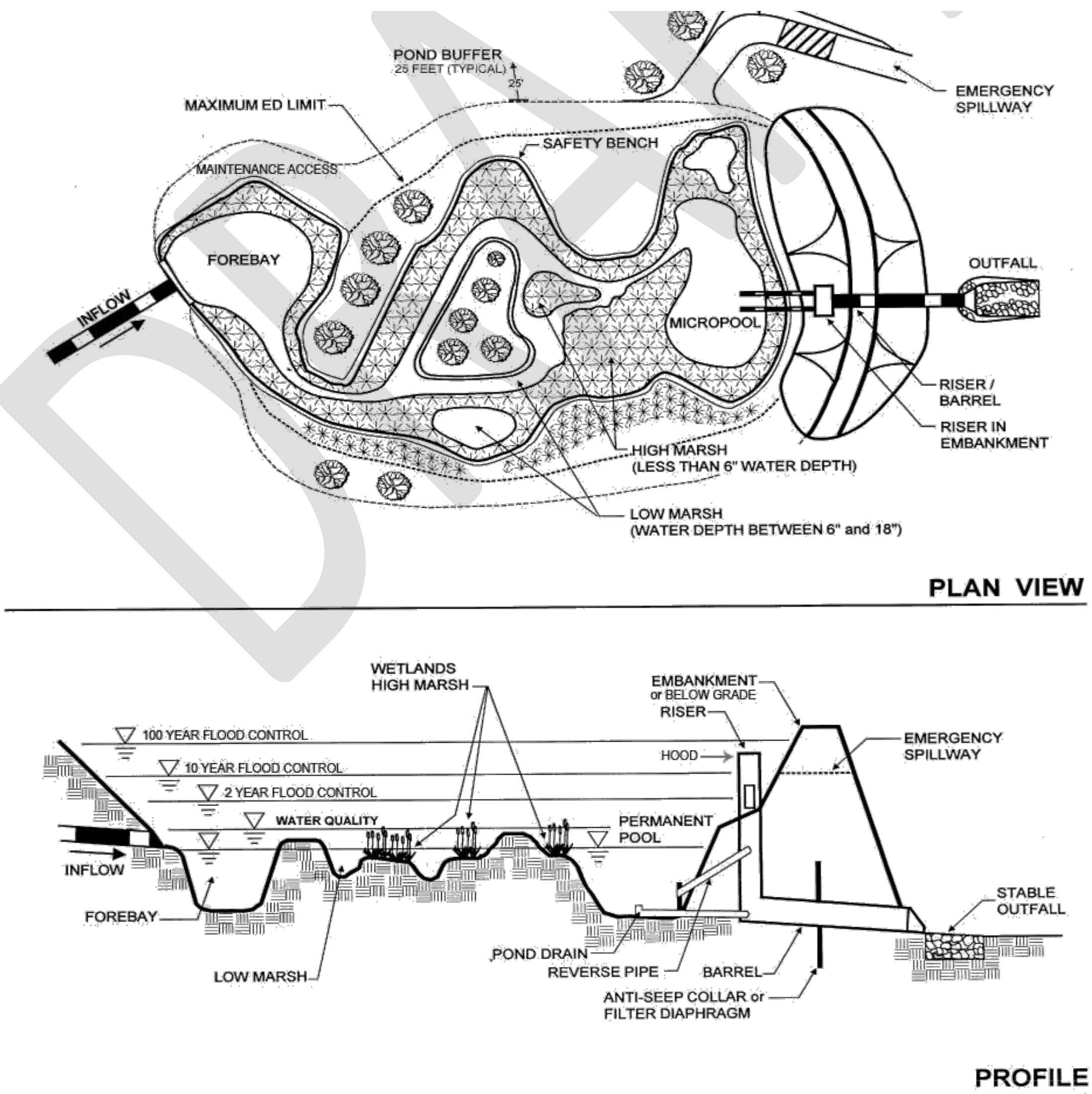
Example Basin Wetland - Adapted from Schueler 1992



Extended Detention Wetlands

Extended detention wetlands provide a greater degree of downstream channel protection. These systems require less space than shallow marsh systems, because temporary vertical storage substitutes for shallow marsh storage. The additional vertical storage area also provides extra runoff detention above normal elevations. Water levels in the extended detention wetlands may increase by as much as three feet after a storm, and return gradually to normal within 24 hours of the rain event. The growing area in extended detention wetlands expands from the normal pool elevation to the maximum Surface Water elevation. Wetlands plants that tolerate intermittent flooding and dry periods should be selected for the extended detention area above the shallow marsh elevations.

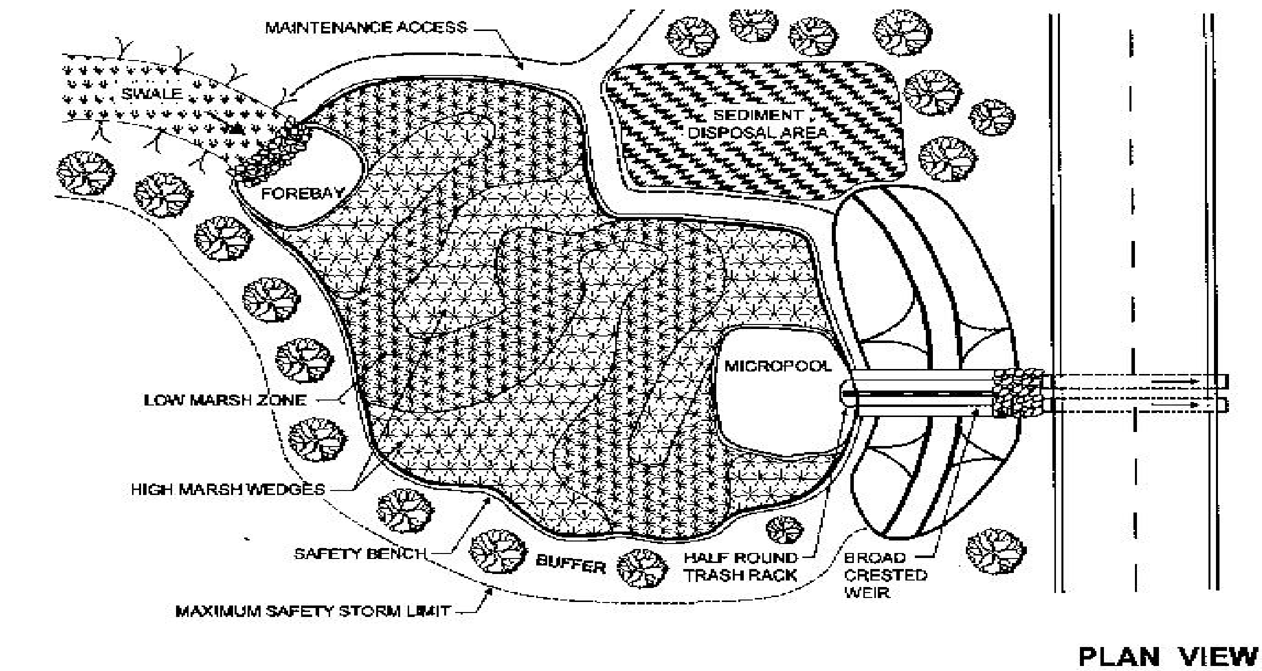
Example Extended Detention Wetland - Adapted from Schueler 1992

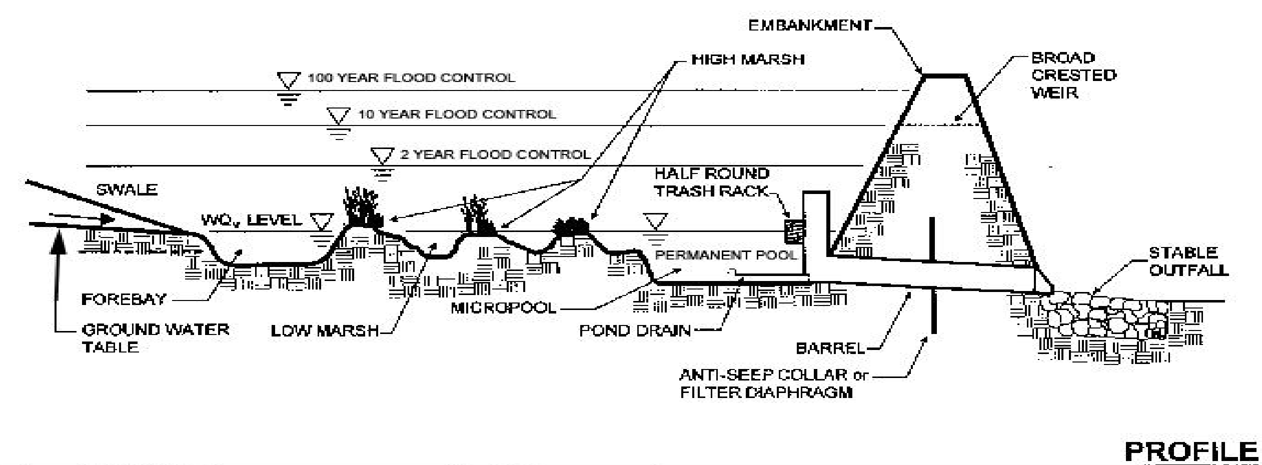


Pocket Wetlands

Use these systems for smaller drainage areas from one to ten acres. To maintain adequate water levels, excavate pocket wetlands to the groundwater table. Pocket wetlands that are supported exclusively by stormwater runoff generally will have difficulty maintaining marsh vegetation during normal dry periods each summer.

Example Pocket Wetland - Adapted from Schueler 1992

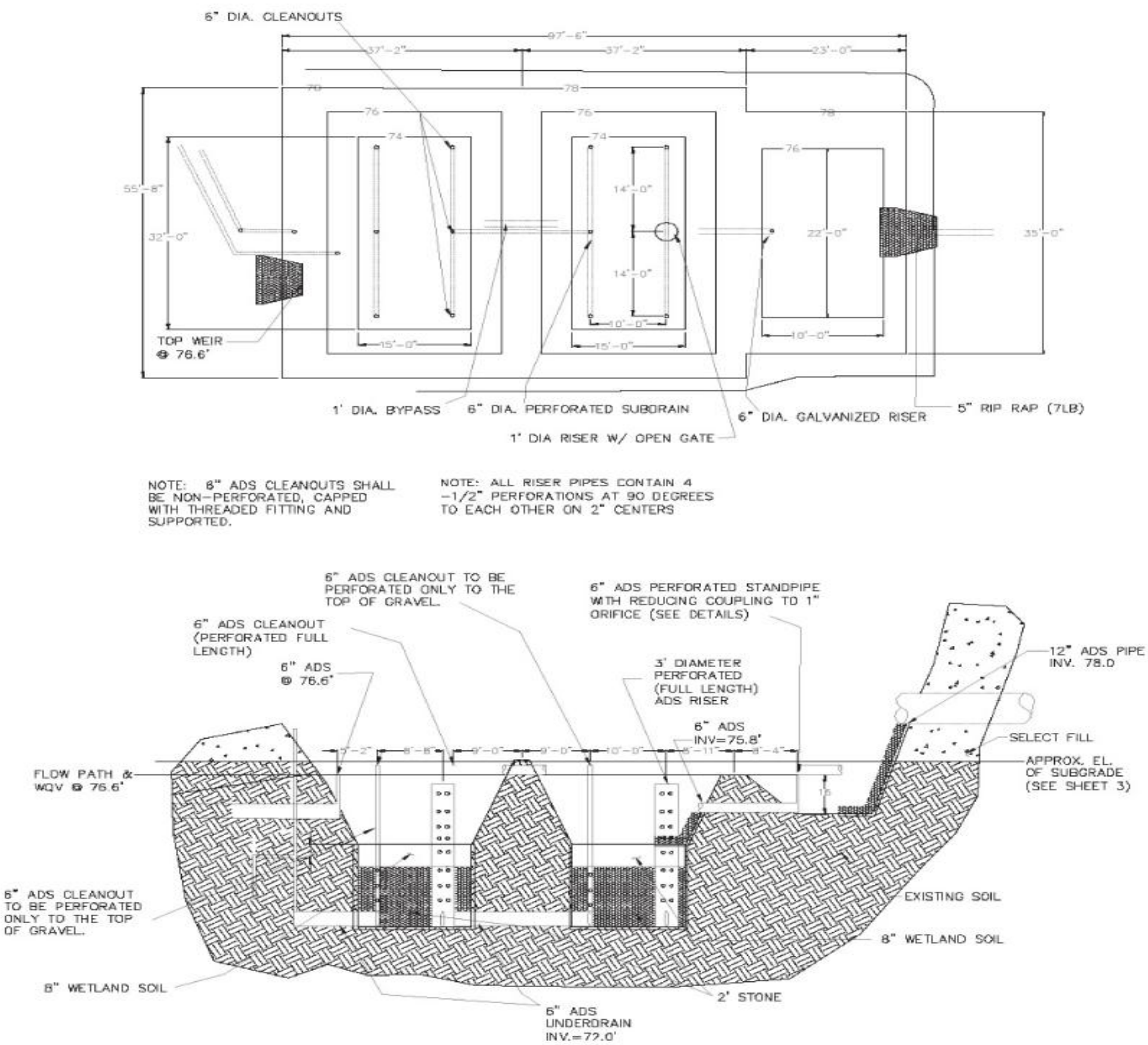




Gravel Wetlands

The gravel wetland consists of a series of horizontal flow through treatment cells preceded by a sediment forebay. The University of New Hampshire (UNH) has developed specifications that allow the gravel wetland to treat the required water quality volume; 10% in the forebay and 45% in each treatment cell. The UNH design calls for excess runoff to overflow into an adjacent swale with side slopes graded at 3:1 or flatter.

Treatment occurs in each cell as stormwater passes horizontally through the microbe rich gravel substrate. The wetland is designed to continuously saturate at a depth that begins four inches below the treatment's surface. This design permits treatment and vegetation growth. To generate this condition, UNH designs the device with an outlet pipe that has an invert 4 inches below the surface. For information on gravel wetland design, see https://www.unh.edu/unhsc/sites/default/files/media/unhsc_gravel_wetland_spec_6-2016.pdf.



Example Gravel Wetland

Applicability

Never use constructed stormwater wetlands to manage runoff during site grading and construction. Site constraints that can limit the suitability of constructed stormwater wetlands include inappropriate soil types, depth to groundwater, contributing drainage area, and available land area. Soils consisting entirely of sands are inappropriate unless the groundwater table intersects the bottom of the constructed wetland or the constructed stormwater wetland is installed over the sand to hold water. Where land area is not a limiting factor, several wetland design types may be possible. Consider pocket wetlands where land area is limited.

Do not locate constructed stormwater wetlands within natural wetland areas. These engineered stormwater wetlands differ from wetlands created for restoration or replication. Typically, constructed stormwater wetlands will not have the full range of ecological functions of natural wetlands. Constructed stormwater wetlands are designed specifically to improve water quality. Note that constructed stormwater wetlands do not create any additional wetland Resource Area or Buffer Zones as discussed in **Section 3**.

Before designing and siting constructed stormwater wetlands, investigate soil types, depth to bedrock, and depth to water table. Medium-fine texture soils (such as loams and silt loams) are best at establishing vegetation, retaining Surface Water, facilitating groundwater discharge, and capturing pollutants.

At sites where infiltration is too rapid to sustain permanent soil saturation (such as sandy soils), consider using an impermeable liner. Liners are also required where the potential for groundwater contamination from runoff is high, such as from sites with high potential pollutant loads.

At sites where bedrock is close to the surface, high excavation costs may make constructed stormwater wetlands infeasible. Table CSW.1 lists the recommended minimum design criteria for constructed stormwater wetlands.

Effectiveness

A review of the existing performance data indicates that the removal efficiencies of constructed stormwater wetlands are significantly higher than the removal efficiencies of dry extended detention basins. Constructed stormwater wetlands are among the most effective treatment practices.

To preserve their effectiveness, MassDEP requires placing a sediment forebay as pretreatment for all constructed stormwater wetlands.

Studies indicate that removal efficiencies of constructed stormwater wetlands decline when they are covered by ice or receive runoff derived from snow melt. Performance also declines during the non- growing season and the fall when vegetation dies off. Expect lower pollutant removal efficiencies until vegetation is re-established.

One preferred wetland installation is to combine an off-line stormwater wetland design, for runoff quality treatment, with an on-line runoff quantity control, because large surges of water can damage wetlands. Further, the shallow depths required to maintain the wetlands conflict with the need to store large volumes to control runoff quantity.

Planning Considerations

Carefully evaluate sites when planning constructed stormwater wetlands. Investigate soils, depth to bedrock, and depth to water table before designing, permitting, and siting constructed wetlands. Applicants must consider a “pond-scaping plan” for each constructed stormwater wetland. The plan must contain the location, quantity and propagation methods for the wetland plants as well as site preparation and maintenance. The plan should also include a wetland design and configuration, elevations and grades, a site/soil analysis, estimated depth zones, and hydrological calculations or water budgets.

The water budget must demonstrate that a continuous supply of water is available to sustain the constructed stormwater wetland. Develop the water budget during site selection and then check it after the preliminary site design. The water budget analysis must be based on the Thornwaite method, arranging data in a “bookkeeping” or “spreadsheet” format. The water budget must take into account precipitation, runoff, evapotranspiration, soil moisture, and groundwater inputs. Drying periods of longer than two months adversely affect the richness of the plant community, so make sure that the water budget confirms that the drying time will not exceed two months.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Table CSW.1 Recommended Design Criteria for Stormwater Constructed Wetlands Designs

Design Criteria	Shallow Marsh	Basin/Wetland	ED Wetland	Pocket Wetland	Gravel Wetland (sub-Surface)
Minimum Drainage Area (acres)	≥25	≥25	≥10	≥1 to 10	
Constructed Wetland Surface Area[1]/Watershed Area Ratio	≥0.02	≥0.01	≥0.01	≥0.01	
Length to Width Ratio (minimum)	≥2:1	≥2:1	≥2:1	≥2:1	
Extended Detention (ED)[2]	NOT ALLOWED	OPTIONAL	YES	OPTIONAL	
Allocation of WQv Volume (wet pools[3]/low and high marsh/ED) in %	30/70/0	70/30/02	20/30/50	20/80/02	
Allocation of Surface Area (wet pools/low marsh/high marsh/semi-wet) in %	15/40/40/5	45/25/25/5	10/40/40/10	10/45/40/5	
Sediment Forebay	REQUIRED	REQUIRED	REQUIRED	REQUIRED	
Micropool	REQUIRED	REQUIRED	REQUIRED	REQUIRED	
Outlet Configuration	Reverse slope pipe or hooded broad crested weir	Reverse slope pipe or hooded broad crested weir	Reverse slope pipe or hooded broad crested weir	Hooded broad crested weir	
Target Allocations	**Shallow Marsh**	**Basin/Wetland**	**ED Wetland**	**Pocket Wetland**	***SEE SPECIFICATIONS***
% Surface Area					
Percent Wetland Plants	85%	>55%	>90%	>90%	
Sediment Forebay[4]	5%	0%[5]	5%	5%	
Micropool	5%	5%	5%	5%	
Deep Water Channel	5%	40%	0%	0%	
Low Marsh	40%	25%	40%	45%	
High Marsh	40%	25%	40%	40%	
Semi Wet	5%	5%	10%	5%	
% WQv Volume					
Sediment Forebay	10%	0%[5]	10%	10%	
Micropool	10%	10%	10%	10%	
Deep Water Channel[6]	10%	60%	0%	0%	
Low Marsh	45%	20%	20%	55%	
High Marsh	25%	10%	10%	25%	
Semi Wet	0%	0%	50%(ED)	0%	
Low/High/Semi Wet Depth	6/18/24 inches	6/18/24 inches	6/18/24 inches	6/18/24 inches	

Notes:

1. Constructed Wetland Surface Area includes wet pool, deep water channel, marshes, and semi-wet zone.
2. ED volume shall be an additional volume above the WQv (except for the ED Wetland)
3. Wet Pool = Forebay+Micropool+Deep Water
4. Sediment Forebay for 1/2-inch WQv is 20% of WQv. Only 10% of that Volume may be included in the Constructed Wetland.
5. Basin Wetland Forebay: Forebay sizing must not be counted as part of WQv. Sediment Forebay Volume = 0.1-inch x Impervious area
6. Includes “basin” volume in Basin/Wetland Design

Design Considerations

Constructed stormwater wetlands may be designed as on-line systems with permanent pools for both treatment and storage of peak flows. Constructed stormwater wetlands can also be designed as off-line systems with high flows routed around the wetland. The basic constructed stormwater wetland design sizing criteria is set forth in **Table CSW.1**. Whether designed as an on-line or off-line system, a constructed stormwater wetland must be sized for the required water quality volume. The required water quality volume to achieve 90% TSS/60% TP removal or 80% TSS/50% TP removal is determined using the EPA curve for gravel wetlands.

All types of Constructed Stormwater Wetlands may be designed so as to intersect the groundwater table, except for the gravel wetland types. Gravel wetlands types must be designed to have the lowest portion of the gravel layer at least 2 feet above seasonal high groundwater. Siting CSWs in relation to seasonal high groundwater table is critical to ensure adequate hydrology to support hydrophytic vegetation. See **Section 6.3** for procedures to identify seasonal high groundwater. When CSWs are constructed above the groundwater table, the designer needs to ensure that the contributing impervious area will be large enough to provide adequate hydrology to support the growth of hydrophytic vegetation.

The ratio of the surface area of the constructed stormwater wetland to longer flow paths through the constructed stormwater wetlands to the contributing watershed area must meet the criteria specified in **Table CSW.1**. The reliability of pollutant removal tends to increase as the ratio of constructed stormwater wetlands area to watershed area increases.

Design the constructed stormwater wetlands with the required proportion of "depth zones." Each of the constructed wetland designs other than the gravel wetland, has depth zone allocations, which are given as a percentage of the stormwater wetland surface area. Target allocations for these constructed wetland designs are listed in **Table CSW.1**. The four basic depth zones are (see **Figure CSW.1**):

Deepwater zone

From 1.5 feet to six feet below normal pool elevation. This zone supports little emergent vegetation, but may support submerged or floating vegetation.

This zone can be further broken down into forebay, micropool and deepwater channels.

Low marsh zone

Ranges from 6 inches to s18 inches below the normal pool elevation. This area is suitable for growing several emergent wetland plant species.

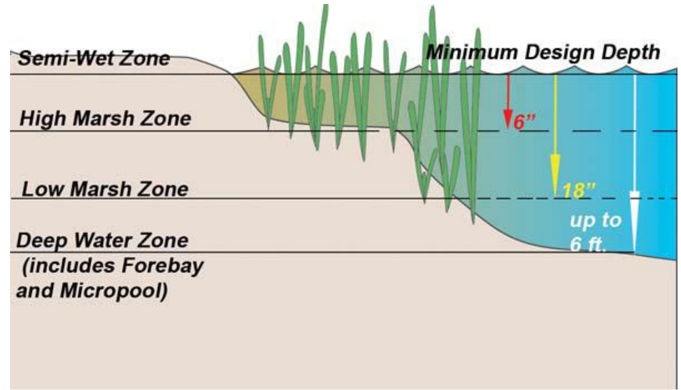


Figure CSW.5 Example Design Depth Zones *(see Table CSW.1 for actual recommended design criteria)*

High marsh zone

Ranges from the normal pool elevation to 6 inches below normal pool elevation. This zone will support a greater density and diversity of emergent wetland species than the low marsh zone. The high marsh zone must have a higher surface area to volume ratio than the low marsh zone (see **Table CSW.1**).

Semi-wet zone

This zone includes those areas above the normal pool elevation that are intermittently inundated and that can be expected to support wetland plants.

Design each constructed stormwater wetland with the required proportion of treatment volumes, which have been represented as a percentage of the three basic depth zones (pool, marsh, extended detention). **Table CSW.1** specifies the allocations of treatment volume per zone.

Increase the contact time over the surface area of the marsh, thereby improving treatment efficiency. The constructed stormwater wetland must be designed to achieve a dry weather flow path of 2:1 (length: width) or greater.

Prepare a water budget to demonstrate that the water supply to the constructed stormwater wetland is greater than the expected loss rate. The water budget must be based on the Thornwaite method.

Provide extended detention (ED) for smaller storms. Schueler 1992 lists the following design standards for ED wetlands:

- The volume of the extended detention must be no more than 50% of the total treatment volume.
- The target ED detention time for this volume must be 12 to 24 hours.

- Use V-shaped or proportional weirs to ensure constant detention time for all storm events.
- Extended detention is defined here as the retention and gradual release of a fixed volume of stormwater runoff. For ED wetlands less than 100 acres, the extended detention volume can be assumed to fill instantaneously for design purposes.
- Use a reverse slope pipe and increase the actual diameter of the orifice to the next greatest diameter on the standard pipe schedule. The pipe must be equipped with a gate valve.
- Protect the ED orifice from clogging.
- Make the maximum ED water surface elevation no greater than three feet above the normal pool elevation.

Design each constructed stormwater wetland with a separate cell near the inlet to act as a sediment forebay. Design the forebay with a capacity of at least 10% of the total treatment volume, normally 4 to 6 feet deep. Provide a direct and convenient access for cleanout.

Surround all deep-water cells with a safety bench that is at least ten feet wide, and zero to 18 inches below the normal water depth of the pool.

Place above-ground berms or high marsh wedges at approximately 50-foot intervals, and at right angles to the direction of the flow to increase the dry-weather flow path within the wetland.

Include a four- to six-foot deep micropool before the outlet to prevent the outlet from clogging. Provide a micropool capacity of at least ten percent of the total treatment volume. Use a reverse slope pipe or a hooded, broad- crested weir for outlet control. Locate the outlet from the micropool at least one foot below the normal pool surface.

To prevent clogging, install trash racks or hoods on the riser. To facilitate access for maintenance, install the riser within the embankment. Install anti-seep collars on the outlet barrel to prevent seepage losses and pipe failures. Install a bottom drainpipe with an inverted elbow to prevent clogging and to facilitate complete draining of the wetland for emergency purposes or routine maintenance. Fit both the outlet pipe and the bottom drainpipe with adjustable valves at the outlet ends to regulate flows. Design embankments and spillways in accordance with the state regulations and criteria for dam safety.

All constructed stormwater wetlands must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure.

Provide an access for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, through public or private rights-of-way. Make sure this access extends to the forebay, safety bench, outflow structure, and entire perimeter. It need not cross the emergency spillway, unless the spillway has been designed and constructed for this purpose.

Locate vegetative buffers around the perimeter of the constructed stormwater wetland to control erosion and provide additional sediment and nutrient removal for sheet flow discharging to the constructed stormwater wetland.

Construction

This seven-step process is recommended to prepare a wetland bed prior to planting (Shueler 1992):

1. Prepare final pond-scaping and grading plans for the constructed stormwater wetland. At the same time, order wetland plant stocks from aquatic nurseries.
2. Once the constructed stormwater wetland volume has been excavated, grade the wetland to create the major internal features (pool, aquatic bench, deep water channels, etc.).
3. Because deep subsoils often lack the nutrients and organic matter needed to support vigorous plant growth, add topsoil and/or wetland mulch to the wetland excavation. If available, wetland mulch is preferable to topsoil.
4. After the mulch or topsoil has been added, grade the constructed stormwater wetland to its final elevations. Temporarily stabilize all wetland features above the normal pool. After final grading, close the pool drain to allow the pool to fill. MassDEP recommends evaluating the wetland elevations during a standing period of approximately six months to assess how the constructed stormwater wetland responds to storm flows and inundation, where the pond-scaping zones are located, and whether the final grade and micro-topography will persist over time.
5. Before planting, measure the constructed stormwater wetland depths to the nearest inch to confirm planting depth. If necessary, modify the pond-scape plan at this time to reflect altered depths or availability of plant stock.
6. Aggressively apply erosion controls during the standing and planting periods. Stabilize the vegetation in all areas above the normal pool elevation during the standing period (typically by hydroseeding).
7. Dewater the constructed stormwater wetland at least three days before planting, because a dry wetland is easier to plant than a wet one.

Wetland Vegetation

The Plans to be submitted with the Wetlands NOI or WQC application must state the wetland plant species proposed to be established. Phragmites must not be established or maintained in CSWs. The required O/M plan must include measures to remove or eliminate any invasive Phragmites. Cat tails (Typha latifolia and other Typha species) must not be established in CSWs because they create monocultures, limiting diversity. Establishing and maintaining wetland vegetation is important when creating a constructed stormwater wetland. Horner et al. (1994) recommend the following actions when constructing stormwater wetlands:

- In selecting plants, consider the prospects for success over the specific pollutant removal capabilities and plant species growing in nearby natural wetlands. Plant uptake is an important removal mechanism for nutrients, but not for other pollutants. The most versatile genera for pollutant removal are *Carex, Scirpus, Juncus, and Lemna.* Consult the NRCS plant database to determine if the plant is appropriate. The NRCS database lists the plants prohibited for sale in Massachusetts.
- Select native species, avoiding those that are invasive. Because diversification will occur naturally, use a minimum of species adaptable to the various elevation zones within the stormwater wetland.
- Give priority to perennial species that establish themselves rapidly.
- Select species adaptable to the broadest ranges of depth, frequency and duration of inundation (hydroperiod).
- Match site conditions to the environmental requirements of plant selections.
- Take into account hydroperiod and light conditions.
- Give priority to species that have already been used successfully in constructed stormwater wetlands and that are commercially available.
- Avoid using only species that are foraged by the wildlife expected on site.
- Establish woody species after herbaceous species.
- Where applicable, add vegetation that will achieve other objectives, in addition to pollution control.

Plants will develop best when soils are enriched. Use a “mulch mixture” to enhance the diversity of the plant community and speed its establishment.

A mulch mixture utilizes sediments removed during cleaning and dredging of stormwater drainage channels, swales, sedimentation basins, dry detention basins, and infiltration basins. Hydric soils that may be commercially available may also be utilized. The upper 6-inches of the donor mulch mixture or soil should be obtained at the end of the growing season, and kept moist until installation. Drawbacks to using a mulch mixture are the unpredictable content, limited donor sites, and the potential for the introduction of opportunistic species, such as Phragmites, Typha species, and Japanese knotweed (Polygonum cuspidatum Sieb. & Zucc.). Measures in the Operation and Maintenance Plan required by Stormwater Standard No. 9 must address invasive species removal. Wetland plants are commercially available through wetland plant nurseries.

Maintenance

Activity	Frequency
Inspect wetland during both growing and non-growing seasons	Twice a year for the first three years of construction.
Remove debris and sediment from the forebays.	Once a year
Remove sediment in basin/wetland systems.	Once every ten (10) years

Unlike conventional wet basin systems that require large-scale sediment removal at infrequent intervals, constructed stormwater wetlands require small- scale maintenance at regular intervals to evaluate the health and composition of the plant species.

Applicants must carefully observe the constructed stormwater wetland system over time. In the

first three years after construction, inspect the constructed stormwater wetlands twice a year during both the growing and non-growing seasons. This requirement must be included in the Operation & Maintenance plan. During these inspections, record and map the following information:

- Whether the Constructed Stormwater Wetlands have appropriate hydrology (sufficiently wet to support hydrophytic vegetation community). The following are not appropriate hydrology: too dry or too wet to support a hydrophytic vegetation community;
- The types and distribution of the dominant wetland plants in the marsh;
- The presence and distribution of planted wetland species;
- Whether the Constructed Stormwater Wetland has obtained the design percent hydrophytic vegetation coverage (e.g., >90% spatial coverage for pocket wetlands).
- The presence and distribution of invasive and opportunistic wetland species (invasives species

such as Phragmites and opportunistic species such as Typha must be removed);

- Indications that other species are replacing the planted wetland species;
- Percentage of standing water that is unvegetated (excluding the deep water cells which are not suitable for emergent plant growth);
- The maximum elevation and the vegetative condition in this zone, if the design elevation of the normal pool is being maintained for wetlands with extended zones;
- Stability of the original depth zones and the micro-topographic features; and
- Accumulation of sediment in the forebay and micropool; and survival rate of plants (cells with dead plants must be replanted).

Operation and Maintenance Plans must include the corrective actions that will be taken be correct the hydrology and establish the appropriate percent coverage of the hydrophytic plant community, when inspection indicates the hydrology and hydrophytic plant community have failed to meet the design specifications listed herein.

Any deficiencies noted in the first three years after construction must be corrected before the Applicant requests a Certificate of Compliance.

Maintenance of Sediment Forebay

Another important maintenance activity is regulating the sediment loading into the constructed stormwater wetland. All constructed stormwater wetlands are required to have a sediment forebay. Sediment accumulating in wetlands reduces water depths, changes the growing conditions for emergent plants, and alters the wetland plant community. Most sediment should be trapped and removed by the forebay or other type of basin before it reaches the wetland.

The sediment in the forebay should be removed at least once a year.

References

Shuler, Thomas, 1992. Design of Stormwater Wetlands Systems: Guidelines for Creating Diverse and Effective Stormwater Wetlands in the Middle Atlantic Regions, Metropolitan Washington Council of Governments, Washington, D.C.

Carleton, J.N., Grizzard, T.J., Godrej, A.N., and Post, H.E., 2001, Factors Affecting the Performance of Stormwater Treatment Wetlands, Water Research, Volume 35, No. 6, pp 1552-1562

UNH Stormwater Center, 2016, Gravel Wetland Fact Sheet, https://www.unh.edu/unhsc/sites/default/files/media/unhsc_gravel_wetland_spec_6-2016.pdf

Extended Dry Detention Basin

Ability to meet specific standards

Standard	Description
2 - Peak Flow	If properly designed, can provide peak flow attenuation.
3 - Recharge	Provides no groundwater recharge
4 - TSS/TP Removal	Use EPA Dry Pond Performance Curve to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves. Sediment forebay required for pretreatment.
5 - Higher Pollutant Loading	May be used as treatment SCM provided basin bottom is lined and sealed. For some land uses with higher potential pollutant loads, may also need oil/grit separator, sand filter, lined bioretention area, or equivalent prior to discharge to extended dry detention basin.
6 - Discharges near or to Critical Areas	Shall not be used for discharges near or to critical areas.
7 - Redevelopment	Existing dry detention basins bay be retrofitted to become extended dry detention basins.
8 - Construction Phase	Construction phase runoff is not to be diverted to these areas; divert stormwater runoff to these areas only once the site has been stabilized.
9 - O&M	An O&M plan is required for this SCM.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Extended dry detention basins are modified conventional dry detention basins, designed to hold stormwater for at least 24 hours to allow solids to settle and to reduce local and downstream flooding. Extended dry detention basins may be designed with either a fixed or adjustable outflow device. Pretreatment is a fundamental design component of an extended dry detention basin to reduce the potential for clogging. Other components such as a micropool or shallow marsh may be added to enhance pollutant removal.

Advantages/Benefits

- Least costly SCM that controls both stormwater quantity and quality.
- Good retrofitting option for existing basins.
- Can remove significant levels of sediment and absorbed pollutants.
- Potential for beneficial terrestrial and aquatic habitat.
- Less potential for hazards than deeper permanent pools.

Disadvantages/Limitations

- Infiltration and groundwater recharge is negligible, resulting in minimal runoff volume reduction.
- Removal of soluble pollutants is minimal.
- Requires relatively large land area.
- Moderate to high maintenance requirements.
- Potential contributor to downstream warming.
- Sediment can be resuspended after large storms if not removed.

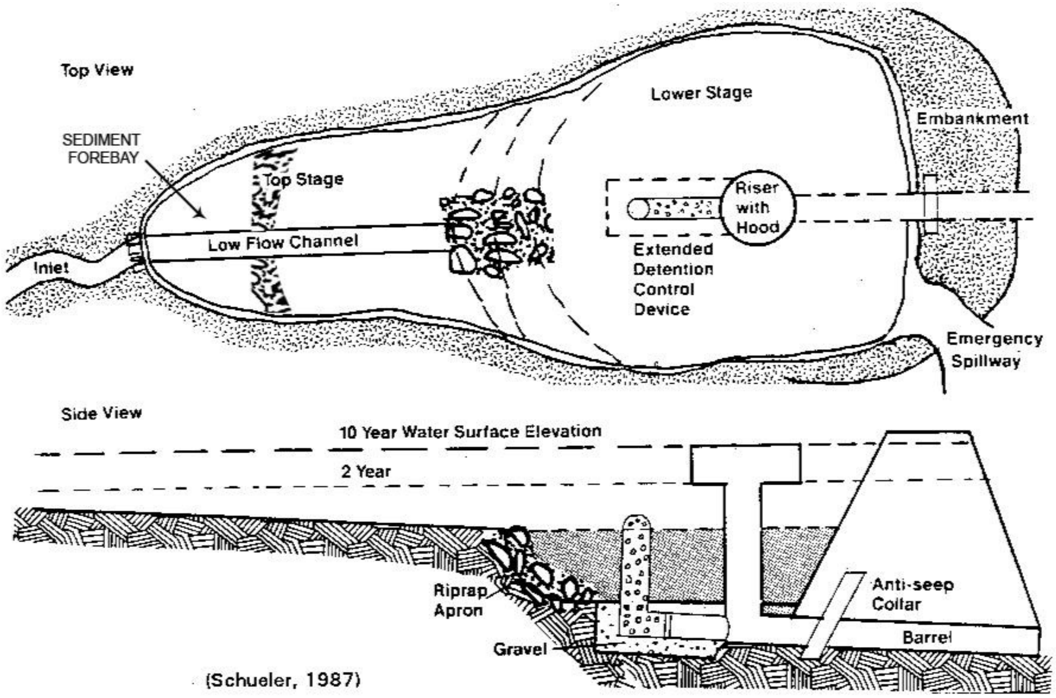
Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	N
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Example Extended Dry Detention Basin -adapted from Controlling Urban Runoff, Schueler 1987



Unit Process for Treatment

- Gravity Separation

Special Features

Design extended dry detention basins with three distinct stages;

1. The **upper stage** should have the capacity to regulate peak flow rates of large, infrequent storms (10, 25, or 100 -year recurrence intervals).
2. The **middle stage** is designed to regulate peak flow from the 2-year storm.
3. Design the **lowest stage** of the basin to detain the water quality volume for at least 24 hours to remove pollutants from the runoff. The water quality volume stage is determined using the EPA curve for dry ponds. For example, the water quality volume needed to provide 49% TSS/36% TP removal using the EPA curve is approximately 2-inches times the impervious area of the site.

ESSD/LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Applicability

Generally, extended dry detention basins are not practical if the contributing watershed area is less than ten acres. MassDEP recommends four acres of drainage area for each acre -foot of storage in the basin. Extended dry detention basins can be used at residential, commercial and industrial sites.

Because they have a limited capability for removing soluble pollutants, extended dry detention basins are more suitable for commercial applications where there are high loadings of sediment, metals and hydrocarbons. Do not use extended dry detention basins by themselves in low-density residential areas, where soluble nutrients from pesticides and fertilizers may be a concern. Combine extended dry detention basins with a shallow marsh system or other SCMs for more efficient pollutant removal.

Existing dry detention basins can be retrofitted as extended dry detention basins at a relatively low cost by simply modifying the outlet structure. Because of the land requirements, extended dry detention basins are not feasible at sites where land costs or space is at a premium. Investigate soils, depth to bedrock, and depth to water table before designing an extended dry detention basin for a site.

Effectiveness

The primary pollutant removal mechanism in extended dry detention basins is settling; therefore, the degree of pollutant removal depends on whether the pollutant is in the particulate or dissolved form. Expect limited removal for soluble pollutants, but high removal rates for particulate pollutants. When designed properly, extended dry detention basins are effective in reducing pollutant loads and controlling post-development peak discharge rates. Extended dry detention basins may be used to meet Stormwater Management Standards 2 and 4. However, extended dry detention basins do not reduce post-development increases in runoff volume. Additionally, extended dry detention basins provide no groundwater recharge.

Planning Considerations

Check the soils, depth to bedrock and depth to water table before designing an extended dry detention basin. Where bedrock is close to the surface, high excavation costs may make extended dry detention basins infeasible. Maximum depth of the extended dry detention basin may range from 3 to 12 feet. The depth of the basin may be limited by groundwater conditions or by soils.

If soils on -site are relatively impermeable such as soil group D (as defined by the NRCS), or the water table is within two feet of the bottom of the basin, the basin may experience problems with standing water, Therefore, design the bottom of extended dry detention basin to be at least 2 feet in elevation above the seasonal high groundwater elevation. If runoff is from a land use with a higher potential pollutant load, provide adequate pretreatment and a greater separation between the bottom of the basin and the seasonal high groundwater table. Separation of the bottom of the basin from groundwater is needed to ensure that the basin fully dewaters between storms.

To be effective in reducing peak runoff rates, the extended dry detention basin is ordinarily located where it can intercept most of the runoff from the site, usually at the lowest elevation of the site where freshwater wetlands are frequently found. Like all other best management practices, extended dry detention basins may not be constructed in wetland Resource Areas other than isolated land subject to flooding (ILSF), bordering land subject to flooding (BLSF), land subject to coastal storm flowage and riverfront areas. Select a location that will not adversely affect wetland Resource Areas but will still provide the peak rate attenuation required by Standard 2.

Embankments, or dams, created to store more than 15 acre-feet, or that are more than 6 feet high, are under the jurisdiction of the state Office of Dam Safety and are subject to regulation. Placing stormwater treatment structures in ILSF and BLSF can be challenging in part because high groundwater levels may limit suitable locations. If constructed in ILSF or BLSF, compensatory storage is required pursuant to 310 CMR 10.57 for any fill. The design water level should be considered fill for purposes of any compensatory flood storage computations, as the volume will not be available for flood storage when the basin is occupied by stormwater. Locating these basins in ILSF and BLSF, although allowed, is not advisable because they will not function when they are inundated with flood waters. Extended dry detention basin shall not to be credited as compensatory flood storage.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

[See the following document for complete design references: Design of Stormwater Pond Systems. 1996. Schueler. Center for Watershed Protection.]

Extended dry detention basin design must accommodate large, infrequent storm events for runoff quantity control, as well as small, frequent storm events for runoff quality control. Typically, the first flush of runoff contains the highest concentrations of pollutants. Consequently, design the extended dry detention basin to maximize the detention time for the most frequent storms. Routing calculations for a range of storms should provide the designer with the optimal basin size.

The bottom of the extended dry detention basin must be set in elevation at least 2-feet above seasonal high groundwater.

Generally, most particulates settle within the first 12 hours of detention; however, finer particulates may require additional time to settle. The minimum detention time for the Water Quality Volume is 24- hours. The most traditional and easiest method for extended detention routing is the 24 hour brimfull draw down (Required Water Quality Volume/24 hours = Qavg). This sets the average discharge rate. An orifice is then sized based on a max Q = 2*Qavg, using the brimfull head ($Q_{max} = (CA(2gh)^{1/2})$ where h is the head when the basin is full to the Required Water Quality Volume (WQv) elevation, g is acceleration due to gravity, A is the net opening area, and C is the orifice coefficient. The orifice coefficient is determined by consulting tables in standard references such as the Civil Engineering Reference Manual for the PE Exam, 10th Edition, by Michael R. Lindeburg, P.E., 2006.

For extended detention basins proposed in ILSF or BLSF, the peak runoff rate computations shall assume the runoff dosed to the extended detention basin is operating under tailwater conditions and not free discharge.

The critical parameters in sizing an extended dry detention basin are storage capacity and the maximum rate of runoff released from the basin. To meet the requirements of Standard 2, design the storage volume to hold the pre-development peak flow.

To maximize sedimentation, design the extended dry detention basin to lengthen the flow path, thereby increasing detention time. To maximize the detention time, locate the inflow points as far from the outlet structure as possible. Long, narrow configurations with length to width ratios of 2:1 provide better removal efficiencies than small deep basins. Consider using internal berms and other baffles to minimize short-circuiting of flows and increase detention times.

Reducing inflow velocities lengthens detention times, enhances sedimentation of solids in incoming runoff, and minimizes the potential for resuspension of settled pollutants. Design all inflow points with riprap or other energy dissipators, such as a baffle below the inflow structure. MassDEP requires a sediment forebay to enhance the removal rates of particulates, decrease the velocity of incoming runoff, and reduce the potential for failure due to clogging.

Design sediment forebays for ease of maintenance. Hard bottom forebays, such as those constructed from concrete, make sediment removal easier. All forebays must be accessible for maintenance by heavy machinery, if necessary.

A low flow channel routes the last remaining runoff, dry weather flow and groundwater to the outlet, which should be installed in the upper stage of the basin to ensure that the extended dry detention basin dries out completely. The maximum flow velocity (which should be set at the 2-year peak discharge rate) depends on the nature of the material used to line the channel. Consider whether a pervious or impervious channel lining is most appropriate.

Pervious linings are preferred as they allow runoff to interact with soil and vegetation, thereby increasing the sorption of pollutants. Make design velocities in pervious low flow channels high enough to prevent sedimentation but low enough to prevent scouring and erosion.

Impervious channels are simple to construct, easy to maintain, and empty completely after a storm event. Runoff flows and differential settling can undermine impervious channels unless constructed and maintained properly. Locate the top of the impervious channel lining at or below the level of the adjacent grassed areas to ensure thorough drainage of these areas. When designing impervious channels, take into account settlement of the lining and the adjacent areas as well as the potential for frost impacts on the lining. Provide impervious lining with broken stone foundations and weep holes. Consider the potential for erosion or scour along the edges of the lining caused by bank-full velocities. Maintain a low outflow discharge rate at the downstream end of the impervious channel to ensure sufficient treatment of runoff, which backs up and overflows onto the grassed basin bottom.

Use low flow underdrains connected to the principal outlet structure or other downstream discharge point to promote thorough drying of the channel and the basin bottom. Take into account the depth of the low flow channel when preparing the final bottom grading plan. Establish wetland vegetation in a shallow marsh component or on an aquatic bench in the lower stage of the extended dry detention basin to enhance removal of soluble nutrients, increase sediment trapping, prevent sediment resuspension, and provide wildlife and waterfowl habitat. Proper soils and surface depth or groundwater depth are needed to maintain wetland vegetation.

Make the side slopes of the extended dry detention basin no steeper than 3:1, and use intermittent benches to foster vegetative growth and provide for safety. Flatter slopes help to prevent bank erosion during larger storms, make routine bank maintenance tasks (such as mowing) easier, prevent animals from getting trapped, and allow easier access to the basin. Include a multi-stage outlet structure to provide an adequate level of water quality and flood control. To meet the water quantity control standards, use the required design storm runoff rates as the outlet release rates. For water quality control, the release rate will vary with the design storm selected. For extended dry detention basins with shallow marshes or permanent pools, place the lowest stage outlet at an elevation that will create a permanent pool of water.

The type of outlet structure needed will depend on factors such as the type of spillway, basin configuration and extended detention outflow rate. Design the outlet to control the outflow rate without clogging. Locate the outlet structure in the embankment for maintenance, access, safety and aesthetics. Design the outlet to facilitate maintenance; the vital parts of the structure must be accessible during normal maintenance and emergency situations. It also must contain a draw-down valve for complete detention basin draining within 24 hours.

To prevent scour at the outlet, use a flow transition structure, such as a lined apron or plunge pad, to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area. Design embankments and spillways in accordance with the state regulations for Dam Safety (302 CMR 10.00). All extended dry detention basins must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure.

Provide a public or private right-of-way access for maintenance that is at least 15 feet wide with a maximum slope of 5:1. Make sure this access extends to the forebay, safety bench, outflow structure and entire perimeter. The access way need not cross the emergency spillway, unless the spillway has been designed for that purpose. Use vegetative buffers around the perimeter of the basin for erosion control and additional sediment and nutrient removal.

Maintenance

Activity	Frequency
Inspect extended dry detention basins	At least twice a year and during and after major storms
Examine the outlet structure for evidence of clogging or outflow release velocities that are greater than design flow	At least twice a year
Mow the upper-stage, side slopes, embankment, and emergency spillway.	At least twice a year
Remove trash and debris	At least twice a year
Remove sediment from the basin	At least once every 5 years

A **major storm event** for on-going post-construction monitoring is defined as equal to or greater than 1 inch in a 24-hour period.

Inspect extended dry detention basins at least once per year to ensure that the basins are operating as intended. Inspect extended dry detention basins during and after 1 inch/day or greater storm events to determine if the basin is meeting the expected detention times.

Examine the outlet structure for evidence of clogging, subdrain failure, or outflow release velocities that are greater than design flow. Potential problems that should be checked include: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks. Commence any necessary repairs within 24-hours after inspection indicates a deficiency, and no later than the next storm. During inspections, note any changes to the extended dry detention basin or the contributing watershed, because these could affect basin performance.

Mow the upper- stage, side slopes, embankment, and emergency spillway at least twice per year. Also remove trash and debris at this time. Remove sediment from the extended dry detention basin as necessary, but at least once every 5 years. Providing an on-site sediment disposal area will reduce the overall sediment removal costs.

Proprietary Media Filters

Ability to meet specific standards

Standard	Description
2 - Peak Flow	N/A
3 - Recharge	N/A
4 - TSS/TP Removal	No EPA Curve. **TSS**: MassDEP variable credit, up to 60% **TP**: MassDEP variable credit, up to 30%. Pollutant removal credit must be determined on a case-by-case basis in accordance with procedures described in **Section 5.3** of the Stormwater Handbook
5 - Higher Pollutant Loading	Suitable as treatment device.
6 - Discharges near or to Critical Areas	Suitable as treatment device for some critical areas.
7 - Redevelopment	Suitable; if site is severely constrained, may be preferred.
8 - Construction Phase	May not be used for construction phase runoff.
9 - O&M	An O&M plan is required for this SCM.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Media Filters are typically proprietary two -chambered underground concrete vaults that reduce both TSS and other pollutants (e.g., organics, heavy metals, soluble nutrients). After larger particles settle out in the first chamber, stormwater flows through the specific filter media in the second chamber. Selection of the specific media largely depends on the pollutant targeted.

Advantages/Benefits

- Suitable for specialized applications, such as industrial sites, for specific target pollutants
- Preferred for Redevelopments or in the ultra-urban setting when LID or larger conventional practices are not practical

Disadvantages/Limitations

- Requires intensive maintenance
- Performance varies depending upon media
- TSS/TP removal variable, depending on media
- “Wet” systems that are designed to retain water can cause mosquito and vector problems unless access points are sealed

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?[3]
TSS	Varies
Total Nitrogen	Varies
Total Phosphorous	Varies
Pathogens	Varies
Metals	Varies

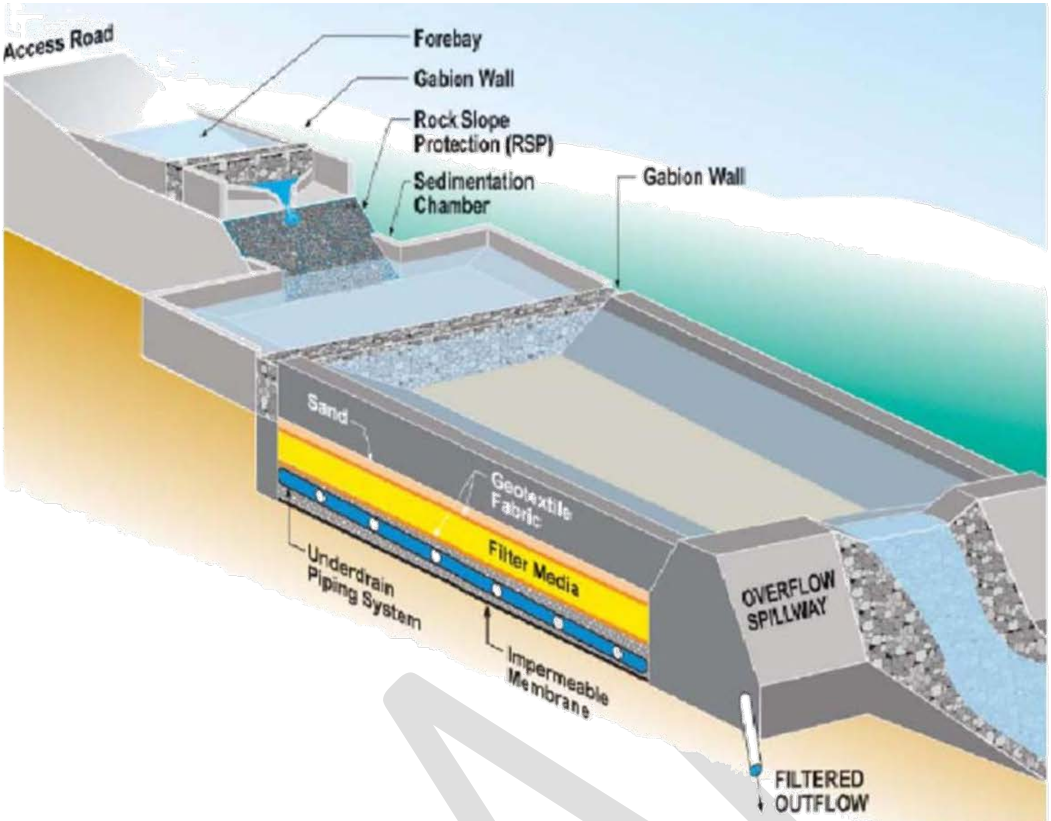
Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*
3. *Pollutant removal ability must be determined on a case-by-case basis in accordance with procedures described in **Section 5.3***

Unit Treatment Process

- Filtration

Example Proprietary Media Filter:
Public domain media filter: CALTRANS - California Department of Transportation.



Special Features

Redevelopment, pretreatment for LUHPPL and Critical Areas, and removal of pollutants in addition to TSS

ESSD / LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Applicability

Media Filters are typically two-chambered underground concrete vaults designed to reduce both TSS and other pollutants. The first chamber is usually a pretreatment settling basin. The second chamber is a filter bed containing either sand or other filtering media or an array of media- containing cartridge filters. After larger particles (e.g., TSS) settle out in the first chamber, stormwater flows through the specific filter media in the second chamber, and a portion of the target pollutants are sorbed to the filter media.

Various media are used, including leaf compost, pleated fabric, activated charcoal, perlite, amended sand and perlite, and zeolite, and tend to vary by manufacturer. Selection of the specific media largely depends on the pollutant targeted. Because MassDEP regulates both TSS and TP, and additional constituents when a TMDL has been established, the media selected must be capable of removing a range of different contaminates. Media filters must have the filter medium in the filter beds or the cartridges replaced periodically; following the manufacturer’s schedule for operation and maintenance is critical to successful continued effectiveness.

Since Media Filters are Proprietary SCMs, MassDEP has not assigned this group of SCMs a TSS or TP removal rate. Their performance varies depending upon the specific unit selected, the targeted pollutants, and successful design of the system. The procedure described in **Section 5.3** of the Stormwater Handbook, must be used by the Issuing Authority to establish the TSS removal rate that will be used for permitting purposes.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Media filters may require an upgradient storage chamber to queue or store runoff. Some media filters may require pretreatment, just like many traditional types of treatment practices. Media Filters are most efficient when designed to operate off-line. Media Filters must contain a by-pass device to allow large stormwater flows from intense precipitation to by-pass the media filters, so as to not cause resuspension of material trapped by the filters. Media Filters must be sized to treat the water quality volume (1.0 inch), depending on whether there is a discharge to a critical area, if the drainage is from a land use with higher potential pollutant load (LUHPPL), or is being directed to a soil with a rapid infiltration rate (hydraulic permeability >2.4 inches/hour). Since most Media Filter designs are based on flow rate, the flow rate must be converted to a Volume MassDEP method to convert the WQV to a peak flow rate. See **Appendix D** for the standard method to perform this calculation.

Media Filters can be either “dry” or “wet” design. “Dry” Media Filters are designed to dewater completely between storms.

For design purposes, use 72 hours to evaluate dewatering, using the storm that produces 1.0 inch of runoff (water quality volume) in a 24-hour period. “Wet” Media Filters maintain a permanent pool of water as part of the treatment system.

For media filters constructed or placed below grade, inspection ports and cleanout ports must be included in the design to allow access to the system for maintenance.

Maintenance

For proprietary systems, maintenance must be conducted in strict accordance with the manufacturer’s requirements. Spare filters must be stored on site, so filters can be replaced quickly when inspection indicates replacement is necessary. Clean-out of trapped sediment in the concrete vaults housing the media filters may require the party conducting the maintenance to be trained for confined space entry under OSHA requirements.

“Dry” Media Filters are designed to dewater completely in 72 hours. Prevention of mosquito and vector breeding in dry designs depends on maintenance that ensures that dewatering occurs in 72 hours, that filters are not clogged and trapping water, and that associated SCM accessories (such as level spreaders) dewater as designed. “Wet” Media Filters are more conducive to mosquito and vector problems. Tight-fitting seals can be used to keep mosquitoes and vectors from entering and breeding in the permanent pools, and maintenance may include routine inspection and treatment.

Activity	Frequency
Inspect for standing water, sediment, trash, and debris and clogging	At least twice a year; follow manufacturer’s schedule
Remove accumulated trash and debris	During every inspection
Inspect to determine if system drains in 72 hours	Once a year during wet season, and after large storms
Inspect filtering media for clogging; replace if clogged	Per manufacturer’s specifications

References

California Stormwater Quality Association, 2003, California Stormwater SCM Handbook, Media Filter, Practice No. TC-40, http://www.caSCMhandbooks. com/Documents/Development/TC-40.pdf

Connecticut Department of Environmental Protection, 2004, Connecticut Stormwater quality Manual, Media Filters, pp. II-S11-1 to II-S11-3, http:// https://portal.ct.gov/DEEP/Water-Regulating-and-Discharges/Stormwater/Stormwater-Manual

Idaho Department of Environmental Quality, 2005, Storm Water Best Management Practices Catalog, Media Filter, SCM 7, pp. 43-44, http://www.deq.idaho. gov/water/data_reports/storm_water/catalog/sec_4/ SCMs/7.pdf

Sand and Organic Filters

Ability to meet specific standards

Standard	Description
2 - Peak Flow	N/A
3 - Recharge	N/A
4 - TSS/TP Removal	Use EPA Sand Filter Performance Curve to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves. Pretreatment is required.
5 - Higher Pollutant Loading	Can be used in lieu of an oil/grit separator for certain land uses with higher potential pollutant loads of oil and grease, such as high intensity parking lots and gas stations.
6 - Discharges near or to Critical Areas	Suitable for discharges near or to Critical Areas.
7 - Redevelopment	Suitable when combined with pretreatment SCM. Good option for ultra-urban areas, since they consume no surface space.
8 - Construction Phase	May not be used for construction phase runoff.
9 - O&M	An O&M plan is required for this SCM.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutant Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Also known as filtration basins, sand and organic filters consist of self-contained beds of sand or peat (or combinations of these and other materials) either underlaid with perforated underdrains or designed with cells and baffles with inlets/outlets. Stormwater runoff is filtered through the sand, and in some designs may be subject to biological uptake. Runoff is discharged or conveyed to another SCM for further treatment. Another type of filter is the tree box filter. Information on this practice appears at the end of this section.

Advantages/Benefits

- Applicable to small drainage areas of 1 to 10 acres, although some designs may accept runoff of up to 50 acres.
- Good retrofit capability.
- Long design life if properly maintained
- Good for densely populated urban areas and parking lots with high intensity use

Disadvantages/Limitations

- Pretreatment required to prevent the filter media from clogging.
- Frequent maintenance required.
- Without grass cover, the surface of sand filters can be extremely unattractive.
- May have odor problems, which can be overcome with design and maintenance.
- May not be able to be used on certain sites because of inadequate depth to bedrock or high groundwater
- May not be effective in winter

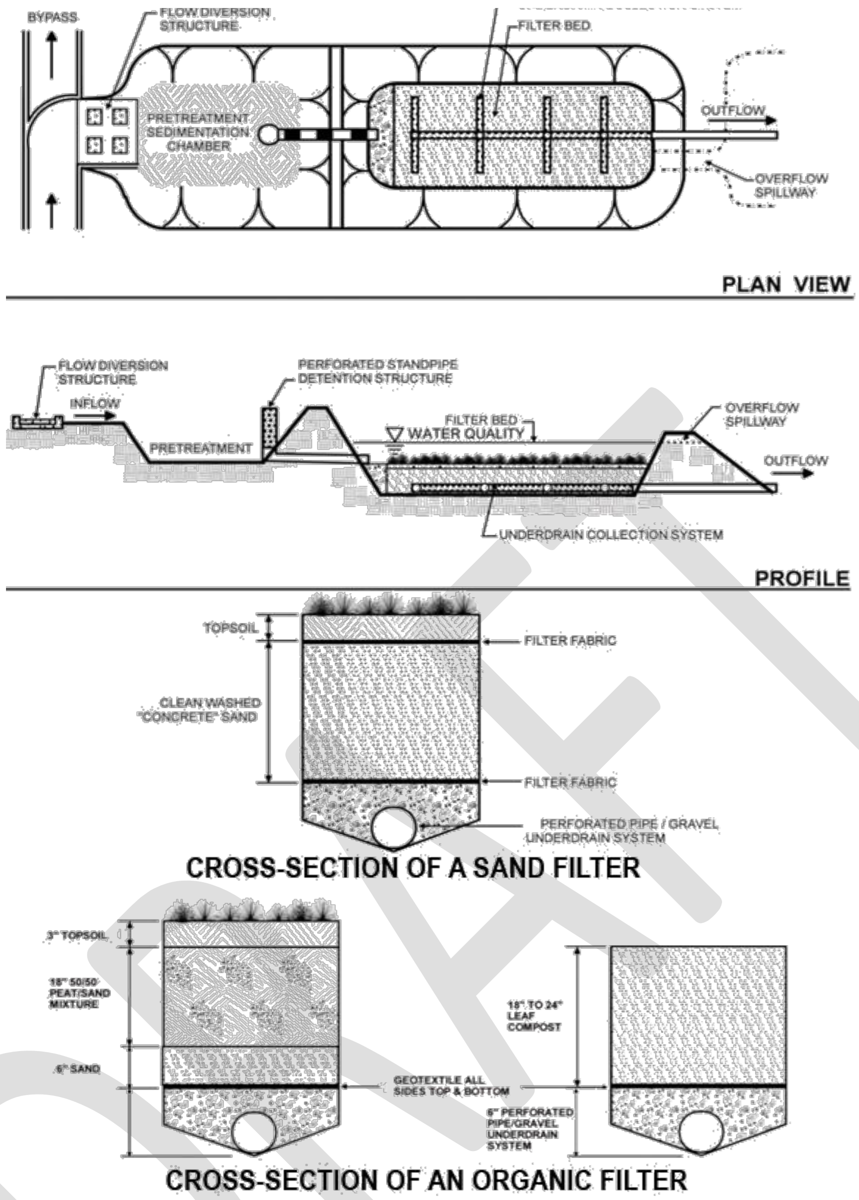
Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	N
Total Phosphorous	N
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Example Sand and Organic Filter (adapted from the Vermont Stormwater Manual)
(***Note:*** *Concrete boxes backfilled with sand are also acceptable*)



Unit Treatment Process

- Filtration

Special Features

Design as off-line device. Include a Sediment Forebay or equivalent pretreatment device.

ESSD / LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Applicability

Sand filters are adaptable to most developments. They can be installed in areas with thin soils, high evaporation rates, low soil infiltration rates and limited space. Sand filters can be used in ultra-urban sites with small drainage areas that are completely impervious, such as small parking lots and fast food restaurants. They are suitable for many areas that are difficult to retrofit due to space limitations.

Sand filters can be used in areas with poor soil infiltration rates, where groundwater concerns restrict the use of infiltration, or for high pollutant loading areas. Design sand filters as off-line SCMs; they are intended primarily for quality control, not quantity control. A diversion structure, such as a flow splitter or weir, typically routes a portion of the runoff into the sand filter, while the remainder continues on to a stormwater quantity control SCM. Large sand filters can be designed to play a role in the control of peak discharge rates.

Because of the potential for clogging, install sand filters only at sites that have been stabilized. Never use sand filters as sedimentation traps during construction.

Effectiveness

Sand filters improve water quality by straining pollutants through a filtering media and by settling pollutants on top of the sand bed and/or in a pretreatment basin.

Planning Considerations

The surface of sand filters can be unattractive and create odors and may not be appropriate for residential areas. The location selected to site the sand or organic filter must be accessible via road or driveway for maintenance purposes. Maintenance access with a width of at least 15-feet is needed around the full perimeter of the filter.

Cold Weather Modifications

Surface sand filters will not provide treatment during the winter. To ensure treatment occurs year-round, including the winter, design the filters to be placed underground, below the frost line. Underground filters are not effective in winter unless the filter bed is placed below the frost line. Peat and compost media may be ineffective during the winter in cold climates. These filters retain water and can freeze solid, and thus become impervious.

To prevent freezing, the diameter of the underdrain pipe should be at least 8 inches, and the slope of the underdrain pipe should be at least 1%. Place eighteen inches of gravel at the base of the filter. Make the slope of the inflow pipes at least 2%. In addition, place the filter below the frost line. If freezing cannot be prevented, remove snow from the contributing area and place it elsewhere.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Sand filters require a sediment forebay or equivalent pretreatment device. Locate sand filters off-line from the primary conveyance/ detention systems This may require two manholes to act as flow diverters. Design sand filters large enough to handle runoff from the storm event and the water quality volume associated with the EPA curve for sand filters to achieve 90% TSS removal/60% TP removal if new development or 80% TSS removal/50% TP removal for Redevelopment.

Fit stormwater conveyances with flow splitters or weirs to route the required volume of runoff to the sand filter. Sand filters must be designed to be offline. Allow runoff in excess of the design volume to bypass the sand filter and continue on to another SCM designed to provide peak runoff rate reduction

Two key design principles for sand filters are visibility and simplicity. A visible sand filter is more apt to be adequately operated and maintained. Complex designs are more expensive and difficult to operate and maintain. Typically, sand filter systems are designed with two components, a pretreatment component and a filtering component. The pretreatment component is a sediment forebay or vegetated filter strip designed to reduce the sediment load to the filtering component. Pre-settling also slows the runoff velocity and spreads it evenly across the top of the filter component.

The bottom of sand filters must be installed at least 2-feet above Seasonal High Groundwater. Maintenance access must be provided in the design. Sand filters need to meet setback requirements.

Generally, the volume of the sediment forebay should be equal to or greater than the filtering capacity. Design the filter to capture finer silt and clay particles and other pollutants in the runoff. Sand filters are designed to function as a stormwater quality control practice, and not to provide detention for downstream areas. Therefore, locate them as off-line systems, away from the primary conveyance/detention system. Design the pretreatment component to settle out coarse sediments that may clog the sand filter and reduce its effectiveness.

Use a design filtration rate of 2 inches/hour. Although this rate is low compared to published values for sand, it reflects actual rates achieved by sand filters in urban areas. Using Darcy's Law, design the sand filter to completely drain within 24 hours or less, because there is little storm storage available in the sand filter if a second storm occurs.

Use eighteen inches of 0.02-inch to 0.04-inch diameter sand (smaller sand is acceptable) for the sand bed. Consider that sand may consolidate during construction. Stabilize the depth of the bed by wetting the sand periodically, allowing it to consolidate, and then adding extra sand. There are several possible sand bed configurations; most use a gravel bed at the bottom overlaid with a layer of sand and/or peat, leaf compost, or topsoil/grass. In all configurations, make sure the top surface layer of the bed is level to provide equal distribution of the runoff in the bed. The gravel bed layer is generally composed of 4 to 6 inches of 0.5-inch to 2-inch diameter gravel. Separate the gravel and top media layers with a layer of geotextile fabric to prevent sand from infiltrating into the gravel layer and the underdrain piping.

Recent research (Erickson, et al., 2007) shows that enhancing sand filters with steel wool can reduce phosphorus concentrations by as much as 80%.

Organic Media Filters

Organic media filters are essentially the same as sand filters with the sand media replaced or supplemented with another medium. Two examples are the peat sand filter and the compost sand filter. According to the Center for Watershed Protection, many practitioners believe that organic sand filter systems have enhanced pollutant removal for many compounds due to the increased cation exchange capacity achieved by increasing the organic matter. See Performance of Delaware Sand Filter Assessed, Article 107 of the Practice of Watershed Protection.

Maintenance Features Incorporated in Filter Design

Ease of access is essential for sand filter maintenance. Some designs use a geotextile layer, surface screen, or grating at the top to filter out coarse sediment and debris and for ease of maintenance. Typical maintenance for sand filters includes removing the top several inches of discolored sand and replacing it with clean media. Designs should include ramps, manhole steps, or ringbolts that allow a maintenance worker to manually remove this material. In addition, avoid heavy grates or manhole covers that cannot be lifted manually.

Trench Design

Trench designs have lateral underdrain pipes that are covered with 0.5- inch to 2-inch diameter gravel and geotextile fabric. The underdrains are underlaid with drainage matting, which is necessary to provide adequate hydraulic conductivity to the lateral pipes. Reinforce the underdrain piping so it withstands the weight of the overburden. The minimum grade of the piping should be 1/8 inch per foot (at 1% slope). An impermeable liner (clay, geomembrane, concrete) may be required under the filter to protect groundwater. If the impermeable liner is not required, install a geotextile liner, unless the bed has been excavated to bedrock. Make sure that the side slopes of the earthen embankments do not exceed 3:1 (horizontal: vertical). Fencing around sand filters may be needed to reduce safety hazards. Carefully selecting topsoil and sod for natural cover will help reduce the potential for failure. Sod with fine silts and clays will clog the top of the sand filter. Maximize the life of the sand filter by limiting its use to treating runoff from impervious areas only.

Construction

- Take care during construction to minimize the risk of premature failure of the sand filter.
- Diversion berms should be placed around the perimeter of the sand filters during all phases of construction.
- Sand filters should not be used as temporary sediment traps for construction activities.
- Consolidation of material in the sand filters during construction must be taken into consideration. The depth of the bed can be stabilized by wetting the sand periodically, allowing it to consolidate, and then adding extra sand.
- During and after excavation, all excavated materials should not be placed in an area upgradient from the sand filters, to prevent redeposition during runoff events. All excavated materials should be handled properly and disposed of properly during and after construction.

Maintenance

Activity	Frequency
Inspect filters and remove debris	After every .25 inch/day or greater storm event for the first three months after construction is complete to ensure proper function; and every 6 months thereafter.

Inspect sand filters after every significant storm of at least 0.25-inch/day of precipitation in the first three months after construction to ensure proper function. Thereafter, inspect the sand filter at least once every 6 months. Sand filters require frequent manual maintenance. Important maintenance tasks include raking the sand and removing surface sediment, trash and debris. Eventually a layer of sediment will accumulate on the top of the sand, which can be easily scraped off using rakes or other devices. Finer sediments will penetrate deeper into the sand over time, necessitating replacement of some (several inches) or all of the sand. Discolored sand indicates the presence of fine sediments. De-water and properly dispose of sand removed from the filter.

References

Erickson, Andrew J., et al., Enhanced Sand Filtration for Storm Water Phosphorus Removal, Journal of Environmental Engineering. Volume 133, Issue 5, pp. 485-497, May 2007.

Developments in Sand Filter Technology to Treat Stormwater Runoff, Article 105, and Further Developments in Sand Filter Technology, Article 106, in the Practice of Stormwater Protection

Center for Watershed Protection, Stormwater Design Example: Sand Filter, WEB: *https://www.stormwatercenter.net/Manual_Builder/sand_filter_design_example.htm*

Georgia Stormwater Manual 2016, Volume 2, Appendix B3, page 510, Georgia Stormwater Manual 2016.

2004 Connecticut Stormwater Manual, https://portal.ct.gov/DEEP/Water-Regulating-and-Discharges/Stormwater/Stormwater-Manual.

North Carolina Department of Environment and Natural Resources Stormwater SCM Manual 2007, https://deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-permit-guidance/stormwater-bmp-manual/archive.

Tree Box Filter

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Does not provide peak flow attenuation.
3 - Recharge	**Tree Box Filter (filtering)** does not provide groundwater recharge. **Tree Box Filter (exfiltrating)** provides groundwater recharge.
4 - TSS/ TP Removal	**Tree Box Filter (filtering)** • Use EPA Performance Curve for Biofiltration. **Tree Box Filter (exfiltrating)** • Use EPA Performance Curve for Infiltration Basin. See "Introduction" Section of this Appendix for more information the EPA Performance Curves.
5 - Higher Pollutant Loading	May be used as pretreatment device if lined
6 - Discharges near or to Critical Areas	Not suitable for vernal pools or swimming areas.
7 - Redevelopment	May be used for Redevelopment
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

The Tree Box Filter consists of an open bottom concrete structure filled with a porous soil media. Stormwater is directed from surrounding impervious surfaces through the top of the soil media. Stormwater percolates through the media to the underlying ground. Treated stormwater beyond the design capacity is typically directed to an underdrain where it may be directed to a storm drain, other device, or Surface Water discharge.

Tree Box Filters may be designed to act as a filtering practice or an infiltration practice. **Filtering Tree Box Filters** do not infiltrate and cannot be used receive recharge credit towards Standard 3 – they have an underdrain that captures and conveys runoff downstream. Filtering Tree Box Filters may be lined. **Exfiltrating Tree Box Filters** are designed to provide infiltration.

Advantages/Benefits

- Provides decentralized stormwater treatment
- Ideal for new development, Redevelopment or retrofits, especially in ultra-urban settings

Disadvantages/Limitations

- Treats small volumes

Suitability to Treat TMDL Pollutants

Filtering Tree Box Filter

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	N
Total Phosphorous	N
Pathogens	Y
Metals	Y

Exfiltrating Tree Box Filter

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

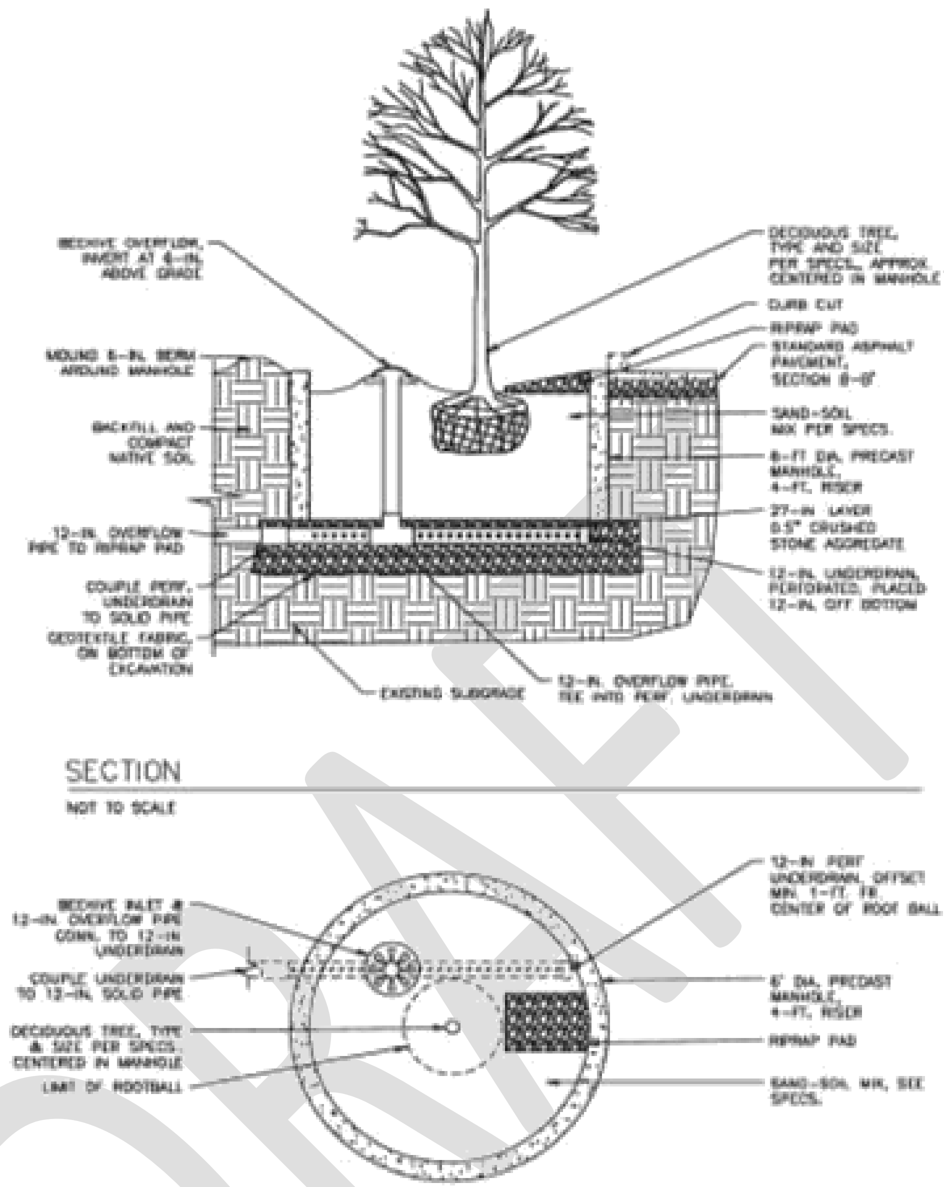
Table Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*

- *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Description

Example Tree Box Filter – adapted from the Vermont Stormwater Manual



ESSD/LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

When designed to infiltrate, geotextile fabric shall not be used. When designed as a filter without infiltration, fabric may be used. When designed to infiltrate, the underdrain shall not be connected to a drainage system and stormwater outlet.

Maintenance

- Check tree at least annually. Expected tree life is 5 to 10 years.
- Rake media surface to maintain permeability at least twice per year.
- Replace media when tree is replaced.

Wet Basins

(formerly wet retention ponds)

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Can be designed to provide peak flow attenuation. Only elevations above permanent wet pool may be credited toward peak rate reduction.
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	Use EPA Wet Pond Performance Curve to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves. Sediment forebay required for pretreatment.
5 - Higher Pollutant Loading	May be used as pretreatment SCM provided basin bottom is lined and sealed. For some land uses with higher potential pollutant loads, may require pretreatment by oil/grit separator, sand filter, or equivalent prior to discharge to wet basin.
6 - Discharges near or to Critical Areas	Do not use for discharges to Cold-Water Fisheries.
7 - Redevelopment	Not usually suitable due to space constraints.
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control.
9 - O&M Plan	An O&M Plan is required for this SCM
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Wet basins use a permanent pool of water as the primary mechanism to treat stormwater. The pool allows sediments to settle (including fine sediments) and removes soluble pollutants. Wet basins must have additional dry storage capacity to control peak discharge rates. Wet basins have a moderate to high capacity to remove most urban pollutants, depending on how large the volume of the permanent pool is in relation to the runoff from the surrounding watershed.

Advantages/Benefits

- Capable of removing both solid and soluble pollutants
- Capable of removing nutrients and metals
- Aesthetically pleasing SCM.
- Can increase adjacent property values when properly planned and sited.
- Sediment generally needs to be removed less frequently than for other SCMs.
- Can be used in retrofits

Disadvantages/Limitations

- More costly than extended dry detention basins.
- Larger storage volumes for the permanent pool and flood control require more land area.
- Infiltration and groundwater recharge is minimal, so runoff volume control is negligible.
- Moderate to high maintenance requirements.
- Can be used to treat runoff from land uses with higher potential pollutant loads if bottom is lined and sealed.
- Invasive species control required

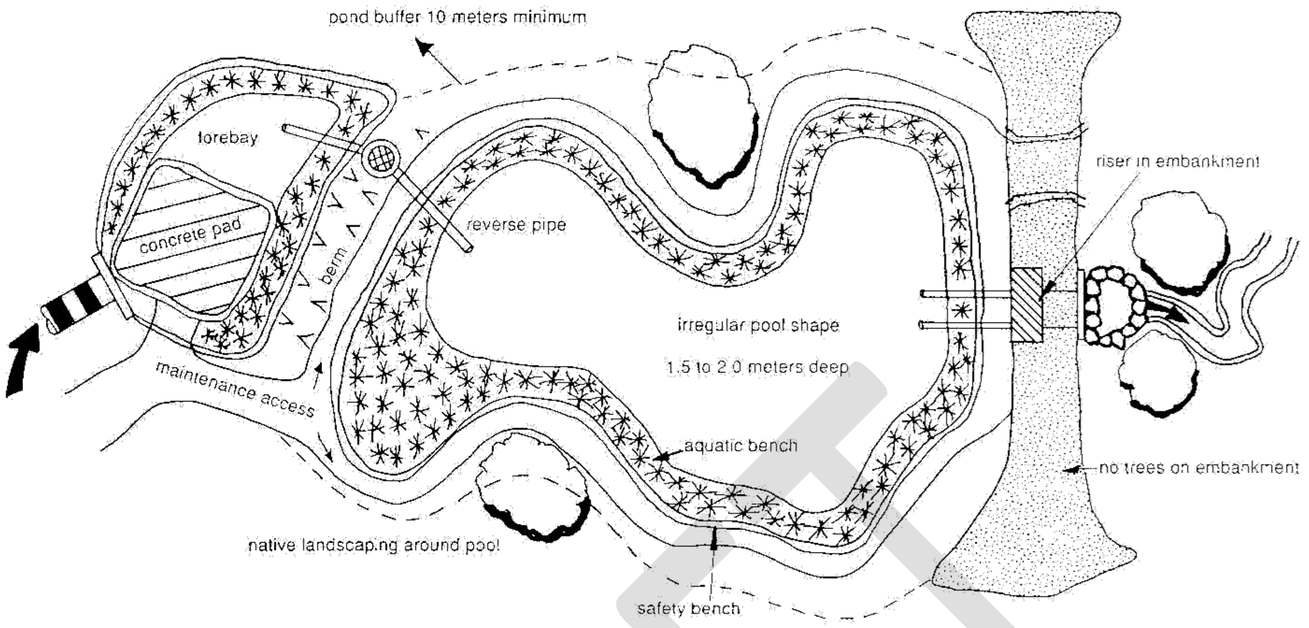
Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Example Wet Basin (Adapted from Schueler, 1992)



Unit Treatment Process

- Gravity separation

Special Features

- MassDEP requires a sediment forebay as pretreatment to a wet basin.

ESSD/LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Applicability

A wet basin may be created by constructing an embankment or excavating a pit. The primary component of a wet basin is the deep, permanent pool, but other components, such as a shallow marsh, may be added to the design *(see basin/ wetland design in constructed wetlands section)*. MassDEP requires a sediment forebay as pretreatment to a wet basin.

The basic operation of a wet basin allows incoming stormwater to displace the water present in the pool. This stormwater remains until displaced by runoff from another storm event. Increased retention time allows particulates, including fine sediments, to settle out of the water column. The permanent pool also serves to protect deposited sediments from resuspending during large storm events. Another advantage of wet basins is the biological activity of algae and fringe wetland vegetation, which reduces the concentration of soluble pollutants. Wet basins may be designed with a multi-stage outlet structure to control peak rate discharges from different design storms. When properly designed and maintained, wet basins can add recreation, open space, fire protection, wildlife habitat, and aesthetic values to a property.

Generally, dry weather base flow and/or large contributing drainage areas are required to maintain pool elevations. The minimum contributing drainage area must be at least 10 acres, but not more than one square mile. Sites with less than 10 acres of contributing drainage area may be suitable only if sufficient groundwater flow is available to maintain the permanent pool. Use wet basins at residential, commercial and industrial sites. Because wet basins remove soluble pollutants, they are ideal for sites where nutrient loadings are expected to be high. In such instances, source controls must also be implemented to further reduce nutrient loadings.

Planning Considerations

Evaluate soils and depth to bedrock and groundwater before designing a wet basin. At sites where bedrock is close to the surface, high excavation costs may make wet basins infeasible. If the soils are permeable (A and B soils), heavy drawdown of the basin may occur during dry periods. In these situations, compact the basin soils or install a liner at the bottom of the basin to minimize the potential for drawdown. Specifications for basin materials include (in order of decreasing costs):

- 6-inch clay
- Polyvinyl liner
- Bentonite
- 6 inches of silt loam or finer material

To be effective in reducing peak runoff rates, locate the basin where it can intercept most of the runoff from the site, typically a low elevation that is near freshwater wetlands. Like all stormwater best management practices, wet basins must not be constructed in wetland Resource Areas other than isolated land subject to flooding, bordering land subject to flooding, land subject to coastal storm flowage, and riverfront area. Select a location that can accommodate the need to attenuate peak discharge rates without adversely impacting nearby wetland resources.

Designing wet basins for multiple storms will provide peak rate control. In such instances, design the upper stages of wet basins to provide temporary storage of larger storms (i.e., 10, 25, and 100-year 24-hr. storms). Wet basins are generally ineffective in controlling the post-development increase in runoff volume, although some infiltration does occur, as well as evaporation in summer months.

It is preferable to create the wet basin by excavating a pit below the grade of land. When this is not feasible, an earthen embankment can be created. Embankments or dams created to store more than 15 acre-feet, or that are more than 6 feet high, are under the jurisdiction of the Massachusetts Department of Conservation and Recreation (DCR) Office of Dam Safety and must be constructed, inspected, and maintained according to DCR guidelines.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

See the following for complete design references:
Wet Extended Detention Pond Design: Step by Step Design. 1995. Claytor.

Volume and geometry are the critical parameters in a wet basin design; the relationship of the volume in the permanent pool to the contributing runoff volume directly affects pollutant removal rates. Generally, bigger is better; however, after a certain threshold level, increasing the pool size results in only marginal increases in pollutant removal. The permanent pool must be sized at a minimum to hold twice the water quality volume (this is equivalent to a VB/VR of 2) when a wet basin is designed to provide peak rate attenuation in addition to water quality treatment. The peak rate volume is an additional volume above the permanent pool. The permanent pool volume must not be counted as part of the volume devoted to storage associated with peak rate attenuation. When designing a wet basin to also accommodate peak rate attenuation, a multiple stage outlet must be included as part of the design.

Pool depth is an important design factor, especially for sediment deposition. Use an average pool depth of 3 to 6 feet. Settling column studies and modeling analyses show that shallow basins remove more solids than deeper ones. However, resuspension of settled materials by wind action might be a problem in shallow basins that are less than two feet deep.

Depths greater than eight feet may cause thermal stratification. Stratified pools tend to become anoxic (low or no oxygen) more often than shallower ponds. If possible, vary depths throughout the basin.

Providing deeper pools can provide fish habitat. It may be advantageous to introduce fish to the wet basins to reduce mosquito breeding. When designing wet basins to support fish, a fisheries biologist should be consulted. Fish habitat features may include trees to provide shading over the deeper depths. Selection of trees should be done carefully to avoid embankment or sidewall failure. Use intermittent benches around the perimeter of the basin for safety and to promote vegetation. Design the safety bench to be at least ten feet wide and above normal pool elevations. Make the aquatic bench at least ten feet wide and maintain depths of 12 to 18 inches at normal elevations to support aquatic vegetation. Shallow depths near the inlet will concentrate sediment deposition in a smaller, more accessible area. Deeper depths near the outlet will yield cooler bottom water discharges that may mitigate downstream thermal effects. Use a minimum pool surface area of 0.25 acres. Enhance the performance of the wet basin by enlarging the surface area to increase volume, instead of deepening the pool, although this increases water temperatures and evaporation rates. The original design of wet basin depths and volumes should take into account the gradual accumulation of sediment. Accumulating sediment in the pool will decrease storage volume and reduce pollutant removal efficiency.

MassDEP requires a sediment forebay to pretreat stormwater before it enters the wet basin. Forebays trap sediment before the runoff enters the primary pool, effectively enhancing removal rates and minimizing long-term operation and maintenance problems. Removing sediment from the forebay is easier and less costly than from the wet basin pool, so design sediment forebays for ease of maintenance. Hard bottom forebays make sediment removal easier. Make forebays accessible by heavy machinery to facilitate maintenance.

To avoid reducing the pollutant removal capability and to maximize travel distance, locate the inflow points as far from the outlet structure as possible. To maximize stormwater contact and retention time in the pool, use a length to width ratio of at least 3:1.

Set the invert elevation of the inlet pipe at or below the surface of the permanent pool, preferably within one foot of the pool. Pipes discharging above the pool can erode the banks and side slopes. Design all inflow points with riprap or other energy dissipators to reduce inflow velocities.

Establish wetland vegetation on the aquatic bench to enhance the removal of soluble nutrients, facilitate sediment trapping, prevent sediment resuspension, provide wildlife and waterfowl habitat, and conceal trash and debris that may accumulate near the outlet. Six to eighteen inches of water depth are needed for wetland vegetation growth.

Make the slopes of the pools no steeper than 3:1. Flatter slopes help to prevent bank erosion during larger storms and facilitate routine bank maintenance tasks, such as mowing. Flat slopes also provide for public safety, and allow easier access. In addition, design the sides of the pool that extend below the safety and aquatic benches to the bottom of the pool at a slope that will remain stable, usually no steeper than 2:1 (horizontal to vertical).

Design the invert of the wet basin outlet pipe to convey stormwater from approximately one foot below the pool surface and to discharge into the riser in the pond embankment. To prevent clogging, install trash racks or hoods on the riser.

To facilitate access for maintenance, install the riser within the embankment. Place anti-seep collars or filter and drainage diaphragms on the outlet barrel to prevent seepage and pipe failure. Make the vital parts of the structure accessible to maintenance personnel during normal and emergency conditions. Install a bottom drainpipe to allow complete draining of the wet basin in case of emergencies or for routine maintenance.

Fit both the outlet pipe and the bottom drain pipe with adjustable valves at the outer end of the outlet to permit adjustment of the detention time, if necessary.

To prevent scour at the outlet, install a flow transition structure, such as a lined apron or plunge pad, to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area.

Design embankments and spillways to conform with DCR Dam Safety regulations, if applicable. All wet basins must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure.

Provide an access way for maintenance, with a minimum width of 15 feet and a maximum slope of 15%, by public or private right-of-way. Equipment that will be used for maintenance must be capable of using this access way. This access should extend to the forebay, safety bench, outflow structure, and around the entire perimeter. It need not cross the emergency spillway, unless the spillway has been designed for that purpose. Place vegetative buffers around the perimeter of the wet basin to control erosion and remove additional sediment and nutrients. The vegetative buffer must be at least 33 feet (10 meters). Vegetation must be designed to prevent the introduction of invasive species.

Wet Basin Design Criteria

Factor	***Criteria***
Max. Drainage Area	≥ 20 acres unless sufficient groundwater flow
Permanent Pool Volume	≥ 2 x WQV (equivalent to Vb/Vr ratio of 2)
Min. Pool Surface Area	≥ 0.25 acres
Min. Length to Width Ratio	≥ 3:1
Mean Permanent Pool Depth	3 to 6 feet
Max. Permanent Pool Depth	8 feet
Max. Pool Slopes	≤ 3H:1V
Max. Safety and Aquatic Bench Slopes	≤ 2H:1V
Perimeter Accessway Width	≥ 15 feet
Perimeter Vegetative Buffer	≥ 25 feet
Sediment Forebay	Required (not included in wet basin sizing)
Pool Drain (for maintenance)	Required maximum pool drain time: 40 hours

Maintenance

Activity	Frequency
Inspect wet basins to ensure they are operating as designed	At least once a year
Mow the upper stage, side slopes, embankment, and emergency spillway.	At least twice per year
Inspect to make sure emergent or submergent plants are not present	At least twice per year, remove all emergent or submergent plants. Assess whether design changes are necessary to discourage emergent or submergent plant growth.
Check the sediment forebay for accumulated sediment, trash, and debris and remove it.	At least twice per year
Remove sediment from the basin.	As necessary, and at least once every 10 years.

Inspect wet basins at least once per year to ensure they are operating as designed. Inspect the outlet structure for evidence of clogging or excessive outflow releases.

Potential problems to check include: subsidence, erosion, cracking or tree growth on the embankment, damage to the emergency spillway, sediment accumulation around the outlet, inadequacy of the inlet/outlet channel erosion control measures, changes in the condition of the pilot channel, erosion within the basin and banks, and the emergence of invasive species. Make any necessary repairs immediately. During inspections, note any changes to the wet basin or the contributing watershed area because these may affect basin performance. At least twice a year, mow the upper-stage, side slopes, embankment and emergency spillway. At this time, also check the sediment forebay for accumulated material, sediment, trash, and debris and remove it. Remove sediment from the basin as necessary, and at least once every 10 years. Providing an on on-site sediment disposal area will reduce the overall sediment removal costs.

References

Galli, J. 1990, Thermal Impacts Associated with Urbanization and Stormwater Best Management Practices. Prepared for the Maryland Department of Environment, Baltimore, MD, by the Metropolitan Council of Governments, Washington, D.C.

Roof Dripline Filter

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Does not provide peak flow attenuation.
3 - Recharge	**Roof Dripline Filter (filtering)** does not provide groundwater recharge. **Roof Dripline Filter (exfiltrating)** provides groundwater recharge.
4 - TSS/TP Removal	**Roof Dripline Filter (filtering)** • Use EPA Performance Curve for Biofiltration. **Roof Dripline Filter (exfiltrating)** • Use EPA Performance Curve for Infiltration Basin. See "Introduction" Section of this Appendix for more information the EPA Performance Curves.
5 - Higher Pollutant Loading	May be used to treat rooftop runoff of buildings located in LUHPPL except for LUHPPL that have metal roofs.
6 - Discharges near or to Critical Areas	May be used for discharge near Critical Areas.
7 - Redevelopment	Good option for suburban and residential areas - requires surface area adjacent to building foundations.
8 - Construction Phase	May not be used for construction phase runoff.
9 - O&M	An O&M plan is required for this SCM.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutant Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

Dripline filters are designed to capture and treat runoff from a peaked roof without gutters. They provide temporary storage of runoff in the void spaces of a surface, stone reservoir layer. The reservoir layer is typically underlain with a sand filter course for treatment of runoff and a layer of crushed stone underdrain material prior to discharge by way of a perforated pipe. The filtration trench extends along the full length of the building or roof area to be treated.

Roof Dripline Filters may be designed to act as a filtering practice or an infiltration practice. **Filtering Roof Dripline Filters** do not infiltrate and cannot be used receive recharge credit towards Standard 3 – they have an underdrain that captures and conveys runoff downstream. Filtering Roof Dripline Filters may be lined. **Exfiltrating Roof Dripline Filters** are designed to provide infiltration.

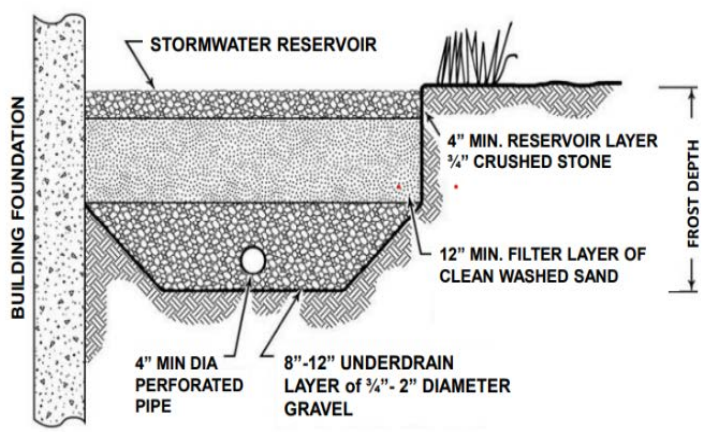
Advantages/Benefits

- Applicable to peaked rooftop drainage areas
- Long design life if properly maintained
- Good for stormwater retrofits
- Good for residential subdivisions, and single-family homes.
- Reduces back splash to protect foundation
- Reduces soil erosion from rooftop runoff
- Improves the quality of runoff flowing from rooftops to storm drains or infiltration areas.

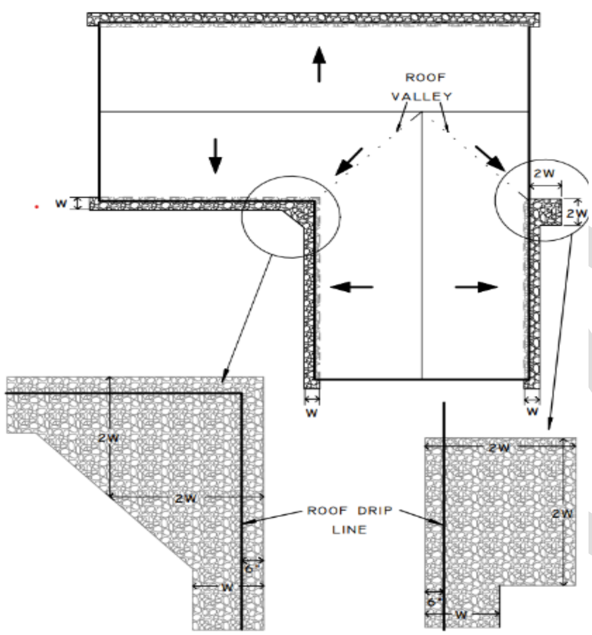
Disadvantages/Limitations

- Require frequent maintenance
- May not be effective in winter
- May not be able to be used on certain sites because of inadequate depth to bedrock or high groundwater
- Not effective in controlling peak discharge.

Cross Section



Example Dripline Filter
(adapted from the Maine Stormwater Manual)



Detail - Additional Armoring at Roof Valleys

Suitability to Treat TMDL Pollutants

Filtering Roof Dripline Filter

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	N
Total Phosphorous	N
Pathogens	Y
Metals	Y

Exfiltrating Roof Dripline Filter

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Unit Treatment Process

Filtration

Special Features

Design as off-line small-scale control.

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Applicability

Dripline filters are adaptable to most residential developments with relatively few constraints and can apply in commercial settings. See Massachusetts Division of Fisheries and Wildlife – Field Headquarters Building. They are a variation of surface sand filters that can be installed in areas with high evaporation rates, low soil infiltration rates, and where groundwater concerns restrict the use of infiltration. Drip line filters can be used as stormwater controls for roof drainage areas that are completely impervious such as single-family homes. They are intended primarily for quality control, not quantity control.

This SCM may not be appropriate for home designs with at grade entrances (i.e., walkout basements) where frozen conditions could direct Surface Water into the house.

Effectiveness

The stormwater filtration improves water quality by straining through a sand filtering media and by settling particulate pollutants on top of the sand bed.

Planning Considerations

The location of this filter is adjacent to the foundation must be accessible from a driveway or landscaped area for maintenance purposes.

Because of the potential for clogging, install dripline filters only at sites that have been stabilized. Never use these filters as sedimentation traps during construction.

Cold Weather Modifications

Dripline filters retain water and may freeze or have limited functionality during the winter. To ensure year-round treatment, including the winter, design the filter layer to be below the frost line when possible. If freezing cannot be prevented, remove snow from the contributing area and place it elsewhere.

This SCM may not be appropriate for home designs with at grade entrances where frozen conditions could direct Surface Water into the house.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Dripline filters are adjacent to building foundations and off-line from the primary conveyance systems.

These filter designs do not include a sediment forebay or equivalent pretreatment component. However, since rooftop runoff is considered relatively free from pollutants, the pretreatment requirement is waived.

Basement waterproofing is essential. The bottom of filter and/or infiltration practice must be at least 2-feet above Seasonal High Groundwater. Surface grading away from the foundation and robust waterproofing of basement walls are required to prevent the penetration of water into a basement. Maintenance access must be provided in the design.

This SCM may not be appropriate for all foundation types. Freeze-thaw cycles could cause damage to the foundation. If the site has potential freeze/thaw issues, or general concerns of water buildup outside of the foundation walls, use of this SCM must be restricted to pile or slab or foundations.

These practices function as a stormwater quality control practice and do not provide detention for downstream areas. Therefore, locate them as off-line systems, away from the primary conveyance/detention system. Dripline filters must not be connected to any municipal closed drainage system.

Use a design filtration rate of 2 inches/hour. Although this rate is low compared to published values for sand, it reflects actual rates achieved by sand filters in urban areas. Using Darcy's Law, design the sand filter to completely drain within 24 hours or less, because there is little storm storage available in the sand filter if a second storm occurs.

Drip line edge: The drip line trench should extend the length of the building or area of roof.

Reservoir Layer: The reservoir layer at the drip line should consist of clean washed stone with a porosity of 40%. The width and depth of the reservoir course is sized based on the desired runoff volume from the roof. For example, a 30-foot wide roof panel will need a 4 foot wide by 1.5 foot deep rock storage bed to store 1" of runoff.

Filter Layer: Use a minimum of 12 inches of 0.02-inch to 0.04-inch diameter sand (smaller sand is acceptable) for the sand bed. Consider that sand may consolidate during construction. Stabilize the depth of the bed by wetting the sand periodically, allowing it to consolidate, and then add extra sand.

Underdrain Layer (for filtering type): An underdrain layer consisting of a 4" diameter slotted underdrain pipe bedded in 8 to 12 inches of underdrain backfill material consisting of ¾ inch to 2-inch diameter gravel. Separate the gravel and top media layers with a layer of geotextile fabric to prevent sand from infiltrating into the gravel layer and the underdrain piping.

Detention Time: Stored volume needs to fully drain within 24 hours. An overflow should be provided for runoff above the combined capacity of the reservoir and drainage layers.

Basement Waterproofing: Surface grading away from the foundation and robust waterproofing of basement walls is required to prevent the penetration of water into a basement.

Maintenance Features Incorporated in Filter Design

Ease of access is essential feature for drip line filter maintenance. Designs should include easy access from a driveway or landscaped area to allow for removal of material as needed.

Geotextile fabric placed between the filter course and underdrain material will prevent sand from infiltrating into the gravel layer and the underdrain piping.

Construction

Take care during construction to minimize the risk of premature failure of the sand filter.

Appropriate construction phase SCMs should be placed around the perimeter of the sand filters during all phases of construction.

Sand filters should not be used as temporary sediment traps for construction activities.

Consolidation of material in the sand filters during construction must be taken into consideration. The depth of the bed can be stabilized by wetting the sand periodically, allowing it to consolidate, and then adding extra sand.

During and after excavation, all excavated materials should not be placed in an area upgradient from the sand filters, to prevent redeposition during runoff events. All excavated materials should be handled properly and disposed of properly during and after construction.

Maintenance

The dripline filter bed requires regular post-construction maintenance to ensure full function. Periodic inspections, especially following significant storm events of 0.25-inch/day of precipitation or greater for the first few months should be conducted. Check for stability, proper function, and damage to components. Thereafter, schedule inspections at 6-month intervals to remove leaves, debris, and sediment from the surface reservoir course, to control vegetation adjacent to trench, and look for signs of stress or potential failure. Check and promptly repair any damage to the foundation waterproofing or filtration system components.

Activity	Frequency
Inspect filters and remove debris	After every .25 inch/day or greater storm event for the first few months after construction is complete to ensure proper function; and every 6 months thereafter.

Over time, a layer of sediment can accumulate on top of the sand clogging the system. When the system clogs, clean out the accumulated sediment on the surface of the sand filter and replace an appropriate amount of sand needed to reestablish free flowing characteristics of washed sand. De-water and properly dispose of sand removed from the filter.

The post-construction maintenance plan should address that these filter structures are part of the stormwater management plan for the project and cannot be paved over or altered in anyway. No gutter may be installed on the roof line.

References

Erickson, Andrew J., et al., Enhanced Sand Filtration for Storm Water Phosphorus Removal, Journal of Environmental Engineering. Volume 133, Issue 5, pp. 485-497, May 2007.

Developments in Sand Filter Technology to Treat Stormwater Runoff, Article 105, Further Developments in Sand Filter Technology, Article 106, in the Practice of Stormwater Protection, Center for Watershed Protection, Stormwater Design Example: Sand Filter, WEB: https://www.stormwatercenter.net/Manual_Builder/sand_filter_design_example.htm

Georgia Stormwater Manual 2016, Volume 2, Appendix B3, page 510, Georgia Stormwater Manual 2016.

2004 Connecticut Stormwater Manual, https://portal.ct.gov/DEEP/Water-Regulating-and-Discharges/Stormwater/Stormwater-Manual.

North Carolina Department of Environment and Natural Resources Stormwater SCM Manual 2007, https://deq.nc.gov/about/divisions/energy-mineral-land-resources/energy-mineral-land-permit-guidance/stormwater-bmp-manual/archive.

Maine Department of Environmental Protection Stormwater Management Manual, Vol. 3 BMP Technical Design Manual, Chapter 7.5, Roof Dripline Filtration BMP

https://www.maine.gov/dep/land/stormwater/stormwaterbmps/vol3/chapter7_5.pdf

http://www.state.me.us/dep/blwq/docstand/stormwater/stormwaterbmps/index.htm

Maine Department of Environmental Protection Stormwater Management Manual, Vol. 3 BMP Technical Design Manual, Chapter 7.3, Underdrained Subsurface Sand Filter BMP

https://www.maine.gov/dep/land/stormwater/stormwaterbmps/vol3/chapter7_3.pdf

NH Department of Environmental Services, *A Shoreland Homeowner's Guide to Stormwater Management*, Protecting your Home and Environment - NH Lakes https://nhlakes.org

MAPC, U.S. EPA, Massachusetts Low Impact Development Toolkit, https://www.mapc.org/resource-library/low-impact-development-toolkit/

Fact Sheet #7, Infiltration Trenches and Dry Wells. https://www.mapc.org/resource-library/trenches-drywells/

Structural Conveyance

- **Drainage Channels**
- **Grassed Channel (Biofilter Swale)**
- **Water Quality Swale**

Drainage Channels

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides no peak flow attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	No MassDEP removal credit.
5 – Higher Pollutant Loading	Use as conveyance.
6 – Discharges near or to Critical Areas	May be used to achieve temperature reduction for runoff discharging to coldwater fisheries, provided the channel in lined with vegetation and has a hydraulic residence time of at least 9 minutes as calculated using Manning's Equation.
7 - Redevelopment	Limited applicability.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained..
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Drainage channels are traditional vegetated open channels that are designed to provide for non-erosive conveyance. They receive no infiltration or TSS/TP removal credit (Standards 3 and 4).

Advantages/Benefits

- Conveys stormwater
- Accents natural landscape.
- Compatible with LID design practices
- Roadside channels reduce driving hazards by keeping stormwater flows away from street surfaces during storms

Disadvantages/Limitations

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside channels are subject to damage from off-street parking and snow removal.
- Provides limited pollutant removal compared to water quality swales
- May be impractical in areas with flat grades, steep topography or poorly drained soils
- Large area requirements for highly impervious sites.

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	N
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	N

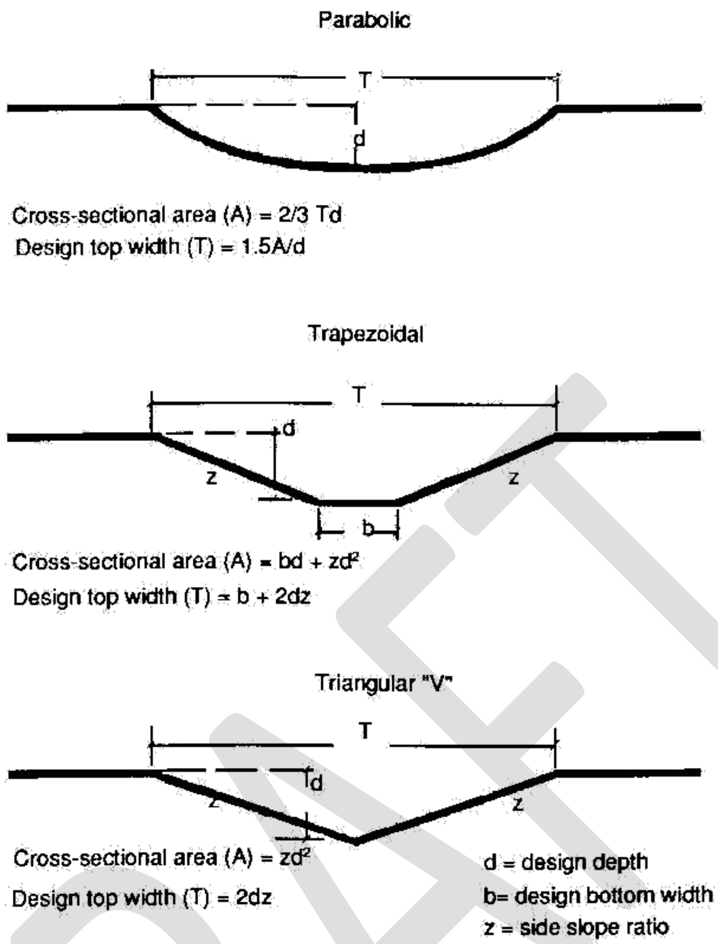
Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Unit Treatment Process

- No treatment provided

Example Drainage Channel (Adapted from the University of New Hampshire)



Special Features

Drainage channels cannot be used to meet the Stormwater Management Standards. They are a component of a larger stormwater management system and serve to convey runoff from impervious surfaces to or from stormwater treatment SCMs.

ESSD / LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Drainage Channels versus Water Quality Swales

The distinction between drainage channels and water quality swales lies in the design and planned use of the open channel conveyance. Drainage channels are designed to have sufficient capacity to convey runoff safely during large storm events without causing erosion. Drainage channels typically have a cross-section with sufficient hydraulic capacity to handle the peak discharge for the 10-year storm. The dimensions (slope and bottom width) of a drainage channel must not exceed a critical erosive velocity during the peak discharge. They must be vegetated with grasses to maintain bank and slope integrity. Other than basic channel size and geometry, there are no other design modifications to enhance pollutant removal capabilities. Therefore, pollutant removal efficiency is typically low for drainage channels.

Water quality swales and grass channels, on the other hand, are designed for the required water quality volume and incorporate specific features to enhance their stormwater pollutant removal effectiveness. Pollutant removal rates are significantly higher for water quality swales and grass channels. A water quality swale or grass channel must be used in place of the drainage channel when a water quality treatment credit is sought.

Applicability

Drainage channels are suitable for residential and institutional areas of low to moderate density. The percentage of impervious cover in the contributing areas must be less than 50%. Drainage channels can also be used in parking lots to break up areas of impervious cover.

Along the edge of roadways, drainage channels can be used in place of curb and gutter systems. However, the effectiveness of drainage channels may decrease as the number of driveway culverts increases. They are also generally not compatible with extensive sidewalk systems. When using drainage channels in combination with roadways and sidewalks, it is most appropriate to place the channel between the two impervious covers (e.g., between the sidewalk and roadway).

Planning Considerations

The two primary considerations when designing a drainage channel are maximizing channel capacity and minimizing erosion. Use the maximum expected retardance when checking drainage channel capacity. The greatest flow retardance usually occurs when vegetation is at its maximum growth for the year. This usually occurs during the early growing season and dormant periods.

Other factors to be considered when planning for the drainage channel are land availability, maintenance requirements and soil characteristics. The topography of the site should allow for the design of a drainage channel with sufficient slope and cross-sectional area to maintain a non-erosive flow velocity, generally less than five feet per second.

The shape of the cross-sectional channel is also an important planning consideration. Figure DC 1 shows three different design shapes. The V- shaped or triangular cross-section can result in higher velocities than other shapes, especially when combined with steeper side slopes, so use this design only if the quantity of flow is relatively small. The parabolic cross-section results in a wide shallow channel that is suited to handling larger flows and blends in well with natural settings. Use trapezoidal channels when deeper channels are needed to carry larger flows and conditions require relatively high velocities. Select a grass type for the channel lining that is appropriate for site conditions, including one that is able to resist shear from the design flow, is shade tolerant, is drainage tolerant, and has low maintenance requirements. Use vegetation that is water tolerant and has a dense root system. Alternatively, the drainage channel may be lined with stone.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

See the following for complete design references: Site Planning for Urban Stream Protection. 1995. Schueler. Center for Watershed Protection.

The length of the drainage channel depends on the slope, contributing impervious surface area, and runoff volume. Because drainage channels with low velocities can act as sediment traps, add extra capacity to address sediment accumulation without reducing design capacity. Add an extra 0.3 to 0.5 feet of freeboard depth, if sediment accumulation is expected. Use side slopes of 3:1 or flatter to prevent side slope erosion. The longitudinal slope of the drainage channel should be as close to zero as possible and not greater than 5%.

Install check dams in drainage channels when necessary to achieve velocities of 5 feet per second or less. Do not use earthen check dams because they tend to erode on the downstream side, and it is difficult to establish and maintain grass on the dams. The maximum ponding time behind the check dam should not exceed 24 hours. Use outlet protection at discharge points from a drainage channel to prevent scour at the outlet.

The design for the drainage channel must include access for maintenance. When located along a highway, provide a breakdown lane with a width of 15 feet. When located along a street, off-street parking can be doubled up as the access, provided signs are posted indicating no parking is allowed during maintenance periods. When locating drainage channels adjacent to pervious surfaces, include a 15-foot-wide grass strip to provide access for maintenance trucks.

Construction

Use temporary erosion and sediment controls during construction. Soil amendments, such as aged compost that contains no biosolids, may be needed to encourage vegetation growth. Select a vegetation mix that suits the characteristics of the site. Seeding will require mulching with appropriate materials, such as mulch matting, straw, wood chips, other natural blankets, or synthetic blankets. Anchor blanket immediately after seeding. Provide new seedlings with adequate water until they are well established. Refer to the “Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials” for information regarding seeding, mulching, and use of blankets.

Maintenance

Activity	Frequency
Inspect channels to make sure vegetation is adequate and for signs of rilling and gullying. Repair any rills or gullies. Replace dead vegetation.	The first few months after construction and twice a year thereafter.
For stone lined channels, grade the stone to original design elevation	At least once every 5-years
Mow	As necessary. Grass height shall not exceed 6 inches.
Remove sediment and debris manually	At least once a year
Reseed.	As necessary. Use of road salt or other deicers during the winter will necessitate yearly reseeding in the spring.

The maintenance and inspection schedule should take into consideration the effectiveness of the drainage channel. Inspect drainage channels the first few months after construction to make sure that there is no rilling or gullying, and that vegetation in the channels is adequate. Thereafter, inspect the channel twice a year for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding, and sediment accumulation.

Regular maintenance tasks include mowing, fertilizing, liming, watering, pruning, weeding, and pest control. Mow channels at least once per year. Do not cut the grass shorter than three to four inches. Keep grass height under 6 inches to maintain the design depth necessary to serve as a conveyance. Do not mow excessively, because it may increase the design flow velocity.

Remove sediment and debris manually at least once per year. Re- seed periodically to maintain the dense growth of grass vegetation. Take care to protect drainage channels from snow removal procedures and off-street parking. When drainage channels are located on private residential property, the operation and maintenance plan must clearly specify the private property owner who is responsible for carrying out the required maintenance. If the operation and maintenance plan call for maintenance of drainage channels on private properties to be performed by a public entity or an association (e.g., homeowners association), maintenance easements must be obtained.

Grass Channel

(Biofilter Swale)

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Does not provide peak attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	Use EPA Grass Swale Performance Curve to calculate required sizing to meet pollutant removal requirements. See “Introduction” Section of this Appendix for more information the EPA Performance Curves. Pretreatment must be provided such as a sediment forebay, or equivalent.
5 - Higher Pollutant Loading	N/A
6 - Discharges near or to Critical Areas	Not suitable for discharges near or to vernal pools or bathing beaches. At other critical areas, may be used as pretreatment practice.
7 - Redevelopment	Typically not suited for retrofits.
8 - Construction Phase Pollution Controls	Construction phase runoff is not to be diverted to these areas; divert stormwater runoff to these areas only once the site has been stabilized.
9 - O&M Plan	An O&M Plan is required for this SCM
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

Grassed Channels (formerly known as Biofilter swales) are treatment systems with a longer hydraulic residence time than drainage channels. The removal mechanisms are sedimentation and gravity separation, rather than filtration. To receive TSS/TP credit, a sediment forebay or equivalent must be provided for pretreatment. Note that the sediment forebay does not receive a separate TSS/TP removal credit.

Advantages/Benefits

- Provides pretreatment if used as the first part of a treatment train.
- Open drainage system aids maintenance
- Accepts sheet or pipe flow
- Compatible with LID design measures.
- Little or no entrapment hazard for amphibians or other small animals

Disadvantages/Limitations

- Does not provide peak attenuation
- Short retention time does not allow for full gravity separation.
- Limited biofiltration provided by grass lining.
- Must be trained with other SCMs to meet TSS and TP removal requirements.
- Must be designed carefully to achieve low flow rates for Water Quality Volume purposes (<1.0 fps)
- Mosquito control considerations

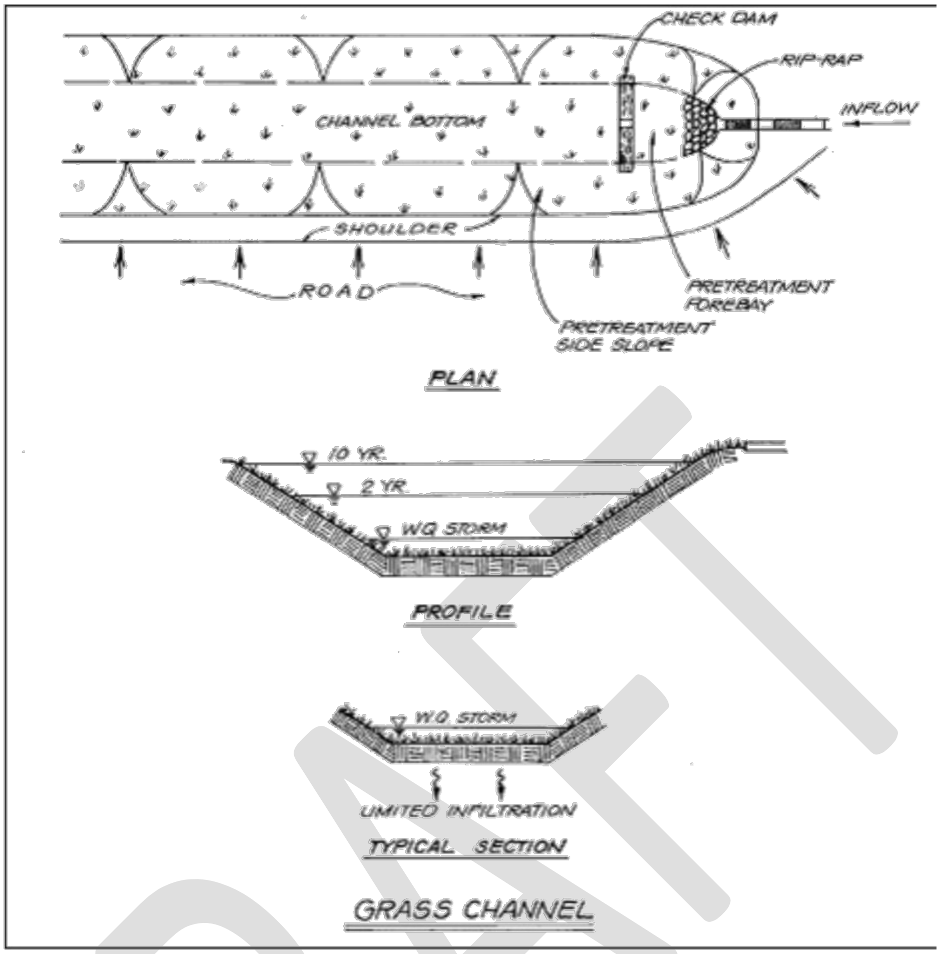
Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	N

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Example Grass Channel (adapted from the Vermont Stormwater Manual)



Unit Treatment Process

- Sedimentation & gravity separation

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Applicability

Grass channels convey and treat stormwater. Grass channels were referred to as biofilter swales in the 1996 MassDEP/CZM Stormwater Handbook, based on the nomenclature coined by the Center for Watershed Protection (CWP). The CWP is now referring to biofilter swales as grass channels – so MassDEP is adopting the same name as the CWP to minimize confusion.

Properly designed grass channels are ideal when used adjacent to roadways or parking lots, where runoff from the impervious surfaces can be directed to the channel via sheet flow. Runoff can also be piped to the channel. If piped, locate the sediment forebay at the pipe outlet and include a check dam separating the forebay from the channel. For sheet flow, use a vegetated filter strip on a gentle slope or a pea gravel diaphragm. Make the longitudinal slope as flat as possible. This increases the Hydraulic Residence Time (HRT) and allows gravity separation of solids and maximizes sediment removal. Install check dams to further increase the HRT.

Differences from dry water quality swales, wet water quality swales, bioretention cells, and drainage channels:

Dry water quality swales contain a specific soil media mix and underdrain, providing greater treatment than grass channels. Wet water quality swales are designed with a permanent wet channel, whereas grass channels must be designed to completely drain between storms. Bioretention areas, including rain gardens, are designed solely as a treatment practice, and not for conveyance. Lastly, drainage channels act solely as a conveyance, in contrast to properly designed grass channels where runoff flow is deliberately lagged to provide treatment.

Planning Considerations

An Applicant may not be able to install a grass channel swale because of:

- High groundwater;
- Presence of utilities; or
- Other site conditions that limit depth of excavation because of stability.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Water Quality Volume: Design grass channels to maximize contact with vegetation and soil surface to promote greater gravity separation of solids during the storm associated with the water quality event. Design the channel such that the velocity does not exceed 1 foot per second during the 24-hour storm associated with the water quality event. Do not allow the water depth during the storm associated with the water quality event to exceed 4 inches (for design purposes). Make sure the selected design storm provides at least 9 minutes of HRT within the channel. Increasing the HRT beyond 9 minutes increases the likelihood of achieving pollutant removal efficiency. Adding meanders to the swale increases its length and may increase the HRT.

2-year and 10-year conveyance capacity: Design grass channels to convey both the 2-year and 10-year 24-hour storms. Provide a minimum of 1-foot freeboard above the 10 -year storm. Make sure that the runoff velocities during the 2-year 24-hour storm do not cause erosion problems.

Channel Length: Length depends on design factors to achieve the minimum 9-minute residence time for the storm associated with the water quality event.

Channel Crossings: In residential settings, driveways will cross over the channel, typically via culverts (pre-cast concrete, PVC, or corrugated metal pipe).

Soils: Grass channels may be constructed from most parent soils, unless the soils are highly impermeable. Any imported soils must be brought to a minimum 6-inch depth prior to being tilled into the parent material. Soils must be able to support a dense grass growth. MassDEP recommends sandy loams, with an organic content of 10 to 20%, and no more than 20% clay. Highly impermeable soils, such as clays, are not suitable for grass channels, because they do not support dense grass stands. Similarly, gravelly and coarse soils may not be suitable due to their lower moisture retention capability, leading to potential die-back of the grass lining during the summer when the inter-event period between storms is longer than during other times of the year.

Grasses: The grasses serve to stabilize the channel, and promote conditions suitable for sedimentation, such as offering resistance to flow, which reduces water velocities and turbulence. Select a grass height of 6 inches or less. Grasses over that height tend to flatten when water flows over them, inhibiting sedimentation. Select grasses that produce a fine, uniform and dense cover that can withstand varying moisture conditions. Select grasses that are salt tolerant to withstand winter deicing of roadways. In the spring, replant any areas where grasses died off due to deicing. (Franklin 2002 and Knoxville 2003 provide recommendations for the best grass species.)

Pea Gravel Diaphragm: Use clean bank-run gravel, conforming to ASTM D 448, varying in size from 1/8 inch to 3/8 inch (No. 6 stone).

Outlet Protection: Must be used at discharge points to prevent scour downstream of the outlet.

Construction Considerations: Stabilize the channel after it is shaped before permanent turf is established, using natural or synthetic blankets. Never allow grass channels to receive construction period runoff.

Maintenance

Activity	Frequency
Remove sediment from forebay	Annually
Remove sediment from grass channel	Annually
Mow	Once a month during growing season
Repair areas of erosion and revegetate	As needed, but no less than once a year.

Access: Maintenance access must be designed as part of the grass channel.

When combined with on- street parking, post signs prohibiting parking when the swale is to be inspected and cleaned. Do not use travel lanes along highways and streets as the required maintenance access.

Mowing: Set the mower blades no lower than 3 to 4 inches above the ground. Do not mow beneath the depth of the design flow during the storm associated with the water quality event (e.g., if the design flow is no more than 4 inches, do not cut the grass shorter than 4 inches). Mow on an as-needed basis during the growing season so that the grass height does not exceed 6 inches.

Inspection: Inspect semi-annually the first year, and at least once a year thereafter. Inspect the grass for growth and the side slopes for signs of erosion and formation of rills and gullies. Plant an alternative grass species if the original grass cover is not successfully established. If grass growth is impaired by winter road salt or other deicer use, re-establish the grass in the spring.

Trash/Debris Removal: Remove accumulated trash and debris prior to mowing.

Sediment Removal: Check on a yearly basis and clean as needed. Use hand methods (i.e., a person with a shovel) when cleaning to minimize disturbance to vegetation and underlying soils. Sediment build-up in the grass channel reduces its capacity to treat and convey the water quality event, 2-year and 10-year 24-hour storm.

References

Atlanta Regional Commission et al, 2001, Georgia Stormwater Management Manual, Volume 2, Section 3-3-2, Grass Channel, https://atlantaregional.org/what-we-do/natural-resources/georgia-stormwater-management-manual/

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Idaho Department of Environmental Quality, 2005, Storm Water Best Management Practices Catalog, SCM 1, Biofiltration Swale (Vegetated Swale).

International Stormwater SCM Data Base, 2016

Minton, G., 2002, Stormwater Treatment, Resource Planning Associates, Seattle, WA, p. 174

Atlanta Regional Commission et al, 2001, Georgia Stormwater Manual, Volume 2, Section 3-3-2, http://georgiastormwater.com/vol2/3-3-2.pdf

International Stormwater Database, based on MassDEP analysis of raw influent & effluent values reported in 2005.

Water Quality Swale

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Does not provide peak attenuation.
3 - Recharge	Provides no groundwater recharge.
4 - TSS/ TP Removal	No EPA Curve. MassDEP Removal. **TSS:** 70% removal **TP:** 0% removal
5 - Higher Pollutant Loading	Dry swale recommended as pretreatment SCM. Must be lined. For some land uses with higher potential pollutant load, an oil/grit separator or equivalent may be required before discharge to the swale.
6 - Discharges near or to Critical Areas	Not suitable for discharges near or to vernal pools or bathing beaches. At other critical areas, may be used as pretreatment practice.
7 - Redevelopment	Suitable for Redevelopments and urban applications if sufficient land is available.
8 - Construction Phase Pollution Controls	Construction phase runoff is not to be diverted to these areas; divert stormwater runoff to these areas only once the site has been stabilized.
9 - O&M Plan	An O&M Plan is required for this SCM
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

Water quality swales are vegetated open channels designed to treat the required water quality volume and to convey runoff from the 10-year storm without causing erosion.

There are two different types of water quality swales that may be used to satisfy the Stormwater Management Standards:

- Dry Swales
- Wet Swales

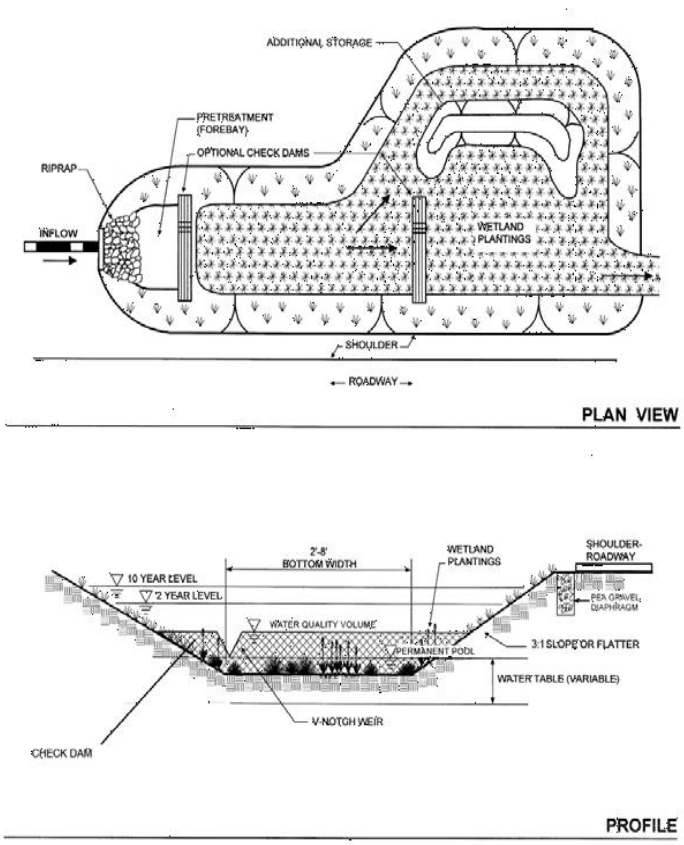
Unlike drainage channels which are intended to be used only for conveyance, water quality swales and grass channels are designed to treat the required water quality volume and incorporate specific features to enhance their stormwater pollutant removal effectiveness. Water quality swales have higher pollutant removal efficiencies than grass channels.

Advantages/Benefits

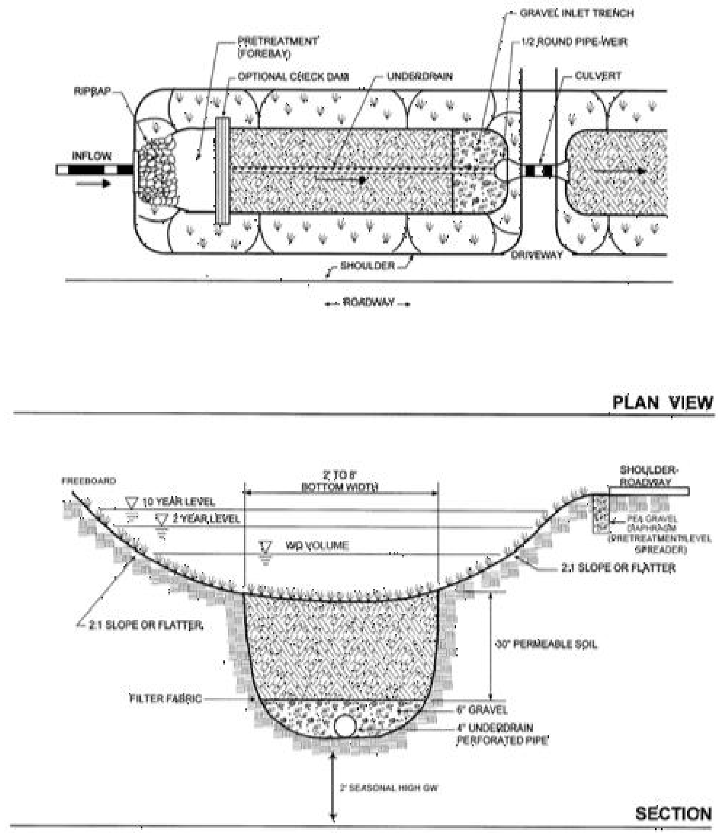
- May be used to replace more expensive curb and gutter systems.
- Roadside swales provide water quality and quantity control benefits, while reducing driving hazards by keeping stormwater flows away from street surfaces.
- Accents natural landscape.
- Compatible with LID designs
- Can be used to retrofit drainage channels and grass channels
- Little or no entrapment hazard for amphibians or other small animals

Disadvantages/Limitations

- Higher degree of maintenance required than for curb and gutter systems.
- Roadside swales are subject to damage from off-street parking, snow removal, and winter deicing.
- Subject to erosion during large storms
- Individual dry swales treat a relatively small area
- Impractical in areas with very flat grades, steep topography, or poorly drained soils
- Wet swales can produce mosquito breeding



Example of Wet Swale



Example of Dry Swale

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	N

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Special Features

May be configured as either a dry swale or a wet swale.

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Dry Swale

Dry swales are designed to temporarily hold the water quality volume of a storm in a pool or series of pools created by permanent check dams at culverts or driveway crossings. The soil bed consists of native soils or highly permeable fill material, underlaid by an underdrain system.

Wet Swale

Wet swales also temporarily store and treat the required water quality volume. However, unlike dry swales, wet swales are constructed directly within existing soils and are not underlaid by a soil filter bed or underdrain system. Wet swales store the water quality volume within a series of cells within the channel, which may be formed by berms or check dams and may contain wetland vegetation (Metropolitan Council, 2001). The pollutant removal mechanisms in wet swales are similar to those of stormwater wetlands, which rely on sedimentation, adsorption, and microbial breakdown.

Applicability

Use water quality swales:

- As part of a treatment train
- As one of the best SCMs for areas discharging to Cold-Water Fisheries if they are lined.

- As one of the best SCMs for Redevelopments and urban applications.
- For residential and institutional settings (especially dry swales)

Water quality swales have many uses. Dry swales are most applicable to residential and institutional land uses of low to moderate density where the percentage of impervious cover in the contributing areas is relatively low. Wet swales may not be appropriate for some residential applications, such as frontage lots, because they contain standing water that may attract mosquitoes.

Water quality swales may also be used in parking lots to break up areas of impervious cover. Along the edge of small roadways, use water quality swales in place of curb and gutter systems. Water quality swales may not be suitable for sites with many driveway culverts or extensive sidewalk systems. When combining water quality swales with roadways and sidewalks, place the swale between the two impervious areas (e.g., between road and sidewalk or in-between north and south bound lanes of a roadway/highway).

Planning Considerations

The primary factors to consider when designing a water quality swale are soil characteristics, flow capacity, erosion resistance, and vegetation. Site conditions and design specifications limit the use of water quality swales.

The topography and soils on the site will determine what is appropriate. The topography should provide sufficient slope and cross-sectional area to maintain non-erosive flow velocities. Porous soils are best suited to dry swales, while soils with poor drainage or high groundwater conditions are more suited to wet swales.

Other important factors to consider are land availability, maintenance requirements and soil characteristics. The topography of the site should allow for the design of a swale with sufficient slope and cross-sectional area to maintain a non-erosive flow rate, and to retain or detain the required water quality volume. The longitudinal slope of the swale should be as close to zero as possible and not greater than 5%.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Design water quality swales to retain and treat the required water quality volume (1 inch). Because they must also be designed to convey the 2-year and 10-year 24 -hour storms, they may have to convey additional runoff volume to other downgradient SCMs.

The grass or vegetation types used in swales should be suited to the soil and water conditions. Wetland hydrophytes (plants adapted to grow in water) or obligate species (i.e., species that occur99% of the time under natural conditions in wetlands) are generally more water-tolerant than facultative species (i.e., species that occur 67% to 99% of the time under natural conditions in wetlands) and are good selections for wet swales, while dry swales should be planted with species that produce fine and dense cover and are adapted to varying moisture conditions.

Swale storage capacity should be based on the maximum expected reduction in velocity that occurs during the annual peak growth period. Usually, the maximum expected drop in velocity occurs when vegetation is at its maximum growth for the year. Use the minimum level when checking velocity through the swale or the ability of the swale to convey the 2-year 24-hour storm without erosion. This usually occurs during the early growing season and dormant periods.

Access for maintenance must be incorporated into both designs. The maintenance access way must be a minimum of 15 feet wide on at least one longitudinal side of the swale to enable a maintenance truck to drive along the swale and gain access to any one point. When constructed along a highway, the breakdown lane can be used as the access. When constructed in a residential subdivision, an on-street parking lane may double as the maintenance access, provided signs are posted indicating no parking is allowed during periods when the swales are being maintained.

Dry Swales

- Size dry swales to provide adequate residence time for the required water quality volume. Hydraulic Residence Time (HRT) must be a minimum of 9 minutes. Use Manning’s Equation to determine the HRT.

- Dry swales should have a soil bed that is a minimum of 18 inches deep and composed of approximately 50% sand and 50% loam.
- Pretreatment is required to protect the filtering and infiltration capacity of the swale bed. Pretreatment of piped flows is generally a sediment forebay behind a check dam with a pipe inlet. For lateral inflows (sheet flow), use a vegetated filter strip on a gentle slope or a "pea gravel diaphragm."
- Design dry swales to completely empty between storms. Where soils do not permit full dewatering between storms, place a longitudinal perforated underpipe on the bottom of the swale bed. The inter-event period used in design to dewater the swale must be no more than 72 hours.
- Dry swales must have parabolic or trapezoidal cross-sections, with side slopes no greater than 3:1 (horizontal: vertical) and bottom widths ranging from 2 to 8 feet.
- Size dry swales to convey the 10-year storm and design swale slopes and backs to prevent erosion during the 2-year event. At least one foot of freeboard must be provided above the volume expected for the 10-year storm.
- Make sure that the seasonal high water table is not within 2 to 4 feet of the dry swale bottom.
- Use outlet protection at any discharge point from a dry swale to prevent scour at the outlet.

Wet Swales

- Size wet swales to retain the required water quality volume.
- Pretreatment is required to protect the filtering and infiltration capacity of the wet swale bed. Pretreatment is generally a sediment forebay behind a check dam with a pipe inlet. For lateral inflows, use gentle slopes or a pea gravel diaphragm.
- Use check dams in wet swales to achieve multiple cells. Use V-notched weirs in the check dams to direct low flow volumes. The height of the check dam shall be no less than the elevation associated with the 1 inch Water Quality Volume.
- Plant emergent vegetation or place wetland soils on the wet swale bottom for seed stock.
- Wet swales are parabolic or trapezoidal in cross-section, with side slopes no greater than 3:1 (horizontal: vertical) and bottom widths ranging from 2 to 8 feet.
- Size wet swales to convey the 10-year 24-hour storm and design wet swale slopes to prevent erosion during the 2-year 24-hour event.
- Use outlet protection at any discharge point from wet swales to prevent scour at the outlet.

Construction

Use temporary erosion and sediment controls during construction. Select the vegetation mix to suit the characteristics of the site. Seeding will require mulching with appropriate materials, such as mulch matting, straw, and wood chips. Anchor the mulch immediately after seeding. Water new seedlings well until they are established. Refer to "Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas: A Guide for Planners, Designers, and Municipal Officials" for information on seeding and mulching.

Maintenance

Activity	Frequency
Inspect swales to make sure vegetation is adequate and slopes are not eroding. Check for rilling and gullying. Repair eroded areas and revegetate.	The first few months after construction and twice a year thereafter.
Mow dry swales. Wet swales may not need to be mowed depending on vegetation.	As needed.
Remove sediment and debris manually	At least once a year
Re-seed	As necessary.

Incorporate a maintenance and inspection schedule into the design to ensure the effectiveness of water quality swales. Inspect swales during the first few months after installation to make sure that the vegetation in the swales becomes adequately established. Thereafter, inspect swales twice a year.

During the inspections, check the swales for slope integrity, soil moisture, vegetative health, soil stability, soil compaction, soil erosion, ponding and sedimentation.

Regular maintenance includes mowing, fertilizing, liming, watering, pruning, and weed and pest control. Mow swales as needed for vegetation growth. Do not cut the grass shorter than three to four inches, otherwise the effectiveness of the vegetation in reducing flow velocity and removing pollutants may be reduced. Do not let grass height exceed 6 inches in Dry Swales.

Manually remove sediment and debris at least once per year, and periodically re -seed, if necessary, to maintain a dense growth of vegetation.

Take care to protect water quality swales from snow removal and disposal practices and off- street parking.

When grass water quality swales are located on private residential property, the operation and maintenance plan must clearly identify the property owner who is responsible for carrying out the required maintenance. If the operation and maintenance plan calls for maintenance of water quality swales on private properties to be accomplished by a public entity or an association (e.g., homeowners association), maintenance easements must be secured

References

Site Planning for Urban Stream Protection. 1995. Schueler. Center for Watershed Protection. Watershed Protection Techniques, Volume 2, Number 2, 1996. Center for Watershed Protection.

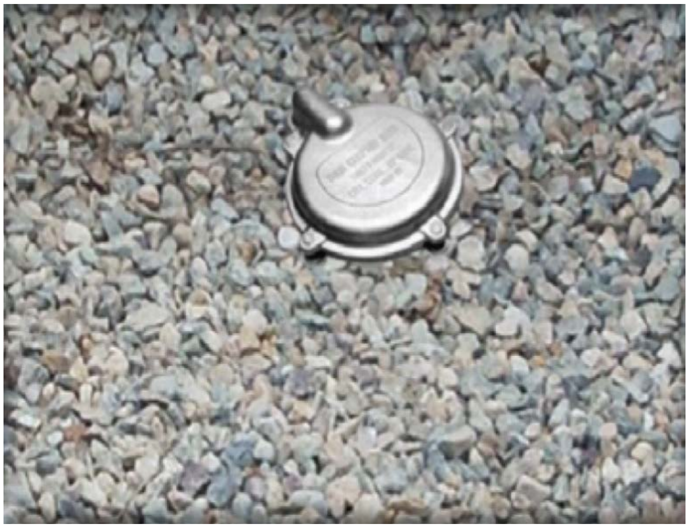
Biofiltration swale performance, recommendations, and design considerations.

1992. Metro Seattle: Water Pollution Control Department, Seattle, WA.

Structural Infiltration

- **Dry Wells**
- **Infiltration Basins**
- **Infiltration Trenches**
- **Leaching Catch Basins**
- **Porous Pavement**
- **Subsurface Structures**

Dry Wells



Ability to meet specific standards

Standard	Description
2 – Peak Flow	Does not provide peak attenuation.
3 – Recharge	Provides groundwater recharge.
4 – TSS/TP Removal	Use EPA Infiltration Trench Performance Curves to calculate required sizing to meet pollutant removal requirements. See “Introduction” Section of this Appendix for more information the EPA Performance Curves. Provides TSS and TP removal credit from non-metal roofs and runoff from metal roofs that are located outside of the Zone II or Interim Wellhead Protection Area of a Public Water Supply or outside an industrial site.
5 – Higher Pollutant Loading	May not be used for runoff from land uses with higher potential pollutant loads, May not be used for runoff from metal roofs located at industrial sites.
6 – Discharges near or to Critical Areas	Within a Zone II or IWPA may be used only for runoff from nonmetal roofs. Outside a Zone II or Interim Wellhead Protection Area, may be used for both metal and nonmetal roofs provided the roof is not located on an industrial site.
7 – Redevelopment	For rooftop runoff from non-metal roofs and from metal roofs located outside a Zone II or IWPA and outside industrial sites.
11 – Total Maximum Daily Loads	See suitability to treat TMDL Pollutants table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

Dry wells are small excavated pits, backfilled with aggregate, and used to infiltrate uncontaminated runoff from non-metal roofs or metal roofs located outside the Zone II or Interim Wellhead Protection Area of a Public Water Supply and outside an industrial site.

Advantages/Benefits

- Applicable for runoff from non-metal roofs and metal roofs located outside of the Zone IIs or IWPA of a Public Water Supply, and outside industrial sites
- Can reduce the size and cost of downstream SCMs and/or storm drains.
- Feasible for new development and retrofit areas
- Provides groundwater recharge

Disadvantages/Limitations

- Clogging likely when used for runoff other than that from residential rooftops.
- May experience high failure rate due to clogging.
- Only applicable in small drainage areas of one acre or less.
- When located near buildings, potential issues with water seeping into cellars or inducing cracking or heaving in slabs.
- Overflow from roof leader must be directed away from sidewalks or driveways.

Suitability to Treat TMDL Pollutants

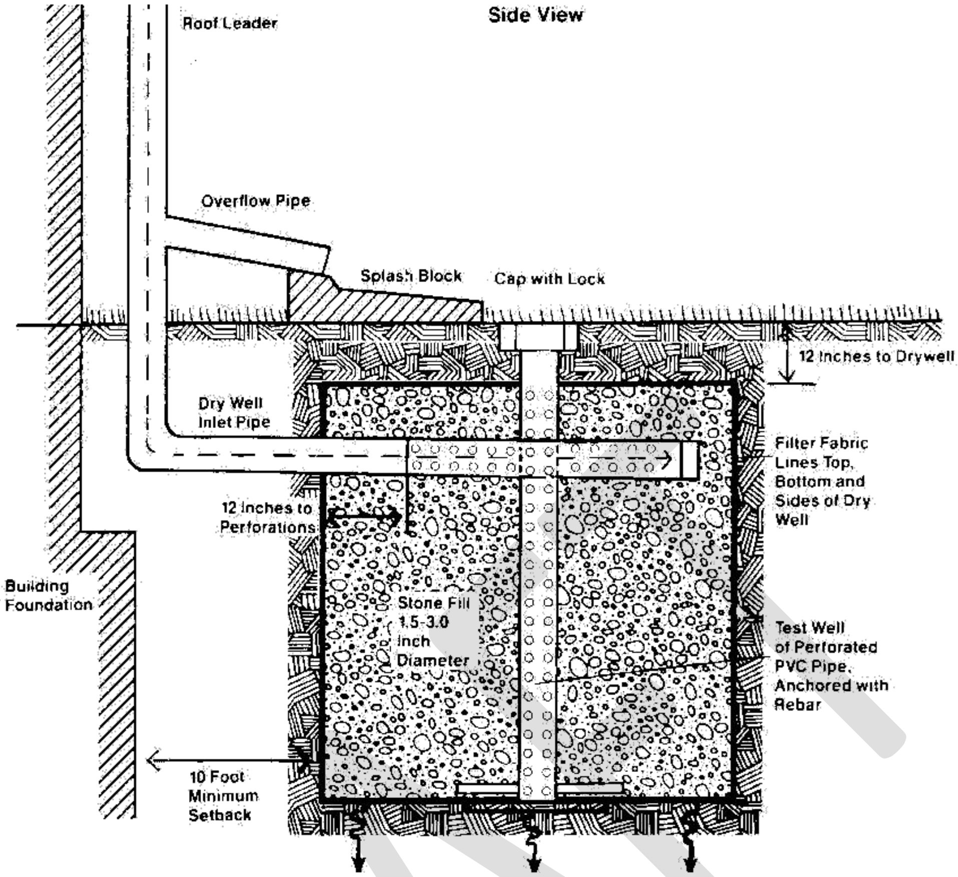
Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

Notes:

1 Pathogens category includes: fecal coliform, E. coli, and enterococcus.

2 Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.

Example Dry Well (adapted from the University of New Hampshire)



Special Features

Small footprint practice, highly compatible with residential land uses in suburban and rural areas.

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Applicability

Stormwater dry wells must only be used for rooftop runoff. Dry wells must not be used for runoff generated from impervious or pervious surfaces located at ground level. The use of dry wells is limited by a number of site constraints, including soil type, contributing drainage area, depth to bedrock, and depth to groundwater.

Dry wells are intended to only infiltrate roof runoff that is unlikely to contribute significant loadings of sediment or pollutants. Do not infiltrate runoff from buildings that are classified as Land Uses with Higher Potential Pollutant Loads (LUHPPL) or contaminated rooftop runoff (metal roofs located in a Zone II of a public drinking water supply). Under no circumstances shall dry wells be used to infiltrate any runoff that potentially contains sediment and pollutants, such as that from parking lots. These requirements are necessary to minimize the potential for dry wells to clog. When pore spaces surrounding dry wells clog, infiltration occurs at a much slower rate. This potentially leads to surcharge and failure of the dry well. Use dry wells where space is limited. They are ideally used in residential subdivisions consisting of detached dwellings.

Effectiveness

Dry wells are effective in two ways. First, dry wells when sited and designed properly, infiltrate runoff assisting sites with meeting Stormwater Standard No. 3 requiring recharge. Second, dry wells are credited with TSS and TP removal rate utilizing crosswalk for Infiltration trenches with meeting Stormwater Standard No. 4, provided the dry wells are designed to meet the criteria specified herein.

Planning Considerations

Parent soils must have a minimum saturated hydraulic conductivity rate of 0.01 inches/hour. Where the parent soils have a saturated hydraulic conductivity rate of 2.4 in/hour or higher (soil with a rapid infiltration rate), pretreatment is required prior to infiltration.

Dry wells must only be used to infiltrate runoff from non-metal rooftops, from metal rooftops of non-industrial buildings, or metal rooftops located outside of Zone IIs of a public drinking water supply. Runoff that is expected to contain sediment or other pollutants must be directed away from the dry well, and towards another type of SCM.

Stormwater dry wells must be sited at least ten (10) feet away building foundations. They should be located down-gradient of foundations. They should not be located up-gradient of foundations to minimize groundwater seepage into basements or cellars. This up-gradient recommendation does not apply at locations where sites are graded flat. However, keep in mind though that the piezometric surface of the groundwater slope may be different than the topographic land surface slope.

Underground Injection Control (UIC): Dry wells are typically deeper than they are wider and require UIC registration through MassDEP. The UIC programs allows for a region wide registration for multiple dry wells located at a single location, such as a residential subdivision. F*or information on the UIC program and its application to infiltration BMPs, s*ee https://www.mass.gov/underground-injection-control-uic

State Plumbing Code: Roof leader connections to a dry well may require compliance with the State Plumbing Code. If compliance is required, the connection must be made by a licensed plumber. Check with the local plumbing or building official.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Dry wells are a variation of infiltration trench, designed to infiltrate only good quality runoff. Roof leaders discharge runoff to the dry well. Roof top gutter screens trap particles, leaves, and other debris, and must be cleaned regularly. Site and install dry wells at least ten (10) feet from building foundations. Do not install a dry well until the drainage area has been stabilized. The roof leader must be able to bypass flows when the dry well is saturated. The dry well must contain an observation well.

The volume and surface area of dry wells is a function of: the quantity of runoff being discharged to the dry well from the contributing roof area and the overlying soil, the void space, and the vertical saturated hydraulic conductivity. At a minimum, size the dry well to hold the full recharge volume for rooftop runoff from new developments, and to the maximum extent practicable for Redevelopments. Because the dry well is filled with stone, only the space between the stone is available for runoff storage. Fill dry wells with 1.5 - 3.0 inch diameter, clean washed stone. This size stone will yield a void space of approximately 30 - 40%. Assume no more than 40% for designed purposes. When saturated hydraulic conductivity is based on soil texture as provided in **Section 6.3** of the Stormwater Handbook, take at least one soil sample at the actual location of each proposed dry well to detect localized soil conditions. Do not assume any sidewall exfiltration for purposes of any analyses.

Determine the maximum depth of the dry well from the infiltration rate, the allowable storage time, and the void space. Design storage times to be a minimum of 48 hours and a maximum of 72 hours.

Install the bottom of the dry well at least two (2) feet above the seasonal high water table and below the frost line. Place excavated material away from the excavated sides to increase wall stability. Trim large roots so they are flush with the sides to prevent fabric puncturing or tearing during installation. Roughen sidewalls where sheared and sealed by heavy equipment. Install an observation well to monitor the runoff clearance from the system. This well should consist of a well-anchored, vertical perforated PVC pipe with a lockable above ground cap. Where bedrock is near the land surface, evaluate whether a dry well is suitable. Bedrock close to the ground surface reduces the amount of treatment provided by the soil and can lead to break-out or failure of the dry well; unless there are fissures or cracks in it, bedrock causes exfiltrated water to only move laterally, and not downward.

Note that these criteria applies to stormwater dry wells, and not to dry wells that may be used for other applications pursuant to other MassDEP regulations.

Site Criteria

Summary Criteria for Stormwater Dry Wells
1. The contributing drainage area to any individual dry well typically should not exceed one rooftop.
2. The minimum depth to the seasonal high groundwater table, bedrock, or impermeable layer must be at least 2 feet from the bottom of the dry well.
3. The minimum saturated hydraulic conductivity rate is 0.01 inches/hour. Dry wells must be sized in accordance with the procedures set forth in **Section 6.2**.
4. One soil test pit or boring per dry well is required to conduct the textural analysis to determine the design saturated hydraulic conductivity rate. This is to allow detection of any localized soil conditions.
5. Dry wells must not be sited where soils have 30% or greater clay content, or 40% or greater silt clay content.
6. Dry wells must not be placed over fill materials.

Construction

Take care during construction to minimize the risk of failure of the dry well. The Construction Period Control Plan required by Stormwater Standard No. 8 must include measures to prevent runoff from entering the dry well during construction. The Construction Period Control Plan must also include provisions to prevent construction operations atop dry well locations and prevent construction vehicles from driving across sites intended for stormwater exfiltration. Typically, the Construction Period Plan should specify construction fence or similar measure to prevent vehicles from driving over dry well locations. High fencing made from a brightly colored material (e.g., orange polypropylene) is more visible from bull dozers than smaller fence or hay bales. During construction, the measures specified in the Construction Period Control Plan must be implemented to prevent construction vehicles from driving across the area intended for exfiltration. Inspections conducted by the Construction Contractor or Conservation Commissions should examine fencing or other measures installed to meet this requirement, to ensure it is being maintained properly.

Maintenance

Activity	Frequency
Inspect dry wells.	After every significant storm of at least 0.25-inches or more in the first six months after construction to ensure proper stabilization and function. Thereafter, inspect annually.
Measure the water depth in the observation well at 24- and 48-hour intervals after a storm of at least 0.25-inches.	After every significant storm of at least 0.25 inch/day or more in the first six months after construction. Thereafter measure clearance rate at least once annually after a storm of at 0.25 inches in depth over a day.
Calculate clearance rates by dividing the drop in water level (inches) by the time elapsed (hr.).	

Because these structures are often installed at single-family dwellings, it is important that developers clearly outline the maintenance requirements to property purchasers.

Check and clean the screens in the roof leaders once a year. Check the bypass leader once a year to determine if it is clear.

Inspect dry wells after every significant storm (as defined in table above) in the first few months after construction to ensure proper stabilization and function. Thereafter, inspect the dry well at least once per year. Measure the water depth in the observation well at 0, 24, and 48-hour intervals after a storm. Calculate clearance rates by dividing the drop in water level (inches) by the time elapsed (hours). A comparison of clearance rate measurements taken over the years provides a useful tool for tracking any clogging problems within the dry well.

The Operation and Maintenance Plan required by Stormwater Standard No. 8 must provide for repair if the exfiltration rate decreases over time. Repair consists of digging up the stone, removing any asphalt or grit from the void space in the stone, and raking the stone to restore the void space. A simple way to check for clogging is to block the bypass pipe during a rain storm. Observe the roof leader to determine if surcharge or a tailwater condition occurs (e.g., water starts dripping from roof gutter overhead or water starts seeping out from joints in the roof leaders. After the rain stops, unblock the bypass pipe. If rain pours out of the bypass, the system has failed and needs repair.

Infiltration Basins

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Can be designed to provide peak flow attenuation (see **Section 6.2.2** of the Stormwater Handbook).
3 - Recharge	Provides groundwater recharge.
4 - TSS/ TP	Use EPA Infiltration Basin Performance Curves to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves. Provide one or more pretreatment SCMs.
5 - Higher Pollutant Loading	May be used if 44% of TSS is removed with a pretreatment SCM prior to infiltration. For some land uses with higher potential pollutant loads, use an oil/grit separator, sand filter or equivalent for pretreatment prior to discharge to the infiltration basin. Infiltration must be done in compliance with 314 CMR 5.00
6 - Discharges near or to Critical Areas	Suitable for discharges near or to Critical Areas, especially for discharges near Cold-Water Fisheries. Requires 44% removal of TSS prior to discharge to infiltration basin.
7 - Redevelopment	Typically not an option due to land area constraints
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

Infiltration basins are stormwater runoff impoundments that are constructed over permeable soils. Pretreatment is critical for effective performance of infiltration basins. Runoff from the design storm is stored until it exfiltrates through the soil of the basin floor.

Advantages/Benefits

- Provides groundwater recharge.
- Reduces local flooding.
- Preserves the natural water balance of the site.
- Can be used for larger sites than infiltration trenches or structures.

Disadvantages/Limitations

- High failure rates due to improper siting, inadequate pretreatment, poor design and lack of maintenance.
- Restricted to fairly small drainage areas.
- Not appropriate for treating significant loads of sediment and other pollutants.
- Requires frequent maintenance.

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

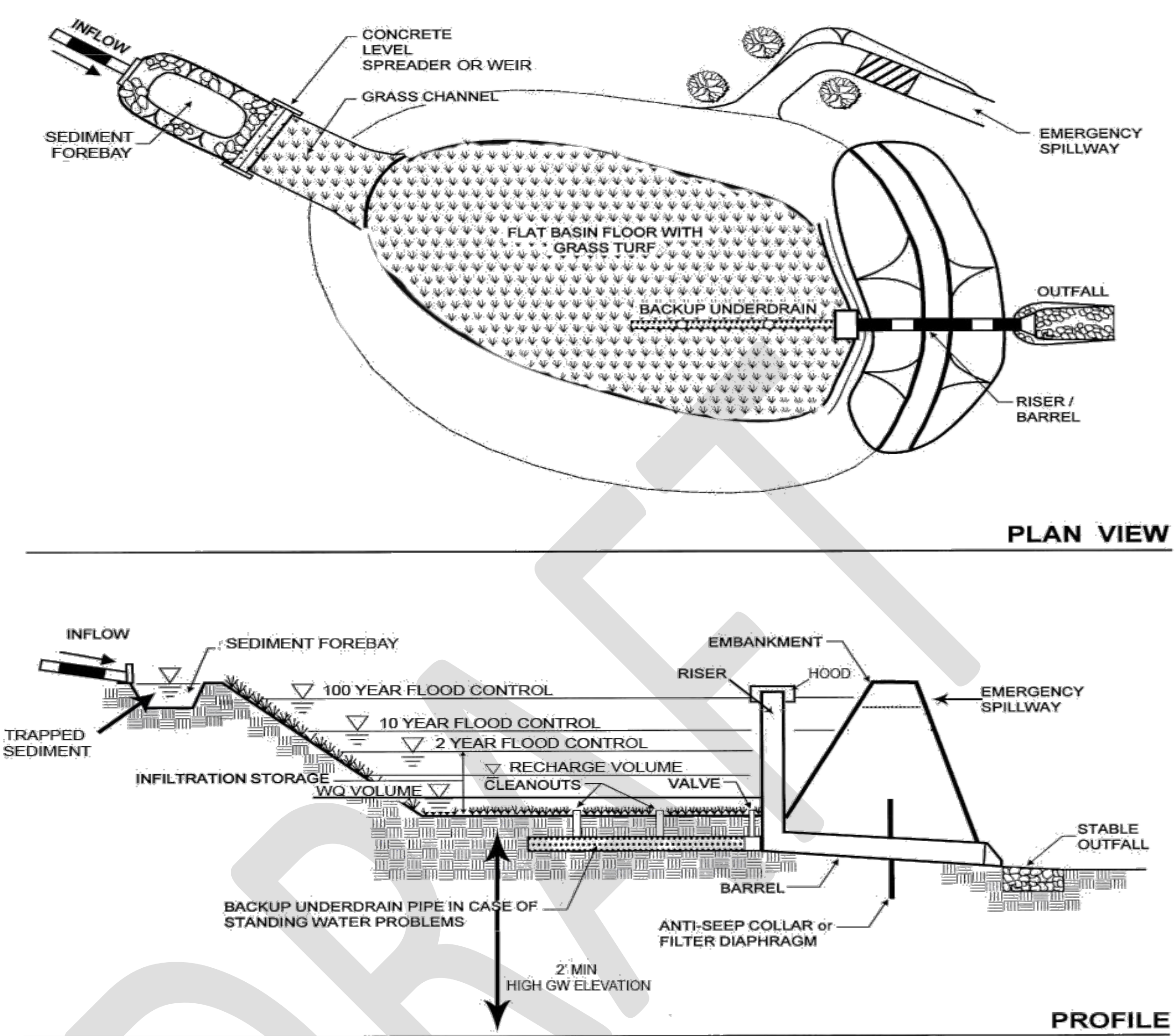
Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Special Features

Provides groundwater recharge

Example Infiltration Basin (adapted from the Vermont Stormwater Manual)



ESSD/LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Infiltration Basin Design Variations

Full Exfiltration Basin Systems

These basin systems are sized to provide storage and exfiltration of the required recharge volume and treatment of the required water quality volume. They also attenuate peak discharges. Designs typically include an emergency overflow channel to discharge runoff volumes in excess of the design storm.

Partial or Off-line Exfiltration Basin Systems

Partial basin systems exfiltrate a portion of the runoff (usually the first flush or the first inch), with the remaining runoff being directed to other SCMs. Flow splitters or weirs divert flows containing the first flush into the infiltration basin. This design is useful at sites where exfiltration cannot be achieved by downstream detention SCMs because of site condition limitations.

Applicability

The suitability of infiltration basins at a given site is restricted by several factors, including soils, slope, depth to water table, depth to bedrock, the presence of an impermeable layer, contributing watershed area, proximity to wells, Surface Waters, and foundations. Generally, infiltration basins are suitable at sites with gentle slopes, permeable soils, relatively deep bedrock and groundwater levels, and a contributing watershed area of approximately 2 to 15 acres. Table IB.1 presents the recommended site criteria for infiltration basins.

Pollution prevention and pretreatment are particularly important at sites where infiltration basins are located, to minimize the potential for clogging. Pollution prevention limits the particulates that are generated. Pretreatment removes the gross solids and coarser suspended solids. Removing solids and the coarser suspended solids by pollution prevention and pretreatment will minimize the potential for clogging and failure of the infiltration basin. The Pollution Prevention and Source Control Plan required by Stormwater Standard 4 must address measures to reduce particulate generation, such as not applying sand to roads and parking areas during winter months.

For land uses with higher potential pollutant loads, provide a bypass to divert contaminated stormwater from the infiltration basin in storms larger than the design storm.

Prior to pretreatment, implement the pollution prevention and source control program specified in the Pollution Prevention and Source Control Plan to reduce the concentration of pollutants in the discharge. Program components include careful management of snow and deicing chemicals, fertilizers, herbicides, and pest control. The Plan must prohibit snow disposal in the basin and include measures to prevent runoff of stockpiled snow from entering the basin. Stockpiled snow contains concentrations of sand and deicing chemicals. At industrial sites, keep raw materials and wastes from being exposed to precipitation. Select pretreatment SCMs that remove coarse sediments, oil and grease, and floatable organic and inorganic materials, and soluble pollutants.

Effectiveness

Infiltration basins are highly effective treatment systems that remove many contaminants, including TSS and TP. However, infiltration basins are not intended to remove coarse particulate pollutants. Use a pretreatment device to remove them before they enter the basin. The pollutant removal efficiency of the basin depends on how much runoff is exfiltrated by the basin.

Infiltration basins can be made to control peak discharges by incorporating additional elevation stages in the design. To do this, design the riser outlet structure or weir with multiple orifices, with the lowest orifice set to achieve storage of the full recharge volume required by Standard 3. Design the upper orifices using the same procedures as extended detention basins. The basins can also be designed to achieve exfiltration of storms greater than the required recharge volume. However, in such cases, make sure the soils are permeable enough to allow the basin to exfiltrate the entire volume in a 72-hour period. This may necessitate increasing the size of the floor area of the basin. Generally, it is not economically feasible to provide storage for large infrequent storms, such as the 100-year 24-hour storm.

Planning Considerations

Carefully evaluate sites before planning infiltration basins, including investigating soils, depth to bedrock, and depth to water table. Suitable parent soils should have a minimum infiltration rate of 0.01 inches per hour. Infiltration basis must be sized in accordance with the procedures set forth in **Section 6.2**.

The infiltration basin must be sited a minimum of 50-feet from any slope greater than 15% gradient.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Table IB.1 - Site Criteria for Infiltration Basins
1. The contributing drainage area to any individual infiltration basin should be restricted to 15 acres or less.
2. The minimum depth to the seasonal high ground water table, bedrock, and/or impermeable layer must be at least 2 ft. from the bottom of the basin.
3. The minimum infiltration rate is 0.01 inches per hour. Infiltration basins must be sized in accordance with the procedures set forth in **Section 6.2**.
4. At least one soil test pit or boring for every 5000 ft. of basin area is required, with a minimum of three test pits or borings for each infiltration basin. Soil analyses and in-situ saturated hydraulic conductivity must be performed at the actual location of the proposed infiltration basin so that any localized soil conditions are detected.
5. Infiltration basins must not be used at sites where soil have 30% or greater clay content, or 40% or greater silt clay content.
6. Infiltration basins must not be placed over fill materials.

Infiltration basins are highly effective treatment and disposal systems when designed properly. The first step before design is providing source control and implementing pollution prevention measures to minimize sediment and other contaminants in runoff discharged to the infiltration basin. Next, consider the appropriate pretreatment SCMs.

Design pretreatment SCMs to pretreat runoff before stormwater reaches the infiltration basin. For Critical Areas, land uses with potentially higher pollutant loads, and soils with rapid infiltration rates (greater than 2.4 inches/hour), pretreatment must remove at least 44% of the TSS. Applicants may comply with this requirement by proposing two pretreatment SCMs capable of removing 25% TSS. However, the issuing authorities (i.e., Conservation Commissions or MassDEP) may require additional pretreatment for other constituents beyond TSS for land uses with higher potential pollutant loads. If the land use has the potential to generate stormwater runoff with high concentrations of oil and grease, treatment by an oil/grit separator or equivalent is required before discharge to the infiltration basin.

For discharges from areas other than Critical Areas, land uses with potentially higher pollutant loads, and soils with rapid infiltration rates, MassDEP also requires some TSS and TP pretreatment. Common pretreatment for infiltration basins includes aggressive street sweeping, deep sump catch basins, oil/grit separators, vegetated filter strips, water quality swales, or sediment forebays. Fully stabilize all land surfaces contributing drainage to the infiltration practice after construction is complete to reduce the amount of sediment in runoff that flows to the pretreatment devices.

Always investigate site conditions. Infiltration basins must have a minimum separation from seasonal high groundwater of at least 2 feet. Groundwater mounding calculations are required when separation to seasonal high groundwater is less than 4 feet from the proposed bottom elevation of the basin and the infiltration basin is used to attenuate the 10-year 24-hour or higher storm (see Section **6.2.3** for more detail). Greater separation is necessary for bedrock. If there is bedrock on the site, conduct an analysis to determine the appropriate vertical separation. The greater the distance in elevation above the bottom of the basin media to the seasonal high groundwater elevation, the less likely the basin will fail to drain in the 72-hour period following precipitation.

Determine soil infiltration rates using samples collected at the proposed location of the basin. Take one soil boring or dig one test pit for every 5,000 feet of basin area, with a minimum of three borings for each infiltration basin. Conduct the borings or test pits in the layer where infiltration is proposed. For example, if the A and B horizons are to be removed and the infiltration will be through the C horizon, conduct the borings or test pits through the C horizon. MassDEP requires that borings be at least 60 inches below the lowest engineered depth of any SCM in accordance with **Section 6.3**.

For each bore hole or test pit, evaluate the saturated hydraulic conductivity of the soil, depth to seasonal high groundwater, NRCS soil textural class, NRCS Hydrologic Soil Group, and the presence of fill materials in accordance with **Section 6.3**. Never locate infiltration basins above existing manmade fill, except when a mounded infiltration basin is being created using newly placed well graded sand. Mounded infiltration systems must be carefully constructed to prevent compaction of the sand being placed as well as the underlying parent material. The minimum acceptable final soil infiltration rate is 0.01 inches per hour. Design the infiltration basin based on the soil evaluation set forth in **Section 6.3**.

If the proposed basin is determined to be in Hydrologic Soil Group “C” soils, incorporate measures in the design to reduce the potential for clogging, such as providing more pretreatment or greater media depth to provide additional storage. Never use the results of a Title 5 percolation test to estimate a saturated hydraulic conductivity rate, because it tends to greatly overestimate the rate that water will infiltrate into the subsurface.

Estimate seasonal high groundwater based on soil mottles or through direct observation when borings are conducted in April or May, when groundwater levels are likely to be highest. If it is difficult to determine the seasonal high groundwater elevation from the borings or test pits, then use the Frimpter method developed by the USGS (Massachusetts/ Rhode Island District Office) to estimate seasonal high groundwater. After estimating the seasonal high groundwater using the Frimpter method, re-examine the bore holes or test pits to determine if there are any field indicators that corroborate the Frimpter method estimate.

Stabilize inlet channels to prevent incoming flow velocities from reaching erosive levels, which can scour the basin floor. Riprap is an excellent inlet stabilizer. Design the riprap so it terminates in a broad apron, thereby distributing runoff more evenly over the basin surface to promote better infiltration.

At a minimum, size the basin to hold the required recharge volume. Determine the required recharge volume using either the static or dynamic methods set forth in **Section 6.2.3**. Remember that the required storage volume of an infiltration basin is the sum of the quantity of runoff entering the basin from the contributing area and the precipitation directly entering the basin. Include one foot of freeboard above the total of the required recharge volume and the direct precipitation volume to account for design uncertainty. When applying the dynamic method to size the basin, use only the bottom of the basin (i.e., do not include side wall exfiltration) for the effective infiltration area.

Design the infiltration basin to exfiltrate in less than 72 hours. See **Section 6.2.3** for description of the drawdown analysis. Consider only the basin floor as the effective infiltration area when determining whether the basin meets this requirement.

Design the basin floor to be as flat as possible to provide uniform ponding and exfiltration of the runoff. Design the basin floor to have as close to a 0% slope as possible. In no case shall the longitudinal slope exceed 1%. Enhanced deposition of sediment in low areas may clog the surface soils, resulting in reduced infiltration and wet areas. Design the side slopes of the basin to be no steeper than 3:1 (horizontal: vertical) to allow for proper vegetative stabilization, easier mowing, easier access, and better public safety.

For basins with a 1% longitudinal slope, it will be necessary to incorporate cells into the design, making sure that the depth of ponded water does not exceed 2 feet, because sloped basin floors cause water to move downhill, thereby decreasing the likelihood of infiltration. Make lateral slopes flat (i.e., 0% slope).

After the basin floor is shaped, place soil additives on the basin floor to amend the soil. The soil additives shall include compost, properly aged to kill any seed stock contained within the compost. Do not put biosolids in the compost. Mix native soils that were excavated from the A or B horizons, cover the compost, and then scarify the native materials and compost into the parent material using a chisel plow or rotary device to a depth of 12 inches. Immediately after constructing the basin, stabilize its bottom and side slopes with a dense turf of water-tolerant grass. Use low-maintenance, rapidly germinating grasses, such as fescues. The selected grasses must be capable of surviving in both wet and dry conditions. Do not use sod, which can prevent roots from directly contacting the underlying soil. During the first two months, inspect the newly established vegetation several times to determine if any remedial actions (e.g., reseeding, irrigating) are necessary.

Never plant trees or shrubs within the basin or on the impounding embankments as they increase the chance of basin failure due to root decay or subsurface disturbance. The root penetration and thatch formation of the turf helps to maintain and may even enhance the original infiltration capacity. Soluble nutrients are taken up by the turf for growth, improving the pollutant removal capacity. Dense turf will impede soil erosion and scouring of the basin floor.

As an alternative to turf, use a basin liner of 6 to 12 inches of fill material, such as coarse sand. Clean and replace this material as needed. Do not use loose stone, riprap, and other irregular materials requiring hand removal of debris and weeds (i.e., stone linings are not acceptable).

Design embankments and spillways to conform to the regulatory guidelines of the state's Office of Dam Safety (302 CMR 10.00). Design infiltration basins to be below surrounding grade to avoid issues related to potential embankment failure. All infiltration basins must have an emergency spillway capable of bypassing runoff from large storms without damage to the impounding structure. Design the emergency spillway to divert the storm associated with brimful conditions without impinging upon the structural integrity of the basin. The brimful condition could be the required recharge volume or a design storm (such as the 2-year, 10-year, or 100-year storm if the basin is designed to provide peak rate attenuation in addition to exfiltration). The storm associated with the brimful conditions should not include the one foot of freeboard required to account for design uncertainty.

Design the emergency spillway to shunt water toward a location where the water will not damage wetlands or buildings. A common error is to direct the spillway runoff toward an adjoining property or roadway not owned by an Applicant. If the emergency spillway is designed to drain the emergency overflow toward an adjoining property, obtain a drainage easement and submit

it to the Conservation Commission as part of the Wetlands NOI submission. Place vegetative buffers around the perimeter of the basin for erosion control and additional sediment and nutrient removal.

Monitoring wells: Install one monitoring well in the basin floor per every 5,000 square feet of basin floor. Monitoring well(s) must extend at least 5 feet below the lowest engineered depth of the SCM, or to the limiting layer.

Access: Include access in the basin design. There must be unimpeded vehicular access around the entire basin perimeter. The access area shall be at least 15 feet wide.

Inlet Structures: Place inlet structures at one longitudinal end of the basin, to maximize the flow path from the inlet to the overflow outlet. A common error is to design multiple inlet points around the entire basin perimeter.

Outlet structures: Infiltration basins must include an overflow outlet in addition to an emergency spillway. Whether using a single orifice or multiple orifices in the design, at a minimum, set the lowest orifice at or above the required recharge volume.

Drawdown device: Include a device to draw the basin down for maintenance purposes. If the basin includes multiple cells, include a drawdown device for each cell.

Fences: Do not place fences around basins located in Riverfront Areas, as required by 310 CMR 10.58(4) (d)1.d. to avoid impeding wildlife movement. In such cases, consider including a safety bench as part of the design.

Construction

- Prior to construction, rope or fence off the area selected for the infiltration basin. Never allow construction equipment to drive across the area intended to serve as the infiltration basin.
- Never use infiltration basins as temporary sediment traps for construction activities.
- Construction-phase sedimentation basins should never be located within or above the footprint of a proposed infiltration basin, as this may result in clogging of the underlying soils
- To limit smearing or compacting soils, never construct the basin in winter or when it is raining. Use light earth-moving equipment to excavate the infiltration basin because heavy equipment compacts the soils beneath the basin floor and side slopes and reduces infiltration capacity. Because some compaction of soils is inevitable during construction, add the required soil amendments and deeply till the basin floor with a rotary tiller or a disc harrow to a depth of 12 inches to restore infiltration rates after final grading.

Use proper erosion/sediment control during construction. Immediately following basin construction, stabilize the floor and side slopes of the basin with a dense turf of water-tolerant grass. Use low maintenance, rapidly germinating grasses, such as fescues. Do not sod the basin floor or side slopes. After the basin is completed, keep the basin roped or fenced off while construction proceeds on other parts of the site. Never direct construction period drainage to the infiltration basin. After construction is completed, do not direct runoff into the basin until the bottom and side slopes, and contributing drainage areas are fully stabilized.

Maintenance

Activity	Frequency
Preventative maintenance	Twice a year
Inspect to ensure proper functioning	After every major storm during first 3 months of operation and twice a year thereafter and when there are discharges through the high outlet orifice
Mow the buffer area, side slopes, and basin bottom if grassed floor; rake if stone bottom; remove trash and debris; remove grass clippings and accumulated organic matter	Twice a year
Inspect and remove sediment/pollutants from pretreatment devices	Every other month recommended. At a minimum, twice a year, and after every major storm event.

A **major storm event** for on-going post-construction monitoring is defined as equal to or greater than 1 inch in a 24-hour period.

Infiltration basins are prone to clogging and failure, so it is imperative to develop and implement aggressive maintenance plans and schedules. Installing the required pretreatment SCMs will significantly reduce maintenance requirements for the basin.

The Operation and Maintenance Plan required by Standard 9 must include inspections and preventive maintenance at least twice a year, and after every time drainage discharges through the high outlet orifice or over the emergency spillway. The Plan must require inspecting the pretreatment SCMs after every major storm event and regularly twice a year, at a minimum (ideally every other month).

Once the basin is in use, inspect it after any storm of 0.25-inches or more for the first 3 months to ensure it is stabilized and functioning properly and, if necessary, take corrective action. Note how long water remains standing in the basin after a storm; standing water within the basin 72 hours after a storm indicates that the infiltration capacity may have been overestimated. If the ponding is due to clogging, immediately address the reasons for the clogging (such as upland sediment erosion, excessive compaction of soils, or low spots).

Thereafter, inspect the infiltration basin at least twice per year. Important items to check during the inspection include:

- Signs of differential settlement,
- Cracking,
- Erosion,
- Leakage in the embankments
- Tree growth on the embankments
- Condition of riprap,
- Sediment accumulation and
- The health of the turf.

At least twice a year, mow the buffer area, side slopes, and basin bottom. Remove grass clippings and accumulated organic matter to prevent an impervious organic mat from forming. Remove trash and debris at the same time. Use deep tilling to break up clogged surfaces, and revegetate immediately.

Remove sediment from the basin as necessary, but wait until the floor of the basin is thoroughly dry. Use light equipment to remove the top layer so as to not compact the underlying soil. Deeply till the remaining soil, and revegetate as soon as possible.

References:

Center for Watershed Protection, http://www.stormwatercenter.net/Manual_Builder/Construction%20Specifications/Infiltration%20Trench%20Specifications.htm

Center for Watershed Protection, http://www.stormwatercenter.net/Manual_Builder/Performance%20Criteria/Infiltration.htm

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Nonintentional Stormwater Infiltration, EPA/600/R-94/051, Risk Reduction Engineering Laboratory, U.S. EPA, Cincinnati, OH

Schroeder, R.A., 1995, Potential for Chemical Transport Beneath a Storm-Runoff Recharge (Retention) Basin for an Industrial Catchment in Fresno, CA, USGS Water-Resource Investigations Report 93-4140.

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Infiltration Trenches

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Does not provide peak attenuation.
3 - Recharge	Provides groundwater recharge.
4 - TSS/TP Removal	Provide one or more pretreatment SCMs and use EPA Infiltration Trench Performance Curves to calculate required sizing to meet pollutant removal requirements. See “Introduction” Section of this Appendix for more information the EPA Performance Curves.
5 - Higher Pollutant Loading	May be used if 44% of TSS is removed with pretreatment SCMs prior to infiltration. For some land uses with higher potential pollutant loads an Oil/grit separator or equivalent must be used prior to discharge to the infiltration structure. Infiltration must be done in compliance with 314 CMR 5.00.
6 - Discharges near or to Critical Areas	Suitable for discharges near or to Critical Areas, requires removal of 44% TSS prior to discharge.
7 - Redevelopment	Suitable with pretreatment.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

Infiltration trenches are shallow excavations filled with stone. They can be designed to capture sheet flow or piped inflow. The stone provides underground storage for stormwater runoff. The stored runoff gradually exfiltrates through the bottom and/or sides of the trench into the subsoil and eventually into the water table.

Advantages/Benefits

- Provides groundwater recharge.
- Reduces downstream flooding and protects stream bank integrity for small storms.
- Preserves the natural water balance of the site.
- Provides a high degree of runoff pollution control when properly designed and maintained.
- Reduces the size and cost of downstream stormwater control facilities and/or storm drain systems by infiltrating stormwater in upland areas.
- Suitable where space is limited.

Disadvantages/Limitations

- High failure rates due to improper siting, inadequate pollution prevention and pretreatment, poor design, construction and maintenance.
- Use restricted to small drainage areas.
- Depending on runoff quality, potential risk of groundwater contamination.
- Requires frequent maintenance.
- Susceptible to clogging with sediment.

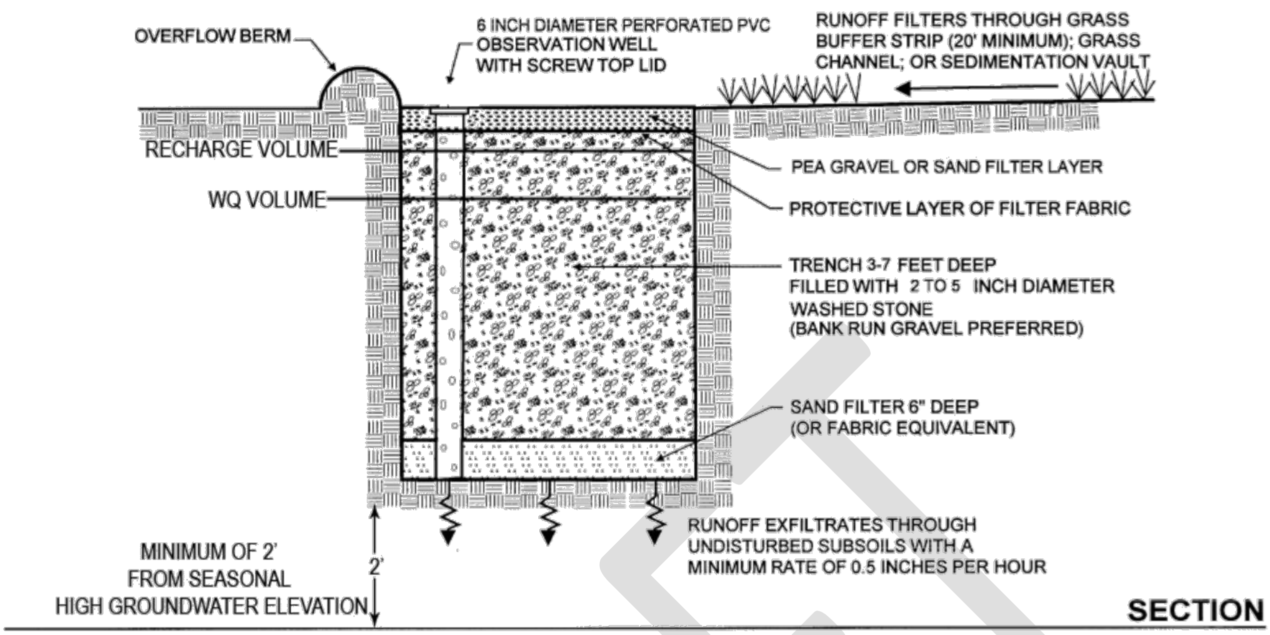
Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Example Infiltration Trench (adapted from the University of New Hampshire)



Special Features

Treats nonconcentrated sheet flow runoff

ESSD/LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Design Types

Infiltration trenches can be designed for complete exfiltration or partial exfiltration, where a portion of the runoff volume is directed to the trench and the remainder is conveyed to other SCMs.

Full Exfiltration Trench Systems

Infiltration trenches must be sized to provide storage and exfiltration of the required water quality volume. An emergency overflow channel is required to discharge runoff volumes in excess of the design storm. Economic and physical constraints can restrict the use of full exfiltration systems. Generally, it is not practical to provide storage for large infrequent storms, such as the 100-year storm.

Partial or Water Quality Exfiltration Trench Systems

These systems exfiltrate a portion of the runoff, while the remainder is conveyed to other SCMs. At a minimum, they must be sized to exfiltrate the recharge volume required by Stormwater Management Standard 3. There are two methods of partial infiltration. The first relies on off-line treatment where a portion of the runoff, or the 1-inch “first-flush,” is routed from the main channel to the trench by means of a weir or other diversion structure. The second method is on-line, and uses a perforated pipe at the top of the trench. This underdrain must be placed near the top of the trench. Refer to the design section below. After the trench fills to capacity, excess runoff is discharged through the perforated pipe and directed to other SCMs.

Applicability

Infiltration trenches always require a pretreatment SCM. For sheet flow, pretreatment SCM structures that may be used include vegetated filter strips and pea stone gravel diaphragms. For piped flow, a sediment forebay should be used.

Infiltration trenches are feasible at sites with gentle slopes, permeable soils, and where seasonal high groundwater levels are at least two feet below the bottom of the trench. MassDEP recommends providing greater depths from the bottom of the trench to seasonal high groundwater elevation to reduce the potential for failure. Depth to bedrock will need to be evaluated to determine if use of an infiltration trench is feasible.

Contributing drainage areas must be relatively small and not exceed 5 acres. Infiltration trenches are suitable for parking lots, rooftop areas, local roads, highways, and small residential developments.

Infiltration trenches are adaptable to many sites because of their thin profile. **Table IT.1** lists the recommended site criteria. Infiltration trenches can be used in upland areas of larger sites to reduce the overall amount of runoff and improve water quality while reducing the size and costs of downgradient SCMs.

Infiltration trenches are effective at mimicking the natural, pre-development hydrological regime at a site. Full exfiltration systems that have been carefully designed may be capable of controlling peak discharges from the 2-year and 10-year 24-hour storm.

Table IT.1 – Site Criteria for Infiltration Trenches
1. The contributing drainage area to any individual infiltration trench should be restricted to 5 acres or less.
2. The minimum depth to the seasonal high ground water table, bedrock, and/or impermeable layer must be at least 2 ft. from the bottom of the trench.
3. The minimum acceptable soil infiltration rate is 0.01 inches per hour. Infiltration trenches must be sized in accordance with the procedures set forth in **Section 6.3**.
4. A minimum of 2 soil borings or test pits must be taken for each infiltration trench. Trenches over 100 ft. in length must include at least one additional boring or test pit location for each 50 ft. increment. Borings and test pits must be located at the actual location of the proposed infiltration trench so that any localized soil conditions are detected.
5. Infiltration trenches must not be used at sites where soils have 30% or greater clay content, or 40% or greater silt clay content. Infiltration trenches will not function adequately in areas with hydrologic soils in group D and infiltration will be limited for hydrologic soils in group C.
6. Infiltration trenches must not be placed over fill materials.

Planning Considerations

MassDEP highly recommends using infiltration trenches near Critical Areas. They may be used to treat stormwater discharges from areas of higher potential pollutant loads, provided 44% of TSS is removed prior to infiltration. For some land uses with higher potential pollutant load, an oil/grit separator or equivalent device may be required prior to discharge to the infiltration trench. When an oil/grit separator is used, pipe the runoff to the infiltration trench. Discharges from land uses with higher potential pollutant loads require compliance with 314 CMR 5.00.

Before planning infiltration trenches, carefully evaluate the subsurface of the site including soils, depth to bedrock, and depth to the water table. Make sure soils have a minimum saturated hydraulic conductivity rate of 0.01 inches per hour.

Make the slopes of the contributing drainage area less than 5%. Infiltration trenches have extremely high failure rates, usually due to clogging, so pretreatment is essential. Infiltration trenches are not intended to remove coarse particulate pollutants, and generally are difficult to rehabilitate once clogged. Typical pretreatment SCMs for infiltration trenches include oil/grit separators, deep sump catch basins, vegetated filter strips, pea stone gravel diaphragms, or sediment forebays.

Clogging can be an issue even when infiltrating uncontaminated rooftop runoff as well, so it is important to implement some form of pretreatment to remove sediments, leaf litter, and debris to ensure the proper functioning of the trench and allow for longer periods between maintenance.

Consider the impacts of infiltrating stormwater on nearby resources. Infiltration trenches need to be set back outside Zone Is and Zone As for public drinking water supplies. Finally, avoid creating groundwater mounds near Chapter 21e sites that could alter subsurface flow patterns and spread groundwater pollution.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

See the following for complete design references:

Maryland Stormwater Design Manual, Volumes I and II. October 2000. Maryland Department of Environment. Baltimore, MD.

The volume and surface area of an infiltration trench relate to the quantity of runoff entering the trench from the contributing area, the void space, and the infiltration rate. Because the infiltration trench is filled with stone, only the space between the stone is available for runoff storage.

Effective designs call for infiltration trenches to be filled with 1.5-inch to 3.0-inch diameter clean washed stone. Conduct a geotechnical study to determine the final soil infiltration rate below the trench. For sizing purposes, assume a void ratio of 0.4.

Take a minimum of two borings or observation pits for each infiltration trench. For trenches over 100 feet long, include at least one additional boring or pit for each 50-foot increment. Take borings or dig observation pits at the actual location of the proposed infiltration trench to determine localized soil conditions.

Base the design of the infiltration trench on the soil evaluation set forth in **Section 6.3**. The minimum acceptable rate is 0.01 inches per hour. Never use the results of a Title 5 percolation test to estimate an infiltration rate, as these tend to greatly overestimate the rate that water will infiltrate into the subsurface.

Place the maximum depth of the trench at least two feet above the seasonal high water table or bedrock, and below the frost line.

Include vegetated buffers (20-foot minimum) around surface trenches. Use filter fabric, only at the surface to prevent clogging; if failure does occur, it can be alleviated without reconstructing the infiltration trench. Never place fabric at the bottom or sides of the infiltration trench, as fabric will blind, causing premature failure of the infiltration trench. Place twelve inches of sand at the bottom of the trench.

Install an observation well at the center of the trench to monitor how quickly runoff is clearing the system. Use a well-anchored, vertical perforated PVC pipe with a lockable above-ground cap.

The visible surface of the trench may either be stone or grassed. Stone is easier to rake out when clogged. If it is vegetated with grasses, use fabric above the stone to keep the soil that serves as the planting medium from clogging the stone. When trenches are designed to accept sheet flow, take into account the grass surface when determining how much of the runoff will exfiltrate into the trench.

A perforated pipe underdrain is sometimes used as part of the design. The purpose of the underdrain is to facilitate exfiltration into the parent soil. Except for underdrains placed between different trench cells, MassDEP does not allow underdrains placed near the bottom of the trench. Placement of an underdrain near the bottom of the trench reduces the amount of treatment and exfiltration, because more water is conveyed through the underdrain to the outlet point when it rains than exfiltrates into the surrounding soils.

Include an overflow berm on the downgradient side of the infiltration trench no more than 4 inches high to allow for shallow ponding and to discourage potential bypass of the infiltration trench.

Construction

Table IT.2 presents the minimum construction criteria for infiltration trenches. Take precautions before and during construction to minimize the risk of premature failure of the infiltration trench. First, prevent heavy equipment from operating at the locations where infiltration trenches are planned. Heavy equipment will compact soil and adversely affect the performance of the trench. Isolate the areas where the trenches will be located by roping them off and flagging them.

Construct infiltration trenches only after the site has been stabilized. Never use trenches as temporary sediment traps during construction. Use diversion berms or staked and lined hay bales around the perimeter of the trenches during their construction. Excavate and build the trench manually or with light earth-moving equipment. Deposit all excavated material downgradient of the trench to prevent re-deposition during runoff events.

Place twelve inches of sand (clean, fine aggregate) on the bottom. Place one to three inches of clean, washed stone in the trench and lightly compact the stone with plate compactors, to within approximately one foot of the surface. Place fabric filter over the top, with at least a 12-inch overlap on both sides. While fabric may be placed over the top, never place fabric in the bottom or on the sides. An underground trench may be filled with topsoil and planted. A surface trench may be filled with additional aggregate stone.

Divert drainage away from the infiltration trench until the contributing drainage area is fully stabilized, including full establishment of any vegetation.

Table IT.2 – Construction Criteria for Infiltration Trenches
1. Infiltration trenches should never serve as temporary sediment traps for construction.
2. Before a development site is graded, the infiltration trench area should be roped off and flagged to prevent heavy equipment from compacting the underlying soils.
3. Infiltration trenches should not be constructed until the entire contributing drainage area has been stabilized. Diversion berms should be placed around the perimeter or the infiltration trench during all phases of construction. Sediment and erosion controls should be used to keep runoff and sediment away from the trench area.
4. During and after excavation, all excavated materials should be placed downstream, away from the infiltration trench, to prevent redeposition of these materials during runoff events. These materials should be properly handled and disposed of during and after construction.
5. Light earth-moving equipment should be used to excavate the infiltration trench. Use of heavy equipment causes compaction of the soils in the trench floor, resulting in reduced infiltration capacity.

Maintenance

Activity	Frequency
Inspect units and remove debris	Every 6 months and after every major storm
Remove sediment from pretreatment SCMs	Every 6 months and after every major storm

A **major storm event** for on-going post-construction monitoring is defined as equal to or greater than 1 inch in a 24-hour period.

Because infiltration trenches are prone to failure due to clogging, it is imperative that they be aggressively maintained on a regular schedule. Using pretreatment SCMs will significantly reduce the maintenance requirements for the trench itself. Removing accumulated sediment from a deep sump catch basin or a vegetated filter strip is considerably less difficult and less costly than rehabilitating a trench. Eventually, the infiltration trench will have to be rehabilitated, but regular maintenance will prolong its operational life and delay the day when rehabilitation is needed. With appropriate design and aggressive maintenance, rehabilitation can be delayed for a decade or more. Perform preventive maintenance at least twice a year.

Inspect and clean pretreatment SCMs every six months and after every major storm. Check inlet and outlet pipes to determine if they are clogged. Remove accumulated sediment, trash, debris, leaves and grass clippings from mowing. Remove tree seedlings, before they become firmly established.

Inspect the infiltration trench after the first several rainfall events, after all major storms, and on regularly scheduled dates every six months. If the top of the trench is grassed, it must be mowed on a seasonal basis. Grass height must be mowed to a height of no more than four inches. Routinely remove grass clippings leaves and accumulated sediment from the surface of the trench.

Inspect the trench 24 hours or several days after a rain event, to look for ponded water. If there is ponded water at the surface of the trench, it is likely that the trench surface is clogged. To address surface clogging, remove and replace the topsoil or first layer of stone aggregate and the filter fabric. If water is ponded inside the trench, it may indicate that the bottom of the trench has failed. To rehabilitate a failed trench, all accumulated sediment must be stripped from the bottom, the bottom of the trench must be scarified and tilled to induce infiltration, and all of the stone aggregate and filter fabric or media must be removed and replaced.

Observation wells should be assessed as part of infiltration trench inspections. If water depths in the well are getting higher, this indicates clogging and that the well should be needs to re-dug to restore infiltrative surfaces.

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U.S. EPA, 1999, Stormwater Technology Fact Sheet, Infiltration Trench, EPA 832-F-99-019, http://www.epa.gov/owm/mtb/infltrenc.pdf

Leaching Catch Basins

Ability to meet specific standards

Standard	Description
2 - Peak Flow	May provide some limited amount of peak rate attenuation if sufficient number of leaching catch basins are provided. Each leaching chamber must be modeled as a separate pond and the sump volume discarded to the unsaturated zone. See **Section 6.2.2** of the Stormwater Handbook.
3 - Recharge	Provides groundwater recharge.
4 - TSS/TP Removal	Use EPA Infiltration Trench Performance Curves to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves. Use deep sump catch basin for pretreatment.
5 - Higher Pollutant Loading	For land uses that have the potential to generate runoff with high concentrations of oil and grease, an oil/grit separator or equivalent may be required for pretreatment prior to discharge to the leaching catch basin. Infiltration must be done in compliance with 314 CMR 5.00.
6 - Discharges near or to Critical Areas	Not suitable except as terminal treatment for discharges to or near cold water fisheries. Must include a practice to provide for shut down and containment.
7 - Redevelopment	May be a good retrofit for sites with existing catch basins.
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

A leaching catch basin is pre-cast concrete barrel and riser with an open bottom that permits runoff to infiltrate into the ground. There are two configurations:

1 Stand-alone barrel/riser and

2 Barrel/riser combined with a deep sump catch basins that provides pretreatment.

TSS pretreatment removal is awarded to a deep sump catch basin/leaching catch basin pretreatment combination provided the system is off-line.

Advantages/Benefits

- Provide groundwater recharge.
- Remove coarse sediment

Disadvantages/Limitations

- Need frequent maintenance. Can become a source of pollutants via resuspension if not properly maintained.
- Cannot effectively remove soluble pollutants or fine particles.
- Do not provide adequate treatment of runoff unless combined with deep sump catch basin
- Entrapment hazard for amphibians and other small animals

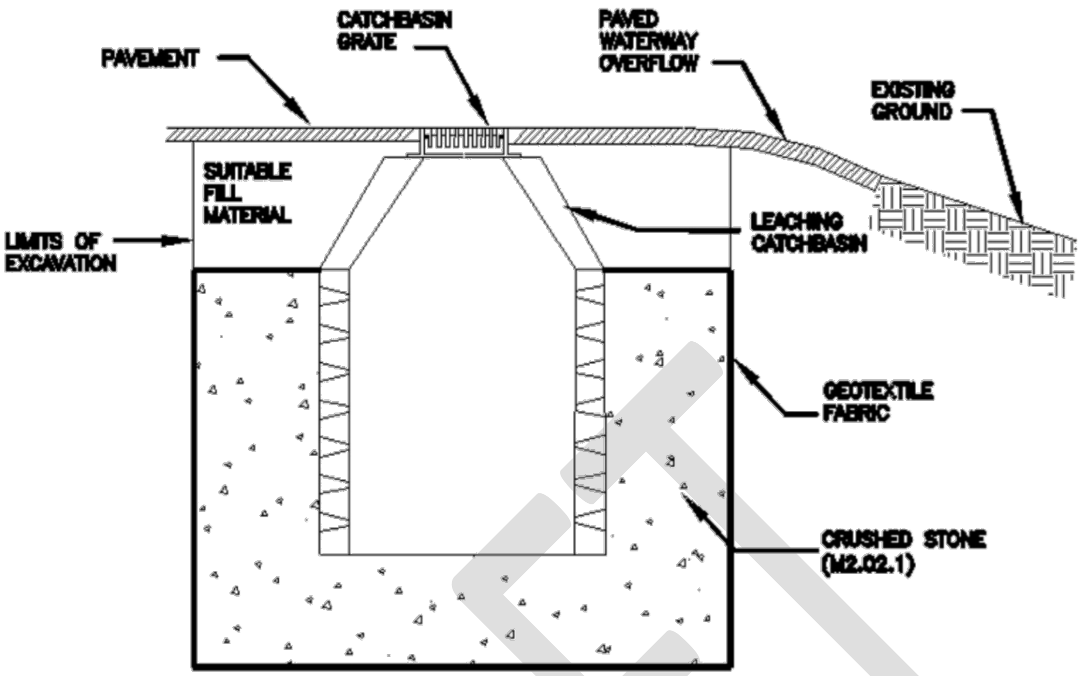
Suitability to Treat TMDL Pollutants

Pollutant	**Suitable to Treat?**
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Example Leaching Catch Basin (adapted from MassDOT)
(Note: example image does not show pretreatment. Deep sump catch basin is required for pretreatment.)



Special Features:

Use as off-line device

ESSD / LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Planning Considerations

Leaching catch basins must be installed as off-line devices only. They shall only be utilized in areas with highly permeable soils. Provide for the safe overflow onto streets, potentially tied into the MS4, from these devices in severe storm events. Because leaching catch basins discharge runoff to groundwater, do not use them in areas of higher potential pollutant loadings (such as gas stations) without adequate pretreatment, such as an oil/grit separator.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundatio ns, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Leaching catch basins are typically set in an excavation lined with a geotextile liner to prevent fine soil particles from migrating into the void spaces of the stone. The basin is placed on a pad of free-draining crushed stone, with the excavation around the basin back-filled with similar material. The base and barrel of the basin are perforated so that water entering the basin can enter the surrounding stone fill and infiltrate into the ground.

Use stone material with a void ratio of 0.35 or less. Make the depth to seasonal high groundwater at least 2 feet below the bottom of the leaching catch basin. When designing structural components, design for dead and live loads as appropriate. Include provisions for overflows such as redundant devices and paved chutes.

The basin inlet cover is an important component. For the first chamber, the Deep Sump Catch Basin, the orifice openings in the inlet grate must be no larger than 2.5-inch square to prevent coarse debris larger than 2.5 inches from entering the basin. The maximum flow through the inlet grate or into the leaching catch sump shall not exceed 3 cubic feet per second. Smaller openings in the inlet grate are preferred to minimize the potential for debris to clog the infiltrating surfaces. The inlet grate must fit tightly into the underlying steel frame to prevent it from being dislodged by traffic. Do not weld the inlet grate to the underlying frame. The second chamber, the leaching barrel, must have a tight fitting manhole cover, to prevent inflow from the street level or at grade level.

The riser section shall be mortared, grouted, gasketed, or otherwise sealed, to prevent exfiltration through the joint. Leaching catch basins shall contain no weep holes. Do not perforate the barrel section.

Make sure leaching catch basins contain no outlet pipes. The only pipe that is allowed in a leaching catch basin is an inlet pipe from an off-line deep sump catch basin paired with that leaching catch basin. Seal all pipe joints.

Site Criteria

- Maximum distance of flow in driveway, parking lot, or road to leaching catch basin: Not to exceed 350 feet.
- Building foundation minimum of 10 feet.
- All other general rules for criteria for infiltration specified in **Table 2-1** of the Stormwater Handbook apply.

Construction

Install construction barriers around the excavation area to prevent access by pedestrians. Use diversions and other erosion control practices up - slope of the leaching catch basin to prevent runoff from entering the site before catch basins are complete. Stabilize the surrounding area and any established outlet. Put controls in place to prevent any drainage from being discharged to the leaching catch basin until the contributing drainage area is fully stabilized. Remove all temporary structures after the contributing drainage area and vegetation is stabilized.

Maintenance

Activity	Frequency
Inspect units and remove debris	Inspect annually or more frequently as indicated by structure performance
Remove sediment	When the basin is 50% filled
Rehabilitate the basin if it fails due to clogging	As needed

Porous Pavement

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides peak flow attenuation for small storms through a reduced Runoff Curve Number.
3 - Recharge	Provides groundwater recharge. Storage bed must be designed and sized to drain within 72 hours
4 - TSS/TP Removal	Use EPA Porous Pavement Performance Curves to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves. Pretreatment consists of use of vacuum or regenerative air street cleaners and good housekeeping practices such as not applying traction agents (e.g., sand) to the pavement during the winter.
5 - Higher Pollutant Loading	Suitable for high intensity parking lots but not suitable for other types of LUHPPLs.
6 - Discharges near or to Critical Areas	Must not be located within Zone Is or Zone As of public water supplies.
7 - Redevelopment	Suitable.
8 - Construction Phase	Not to be used for construction period runoff control.
9 - O&M	An O&M is required for this SCM
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

Porous pavement is a paved surface with a higher-than-normal percentage of air voids to allow water to pass through it and infiltrate into the subsoil. This porous surface replaces traditional hot mix asphalt or dense concrete pavement, allowing parking lot, driveway, and roadway runoff to infiltrate directly into the soil and receive water quality treatment. All permeable paving systems consist of a durable, load-bearing, pervious surface overlying a stone bed that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, roadways, parking stalls, and overflow parking areas.

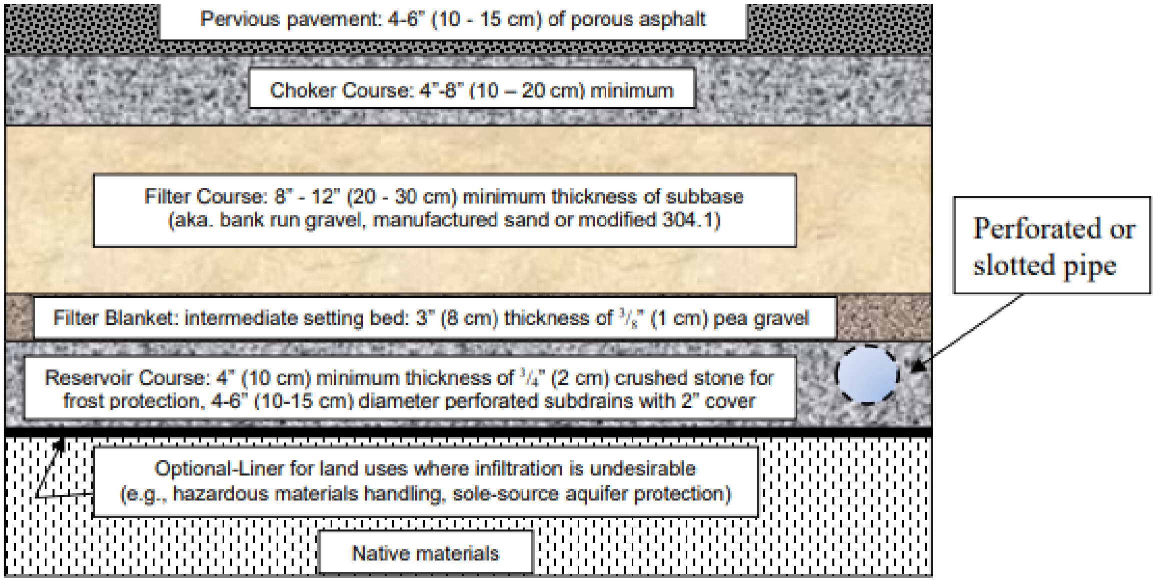
Advantages/Benefits:

- Reduce stormwater runoff volume from paved surfaces.
- Reduce peak discharge rates.
- Increase recharge through infiltration.
- Reduce pollutant transport through direct infiltration.
- Can last for decades in cold climates if properly designed, installed, and maintained
- Improved site landscaping benefits (grass pavers only).
- Can be used as a retrofit when parking lots are replaced.

Disadvantages/Limitations:

- Prone to clogging so aggressive maintenance with jet washing and vacuum street sweepers is required.
- No winter sanding is allowed.
- Winter road salt and deicer runoff concern near drinking water supplies for both porous pavements and impervious pavements.
- Soils need to have a permeability of at least 0.01 inches per hour
- Special care is needed to avoid compacting underlying parent soil

Figure PP.1 Example Cross-section of a Porous Pavement System
(from 2016 UNH Stormwater Center Design Specifications for Porous Asphalt)



Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Applicability

Porous pavement, also known as permeable paving, is appropriate for pedestrian-only areas, <u>low volume</u> roadways, roadway shoulders, parking areas, parking stalls, residential driveways, alleys, bike paths, shared use paths, walkways, and patios. It can be constructed where the underlying soils have a permeability of at least 0.01 inches per hour. Porous paving is an excellent technique for dense urban areas, because it does not require any additional land. Porous pavement can be successfully installed in cold climates as long as the design includes features to reduce frost heaving.

Porous pavements may be used on high intensity parking lots, but not in other types of land uses with higher potential pollutant loads because stormwater cannot be pretreated prior to infiltration. Heavy winter sanding will clog joints and void spaces. On some highways, MassDOT Highway Division uses an Open Graded Friction Course (OGFC) that has a permeable top coat but an impermeable base course. MassDEP provides no Water Quality or Recharge Credit for OGFC, because it does not provide treatment or recharge. The primary benefit of OGFC pavements is reductions in noise and hydroplaning.

Effectiveness

Porous pavement provides groundwater recharge and reduces stormwater runoff volume. Depending on design, paving material, soil type, and rainfall, porous paving can infiltrate as much as 70% to 80% of annual rainfall. To qualify for the Water Quality and Recharge Credits, the depth of the reservoir course must be sized to fully store the entire water quality volume or the required recharge volume, whichever is greater, in the void spaces between the stones. Calculate the Required Water Quality or Required Recharge Volume, whichever is larger, using the Static Method, and design the system to dewater within 72 hours. The required Water Quality Volume is determined using the EPA curve for porous pavements. Porous pavement may reduce peak discharge rates significantly by diverting stormwater into the ground and away from pipe- and-basin stormwater management systems, up to the volume housed in the storage layer. Grass pavers can improve site appearance by providing vegetation where there would otherwise be pavement. Porous paving can increase the effective developable area of a site, because the infiltration provided by permeable paving can significantly reduce the need for large stormwater management structures.

Planning Considerations

Porous paving must not receive stormwater from other drainage areas, especially any areas that are not fully stabilized.

Use porous paving only on gentle slopes (less than 5%). Do not use it in high -traffic areas or where it will be subject to heavy axle loads.

The setbacks listed below are required:

- Porous paving reduces the need for other stormwater conveyances and treatment structures, resulting in cost savings.
- Permeable paving also reduces the amount of land needed for stormwater management.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

There are three major types of permeable paving:

Porous asphalt and pervious concrete Although it appears to be the same as traditional asphalt or concrete pavement, it is mixed with a very low content of fine sand, so that it has from 10%-25% void space.

Paving stones (also known as unit pavers) are impermeable blocks made of brick, stone, or concrete, set on a prepared sand base. The joints between the blocks are filled with sand or stone dust to allow water to percolate to the subsurface. Some concrete paving stones have an open cell design to increase permeability.

Grass pavers (also known as turf blocks) are a type of open-cell unit paver in which the cells are filled with soil and planted with turf. The pavers, made of concrete or synthetic material, distribute the weight of traffic and prevent compression of the underlying soil.

Each of these products is constructed over a storage bed.

Storage Bed Design

The University of New Hampshire has developed specifications for storage beds used in connection with porous asphalt or pervious concrete. According to UNH, the storage bed should be constructed as indicated in **Figure PP.1** with the following components from top to bottom:

- a 4-to-8-inch choker course comprised of uniformly graded crushed stone
- a filter course, at least 8- 12 inches thick, of poorly graded sand (aka bank run gravel or modified 304.1) to provide enhanced filtration and delayed infiltration
- a filter blanket, at least 3 inches thick, of pea stone gravel to prevent material from entering the reservoir course, and
- a reservoir course of uniformly graded crushed stone with a high void content to maximize the storage of infiltrated water and to create
- a capillary barrier to winter freeze thaw. The bottom of the stone reservoir must be completely flat so that runoff can infiltrate through the entire surface. The reservoir course must be sized to fully store the water quality volume or required recharge volume (whichever is larger) within the void spaces between the stones.

If paving stones or grass pavers are used, a top course of sand that is one inch thick should be placed above the choker course.

Overflow Edge

Some designs incorporate an “overflow edge,” which is a trench surrounding the edge of the pavement. The trench connects to the stone reservoir below the surface of the pavement and acts as a backup in case the surface clogs.

Preparation of Porous Asphalt

Care must be taken in batching and placing porous asphalt. Unless batched and installed properly, porous pavement may have a reduced exfiltration ability. At Walden Pond State Reservation, several of the areas paved with porous asphalt did not meet the target exfiltration rate. Cores were taken and it was found that the batches had more sand and/or asphalt than was specified, and those sections had to be removed and repaved.

It is critical to minimize the amount of asphalt binder. Using greater amounts of asphalt binder could lead to a greater likelihood of "binder" or asphalt drawdown and clogging of voids. Sun light heating can liquefy the asphalt. The liquefied asphalt then drains into the voids, clogging them.

Such clogging is not remedied by power washing and vacuuming. The topcoat in such instances needs to be scarified and resurfaced. The University of New Hampshire has prepared detailed specifications for preparing and installing porous asphalt that are intended to prevent asphalt problems.

Additional Design Considerations

- Provide an open-graded subbase with minimum 40% void space.
- Use surface and stone beds to accommodate design traffic loads
- Generally, do not use porous pavement for slopes greater than 5 %.
- Do not place bottom on compacted fill.
- Provide perforated pipe network along bed bottoms for distribution
- Provide minimum of two feet of separation between the bed bottom and the seasonal high groundwater elevation, and also for bedrock.

Cold Weather Design Considerations

Porous pavement performs well in cold climates. Porous pavement can reduce meltwater runoff and avoid excessive water on the road during the snowmelt period.

In cold climates, the major concern is the potential for frost heaving. The storage bed specifications prepared by the University of New Hampshire address this concern.

Maintenance

In most porous pavement designs, the pavement itself acts as pretreatment to the stone reservoir below. Consequently, frequent cleaning and maintenance of the pavement surface is critical to prevent clogging. To keep the surface clean, frequent vacuum sweeping along with jet washing of asphalt and concrete pavement is required. No winter sanding shall be conducted on the porous surface.

As discussed, designs that include an "overflow edge" provide a backup in case the surface clogs. If the surface clogs, stormwater will flow over the surface and into the trench, where some infiltration and treatment will occur. For proper maintenance:

- Post signs identifying porous pavement areas.
- Minimize salt use during winter months. If drinking water sources are located nearby (see setbacks), porous pavements may not be allowed.
- No winter sanding is allowed.
- Keep landscaped areas well maintained to prevent soil from being transported onto the pavement.
- Clean the surface using vacuum sweeping machines as needed. For paving stones, periodically add joint material (sand) to replace material that has been transported.
- Regularly monitor the paving surface to make sure it drains properly after storms.
- Never reseal or repave with impermeable materials.
- Inspect the surface annually for deterioration or spalling.
- Periodically reseed grass pavers to fill in bare spots.
- Attach rollers to the bottoms of snowplows to prevent them from catching on the edges of grass
- Pavers and some paving stones.

Activity	Frequency
Monitor to ensure that the paving surface drains properly after storms	As needed
For porous asphalts and concretes, clean the surface using power washer to dislodge trapped particles and then vacuum sweep the area. For paving stones, add joint material (sand) to replace material that has been transported.	As needed
Inspect the surface annually for deterioration	Annually
Assess exfiltration capability at least once a year. When exfiltration capacity is found to decline, implement measures from the Operation and Maintenance Plan to restore original exfiltration capacity.	As needed, but at least once a year
Reseed grass pavers to fill in bare spots.	As needed

References

Adapted from MassDEP, Massachusetts Nonpoint Source Pollution Management Manual, 2006.

Ferguson, Bruce, K., Porous Pavements, 2005, CRC Press. Taylor and Francis Group, Boca Raton UNH, 2016, UNHSC Design Specifications for Porous Asphalt Pavement and Infiltration Beds, Revised September 2016, https://scholars.unh.edu/cgi/viewcontent.cgi?article=1012&context=stormwater. Asphalt Pavement for Stormwater Management, http://www.unh.edu/erg/cstev/pubs_specs_info/porous_ashpalt_fact_sheet.pdf

University of New Hampshire Center for Stormwater Technology Evaluation and Verification; this research group tests and evaluates stormwater SCMs on the UNH campus.

- An article about the use of permeable pavers at the Westfarms Mall in Connecticut.
- Case Studies from Uni-Group USA, a block paver manufacturer.
- The Nonpoint Education for Municipal Officials program at the University of Connecticut has been involved in numerous permeable paving pilot projects.
- Permeable paver specifications courtesy of the Low Impact Development Center.
- Porous pavement design and operational criteria from the US Environmental Protection Agency, which also publishes a Low Impact Development Page. Also see this report on a Field Evaluation of Permeable Pavements for Stormwater Management (PDF.)
- New Jersey Stormwater Best Management Practices Manual February 2004.

Subsurface Infiltrators

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Can be designed to provide peak flow attenuation (see requirements listed in this Specification)
3 - Recharge	Provides groundwater recharge
4 - TSS/TP Removal	Provide one or more pretreatment SCMs and use EPA Infiltration Trench Performance Curves to calculate required sizing to meet pollutant removal requirements. See "Introduction" Section of this Appendix for more information the EPA Performance Curves.
5 - Higher Pollutant Loading	May be used if 44% of TSS is removed with a pretreatment SCM prior to infiltration. Land uses with the potential to generate runoff with high concentrations of oil and grease require an oil/grit separator or equivalent prior to discharge to the infiltration structure. Infiltration must be done in accordance with 314 CMR 5.00.
6 - Discharges near or to Critical Areas	Suitable for discharges near or to Critical Areas.
7 - Redevelopment	Suitable with pretreatment
8 - Construction Phase	Not to be used for construction period runoff control.
9 - O&M	An O&M is required for this SCM
11 - Total Maximum Daily Loads	See suitability to treat TMDL Pollutants Table (below). Must be properly designed, sized, and maintained.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

Subsurface infiltrators are underground systems that capture runoff, and gradually infiltrate it into the groundwater through rock and gravel. There are a number of underground infiltration systems that can be installed to enhance groundwater recharge. The most common types include pre-cast concrete or plastic pits, chambers (manufactured pipes), perforated pipes, and galleys.

Advantages/Benefits

- Provides groundwater recharge
- Reduces downstream flooding
- Preserves the natural water balance of the site
- Can remove other pollutants besides TSS
- Can be installed on properties with limited space
- Useful in stormwater retrofit applications

Disadvantages/Limitations

- Limited data on field performance
- Susceptible to clogging by sediment
- Potential for mosquito breeding due to standing water if system fails

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	Y
Total Nitrogen	Y
Total Phosphorous	Y
Pathogens	Y
Metals	Y

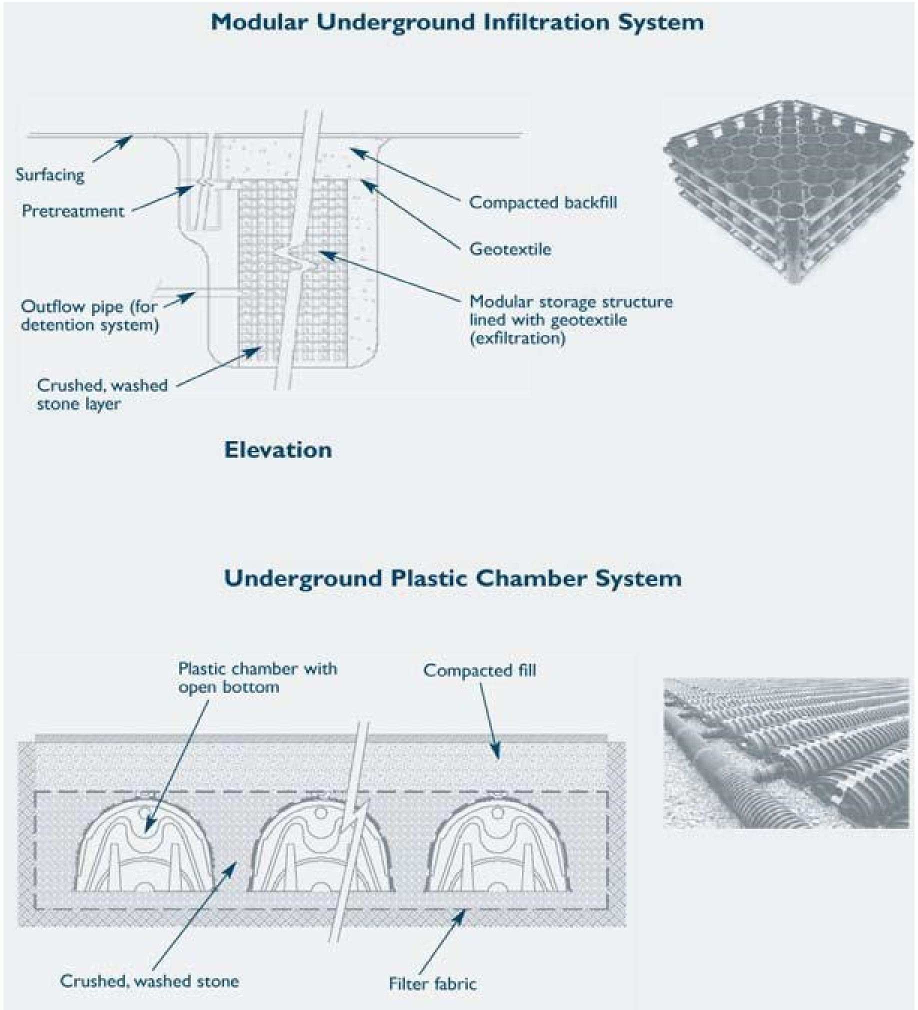
Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

ESSD / LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Example Subsurface Infiltrator (adapted from the Connecticut Stormwater Handbook)



Subsurface Infiltrator Types

There are different types of subsurface structures:

Infiltration Pit: A pre-cast concrete or plastic barrel with uniform perforations. The bottom of the pit should be closed with the lowest row of perforations at least 6 inches above the bottom, to serve as a sump. Infiltration pits typically include an observation well. The pits may be placed linearly, so that as the infiltrative surfaces in the first pit clog, the overflow moves to the second pit for exfiltration. Place an outlet near the top of the infiltration pit to accommodate emergency overflows. Filter fabric may be used on the top of the structure, but never on the bottom or along the sides. MassDEP provides recharge credit for storage below the emergency outflow invert. To make an infiltration pit, excavate the pit, wrap fabric around the barrel, place stone in the bottom of the pit, place the barrel in the pit, and then backfill stone around the barrel. Take a boring or dig an observation trench at the site of each proposed pit.

Chambers: These are typically manufactured pipes containing open bottoms and sometimes perforations. The chambers are placed atop a stone bed. Take the same number of borings or observation pits as for infiltration trenches. Do not confuse these systems with underground detention systems (UDS) that use similar chambers. UDS are designed to attenuate peak rates of runoff--not to recharge groundwater.

Perforated Pipes: In this system, pipes containing perforations are placed in a leaching bed, similar to a Title 5 soil absorption system (SAS). The pipes dose the leaching bed. Take the same number of borings or observation pits as for infiltration trenches. Perforated pipes by themselves do not constitute a stormwater recharge system and receive no credit pursuant to Stormwater Standard No. 3. Do not confuse recharge systems that use perforated pipes with perforated pipes installed to lower the water table or divert groundwater flows.

Galleys: Similar to infiltration pits. Some designs consist of concrete perforated rectangular vaults. Others are modular systems usually placed under parking lots. When the galley design consists of a single rectangular perforated vault, conduct one boring or observation trench per galley. When the galleys consist of interlocking modular units, take the same number of borings or observation pits as for infiltration trenches. Do not confuse these galleys with vaults storing water for purposes of underground detention, which do not contain perforations.

Without adequate pretreatment, subsurface structures are not suitable for stormwater runoff from land uses or activities with the potential for high sediment or pollutant loads. Structural pretreatment SCMs for these systems include, but are not limited to, deep sump catch basins, proprietary separators, and oil/grit separators. They are suitable alternatives to traditional infiltration trenches and basins for space-limited sites. These systems can be installed beneath parking lots and other developed areas provided the systems can be accessed for routine maintenance.

Subsurface systems are highly prone to clogging. Pretreatment is always required unless the runoff is strictly from residential rooftops.

Effectiveness

Performance of subsurface systems varies by manufacturer and system design. Although there are limited field performance data, pollutant removal efficiency is expected to be similar to those of infiltration trenches and basins.

Planning Considerations

Subsurface structures are excellent groundwater recharge alternatives where space is limited. Because infiltration systems discharge runoff to groundwater, they are inappropriate for use in areas with potentially higher pollutant loads (such as gas stations), unless adequate pretreatment is provided. In that event, oil/grit separators, sand filters or equivalent SCMs must be used to remove sediment, floatables and grease prior to discharge to the subsurface structure.

Applicability

Subsurface structures are constructed to store stormwater temporarily and let it percolate into the underlying soil. These structures are used for small drainage areas (typically less than 2 acres). They are feasible only where the soil is adequately permeable and seasonal high groundwater table and/or bedrock elevation is at least 2 feet below the bottom of the structures. They can be used to control the quantity as well as quality of stormwater runoff, if properly designed and constructed. The structures serve as storage chambers for captured stormwater, while the soil matrix provides treatment.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Unlike infiltration basins, widely accepted design standards and procedures for designing subsurface structures are not available. Generally, a subsurface structure is designed to store a ‘‘capture volume’’ of runoff for a specified period of ‘‘storage time.’’ The definition of capture volume differs depending on the purpose of the subsurface structure and the stormwater management program being used. Subsurface structures should infiltrate good quality runoff only. Pretreatment prior to infiltration is essential.

The composition, configuration and layout of subsurface structures varies considerably depending on the manufacturer. Follow the design criteria specified by vendors or system manufacturers. Install subsurface structures in areas that are easily accessible for routine and non-routine maintenance.

As with infiltration trenches and basins, install subsurface structures only in soils having suitable infiltration capacities as determined through field testing. Determine the infiltrative capacity of the underlying native soil through the soil evaluation set forth in **Section 6.3**. Never use a standard septic system percolation test to determine soil permeability because this test tends to greatly overestimate the infiltration capacity of soils.

Subsurface structures are typically designed to function off-line. Place a flow bypass structure upgradient of the infiltration structure to convey high flows around the structure during large storms.

Design the subsurface structure so that it drains within 72 hours after the storm event and completely dewaters between storms. Use a minimum draining time of 6 hours to ensure adequate pollutant removal.

Design all ports to be mosquito-proof, i.e., to inhibit or reduce the number of mosquitoes able to breed within the SCM.

The minimum acceptable field infiltration rate is 0.01 inches per hour. Subsurface structures must be sized in accordance with the procedures set forth in **Section 6.2**.

Manufactured structures must also be sized in accordance with the manufacturers' specifications. Design the subsurface structure for live and dead loads appropriate for their location. Provide measures to dissipate inlet flow velocities and prevent channeling of the stone media. Generally, design the system so that inflow velocities are less than 2 feet per second (fps).

All of these devices must have an appropriate number of observation wells, to monitor the water surface elevation within the well, and to serve as a sampling port.

Each of these different types of structures, with the exception of perforated pipes in leaching fields similar to Title 5 systems, must have entry ports to allow worker access for maintenance, in accordance with OSHA requirements.

Peak Rate Attenuation

Use the following guidelines to design Subsurface Infiltrators to reduce peak runoff rates:

- Subsurface chambers need to contain 5 stages for design purposes.
    - Stage 1: The lowest stage may only be used to store the volume associate with recharge or TSS/TP removal, whichever is larger, and must not be included in the volumetric storage for peak runoff rate.
    - Stages 2-5: The next stage is 2-year storm, next upper stage is 10-year storm, the next upper is 100-year storm, and top most stage is freeboard, to minimize air compression effects on water flow in the chambers.
- The system must attenuate peak discharge for the 2-, 10-, and 100-year storms in accordance with Standard 2. Only runoff in elevation above the max design storm but below the freeboard elevation stage may be routed to a surface discharge. As such, free draining must not be assumed when using TR20 or TR55 methods.
- At least 4-feet of separation to seasonal high groundwater must be provided. The bottom elevation of the stone jacket or stone bed must be assumed to be the bottom of the system, not the lowest elevation of the chamber.
- A mounding analysis is required if results from soil testing indicates that there is less than 4-feet of separation between the lowest engineered portion of the Subsurface Infiltrator and seasonal high groundwater (see **Section 6.3** of the Stormwater Handbook for soil evaluation procedures). Conduct a mounding analysis to demonstrate the groundwater mound does not break upwards into the stone or the chambers, above the ground surface, penetrate through a slope, upwards into a nearby building foundation, or upwards into the nearest wetland Resource Area(s). The mounding analysis must be conducted with MODFLOW. Hantush is not an acceptable method as it assumes a circular or rectangular shape and not a linear shape. See **Section 6.2.3** for more information on mounding analysis.
- The chambers are not allowed in BLSF, ILSF, on LSCSF (as the subsurface is saturated during floods). The chambers shall also not be double counted as compensatory flood storage.
- The overflow drainage must be designed to be by gravity flow, and not rely on pumps. The overflow drainage may not be designed to be surcharged upwards through manholes.
- The system must not be sized using the static method (including the volume to store the peak runoff rate) and not the simple or dynamic field methods.
- The chambers must be situated downgradient of building foundations. Normal setbacks from buildings of greater than 10 feet must be evaluated by the design engineer to determine if further setback is warranted to prevent envelope failure.

Construction

Stabilize the site prior to installing the subsurface structure. Do not allow runoff from any disturbed areas on the site to flow to the structure. Rope off the area where the subsurface structures are to be placed. Accomplish any required excavation with equipment placed just outside of this area. If the size of the area intended for exfiltration is too large to accommodate this approach, use trucks with low-pressure tires to minimize compaction. Do not allow any other vehicles within the area to be excavated. Keep the area above and immediately surrounding the subsurface structure roped off to all construction vehicles until the final top surface is installed (either paving or landscaping). This prevents additional compaction. When installing the final top surface, work from the edges to minimize compaction of the underlying soils.

Before installing the top surface, implement erosion and sediment controls to prevent sheet flow or windblown sediment from entering the leach field. This includes, but is not limited to, minimizing land disturbances at any one time, placing stockpiles away from the area intended for infiltration, stabilizing any stockpiles through use of vegetation or tarps, and placing sediment fences around the perimeter of the infiltration field.

Provide an access port, man-way, and observation well to enable inspection of water levels within the system. Make the observation well pipe visible at grade (i.e., not buried).

Maintenance

- Because subsurface structures are installed underground, they are extremely difficult to maintain. Manholes need to be placed in accessible locations to allow ease of inspections.
- When water levels are observed to be higher, this may indicate that clogging is occurring and failure could be imminent unless corrective action is taken quickly. Corrective action may including flushing the subsurface infiltrators with water and vactoring out water and trapped sediment.
- Inspect inlets at least twice a year. Remove any debris that might clog the system.
- Include mosquito controls in the Operation and Maintenance Plan.

Adapted from:

Connecticut Department of Environmental Conservation. Connecticut Stormwater Quality Manual. 2004

Other Structural

- Dry Detention Basins
- Green Roofs
- Rain Barrels / Cisterns

Dry Detention Basin

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides peak flow attenuation
3 - Recharge	Provides no groundwater recharge
4 - TSS/TP Removal	No EPA Performance Curve. **TSS:** MassDEP 0% TSS Removal **TP:** MassDEP 0% TP Removal
5 - Higher Pollutant Loading	May be used if bottom is lined and sealed
6 - Discharges near or to Critical Areas	Do not use for discharges near or to critical areas
7 - Redevelopment	Dry Detention Basins may be able to be retrofit to function as Extended Dry Detention Basin
8 - Construction Phase Pollution Controls	Not to be used for construction period runoff control. All inlets must be protected until all tributary areas are stabilized.
9 - O&M Plan	An O&M Plan is required. See maintenance section.
11 - Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice.
ESSD / LID?	No, this practice is not a MassDEP recognized ESSD / LID technique.

Description

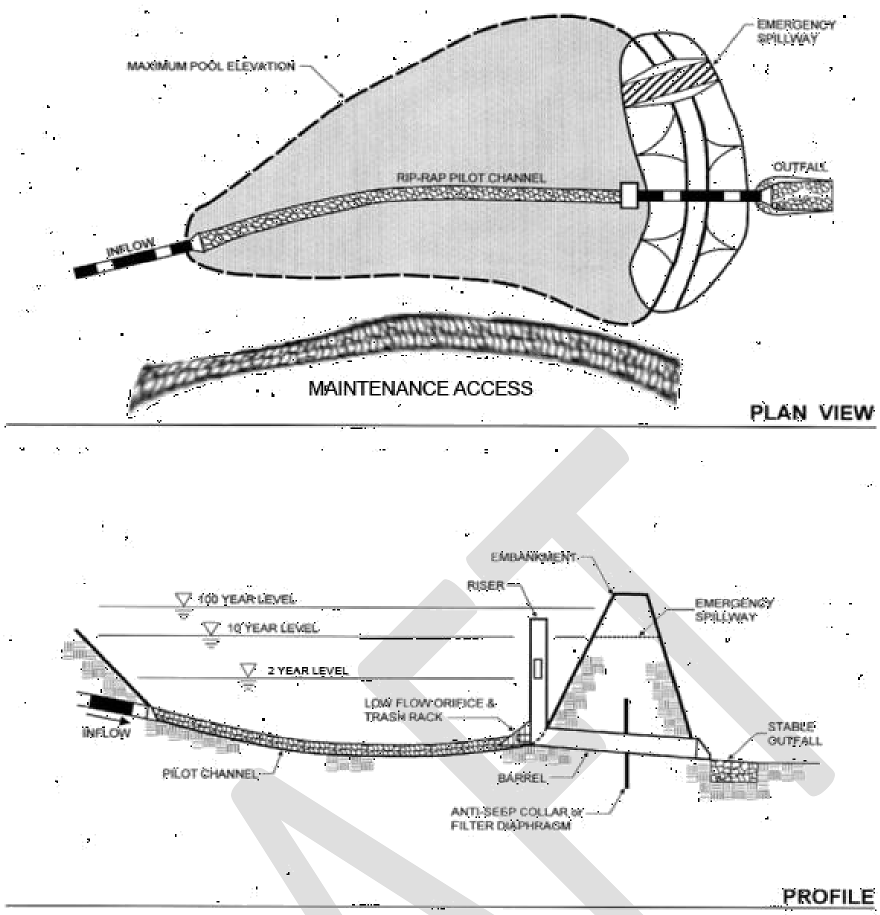
A dry detention basin is an impoundment or excavated basin for the short-term detention of stormwater runoff from a completed development that allows a controlled release from the structure at downstream, pre - development flow rates. Conventional dry detention basins typically control peak runoff for 2-year,10-year and larger 24-hour storms. They are not specifically designed to provide extended dewatering times, wet pools, or groundwater recharge. Sometimes flows can be controlled using an outlet pipe of the appropriate size but this approach typically cannot control multiple design storms. The sections describing Extended Dry Detention Basins and Wet Basins provide information about detention basin designs that provide stormwater pollutant treatment.

Advantages/Benefits

- Controls peak runoff flows for 2-year and 10-year storms
- Low cost SCM

Disadvantages/Limitations

- Provides negligible removal of TSS/TP compared to extended dry detention basins and wet basins.
- Provides negligible groundwater recharge.
- Frequently clogs at inlets and outlets, dramatically affecting retention times and pollutant removal efficiency.
- Susceptible to resuspension of settled materials by subsequent storms
- Requires large land area
- Cannot be used in watersheds with Cold-Water Fisheries



Adapted from the Vermont Stormwater

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	N
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	N

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron*

Special Features

Include a multiple stage outlet structure to control peak discharges for the 2-year, 10-year, and 24-hour storms.

ESSD / LID Alternatives

This practice is not a MassDEP recognized ESSD / LID technique. ESSD and LID techniques must be used unless demonstrated to be impracticable based on a written alternatives analysis. Other SCMs shall only be used to the meet those portions of Standard 3 (i.e., Required Recharge Volume) and Standard 4 (i.e., TSS / TP removal) that cannot be fully met by ESSD and LID techniques. See **Section 4.2** of the Stormwater Handbook for a list of MassDEP recognized ESSD / LID techniques. Most recognized ESSD / LID techniques also have an associated ESSD Credit (see **Table A-1**) of this Appendix.

Applicability

Because they have a limited capability for removing soluble pollutants, dry detention basins are used solely for water quantity control to attenuate peak flows and limit downstream flooding. Generally, dry detention basins are not practical if the contributing watershed area is less than ten acres. MassDEP recommends at least four acres of drainage area for each acre-foot of storage in the basin.

Dry detention basins may be used as part of a stormwater treatment train in combination with other treatment practices that are effective at removing TSS and providing recharge. The size of a dry detention basin can be substantially reduced if it is placed at the end of a treatment train to take advance of reduced runoff volume resulting from upstream practices that provide infiltration.

Effectiveness

Compared to extended dry detention basins or wet basins, dry detention basins have an extremely limited ability to remove TSS. A dry detention basin is designed to empty out completely in less than 24 hours, resulting in limited settling of sediments and the potential for resuspension of sediments in subsequent storms. Extended dry detention basins provide a minimum 24-hour detention time and incorporate in their design additional features aimed at enhancing pollutant removal, such as a sediment forebay, micropool, or shallow marsh.

Planning Considerations

Investigate soils, depth to bedrock, and depth to water table at a site before designing a dry detention basin. At sites where bedrock is close to the surface, high excavation costs may make dry detention basins infeasible. If soils on site are relatively impermeable (such as Soil Group D), a dry detention basin may experience problems with standing water. In this case, building a wet basin may be more appropriate.

The maximum depth of dry detention basins typically ranges from 3 to 12 feet. The depth of the basin may be limited by groundwater conditions or by soils. Locate dry detention basins above the normal groundwater elevation (i.e., the basin bottom should not intercept groundwater). Investigate the effects of seepage on the basin if the basin intercepts the groundwater table.

Like all stormwater SCMs, dry detention basins may not be constructed in wetland Resource Areas except for bordering land subject to flooding, isolated land subject to flooding, land subject to coastal storm flowage, and riverfront areas. Embankments or dams that store more than 15 acre-feet or that are more than 6 feet high are regulated by the state Office of Dam Safety.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

[Note: For complete design references, see: Design of Stormwater Pond Systems. 1996. Schueler. Center for Watershed Protection.]

The critical parameters in determining the size of the basin are the storage capacity and the maximum rate of runoff released from the basin. Design dry detention basins to store the volume required to meet the peak rate attenuation requirements of Standard for the 2-year and 10-year 24-hour storms. In some cases, compliance with Standard 2 may require flood storage volume to prevent an increase in off-site flooding from the 100-year 24-hour storm.

Design a multiple stage outlet structure to control peak discharges for the 2-year,10-year, and larger 24-hour storms. Provide an emergency spillway. Build the spillway in the existing ground--not in the embankment. Make the interior embankment slopes no greater than 3:1. To provide drainage, make the minimum slope of the bottom 2%. Provide access for maintenance. Design embankments to meet safety standards. Stabilize the earthen slopes and the bottom of the basins using seed mixes recommended by the NRCS.

Pervious or impervious channels may be used to direct runoff to or from the Dry Detention Basin. Drainage channels must be designed to empty completely after a storm. Channels can be undermined by runoff velocity and differential settling if they are not constructed and maintained properly. Locate the top of the impervious channel lining at or below the level of the adjacent grassed areas to ensure thorough drainage of these areas. When designing the channels, consider settlement of the lining and the adjacent areas, the potential for frost impacts on the lining and the potential for erosion or scour along the edges of the lining caused by bank-full velocities. Provide impervious linings with broken stone foundations and weep holes. Design the channel to maintain a low outflow discharge rate at the downstream end of the channel.

Use low-flow underdrains, connected to the principal outlet structure or other downstream discharge point, to promote thorough drying of the channel and the basin bottom.

Consider the depth of the low flow channel when preparing the final bottom-grading plan.

Design dry detention basin side slopes to be no steeper than 3:1. Flatter slopes help to prevent erosion of the banks during larger storms, make routine bank maintenance tasks (such as mowing) easier, and allow access to the basin.

Design the outlet to control the outflow rate without clogging. Locate the outlet structure in the embankment for maintenance, access, safety and aesthetics. Design the outlet to facilitate maintenance; the vital parts of the structures should be accessible during normal maintenance and emergency situations. Include a draw-down valve to allow the dry detention basin to completely drain within 24 hours. To prevent scour at the outlet, include a flow transition structure, such as a lined apron or plunge pad, to absorb the initial impact of the flow and reduce the velocity to a level that will not erode the receiving channel or area.

Design embankments and spillways in conformance with the state regulations for Dam Safety (302 CMR 10.00). All dry detention basins must have an emergency spillway capable of bypassing runoff from large storms without damaging the impounding structure. Provide an access for maintenance by public or private right- of-way, using a minimum width of 15 feet and a maximum slope of 5:1. This access should extend to the forebay, safety bench and outflow structure, and should never cross the emergency spillway, unless the spillway has been designed for that purpose. Use vegetative buffers around the perimeter of the basin for erosion control and additional sediment and nutrient removal.

Maintenance

Activity	Frequency
Inspect basins to ensure they are operating as designed	At least once a year.
Mow the upper-stage, side slopes, embankment and emergency spillway.	At least twice a year.
Check the sediment forebay, if applicable, for accumulated sediment, trash, and debris and remove it.	At least twice a year.
Remove sediment from the basin.	As necessary, and at least once every 10 years.

It is critical to provide access for maintenance, especially to the interior of the basin. Inspect dry detention basins at least once per year to ensure that they are operating as intended.

Inspect basins during and after storms to determine if the basin is meeting the expected detention times. Inspect the outlet structure for evidence of clogging or outflow release velocities that are greater than design flow. Potential problems that should be checked include: subsidence, erosion, cracking or tree growth on the embankment; damage to the emergency spillway; sediment accumulation around the outlet; inadequacy of the inlet/outlet channel erosion control measures; changes in the condition of the pilot channel; and erosion within the basin and banks. Make any necessary repairs immediately.

During inspections, note changes to the detention basin or the contributing watershed because these changes could affect basin performance. Mow the side slopes, embankment, and emergency spillway at least twice per year. Remove trash and debris at this time. Remove sediment from the basin as necessary, and at least once every 10 years or when the basin is 50% full. Provide for an on-site sediment disposal area to reduce the overall sediment removal costs.

References

T.R. Schueler. Center for Watershed Protection.
Design of Stormwater Pond Systems. 1996.

Green Roofs

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Provides peak flow attenuation for small storms through a reduced Runoff Curve Number.
3 - Recharge	If sized to retain the required 1-inch Water Quality Volume, consists of a reduction in Effective Impervious Cover (EIC) from the roof which may be deducted from the total area of impervious surface that must be managed as required by Standard 3 (Groundwater Recharge).
4 - TSS/TP Removal	If sized to retain the required 1-inch Water Quality Volume, consists of a reduction in Effective Impervious Cover (EIC) from the roof which may be deducted from the total area of impervious surface that must be managed as required by Standard 4 (Pollutant Removal).
5 - Higher Pollutant Loading	Not suitable.
6 - Discharges near or to Critical Areas	Suitable for discharges to or near to Cold-Water Fisheries.
7 - Redevelopment	Suitable.
11 - Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

Description

A "Green roof" is a permanent rooftop planting system containing live plants in a lightweight engineered soil medium designed to retain precipitation where the water is taken up by plants and transpired into the air. As a result, much less water runs off the roof compared to conventional rooftops. Green roofs have been in use in Europe for more than 30 years; they are easy to incorporate into new construction, and can be used on many existing buildings. There are two main types:

- Extensive: minimal maintenance with restricted variety of plants, resistant to frost, wind and drought: sedum, herbs and grasses, located on almost any flat or low slop roof deck that maximizes water retention;
- Intensive: regular maintenance required (irrigation, fertilizing, pruning, mowing); greater variety of plants (sod grass lawns, perennial, annual flowers, shrubs, small trees); deeper, heavier and richer soil.

Advantages/Benefits

- Reduces volume and peak rate of runoff from more frequent storms.
- Reduces heating and cooling costs for buildings
- Conserves space
- May extend life expectancies of the roof by shielding the roof from UV and temperature
- Provides sound insulation
- Ideal for Redevelopment or in the ultra-urban setting

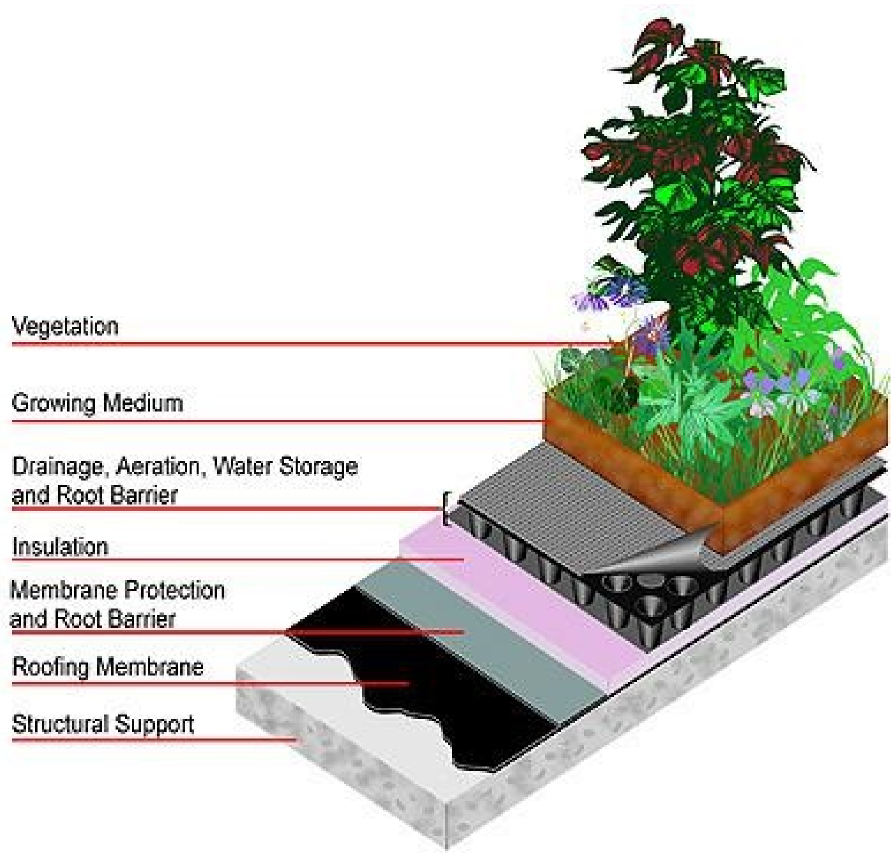
Disadvantages/Limitations

- Precipitation captured by green roofs (through interception, storage, plant uptake, evapotranspiration) is not recharged to groundwater.
- If green roofs require irrigation to maintain plants, they may reduce the volume of water available for other purposes.
- May require additional structural strengthening if used for retrofit.

ESSD / LID Alternatives

This practice is a MassDEP recognized ESSD / LID technique.

Example Green Roof (from www.greenroofs.com)



Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	N
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	N

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron.*

Applicability

Green roofs contribute to stormwater management by attenuating the peak rate of runoff for small storms. Green roofs are appropriate for commercial, industrial, and residential structures, especially those with wide roofs. They can be incorporated into new construction or added to existing buildings during renovation or re-roofing.

If adding a green roof as part of Redevelopment, assess the structural integrity of the roof to determine whether the support structure can withstand the additional loading of the green roof when it is fully saturated. Most green roofs are built on flat or low-angle rooftops, but some have been installed on pitched roofs up to 40% slope, with special design features to prevent slumping and ensure plant survival.

Green roofs are appropriate anywhere it is desirable to reduce the overall amount of stormwater runoff, including areas of chronic flooding or where combined sewer overflows (CSOs) are compromising water quality. Green roofs can incrementally reduce the amount of runoff that contributes to flooding and overflow problems. They are an excellent technique to use in dense urban areas, in areas where infiltration is difficult due to tight soils or shallow bedrock, or on sites where infiltration is undesirable due to existing soil contamination. Because green roofs return rainwater to the atmosphere, they should not be used in situations where groundwater recharge is a priority, such as in stressed basins with chronic low-flow conditions. The roof runoff should be infiltrated instead.

Effectiveness

Many studies indicate that properly designed green roofs are highly effective in intercepting and retaining at least 40% of annual precipitation (e.g., DiNardo, 2003). Green roofs reduce peak discharge rates by retaining runoff and creating longer flow paths. Research indicates that peak flow rates are reduced by 50% to 90% compared to conventional roofs, and that peak discharges are delayed by an hour or more. The main mechanism for peak rate reduction appears to be the depth of the soil media rather than the plants (Forrester, 2007).

Fewer studies have evaluated the water quality of the effluent discharged from green roofs. Berndtsson (2006) indicates that, except for nitrogen, vegetated roofs behave as a source of contaminants. He indicates that while effluent from a green roof contains lower concentrations than those normally found in urban runoff, some metals appear in concentrations that would correspond to moderately polluted natural waters. In addition, the runoff often contains phosphate-phosphorus. Moran (2003) investigated nutrient runoff from a green roof in North Carolina and found that phosphorus increased in the runoff. For this reason, the runoff from green roofs should not be discharged to nutrient-impaired Surface Waters. If using green roofs in such circumstances, treat the rooftop overflow discharge to remove nutrients prior to discharge to the Surface Water. Because total phosphorus binds up in most soils, it is preferable to direct the overflow to a stormwater exfiltration treatment system, rather than a Surface Water body.

Green roofs lower heating and cooling costs, because the trapped air in the underdrain layer and in the root layer help to insulate the roof of the building. During summer, sunlight drives evaporation and plant growth, instead of heating the roof surface. During winter, a green roof can reduce heat loss by 25% or more.

Because green roofs shield roof membranes from intense heat and direct sunlight, the entire roofing system has a longer lifespan than conventional roofs. The presence of a green roof helps to reduce air temperatures around the building, reducing the “heat island” effect and reducing the production of smog and ozone, which forms in the intense heat (175 degrees) created by large conventional roofs. The vegetation on green roofs also consumes carbon dioxide and increases the local levels of oxygen and humidity. Green roofs have demonstrated aesthetic benefits that can increase community acceptance of a high-visibility project; if marketed effectively, they may also increase property values.

Planning Considerations

Green roof slopes greater than 15% require a wooden lath grid or other retention system to hold substrate in place until plants form a thick vegetative mat. Do not use green roofs where groundwater recharge is a priority, such as in aquifer recharge areas or watersheds experiencing chronic low flows.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Conform to the Massachusetts State Building Code when designing green roofs. In particular, consider structural support requirements, waterproof membranes, and fire-resistant materials (some plants such as sedums are flammable). State Plumbing Code requirements must be met for overflow discharge directed to roof leaders.

Us a Runoff Curve Number (RCN) of 86 when performing calculations for peak rate attenuation.

A green roof must include the following elements:

- A synthetic, high quality waterproof membrane;
- A drainage layer;
- A soil layer;
- A geotextile membrane;
- Light-weight plants.

Membranes

To prevent leaks, install a waterproof membrane with a root barrier between the drainage layer and the roof sheeting. To prevent the growth medium from clogging the drainage layer, install a geotextile between the drainage layer and the soil layer as well as a root retardant.

Drainage Layer

The drainage layer shall be capable of conveying the storm associated with the water quality volume (one half inch or one inch volume) without ponding on top of the roof cover. It may be constructed of perforated plastic sheets or a thin layer of gravel. Direct runoff from the drainage layer to a roof leader to discharge precipitation that exceeds the storage capacity of the soil.

Soil Layer

Type of Soil: Use lightweight soils with good water retention capacity such as perlite, clay shale, pumice or crushed terracotta with no more than 5% organic content. Substrates should not be too rich in organic material such as compost, because of the potential for settling, nutrient export and too rapid plant growth.

Soil Depth: Select the thickness of the soil to store precipitation. Only the void spaces in the soil are credited with storage. Void spaces in the soil shall not exceed 0.4 inch for purposes of sizing. The green roof should be designed to retain the required water quality volume (1.0 inch3 times roof area).

Plants

Vegetation on green roofs usually consists of hardy, low-growing, drought-resistant, spreading perennials or self-sowing annuals that provide dense cover and are able to withstand heat, cold, and high winds. Appropriate varieties include sedum (stonecrop), delospermum (ice plant), sempervivium, creeping thyme, allium, phloxes, anntenaria, ameria, and abretia. During dry periods, these plants droop but do not die; when it rains, they quickly revive and absorb large amounts of water. Grasses and herbs are less common on green roofs, because they require irrigation or deep substrates that retain water to survive dry periods.

Vegetation may be planted as vegetation mats, plugs or potted plants, sprigs (cuttings), or seeds. Vegetation mats are the most expensive but achieve immediate full coverage. Potted plants are also expensive and labor-intensive to install. Sprigs are often the most cost-effective option, even considering that initial irrigation is necessary and repeat installations may be required due to mortality. Do not use conventional sod, because it requires irrigation, mowing, and maintenance.

Irrigation systems

To maintain plant materials during Massachusetts's summers, consider installing an irrigation system depending on the type of plants selected. For green roofs built with irrigation systems, make sure that the Operation and Maintenance Plan addresses irrigation needs to minimize the amount of water needed for irrigation. Depending on the water source, excessive irrigation during the summer can reduce base flows in nearby wetland Resource Areas.

Cold Climate Considerations

Green roofs may provide limited peak rate attenuation during winter months when plants are inactive and the soil medium is frozen. Due to changing weather that produces intermittent periods of snow and then rain, design green roofs with an overflow bypass.

Overflow Bypass Connection

Design overflow bypasses to roof leaders in accordance with State Plumbing Code requirements. Never direct the bypass to a wastewater treatment system. Direct the bypass to a drywell to infiltrate the excess rooftop runoff. Although green roofs significantly reduce peak rate of runoff for small storms, they typically do not attenuate the full peak for the 2-year and higher storms (e.g., 10-year and 100-year 24-hour storm). Additional peak rate attenuation measures are usually needed to achieve full compliance with Standard 2.

Construction

Waterproof membranes are made of various materials, such as modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC. The most common design used in Europe is 60-80 mil PVC single-ply roof systems. Modified asphalts usually require a root barrier, while EPDM and reinforced PVC generally do not. Attention to seams is critical, because some glues and cements are not always root impermeable. The underdrain layer may be constructed of perforated plastic sheets or a thin layer of gravel. Pitched roofs and small flat roofs may not require an underdrain.

A common concern about green roofs is the potential for leaks. The performance of green roofs has improved dramatically since the 1970s, when many leak problems were associated with the first generation of green roofs. Current waterproofing materials, root barriers, and rigorous design and construction standards have largely eliminated these problems. Low-cost electronic grids installed under the membrane during construction can help to pinpoint leaks and minimize repair costs.

Maintenance

Activity & Frequency
Green roofs require active maintenance, including irrigating, weeding, mulching, and pruning. For intensive green roofs, use fertilizers containing nitrogen, phosphorus, potassium and micronutrients to support the living plants. Regularly remove any woody plants that become established on the roof.

Both extensive and intensive green roofs require active maintenance. The vegetation in green roofs requires support during establishment and yearly maintenance thereafter. Plants or sprigs must be irrigated until established, and additional plants or sprigs added to ensure good plant coverage. With drought-resistant vegetation, irrigation of an extensive green roof is rarely necessary after the two-year establishment period. Weeding and mulching may be needed during the establishment period and periodically thereafter throughout the life of the roof.

Regularly remove any woody plants that become established on the roof. Many plants can survive on deposition of airborne nitrogen and biomass breakdown. If necessary, however, apply a slow-release fertilizer once a year to ensure continued vigorous growth of the vegetation. Do not use soluble nitrogen fertilizers and compost due to the potential for nutrient and bacteria export.

If fertilizers containing nitrogen, phosphorus, potassium and micronutrients are necessary to support the living plants, the long- term Operation and Maintenance/Pollution Prevention Plan must include an Integrated Fertilizer Management Plan (IFMP). The IFMP should address fertilizer requirements and ensure that no more than the appropriate amount of fertilizer is used. By reducing the potential for excess nitrogen and phosphorus in the green roof runoff, an Integrated Fertilizer Management Plan is an essential component of the pollution prevention plan.

References

- www.greenroofs.org (Green roof industry association; training and design courses)
- www.greenroofs.com (The Green Roof Industry Resource Portal)
- www.bae.ncsu.edu/greenroofs/ (North Carolina State University)
- www.roofmeadow.com (North American Green Roof Provider)

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Moran, Amy, Bill Hunt, and Dr. Greg Jennings, 2003, A North Carolina Field Study to Evaluate Greenroof Runoff Quality, Runoff Quantity, and Plant Growth, World Water Congress 2003, World Water Environmental Resources Congress and Related Symposia, World Water and Environmental Resources Congress 2003, Paul Bizier, Paul DeBarry – Editors, June 23-26, 2003, Philadelphia, Pennsylvania, USARowe DB, Monterusso MA, Rugh CL, Assessment of heat-expanded slate and fertility requirements in green roof substrates, Horttechnology 1 (3): 471-477 JUL-SEP 2006.

Nicholaus D. VanWoert, D. Bradley Rowe, Jeffrey A. Andersen, Clayton L. Rugh, R Thomas Fernandez, and Lan Xiao, Green Roof Stormwater Retention: Effects of Roof Surface, Slope, and Media Depth, Journal of Environmental Quality, 34:1036-1044, 2005.

Rain Barrels & Cisterns

Ability to meet specific standards

Standard	Description
2 - Peak Flow	Does not provides peak flow attenuation.
3 - Recharge	If sized to retain the required 1-inch Water Quality Volume, consists of a reduction in Effective Impervious Cover (EIC) from the roof which may be deducted from the total area of impervious surface that must be managed as required by Standard 3 (Groundwater Recharge).
4 - TSS/TP Removal	If sized to retain the required 1-inch Water Quality Volume, consists of a reduction in Effective Impervious Cover (EIC) from the roof which may be deducted from the total area of impervious surface that must be managed as required by Standard 4 (Pollutant Removal).
5 – Higher Pollutant Loading	Not suitable.
6 – Discharges near or to Critical Areas	Not suitable.
7 - Redevelopment	Suitable.
11 – Total Maximum Daily Loads	Does not meet any TMDL requirements as a stand-alone treatment practice.
ESSD / LID?	Yes, this practice is a MassDEP recognized ESSD / LID technique.

***Note:** Although MassDEP presumes rooftop runoff from non-metal, non-industrial roofs to be 'clean" for purposes of the Stormwater Management Standards, research indicates higher PAHs in runoff from asphalt shingled roofs and zinc from metal roofs. USGS research in Texas indicates rooftop runoff contains mercury. Before using rooftop runoff for vegetable gardens, investigate the quality of the runoff, especially when using larvicides in rain barrels or cisterns for mosquito control.*

Description

Cisterns and rain barrels are structures that store rooftop runoff and reuse it for landscaping and other non-potable uses. Instead of a nuisance to get rid of, consider rooftop runoff as a resource that can be reused or infiltrated. In contrast, conventional stormwater management strategies take rooftop runoff, which is often relatively free of pollutants, and direct it into the stormwater treatment system along with runoff from paved areas.

Advantages/Benefits

- Can reduce water demand for irrigation or other non-potable uses.
- Property owners save money on water bills by using stored water for landscape purposes.
- Public water systems may experience lower peak demand in summer.
- When properly installed, rain barrels and cisterns reduce stormwater runoff volume for small storms.

Disadvantages/Limitations

- Provides mosquito-breeding habitat unless properly sealed.
- May need to be disconnected and drained in winter to avoid cracking of storage structure

ESSD / LID Alternatives

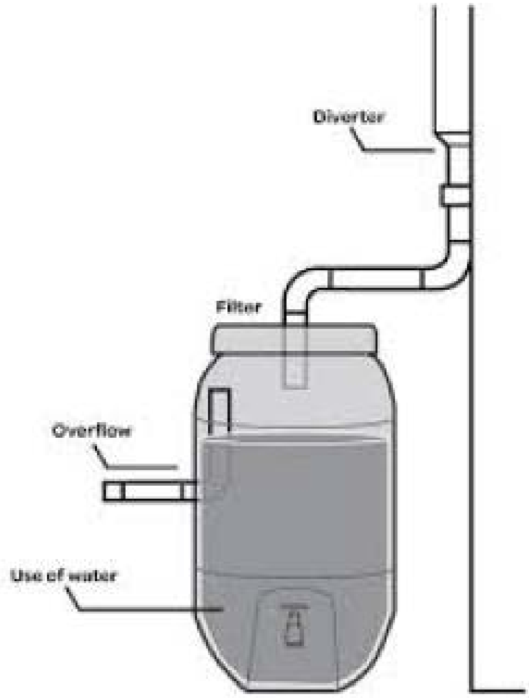
This practice is a MassDEP recognized ESSD / LID technique.

Suitability to Treat TMDL Pollutants

Pollutant	Suitable to Treat?
TSS	N
Total Nitrogen	N
Total Phosphorous	N
Pathogens	N
Metals	N

Notes:

1. *Pathogens category includes: fecal coliform, E. coli, and enterococcus.*
2. *Metals category includes Zinc, Cadmium, Lead, Aluminum, and Iron*



Cisterns and rain barrels can provide benefits by reducing the required water quality volume and peak discharge rates depending on the amount of storage available at the beginning of each storm. One rain barrel may provide a useful amount of water for garden irrigation, but it will have little effect on overall runoff volumes, especially if the entire tank is not drained between storms. Improve effectiveness by having more storage volume and by designing the system with a continuous discharge to an infiltration structure, so that there is always storage available for retention. To operate the system year-round, bury or insulate the unit. State Plumbing Code requirements apply to cisterns and rain barrels located within 10 feet of a building. All applicable requirements of the Massachusetts State Plumbing or State Building Codes must be met.

Cisterns and rain barrels are applicable to most commercial and residential properties where there is a gutter and downspout system to direct roof runoff to the storage tank. They take up little room and can be used in dense urban areas. Rain barrels and cisterns are excellent retrofit techniques for almost any circumstance. Rain barrels are covered plastic tanks that can hold from 50 to 100 gallons with a hole in the top for downspout discharge, an overflow outlet, and a valve and hose adapter at the bottom. They are used almost exclusively on residential properties. Plastic rain barrels are typically installed above ground. They must be disconnected prior to the winter, and the barrel drained completely to prevent the barrel from cracking.

Special Features

Direct overflow from rain barrels and cisterns to a dry well, infiltration trench, rain garden, bioretention area, or other infiltration SCM sized to recharge the overflow volume.

Applications and Design Principles

The most common approach to roof runoff storage involves directing each downspout to a 55- gallon rain barrel. A hose is attached to a faucet at the bottom of the barrel and water is distributed by gravity pressure. A more sophisticated and effective technique is to route multiple downspouts to a partially or fully buried cistern with an electric pump for distribution. Where site designs permit, cisterns may be quite large, and shared by multiple households, achieving economies of scale. Stored rainwater can be used for lawn irrigation, vegetable and flower gardens, houseplants, car washing, and cleaning windows.

The roof surface can be deducted from the impervious surfaces used to determine the Required Water Quality Volume for sizing other structural treatment practices, only when: 1) the cistern or barrel can store the required water quality volume for the roof surface; 2) the stored water is used or discharged to an infiltration SCM within 72-hours, and 3) the system is designed to operate 365 days a year.

Because rain barrels rely on gravity flow, place them near, and slightly higher than, the point of use (whether a garden, flower bed, or lawn). Route the overflow outlet to a dry well, bioretention area, rain garden or other infiltration SCM. It is important for property owners to use the water in rain barrels on a regular basis, otherwise the barrels can fill up and prevent additional roof runoff from being stored. Each house should have the appropriate number of rain barrels or an appropriately sized cistern. A one-inch storm produces over 620 gallons of water from a 1,000 square foot roof. Assuming a rain barrel capacity of 55 gallons, it would take 11 rain barrels to store one inch of runoff from 1,000 square feet of roof.

Cisterns are partially or fully buried tanks with a secure cover and a discharge pump; they provide considerably more storage than barrels, as well as pressurized distribution. They are less susceptible to cracking induced by expansion of freezing water when buried below grade. Cisterns can collect water from multiple downspouts or even multiple roofs, and then distribute this water wherever it needs to go via an electric pump. Property owners may use one large tank or multiple tanks in series. Either way, direct the overflow for the systems to a dry well or other infiltration mechanism so that if the cistern is full, excess roof runoff is infiltrated, and not discharged to the stormwater treatment system. Some cisterns are designed to continuously discharge water into infiltration units at very slow rates, so that the tank slowly empties after a storm, providing more storage for the next storm. The cisterns must also be designed to dewater in 72 hours or less.

Setback Requirements

Stormwater Control Measures (SCMs) and other components of the Stormwater Management System must be setback from wetlands, building foundations, and other features in accordance with 310 CMR 10.05(6)(q). SCMs must also include vertical separation between certain features, such as the depth to seasonally high groundwater. Refer to **Section 2.5** of the Stormwater Handbook for horizontal setback and vertical separation distance requirements. Horizontal setbacks also include maintenance access requirements around the perimeter of certain SCMs.

Design Considerations

Because of the low pressure of the discharge, rain barrels are most effectively used with a drip irrigation system. Secure rain barrels against disturbance by children or animals. Seal any openings with mosquito netting. If present, place the cistern's continuous discharge outlet so that the tank does not empty completely. This ensures water availability at all times, and provides some storage capacity for every storm. A diverter at the cistern inlet can redirect the "first flush" of runoff, which is more likely to have particulates, leaves, and air-deposited contaminants washed off the roof. Keep leaves and debris out of the storage tank by placing a screen at the top of the downspout. Hide rain barrels and cisterns with shrubs or other landscaped features. Direct overflow from rain barrels and cisterns to a dry well, infiltration trench, rain garden, bioretention area, or other infiltration SCM sized to recharge the overflow volume. Use pond routing methods to design cisterns or rain barrels to account for retention of early runoff in the storage tank. Include access ports for any subsurface cisterns. Confined space entry training may be needed to enter large cisterns. MassDEP does not require treatment of runoff from non-metal roofs prior to infiltration. winter, unless the runoff is directed to a qualifying stormwater infiltration practice.

Maintenance

Activity
Maintenance requirements for cisterns and rain barrels are minimal. These requirements include the following: Inspect the unit twice a year, use larvicide for mosquito control, disconnect and drain the system prior to winter to prevent cracking, and replace or repair any worn-out pieces.

Maintenance requirements for rain barrels are minimal and consist only of inspecting the unit as a whole and any of its constituent parts and accessories twice a year. The following components should be routinely inspected and either repaired or replaced as needed:

- *Roof catchment,* to ensure that trash and particulate matter are not entering the gutter and downspout to the rain barrel.
- *Gutters,* to ensure that no leaks or obstructions are occurring.
- *Downspouts,* to assure that no leaks or obstructions are occurring.
- *Entrance at rain barrel,* to ensure that there are no obstructions and/or leaks occurring.
- *Rain barrel,* to check for potential leaks, including barrel top and seal.
- *Runoff / overflow pipe,* to check that overflow is draining in non-erosive manner.
- *Spigot,* to ensure that it is functioning correctly.
- *Any accessories,* such as rain diverter, soaker hose, linking kit, and additional guttering.
- Apply larvicides in strict accordance with all Mass.
- Department of Agricultural Resources Pesticide
- *Bureau regulations* to prevent mosquitoes from reaching adulthood.

- Add bleach or other chemicals annually to kill bacteria present in the system. A qualified professional should determine appropriate treatment.
- *Drain the system before winter* if it is located above ground or partially exposed, to prevent cracking.
- Disconnect the system from roof leaders in the fall, if it is not intended to be used during the winter.
- When the cistern or barrel is connected to a stormwater recharge system, remove particulates trapped in the cistern or rain barrel annually to limit clogging of the stormwater infiltration system.

References

Adapted from: MAPC Low Impact Development Toolkit. For more information, go to www.mapc.org/lid and www.arc-of-innovation.org .

Other Resources:

http://www.rainwaterrecovery.com/about.html

Charles River Watershed Association: www.crwa.org

Accessories

- **Level Spreaders**
- **Check Dams**
- **Outlet Structures**
- **Catch Basin Inserts**
- **Vertical Curb Inlet Grates**

***SCM accessories** are not SCMs themselves, but are required to facilitate the operation and function of SCMs. This section presents four of the most common and important SCM accessories: level spreaders, check dams, outlet structures, and catch basin inserts.*

Level Spreaders

Description

A level spreader receives concentrated flow from channels, outlet structures, or other conveyance structures, and converts it to sheet flow where it can disperse uniformly across a stable slope. A level spreader is not a pollutant reduction device. It improves the efficiency of other SCMs, such as vegetated swales, filter strips, or infiltration systems that depend on sheet flow to operate properly.

Applicability and Planning Considerations

Level spreaders are used in wide, level areas where concentrated runoff occurs. They should be placed on undisturbed soil that has been stabilized with vegetation. Disturbed soils are more erodible. If the spreader is not absolutely level, flow will concentrate at the low point and may worsen erosion problems. Flows to the level spreader should be relatively free of sediment, or the level spreader could be quickly overwhelmed by sediment and lose its effectiveness.

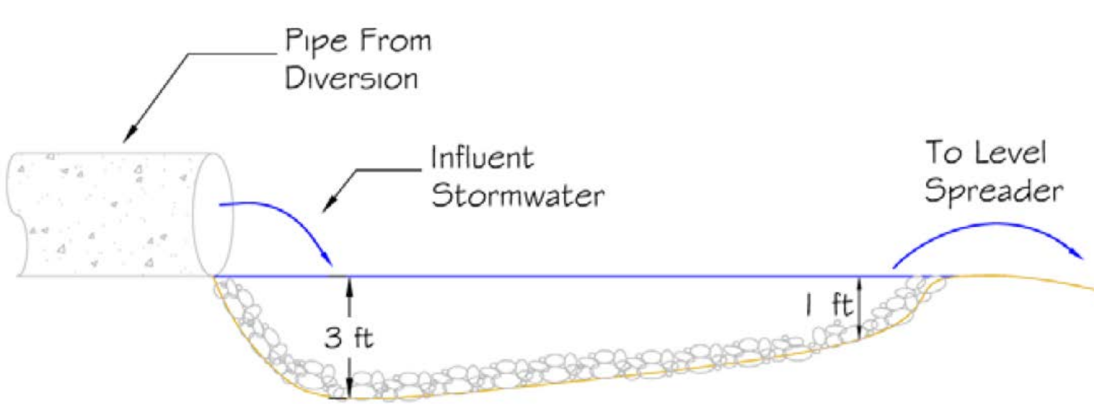
Design and Construction

Level spreaders are usually made of rocks, lumber, or concrete. Typical depths of flow behind each spreader range from 6 to 12 inches.

Construct level spreaders to be absolutely level. Small variations in height of even 0.25 inches can cause water to quickly concentrate and create erosion problems. A 4-inch variation in ground elevation across the entire length of the level spreader can make level construction difficult.

The height of the spreader is based on design flow, allowing for sediment and debris deposition. Design the length of the spreader based on the 10-year design flow for the site or the sheet flow path width, whichever is greater. When designing for the 10-year design flow, use the following table:

Example Section View of Level Spreader



adapted from the North Carolina State University

Drainage Area (length)	Minimum Spreader
1 acre	10 feet
2 acres	10 feet
3 acres	15 feet
4 acres	18 feet
5 acres	20 feet

The slope leading to the level spreader should be less than 1% for at least 20 feet immediately upstream, to keep runoff velocities less than 2 feet per second during the 10-year storm event. The slope at the outlet of the spreader should be 6% or less.

Maintenance

Inspect level spreaders regularly, especially after large rainfall events. Note and repair any erosion or low spots in the spreader.

References

Adapted from:

Idaho Department of Environmental Quality. Catalog of Stormwater SCMs for Cities and Counties, 209-210. MassDEP, Massachusetts Nonpoint Source Pollution Management Manual, 2006. http://www.mass.gov/dep/water/laws/policies.htm#storm

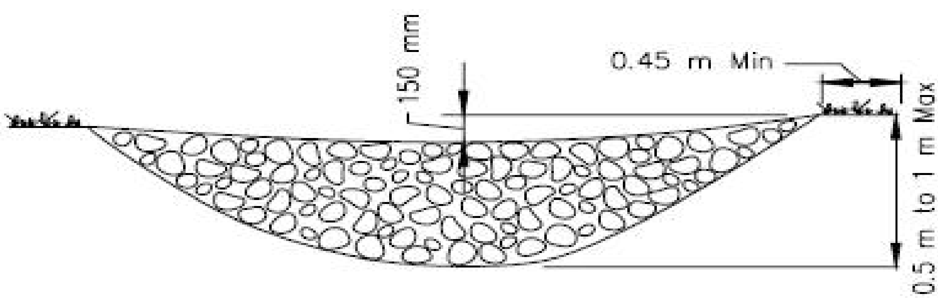
Additional Resources:

Hunt, W.F. et al. Designing Level Spreaders to Treat Stormwater Runoff. North Carolina State University, as presented at North Carolina Department of Transportation Level Spreader Workshop, February 19, 2001, Raleigh, NC.

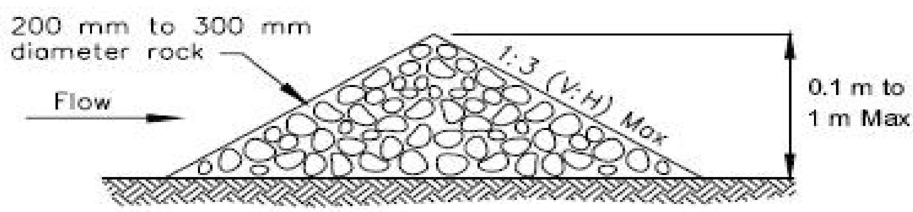
Check Dams

Description

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the velocity of flow. Reduced runoff velocity reduces erosion and gullying in the channel and allows sediments to settle out. A check dam may be built from stone, sandbags (filled with pea gravel), logs, or concrete. Check dams are relatively easy and inexpensive to construct. Permanent check dams should be constructed from stone or concrete. Sandbag dams filled with pea gravel or logs are suitable only as temporary practices. Never use a filter fence or a hay bale as a check dam, either on a temporary or permanent basis.



ELEVATION



TYPICAL ROCK CHECK DAM SECTION

CHECK DAM
NOT TO SCALE

Adapted from Caltrans

Applicability

Use check dams where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible, where velocity checks are needed, or to induce stormwater exfiltration into the ground within a SCM such as a dry water quality swale. Check dams may also be used as a temporary or emergency measure to limit erosion by reducing flow in small open channels. Other uses for check dams include:

- To reduce flow in small temporary channels that are presently undergoing degradation,
- Where permanent stabilization is impractical due to the temporary nature of the problem,
- To reduce flow in small eroding channels where construction delays or weather conditions prevent timely installation of non-erosive liners.

Check dams can be installed in small open channels that drain 10 acres or less, or channels where stormwater velocities exceed 5 feet per second. Note that some SCMs such as grass channels require flows to not exceed 1 foot per second for the water quality volume. Check dams cause water to pond. Under low-flow situations, water ponds behind the structure and then slowly seeps through the check dam and/or exfiltrates into the underlying soil, depending on the soil permeability. Under high-flow situations, water flows over and/or through the structure.

Advantages

- Inexpensive and easy to install.
- Reduces velocity and may provide aeration of the water.
- Prevents gully erosion from occurring before vegetation is established, and also causes a high proportion of the sediment load in runoff to settle out.
- In some cases, if carefully located and designed, check dams can remain as permanent installations with very minor regrading, etc.
- They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to capture sediment coming off that site.
- They must be constructed in dry water quality swales to reduce velocity and induce exfiltration.

Disadvantages

- May kill grass linings in channels if the water level remains high after rainstorms or if there is significant sedimentation.
- Clogging by leaves in the fall may be a problem.
- Should not be used in live streams
- Require extensive maintenance following high velocity flows
- Should not be made from straw bales or silt fences

Design

Install check dams at a distance and a height to allow small pools to form behind them. Install the first check dam about 15 feet from the outfall device and at regular intervals after that, depending on slope and soil type. In multiple check dam installations, design the system so that backwater from the downstream check dam reaches the toe of the next upstream dam. High flows (typically a 2-year or larger storm) should flow over the check dam without increasing upstream flooding or damaging the dam. Form check dams by hand or mechanically. Never dump rock directly into the channel or swale. Rock check dams should consist of well-graded stone consisting of a mixture of rock sizes.

When used in wet or dry water quality swales, the height of the check dam shall be no less than the elevation associated with the Water Quality Volume (1.0 inch times contributing impervious surface).

Exercise care in designing the ends of a check dam to ensure that it is long enough and adequately anchored to prevent ponded water from scouring the soil at the ends, and flowing around the dam.

Some check dam designs may require weirs. For example, if the same check dam is used for water quality treatment (for the water quality volume), and to lag the peak rate of runoff (for the velocity associated with runoff from the 2-year storm), a weir must be included as part of the check dam design. In instances where a permanent check dam is to be used for both water quality treatment and lag peak flows with a weir, use a durable material such as concrete. If the check dam is constructed from stone such as pea gravel, the weir would most likely lose its shape when higher velocities occur.

Maintenance

Inspect check dams after every significant rainfall event. Repair damage as needed. Remove sediment as needed.

Adapted from:

Caltrans, Storm Water Quality Handbooks. Section 4. SC-4 P.

MassDEP, Massachusetts Nonpoint Source Pollution Management Manual, 2006. https://www.mass.gov/info-details/nonpoint-source-pollution

Outlet Structures

Description

Outlets of SCMs are devices that control the flow of stormwater out of the SCM to the conveyance system.

Outlet Protection Design in Relation to Receiving Wetlands

This section describes the various types of common outlets such as flared end structures, risers, single-stage outlets, and multi- stage outlets. Considerations include setting back the outlet from a brook, providing appropriate energy dissipation, and orientating the outlet to reduce scour effects on the opposite bank.

Alignment of Outlets into Regulatory Streams

The Wetlands and 401 regulations require that stormwater treatment be provided prior to discharge into wetland Resource Areas such as vegetated wetlands (BVW, IVW, salt marshes), land under water (streams, lakes, rivers, ponds, ocean), and other Resource Areas, except for Riverfront Areas, Bordering Land Subject to Flooding, and land subject to coastal zone flowage, where such practices may be sited, provided the structures meet the performance standards specified in the Wetland regulations applicable to all projects.

The impact of new pipe outfalls on wetlands can be significantly reduced by locating the outfall point back from the receiving stream, using a flared-end structure, installing riprap or bio-engineered splash pad, and either digging a channel from the outfall to the stream or designing the splash pad to act as a level spreader to sheet the discharged stormwater to the stream.

In addition to not placing the outfall and energy dissipation in a wetland Resource Area such as a BVW or LUW, care must be exercised in the outlet design to ensure its orientation is such to reduce scour at the entry point and opposite bank. The preferred approach is to end the outlet pipe at a headwall or flared- end structure with a riprap or bio-engineered splash pad, discharging to a manmade drainage swale that is aligned at no more than a 45-degree angle to a stream channel. Design the outlet point and riprap or bio- engineered splash pad to reduce the energy sufficiently to eliminate a need to install riprap on the bank opposite the outfall point to protect it from scour.

References

Caltrans, Storm Water Quality Handbooks. 2003. (http://www.dot.ca.gov/hq/construc/stormwater/ manuals.htm)

Connecticut Department of Environmental Protection. Connecticut Stormwater Quality Manual. 2004. (http://dep.state.ct.us/wtr/stormwater/strmwtrman.htm)

Idaho Department of Environmental Quality. Catalog of Stormwater SCMs for Cities and Counties. March 2003. (http://www.google.com/u/DEQ?q=stormwater&domains=www.deq.idaho.gov&sitesearch=www.deq.idaho.gov)

Maine Department of Environmental Protection. Maine Stormwater Best Management Practices Manual. January 2006. (http://www.maine.gov/dep/blwq/docstand/stormwater/stormwaterSCMs/index.htm)

Maryland Department of the Environment. Maryland Stormwater Design Manual, Volumes I and II, October 2000. (http://www.mde.state.md.us/Programs/WaterPrograms/SedimentandStormwater/stormwater_design/index.asp)

New Jersey Department of Environmental Protection. New Jersey Stormwater Best Management Practices Manual. April 2004. http://www.state.nj.us/dep/ stormwater/SCM_manual2.htm

U.S. Department of Transportation. Federal Highway Administration.

Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. (Undated). (http://www.fhwa.dot.gov/environment/ultraurb/index.htm)

U.S. Environmental Protection Agency. Office of Research and Development. The Use of Best Management Practices (SCMs) in Urban Watersheds. EPA/600/R-04/184. September 2004.

Vermont Agency of Natural Resources. The Vermont Stormwater Management Manual. April 2002. (http://www.vtwaterquality.org/stormwater.htm)

Catch Basin Inserts

Description

Catch Basin Inserts are a SCM accessory that add filtering efficiency to traditional catch basins. These proprietary SCMs are capable of removing a range of pollutants, from trash and debris to fine sediments and oil/grease and metals depending upon the filtering medium used. They typically have three components:

- an insert that fits in into the catch basin
- absorbent material (can be a single unit or a series of filters)
- a housing to hold the absorbent material applications.

Additionally, larger sized sediment can clog and significantly reduce the effectiveness of some Catch Basin Insert filtering media. Therefore, it is important to ensure that flow rates, sediment removal, and the frequency of inspection and maintenance are evaluated.

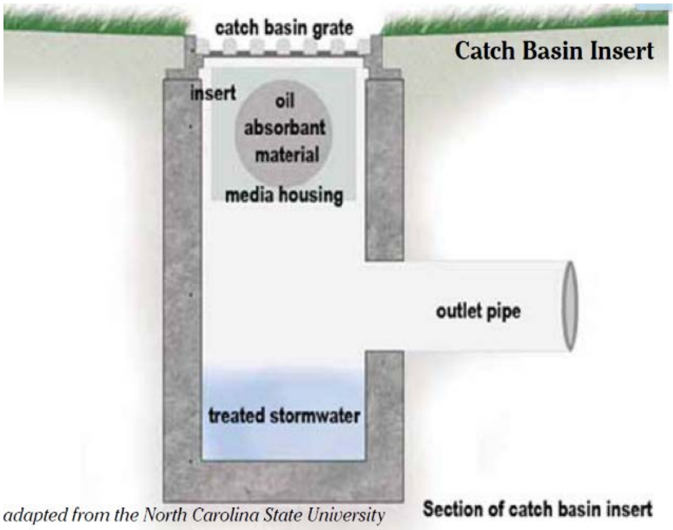
Note: Silt sacks used to provide construction period sediment control are not a post-construction Catch Basin Insert.

Design and Construction

- Since Catch Basin Inserts are usually proprietary devices, the manufacturer should be asked to ensure that the device will work in the type of catch basin in which it is installed.
- Catch Basin Inserts are typically designed and used to filter smaller volume flows. Flow characteristics and sediment loading should be evaluated and any resulting modifications to the catch basin made before installation of the insert.
- When a Catch Basin Insert is proposed, to determine if additional pollutant removal credit for TSS and/or TP is warranted, follow the process specified in **Section 5.3** of the Stormwater Handbook.

Maintenance

Inspect Catch Basin Inserts per the manufacturer's schedule, and especially after large rainfall events. Whoever is responsible for maintenance should explicitly agree to conduct the maintenance per the manufacturer's recommendation and to lawfully dispose of the cleanings or used filtration media.



Applicability and Planning Considerations

- Catch basin inserts can be useful for specialized applications, such as targeting specific pollutants other than TSS, at Land Uses with Higher Potential Pollution Loads, for oil control at small sites, for retrofits of existing catch basins with no or undersized sumps, to add TSS treatment to areas with higher sediment loading, or to improve conditions at size-constrained sites (e.g., catch basins near beaches).
- If using a proprietary Catch Basin Insert, the manufacturer's specifications must be followed, which may include modifications to the catch basin. Such modifications may include a high flow bypass or other feature to handle clogging or larger storm events.

Vertical Curb Inlet Grates

Description

Vertical curb inlet grates are a SCM accessory developed to add filtering efficiency to traditional FHWA "open curb inlets", "curb opening inlets", or "combination inlets". Both generic and proprietary versions are available. These SCMs prevent trash, and leaf litter from entering the catch basin sump through the open curb. They come in two configurations:

- **Fixed (top photo)**. A fixed grate spans across the open curb and allows water to flow through grate openings.
- **Retractable (bottom photo)**. A movable grate inset spans across the open curb opening that opens when water pusses against it.

Applicability and Planning Considerations

All deep sump catch basins that contain a curb inlet must be installed with a vertical curb inlet grate to receive TSS pretreatment credit (see "**Deep Sump Catch Basin**" section of this Appendix for more information).

Vertical curb inlet grates can be useful for specialized applications, such as targeting specific pollutants other than TSS, in areas with commercial and industrial land uses, for trash or litter control at small sites, and for retrofits of existing catch basins to add enhanced prevention of TSS, leaf litter, and trash accumulation, or to improve existing conditions at size-constrained sites (e.g., catch basins near bathing beaches)..

Design and Construction

Since vertical curb inlet grates are usually proprietary devices, the manufacturer should be consulted to ensure that the device will work in the type of catch basin in which it is installed. All manufacturer specifications must be followed to ensure combability and proper installation. Flow characteristics and sediment loading should be evaluated and any resulting modifications to the catch basin made before installation of the insert.

For Vertical curb inlet grates in combination inlets, the clear space in the curb opening, or each individual clear space if the curb opening has two or more clear spaces, shall have an area of no more than seven (7.0) square inches or be no greater than two (2.0) inches across the smallest dimension. Fixed curb guards shall me made of cast iron, coated or uncoated stainless steel. The moveable portion of retractable curb guards can be made of stainless steel or hard plastic.

Maintenance

Inspect vertical curb inlet grates per the manufacturer's schedule, and especially after large rainfall events. Whoever is responsible for maintenance should explicitly agree to conduct the maintenance per the manufacturer's recommendation and to lawfully dispose of cleanings and replace the grate should it become damaged.

Due to the increased litter accumulation on the street, an enhanced street sweeping program is recommended to ensure the litter is not swept off the street.

Since small particles and debris may still enter the catch basin sump, it should be cleaned on a regular schedule, at minimum as frequently as catch basins without a vertical curb inlet.

References

Evaluation of Street Sweeping and Curb Inlet Screens as Measures to Control Trash in Stormwater. 2016. State Water Resources Control Board Grant Agreement No. 12-420-550. EOA Inc. Oakland CA.

Operating and Source Controls

- Auto Salvage Yards
- Auto Fueling Facilities (Gas Stations)
- Building, Repair, and Maintenance of Boats and Ships
- Commercial Animal Handling Areas
- Commercial Composting
- Commercial Printing Operations
- Loading and Unloading Areas for Liquid or Solid Material
- Painting/Finishing/Coating of Vehicles/Boats/Buildings/Equipment
- Railroad Yards
- SCMs for Retail and Wholesale Service Industries
- Vehicle Washing
- Road Salt Storage and Snow Disposal

Operating and Source Controls

This section of **Appendix A** identifies specific pollution prevention measures for use at certain industrial and commercial facilities, snow disposal measures, and deicer storage. The pollution prevention measures listed apply to industrial and commercial land uses. The snow disposal measures apply to all land uses. The deicer storage requirements apply to those who store deicers.

Implementation of these measures described herein for industrial and commercial land uses can help the operators of these facilities prevent the pollutants generated by their operations from entering Surface Waters or groundwater. These measures are required to be included in the Long Term Pollution Prevention Plan (LTPPP) required by Stormwater Standards No. 4 - 6 to be submitted with the Wetlands NOI or 401 Application, when new development or Redevelopment is proposed within a Wetland Resource Area or Buffer Zone (310 CMR 10.05(6)(k)4, 5, and 6. They must be implemented thereafter.

The measures described herein that are applicable to industrial land uses dovetail with the requirements for those industrial land uses subject to the NPDES Multi-Sector General Permit, and must be addressed in the required industrial Stormwater Pollution Prevention Plan (SWPPP). In addition to inclusion in the LTPPP, they also need to be incorporated directly or by reference in the Post Construction Operation and Maintenance Plan required by Stormwater Standard No. 9.

The measures required by the snow disposal and deicer storage guidance published by MassDEP must be consulted to determine if the measures need to be incorporated in the LTPPP and Operation/Maintenance Plans. In general, industrial and commercial land uses that require authorization for proposed activities in Wetland Resource Areas must address the snow disposal requirements as part of the LTPPP, including identifying a location on site at least 50 feet away from bank, BVW, IVW, or salt marsh, where snow will be disposed during the winter months. When Vernal Pools or other critical areas are located on sites, the Snow Disposal Guidance should be consulted directly as part of establishing a snow disposal location and in formulating the LTPPP.

Pollution prevention measures are identified for the following land uses:

- Auto Salvage Yards (Auto recycling facilities)
- Auto Fueling Facilities (Gas stations)
- Building, Repair, and Maintenance of Boats and Ships
- Commercial Animal Handling Areas
- Commercial and Municipal Composting Operations
- Commercial Printing Operations
- Loading and Unloading Areas for Liquid or Solid Material
- Painting/Finishing/ Coating of Vehicles/Boats/ Buildings/ Equipment
- Railroad Yards
- Commercial (Retail and Wholesale)
- Service Industries
- Road Salt Storage and Snow Disposal

Auto Salvage Yards

The auto salvage business offers great opportunities for recycle / reuse. The dismantling of vehicles for reusable parts and fluids and the sale of remaining materials as scrap has gone a long way toward lessening the burden on our landfills. Unfortunately, the methods used in dismantling and storage can, and often have, resulted in serious negative impacts on the environment.

Fluids Handling

Properly remove and handle automobile fluids. Fluids associated with auto salvage include:

- Drained motor oil
- Antifreeze
- Hydraulic oil/fluid
- Transmission fluid
- Brake fluid
- Window cleaner
- Oil recovered from steam cleaning
- Water recovered from steam cleaning
- Storm water runoff from storage area

Drained Motor Oil

Store used oil inside under cover or in covered containers on an impervious pad with adequate containment. An accepted practice is to allow oil to remain in the engine when auto is sold. The oil and the filters are sold with the engine. However, this is not true of all salvage yards. Used motor oil can be stored and sold to a processor or re-refiner or used as a fuel or energy source.

Antifreeze

Most salvaged vehicles have antifreeze in their systems. Spent antifreeze typically contains ethylene-glycol, an environmentally regulated chemical, and an accumulation of heavy metals. As a result, spent antifreeze is managed as hazardous waste in MA. Antifreeze can be reclaimed and reused. Store used antifreeze inside under cover or in covered containers on an impervious pad with adequate containment. For details on antifreeze recycling see Massachusetts Office of Technical Assistance and Technology (OTA) at https://www.mass.gov/files/antifreeze_recycling.pdf

Other Vehicle Fluids

Brake fluid, transmission fluid, and hydraulic oils are not considered financially feasible for recovery. Store these fluids under cover or in covered containers on an impervious pad with adequate containment. Dispose of these fluids as a hazardous waste.

Wastewater and Stormwater Runoff

Steam-cleaning auto engines and parts results in oil-contaminated wastewater. Segregate this water from domestic-type wastewater. Steam clean engines and parts inside and under cover to prevent exposure to rain, snow, snowmelt and runoff.

This wastewater should be given time to allow for solids settlement. If possible, separate the used oil for recycling and collection by a permitted used-oil transporter. Dispose of the remaining sludge as a hazardous waste.

Other Recyclable Materials

Other salvage yard materials that can be recycled include:

- Lead Acid Batteries (State law prohibits disposal in a landfill)
- Radiators, Engines, Air Conditioning Coils, Catalytic Converters
- Scrap Metals and Plastic
- Rubber-Related Materials

All the materials listed above are recyclable and should be recycled instead of being disposed of in landfills.

Auto Fueling Facilities (gas stations)

Description of Pollutant Sources

A fueling station is a facility dedicated to the transfer of fuels from a stationary pumping station to mobile vehicles or equipment. It includes above- or under-ground fuel storage facilities. In addition to general service gas stations, fueling may also occur at 24-hour convenience stores, construction sites, warehouses, car washes, manufacturing establishments, port facilities, and businesses with fleet vehicles. Typically, stormwater contamination at fueling stations is caused by leaks/spills of fuels, lube oils, radiator coolants, and vehicle washwater.

Pollutant Control Approach

Construct new or substantially remodeled fueling stations on an impervious concrete pad under a roof to keep out rainfall and stormwater run-on. Use a treatment SCM such as an oil grit separator, sand filter or equivalent for contaminated stormwater and wastewaters in the fueling containment area.

Applicable Operational BMPs

- Prepare an emergency spill response and cleanup plan and have designated trained person(s) available either on-site or on call at all times to promptly implement that plan and immediately cleanup all spills. Keep suitable cleanup materials, such as dry adsorbent materials, on-site to allow prompt cleanup of a spill.
- Train employees on the proper use of fuel dispensers. Post “No Topping Off” signs (topping off gas tanks causes spillage and vents gas fumes to the air). Make sure that the automatic shutoff on the fuel nozzle is functioning properly.
- The person conducting the fuel transfer must be present at the fueling pump during fuel transfer, particularly at unattended or self-serve stations.
- Keep drained oil filters in a suitable container or drum. Drums should be closed on an impervious pad with adequate containment.

For more information about when you need to report a spill to MassDEP and how quickly you need to report it (in many instances a spill must be reported within 2 hours), go to this MassDEP web page: https://www.mass.gov/how-to/report-a-spill-or-environmental-emergency

Applicable Source Control BMPs

- Design the fueling island to control spills (e.g., use dead-end sumps or spill-control separators) and to treat collected stormwater and/or wastewater to required levels. Slope the concrete containment pad around the fueling island toward drains; either trench drains, catch basins and/or a dead-end sump. Drains to treatment should have a shutoff valve, which must be closed in the event of a spill.
- Alternatively, design the fueling island as a spill-containment pad with a sill or berm raised to a minimum of four inches to prevent the runoff of spilled liquids and to prevent run-on of stormwater from the surrounding area.
- The fueling pad should be paved with Portland cement concrete, or equivalent.
- The fueling island should have a roof or canopy to prevent direct entry of precipitation onto the spill containment pad. The roof or canopy should, at a minimum, cover the spill containment pad (within the grade break or fuel dispensing area) and preferably extend several additional feet to reduce the introduction of windblown rain. Convey all roof drains to storm drains outside the fueling containment area.
- Convey stormwater collected on the fuel island containment pad to a sanitary sewer system, if approved by the sanitary authority; or to an approved treatment system such as an oil/grit separator, sand filter or equivalent. Alternatively, a lined vegetated filter strip can convey stormwater from the fuel island to a bioretention area with an under-drain. Discharges from treatment systems to storm drains or Surface Waters or to the ground must not display ongoing or recurring visible sheen and must meet the requirements of the permit under which they are discharged.
- Stormwater collected on the fuel island containment pad may be collected and held for proper off-site disposal.
- Transfer the fuel from the delivery tank trucks to the fuel storage tank in impervious contained areas and ensure that appropriate overflow protection is used. Alternatively, cover nearby storm drains during the filling process and use drip pans under all hose connections.

Additional BMPs for Vehicles 10 feet high or greater

A roof or canopy may not be practicable at fueling stations that regularly fuel vehicles that are 10 feet high or taller. At those types of fueling facilities, consider using the following additional BMPs:

- If a roof or canopy is impractical, equip the concrete fueling pad with emergency spill controls, including a shutoff valve for the drainage from the fueling area. The valve must be closed in the event of a spill. An electronically actuated valve is preferred to minimize the time lapse between spill and containment. Spills must be cleaned up and contaminated materials disposed off-site in accordance with MassDEP policies and regulations: https://www.mass.gov/topics/cleanup-of-sites-spills

- The valve may be opened to convey contaminated stormwater to a sanitary sewer, if approved by the sewer authority, or to oil removal treatment such as an API oil/grit separator, sand filter or equivalent treatment, and then to a basic treatment BMP. Discharges from treatment systems to storm drains or Surface Water or to the ground must not display ongoing or recurring visible sheen and must not contain a significant amount of oil and grease.

- An explosive or flammable mixture is defined under state and federal regulations, based on a flash point determination of the mixture. See Appendix B IV for sources of information for flammability and other chemical risks: http://www.osha.gov/dsg/hazcom/ghd053107.html If contaminated stormwater is determined not to be explosive or flammable, then it could be conveyed to a sanitary sewer system.

Building, Repair, and Maintenance of Boats and Ships

Description of Pollutant Sources

Sources of pollutants at boat and shipbuilding, repair, and maintenance at boatyards, shipyards, ports, and marinas include pressure washing, surface preparation, paint removal, sanding, painting, engine maintenance and repairs, and material handling and storage, if conducted outdoors. If feasible, these activities should be done inside under cover. If done outside, use an impervious surface with adequate containment. Potential pollutants include spent abrasive grits, solvents, oils, ethylene glycol, wash water, paint over-spray, cleaners/ detergents, anti-corrosive compounds, paint chips, scrap metal, welding rods, resins, glass fibers, dust, and miscellaneous trash. Pollutant constituents include TSS, oil and grease, organics, copper, lead, tin, and zinc.

Pollutant Control Approach

Apply good housekeeping, preventive maintenance and cover and containment BMPs in and around work areas. See:
https://www.mass.gov/files/documents/2016/08/wl/cmg-4-1_0.pdf

Applicable Operational BMPs

Applicable operational BMPs are:

- Regularly clean all accessible work, service and storage areas to remove debris, spent sandblasting material, and any other potential stormwater pollutants.
- Sweep rather than hose debris on the dock. If hosing is unavoidable, collect and convey the hose water to a wastewater treatment system or facility.
- Collect spent abrasives regularly and store under cover to await proper disposal.
- Dispose of greasy rags, oil filters, air filters, batteries, spent coolant, and degreasers properly.
- Drain oil filters before disposal or recycling.
- Immediately repair or replace leaking connections, valves, pipes, hoses and equipment that causes the contamination of stormwater.
- Use drip pans, drop cloths, tarpaulins or other protective devices in all paint mixing and solvent operations unless carried out in impervious contained and covered areas.
- Convey sanitary sewage to pump-out stations, portable on-site pump-outs, or commercial mobile pump-out facilities or other appropriate onshore facilities.
- Maintain automatic bilge pumps in a manner that will prevent waste material from being pumped automatically into Surface Water.
- Prohibit uncontained spray painting, blasting or sanding activities over open water or in any area where these activities may be exposed to rain, snow, snow melt or runoff.
- Do not dump or pour waste materials down floor drains, sinks, or outdoor storm drain inlets that discharge to Surface Water or groundwater. Plug floor drains that are connected to storm drains or to Surface Water. If necessary, install a sump that is pumped regularly.
- Prohibit outside spray painting, blasting or sanding activities during windy conditions that render containment ineffective.
- Do not paint and/or use spray guns on topsides or above decks.
- Immediately clean up any spillage on dock, boat or ship deck areas and dispose of the wastes properly.

Applicable Structural Source Control BMPs

- Use fixed platforms with appropriate plastic or tarpaulin barriers as work surfaces and for containment when performing work on a vessel in the water to prevent blast material or paint overspray from contacting stormwater or the receiving water. Use of such platforms will be kept to a minimum and at no time be used for extensive repair or construction (anything in excess of 25 percent of the surface area of the vessel above the waterline).
- Use plastic or tarpaulin barriers beneath the hull and between the hull and dry dock walls to contain and collect waste and spent materials. Clean and sweep regularly to remove debris.
- Enclose, cover, or contain blasting and sanding activities to the maximum extent practicable to prevent abrasives, dust, and paint chips from reaching storm sewers or receiving waters. Use plywood and/or plastic sheeting to cover open areas between decks when sandblasting scuppers, railings, freeing ports, ladders, and doorways.

- Direct deck drainage to a collection system sump for settling and/or additional treatment.

- Store cracked batteries in a covered secondary container.

- Apply source control BMPs provided in this Appendix for other activities conducted at the marina, boat yard, shipyard, or port facility (BMPs for Fueling at Dedicated Stations, BMPs for Washing and Steam Cleaning Vehicle/Equipment/Building Structures, and BMPs for Spills of Oil and Hazardous Substances).

Recommended Additional Operational BMPs

- Consider recycling paint, paint thinner, solvents, used oils, oil filters, pressure wash wastewater and any other recyclable materials.

- Perform activities like paint mixing, solvent mixing, fuel mixing on shore inside or under cover or on an impervious area with adequate containment.

Commercial Animal Handling Areas

Description of Pollutant Sources

Animals at racetracks, kennels, fenced pens, veterinarians, and businesses that provide boarding services for horses, dogs, cats, and other animals, can generate pollutants from the following activities: manure deposits, animal washing, grazing and any other animal handling activity that could contaminate stormwater. Pollutants can include coliform bacteria, nutrients, and total suspended solids.

Pollutant Control Approach

To prevent, to the maximum extent practicable, the discharge of contaminated stormwater from animal handling and keeping areas.

Applicable Operational BMPs

- Regularly sweep and clean animal keeping areas to collect and properly dispose of droppings, uneaten food, and other potential stormwater contaminants
- Do not hose down to storm drains or to receiving water those areas that contain potential stormwater contaminants
- Do not allow any wash waters to be discharged to storm drains. Wash water is wastewater that must not be discharged to the stormwater management system.
- If animals are kept in unpaved and uncovered areas, the ground should either have vegetative cover or some other type of ground cover such as mulch
- If animals are not leashed or in cages, surround the area where animals are kept with a fence or other means that prevents animals from moving away from the controlled area where BMPs are used.

Commercial and Municipal Composting

Description of Pollutant Sources

Commercial compost facilities, operating outside without cover, require large areas to decompose wastes and other feedstocks. Design these facilities so as to separate stormwater from leachate (i.e., industrial wastewater) to the greatest extent practicable. When stormwater is allowed to contact any active composting areas, including waste receiving and processing areas, it becomes leachate.

Pollutants in leachate include nutrients, biochemical oxygen demand (BOD), organics, coliform bacteria, acidic pH, color, and suspended solids. Stormwater at a compost facility consists of runoff from areas at the facility that are not associated with active processing and curing, such as product storage areas, vehicle maintenance areas, and access roads.

Applicable Operational BMPs

- Ensure that the compost feedstocks do not contain dangerous or hazardous wastes, or solid wastes that are not beneficial to the composting process. Train employees to screen these materials in incoming wastes.
- Store finished compost properly, such as in a covered area, to prevent contamination of stormwater.

Applicable Structural Source Control BMPs

- Provide curbing for all compost pads to prevent stormwater run-on and leachate run-off.
- Slope all compost pads sufficiently to direct leachate to collection devices.
- Provide one or more sumps or catch basins capable of collecting leachate and conveying it to the leachate holding structure for all compost pads.

Applicable Treatment BMPs

- Convey all leachate from composting operations to a sanitary sewer, holding tank, or on-site treatment systems designed to treat the leachate and TSS.
- Line the ponds used to collect, store, or treat leachate and other contaminated waters associated with the composting process to prevent groundwater contamination.

Recommended Additional BMPs

- Regularly clean up debris from yard areas.
- Locate stored residues in areas designed to collect leachate.
- Limit storage times of residues to prevent degradation and generation of leachate.
- Consider using leachate as make-up water in early stages of the composting process. Because leachate can contain pathogenic bacteria, take care to avoid contaminating finished product or nearly finished product with leachate.
- In areas of the state with dry climates, consider using evaporation as a means of reducing the quantity of leachate.

Commercial Printing Operations

Description of Pollutant Sources

Materials used in the printing process include inorganic and organic acids, resins, solvents, polyester film, developers, alcohol, vinyl lacquer, dyes, acetates, and polymers. Waste products may include waste inks and ink sludge, resins, photographic chemicals, solvents, acid and alkaline solutions, chlorides, chromium, zinc, lead, silver, spent formaldehyde, plasticizers, and used lubricating oils. As the printing operations are conducted indoors, the only likely points of potential contact with stormwater are the outside temporary storage of waste materials and offloading of chemicals at external unloading bays. Pollutants can include TSS, pH, heavy metals, oil and grease, and COD.

Pollutant Control Approach

Ensure appropriate disposal of process wastes. Cover and contain stored raw and waste materials.

Applicable Operational BMPs

- Discharge process wastewaters to a sanitary sewer, if approved by the local sewer authority, or to an approved process wastewater treatment system.
- Do not discharge process wastes or wastewaters into storm drains, groundwater or Surface Water.
- Determine whether any of these wastes are regulated as dangerous wastes and dispose of them accordingly.

Applicable Structural Source Control BMP

Store raw materials or waste materials that could contaminate stormwater in covered and contained areas.

Recommended Additional BMPs

- Train all employees in pollution prevention, spill response, and environmentally acceptable materials-handling procedures.
- Store materials in proper, appropriately labeled containers. Identify and label all chemical substances.
- Regularly inspect all stormwater management devices and maintain them as necessary.
- Try to use press washes without listed solvents, and with the lowest VOC content possible. Don't evaporate ink cleanup trays to the outside atmosphere.
- Place cleanup sludges in containers with a tight lid and dispose of as hazardous waste. Do not dispose of cleanup sludges in the garbage or in containers of soiled towels.

Loading and Unloading Areas for Liquid or Solid Material

Description of Pollutant Sources

Loading/unloading of liquid and solid materials at industrial and commercial facilities are typically conducted at shipping and receiving, outside storage, and fueling areas. Materials transferred can include products, raw materials, intermediate products, waste materials, fuels, scrap metals, etc. Leaks and spills of fuels, oils, powders, organics, heavy metals, salts, acids, and alkalis during transfer are potential causes of stormwater contamination. Spills from hydraulic line breaks are a common problem at loading docks.

Pollutant Control Approach

Cover and contain the loading/ unloading area where necessary to prevent run-on of stormwater and runoff of contaminated stormwater.

Applicable Operational BMPs

At All Loading/ Unloading Areas:

- A significant amount of debris can accumulate outside uncovered loading/unloading areas. Sweep these surfaces frequently to remove material that could otherwise be washed off by stormwater. Sweep outside areas that are covered for a period of time by containers, logs, or other material after the areas are cleared.
- Place drip pans, or other appropriate temporary containment device, at locations where leaks or spills may occur, such as hose connections, hose reels and filler nozzles. Always use drip pans when making and breaking connections. Check loading and unloading equipment such as valves, pumps, flanges, and connections regularly for leaks and repair as needed.

At Tanker Truck and Rail Transfer Areas to Above/Below-ground Storage Tanks:

- To minimize the risk of accidental spillage, prepare an "Operations
- Plan" that describes procedures for loading/unloading. Train employees, especially forklift operators, in its execution and post it or otherwise have it readily available to employees.
- Prepare and implement an Emergency Spill Cleanup Plan for the facility that includes the following BMPs:
- Ensure the cleanup of liquid/solid spills in the loading/ unloading area immediately, if a significant spill occurs, and, upon completion of the loading/unloading activity, or at the end of the working day.
- Retain and maintain an appropriate oil spill cleanup kit on-site for rapid cleanup of material spills
- Ensure that an employee trained in spill containment and cleanup is present during loading/unloading.
- Notify MassDEP as required: https://www.mass.gov/topics/cleanup-of-sites-spills

At Rail Transfer Areas to Above/below-ground Storage Tanks:

- Install a drip pan system within the rails to collect spills/leaks from tank cars and hose connections, hose reels, and filler nozzles.

Applicable Structural Source Control BMPs

At All Loading/ Unloading Areas:

- To the extent practicable, conduct unloading or loading of solids and liquids in a manufacturing building, under a roof, or lean-to, or other appropriate cover.
- Berm, dike, and/or slope the loading/unloading area to prevent run-on of stormwater and to prevent the runoff or loss of any spilled material from the area.
- Large loading areas frequently are not curbed along the shoreline. As a result, stormwater passes directly off the paved surface into Surface Water. Place curbs along the edge, or slope the edge such that the stormwater can flow to an internal storm drain system that leads to a treatment BMP.
- Pave and slope loading/unloading areas to prevent the pooling of water. The use of catch basins and drain lines within the interior of the paved area must be minimized as they will frequently be covered by material, or they should be placed in designated “alleyways” that are not covered by material, containers or equipment.

Recommended Structural Source Control BMPs

For the transfer of pollutant liquids in areas that cannot contain a catastrophic spill, install an automatic shutoff system in case of unanticipated off-loading interruption (e.g., coupling break, hose rupture, overfill, etc.).

At Loading and Unloading Docks:

- Install/maintain overhangs, or door skirts that enclose the trailer end, to prevent contact with rainwater.
- Design the loading/unloading area with berms and grading to prevent the run-on of stormwater.
- Retain on-site the necessary materials for rapid cleanup of spills.

At Tanker Truck Transfer Areas to Above/Below-Ground Storage Tanks:

- Pave the area on which the transfer takes place. If any transferred liquid, such as gasoline, is reactive with asphalt, pave the area with Portland cement concrete.
- Slope, berm, or dike the transfer area to a dead-end sump, spill containment sump, an oil/grit separator, or other spill control device.

Painting, Finishing, and Coating of Vehicles, Boats, Buildings and Equipment

Description of Pollutant Sources

Surface preparation and the application of paints, finishes and/or coatings to vehicles, boats, buildings, and/or equipment outdoors can be sources of pollutants. Potential pollutants include organic compounds, oils and greases, heavy metals, and suspended solids.

Pollutant Control Approach

Cover and contain painting and sanding operations and apply good housekeeping and preventive maintenance practices to prevent the contamination of stormwater with painting oversprays and grit from sanding. https://dtsc.ca.gov/dtsc-website-archive/auto-body-and-paint-abp/

Applicable Operational BMPs

- Train employees in the careful application of paints, finishes, and coatings to reduce misuse and over spray. Use ground- or drop-cloths underneath outdoor painting, scraping, sandblasting work, and properly clean and temporarily store collected debris daily.
- Do not conduct spraying, blasting, or sanding activities over open water or where wind may blow paint into water.
- Wipe up spills with rags and other absorbent materials immediately. Do not hose down the area to a storm drain or receiving water or conveyance ditch to receiving water.
- On marine dock areas, sweep rather than hose down debris. Collect any hose water generated and convey to appropriate treatment and disposal.
- Use a storm drain cover, filter fabric, or similarly effective runoff control device if dust, grit, washwater, or other pollutants may escape the work area and enter a catch basin. The containment device(s) must be in place at the beginning of the workday. Collect contaminated runoff and solids and properly dispose of such wastes before removing the containment device(s) at the end of the workday.
- Use a ground cloth, pail, drum, drip pan, tarpaulin, or other protective device for activities such as paint mixing and tool cleaning outside or where spills can contaminate stormwater.
- Properly dispose of all wastes and prevent all uncontrolled releases to the air, ground or water.
- Clean brushes and tools covered with non-water-based paints, finishes, or other materials in a manner that allows collection of used solvents (e.g., paint thinner or turpentine) for recycling or proper disposal.
- Store toxic materials under cover during precipitation events and when not in use to prevent contact with stormwater.

Applicable Structural Source Control BMPs

Enclose and/or contain all work while using a spray gun or conducting sand blasting. Do not conduct outside spraying, grit blasting, or sanding activities during windy conditions that render containment ineffective.

Recommended Additional Operational BMPs

- Clean paintbrushes and tools covered with water-based paints in sinks connected to sanitary sewers or in portable containers that can be dumped into a sanitary sewer drain.
- Recycle paint, paint thinner, solvents, pressure washwater, and any other recyclable materials.
- Use efficient spray equipment such as electrostatic, air-atomized, high-volume/low-pressure, or gravity feed spray equipment.
- Purchase recycled paints, paint thinner, solvents, and other products if feasible.

Railroad Yards

Note: MassDEP requires an oil grit separator, sand filter or equivalent to manage stormwater runoff from this land use.

Description of Pollutant Sources

Pollutant sources can include drips/leaks of vehicle fluids onto the railroad bed, human waste disposal, litter, locomotive/railcar/equipment cleaning areas, fueling areas, outside material storage areas, the erosion and loss of soil particles from the railroad bed, maintenance and repair activities at railroad terminals, switching yards, and maintenance yards, and herbicides used for vegetation management. Waste materials can include waste oil, solvents, degreasers, antifreeze solutions, radiator flush, acids, brake fluids, soiled rags, oil filters, sulfuric acid and battery sludges, and machine chips with residual machining oil and toxic fluids/solids lost during transit. Potential pollutants include oil and grease, TSS, BOD, organics, pesticides, and metals.

Pollutant Control Approach

Apply good housekeeping and preventive maintenance practices to control leaks and spills of liquids in railroad yard areas.

Applicable Operational and Structural Source Control BMPs

- Do not allow discharge to outside areas from toilets while a train is in transit. Pump out facilities should be used to service these units.
- Use drip pans at hose/pipe connections during liquid transfer and other leak-prone areas.
- During maintenance, do not discard debris or waste liquids along the tracks or in railroad yards.

Applicable Treatment BMPs

In areas subjected to leaks/spills of oils or other chemicals, convey the contaminated stormwater to appropriate treatment such as a sanitary sewer, if approved by the appropriate sewer authority, or to an oil/grit separator for floating oils, or other treatment, as approved by the local jurisdiction.

Retail and Wholesale

Restaurants/Fast Food (SIC: 5800)

Description

Businesses that provide food service to the general public, including drive-through facilities.

Potential Pollutant Generating Sources

Potential pollutant sources include high-use customer parking lots and garbage dumpsters. The cleaning of roofs and other outside areas of restaurant and cooking vent filters in the parking lot can cause cooking grease to be discharged to the storm drains. MassDEP prohibits discharging wash water or grease to storm drains or Surface Water.

Retail/General Merchandise (SIC: 5300, 5600, 5700, 5900, and 5990)

Description

This group includes general merchandising stores such as department stores, shopping malls, variety stores, 24-hour convenience stores, and general retail stores that focus on a few product types such as clothing and shoes. It also includes furniture and appliance stores.

Potential Pollutant Generating Sources

Of particular concern are the high-use parking lots of shopping malls and 24-hour convenience stores. Furniture and appliance stores may provide repair services in which dangerous wastes may be produced.

Retail/Wholesale Vehicle and Equipment Dealers (SIC: 5010, 5080, and 5500, 7510 excluding fueling stations)

Description

This group includes all retail and wholesale businesses that sell, rent, or lease cars, trucks, boats, trailers, mobile homes, motorcycles and recreational vehicles. It includes both new and used vehicle dealers. It also includes sellers of heavy equipment for construction, farming, and industry. With the exception of motorcycle dealers, these businesses have large parking lots. Most retail dealers that sell new vehicles and large equipment also provide repair and maintenance services.

Potential Pollutant Generating Sources

Oil and other materials that have dripped from parked vehicles can contaminate stormwater at high-use parking areas. Vehicles are washed regularly, generating vehicle grime and detergent pollutants. The storm- or washwater runoff will contain oils and various organics, metals, and phosphorus. Repair and maintenance services generate a variety of waste liquids and solids including used oils and engine fluids, solvents, waste paint, soiled rags, and dirty used engine parts. Many of these materials are hazardous wastes.

Retail/Wholesale Nurseries and Building Materials (SIC: 5030, 5198, 5210, 5230, and 5260)

Description

These businesses are placed in a separate group because they are likely to store much of their merchandise outside of the main building. They include nurseries, and businesses that sell building and construction materials and equipment, paint, and hardware.

Potential Pollutant Generating Sources

Some businesses may have small fueling capabilities for forklifts and may also maintain and repair their vehicles and equipment. Some businesses may have unpaved areas, with the potential to contaminate stormwater by leaching of nutrients, pesticides, and herbicides. Storm runoff from exposed storage areas can contain suspended solids, and oil and grease from vehicles and forklifts and high-use customer parking lots, and other pollutants. Runoff from nurseries may contain nutrients, pesticides and/or herbicides.

Retail/Wholesale Chemicals and Petroleum (SIC: 5160, 5170)

Description

These businesses sell plastic materials, chemicals and related products. This group also includes the bulk storage and selling of petroleum products such as diesel oil and automotive fuels.

Potential Pollutant Generating Sources

The general areas of concern are the spillage of chemicals or petroleum during loading and unloading, and the washing and maintenance of tanker trucks and other vehicles. Also, the fire code requires that vegetation be controlled within a tank farm to avoid a fire hazard. Herbicides are typically used. The concentration of oil in untreated stormwater is known to exceed the water quality effluent guideline for oil and grease. Runoff is also likely to contain significant concentrations of benzene, phenol, chloroform, lead, and zinc.

Retail/Wholesale Foods and Beverages (SIC 5140, 5180, 542, 54)

Description

Included are businesses that provide retail food stores, including general groceries, fish and seafood, meats and meat products, dairy products, poultry, soft drinks, and alcoholic beverages.

Potential Pollutant Generating Sources

Vehicles may be fueled, washed and maintained at the business. Spillage of food and beverages may occur. Waste food and broken contaminated glass may be temporarily stored in containers located outside. High-use customer parking lots may be sources of oil and other contaminants.

Other Retail/Wholesale Businesses (SIC: 5010 (not 5012), 5040, 5060,5070, 5090)

Description

Businesses in this group include sellers of vehicle parts, tires, furniture and home furnishings, photographic and office equipment, electrical goods, sporting goods and toys, paper products, drugs, and apparel.

Potential Pollutant Generating Sources

Pollutant sources include high-use parking lots, and delivery vehicles that may be fueled, washed, and maintained on premises.

Service Industries

Animal Care Services (SIC: 0740, 0750)

Description

This group includes racetracks, kennels, fenced pens, veterinarians and businesses that provide boarding services for animals including horses, dogs, and cats.

Potential Pollutant Generating Sources

The primary sources of pollution include animal manure, wash waters, waste products from animal treatment, runoff from pastures where larger livestock are allowed to roam, and vehicle maintenance and repair shops. Pastures may border streams and direct access to the stream may occur. Both Surface Water and groundwater may be contaminated. Potential stormwater contaminants include fecal coliform, oil and grease, suspended solids, BOD, and nutrients.

Commercial Car and Truck Washes (SIC: 7542)

Description

Facilities include automatic systems found at individual businesses or at gas stations and 24-hour convenience stores, as well as self-service car washes. There are three main types: tunnels, rollovers and hand-held wands. The tunnel wash, the largest, is housed in a long building through which the vehicle is pulled. At a rollover wash, the vehicle remains stationary while the equipment passes over. Wands are used at self-serve car washes. Some car washing businesses also sell gasoline.

Potential Pollutant Generating Sources

Wash wastewater may contain detergents and waxes. Wastewater should be discharged to sanitary sewers. In self-service operations a drain is located inside each car bay. Although these businesses discharge the wastewater to the sanitary sewer, some wash water can find its way to the storm drain, particularly with the rollover and wand systems. Rollover systems often do not have air-drying.

Consequently, as it leaves the enclosure the car sheds water to the pavement. With the self-service system, wash water with detergents can spray outside the building and drain to storm sewer. Users of self-serve operations may also clean engines and change oil, dumping the used oil into the storm drain. Potential pollutants include oil and grease, detergents, soaps, BOD, and TSS.

Equipment Repair (SIC: 7353, 7600)

Description

This group includes several businesses that specialize in repairing different equipment including communications equipment, radio, TV, household appliances, and refrigeration systems. Also included are businesses that rent or lease heavy construction equipment, as miscellaneous repair and maintenance may occur on-site.

Potential Pollutant Generating Sources

Potential pollutant sources include storage and handling of fuels, waste oils and solvents, and loading/unloading areas. Potential pollutants include oil and grease, low/high pH, and suspended solids.

Laundries and Other Cleaning Services (SIC: 7211 through 7217)

Description

This category includes all types of cleaning services such as laundries, linen suppliers, diaper services, coin-operated laundries and dry cleaners, and carpet and upholstery services. Wet washing may involve the use of acids, bleaches and/or multiple organic solvents. Dry cleaners use an organic-based solvent, and sometimes small amounts of water and detergent. Solvents may be recovered and filtered for further use. Carpets and upholstery may be cleaned with dry materials, hot water extraction processes, or in-plant processes using solvents followed by a detergent wash.

Potential Pollutant Generating Sources

Wash liquids are discharged to sanitary sewers. Stormwater pollutant sources include: loading and unloading of liquid materials, particularly at large commercial operations, disposal of spent solvents and solvent cans, high-use customer parking lots, and outside storage and handling of solvents and waste materials. Potential stormwater contaminants include oil and grease, chlorinated and other solvents, soaps and detergents, low/high pH, and suspended solids.

Marinas and Boat Clubs (SIC: 7999)

Description

Marinas and yacht clubs provide moorage for recreational boats. Marinas may also provide fueling and maintenance services. Other activities include cleaning and painting of boat surfaces, minor boat repair, and pumping of bilges and sanitary holding tanks. Not all marinas have a system to receive pumped bilge water.

Potential Pollutant Generating Sources

Both solid and liquid wastes are produced as well as stormwater runoff from high-use customer parking lots. Waste materials include sewage and bilge water. Maintenance by the tenants will produce used oils, oil filters, solvents, waste paints and varnishes, used batteries, and empty contaminated containers and soiled rags. Potential stormwater contaminants include oil and grease, suspended solids, heavy metals, and low/high pH. Boat wash water is industrial waste water and must not be directed to stormwater inlets, Resource Areas, or groundwaters. It must be captured, pretreated, and then directed to a publicly owned treatment works (POTW). Permission from the POTW is required to dispose of the boat wash wastewater. The POTW may have specific pretreatment requirements. For assistance, contact the Massachusetts Office of Coastal Zone Management (MCZM).

Golf and Country Clubs (SIC: 7992, 7997)

Description

Public and private golf courses and parks are included.

Potential Pollutant Generating Sources

Maintenance of grassed areas and landscaped vegetation has historically required the use of fertilizers and pesticides. Golf courses contain small lakes that are sometimes treated with algaecides and/or mosquito larvicides. The fertilizer and pesticide application process can lead to inadvertent contamination of nearby Surface Waters by overuse, misapplication, or the occurrence of storms shortly after application. Heavy watering of surface greens in golf courses may cause pesticides or fertilizers to migrate to surface and shallow groundwater resources. The use of pesticides and fertilizers generates waste containers. Equipment must be cleaned and maintained.

Miscellaneous Services (SIC: 4959, 7260, 7312, 7332, 7333, 7340, 7395, 7641, 7990, 8411)

Description

This group includes photographic studios, commercial photography, funeral services, amusement parks, furniture and upholstery repair and pest control services, and other professional offices. Pollutants from these activities can include pesticides, waste solvents, heavy metals, pH, and suspended solids, soaps and detergents, and oil and grease.

Potential Pollutant Generating Sources

Leaks and spills of materials from the following businesses can be sources of stormwater pollutants:

1. Building maintenance produces wash and rinse solutions, oils, and solvents.
2. Pest control produces rinse water with residual pesticides from washing application equipment and empty containers.
3. Outdoor advertising produces photographic chemicals, inks, waste paints, and organic paint sludges containing metals.
4. Funeral services produce formalin, formaldehyde, and ammonia.
5. Upholstery and furniture repair businesses produce oil, stripping compounds, wood preservatives and solvents.

Professional Services (SIC: 6000, 7000 and 8000, 806, 807)

Description

The remaining service businesses include theaters, hotels/motels, finance, banking, hospitals, medical/dental laboratories, medical services, nursing homes, schools/universities, and legal, financial and engineering services. Stormwater from parking lots will contain undesirable concentrations of oil and grease, suspended particulates, and metals such as lead, cadmium and zinc. Dangerous wastes might be generated at hospitals, nursing homes and other medical services.

Potential Pollutant Generating Sources

The primary concern is runoff from high-use parking areas, maintenance shops, and storage and handling of dangerous wastes.

Vehicle Maintenance and Repair (SIC: 4000, 7530, 7600)

Description

This category includes businesses that paint, repair and maintain automobiles, motorcycles, trucks, and buses and battery, radiator, muffler, lube, tune-up and tire shops, excluding those businesses listed elsewhere in this manual.

Potential Pollutant Generating Sources

Pollutant sources include storage and handling of vehicles, solvents, cleaning chemicals, waste materials, vehicle liquids, batteries, and washing and steam-cleaning of vehicles, parts, and equipment. Potential pollutants include waste oil, solvents, degreasers, antifreeze, radiator flush, acid solutions with chromium, zinc, copper, lead and cadmium, brake fluid, soiled rags, oil filters, sulfuric acid and battery sludge, and machine chips in residual machining oil. Floor drains are prohibited. Dry shop techniques for maintenance should be utilized to reduce generation of liquids.

Construction Businesses (SIC: 1500, 1600, and 1700)

Description

This category includes builders of homes, commercial and industrial buildings, and heavy equipment as well as plumbing, painting and paper hanging, carpentry, electrical, roofing and sheet metal, wrecking and demolition, stonework, drywall, and masonry contractors. It does not include construction sites.

Potential Pollutant Generating Sources

Potential pollutant sources include leaks/spills of used oils, solvents, paints, batteries, acids, strong acid/alkaline wastes, paint/varnish removers, tars, soaps, coatings, asbestos, lubricants, anti-freeze compounds, litter, and fuels at the headquarters, operation, staging, and maintenance/repair locations of the businesses. Demolition contractors may store reclaimed material before resale.

Roofing contractors generate residual tars and sealing compounds, spent solvents, kerosene, and soap cleaners, as well as non-hazardous-waste roofing materials. Sheet metal contractors produce small quantities of acids and solvent cleaners such as kerosene, metal shavings, adhesive residues and enamel coatings, and asbestos residues that have been removed from buildings. Asphalt paving contractors are likely to store application equipment such as dump trucks, pavers, tack coat tankers and pavement rollers at their businesses. Stormwater passing through this equipment may be contaminated by the petroleum residuals. Potential pollutants include oil and grease, suspended solids, BOD, heavy metals, pH, COD, and organic compounds. A Construction Period Erosion Sedimentation Pollution Prevention Plan (CPPP) must be prepared and implemented as part of any alteration proposed to a wetland Resource Area. The CPPP must be submitted as part of the wetlands Notice of Intent or Water Quality Certification application. Additionally, if the proposed land disturbance is ≥1-acre, a Construction Period Stormwater Pollution Prevention Plan (SWPPP) must be prepared and implemented pursuant to the EPA Construction General Permit (CGP). The CGP requires construction contractors to submit a Notice of Intent to EPA to apply for coverage under the CGP.

The purpose of the CPPP and SWPPP is utilize source controls to prevent construction period runoff from being discharged to Resource Areas and Waters of the United States.

Vehicle Washing

Description

This management measure involves educating the general public, businesses, and municipal fleets (public works, school buses, fire, police, and parks) on the water quality impacts of the outdoor washing of automobiles and how to avoid allowing polluted runoff to enter the storm drain system.

Outdoor car (aka vehicle) washing has the potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions in many water- sheds, as the detergent-rich water used to wash the grime off our cars flows down the street and into the storm drain. Commercial car wash facilities often recycle their water or are required to treat their wash water discharge prior to release to the sanitary sewer system. As a result, most storm water impacts from car washing are from residents, businesses, and charity car wash fundraisers that discharge polluted wash water to the storm drain system.

According to the surveys, 55 to 70 percent of households wash their own cars, with the remainder going to a commercial car wash. Sixty percent of residents could be classified as "chronic car-washers" who wash their cars at least once a month (Smith, 1996, and Hardwick, 1997). Between 70 to 90 percent of residents reported that their car wash water drained directly to the street and, presumably, to the nearest stream.

Applicability

Car washing is a common routine for residents and a popular way for organizations such as scout troops, schools, and sports teams to raise funds. This activity is not limited by geographic region, but its impact on water quality is greatest in more urbanized areas with higher concentrations of automobiles.

Currently, only a few pollution prevention programs incorporate proper car washing practices as part of an overall message to residents on ways to reduce nonpoint source pollution. Other programs have extended this message to include charity car washes and provide these charity groups with equipment and training to alleviate the problems associated with polluted wash water entering the storm drain system.

Implementation

The development of a prevention program to reduce the impact of car wash runoff includes outreach on management practices to reduce discharges to storm drains. Some of these management practices include the following:

- Using a commercial car wash.
- Washing cars on gravel, grass, or other permeable surfaces.
- Blocking off the storm drain during charity carwash events or using an insert to catch wash water.
- Pumping soapy water from car washes into a sanitary sewer drain.
- If pumping into a drain is not feasible, pumping car wash water onto grass or landscaping to provide filtration.
- Using hoses with nozzles that automatically turn off when left unattended.
- Using only biodegradable soaps.
- Minimize the amounts of soap and water used. Wash cars less frequently.
- For businesses, good housekeeping practices can minimize the risk of contamination from wash water discharges. The following are general best management practices that businesses with their own vehicle washing facilities can incorporate to control water quality impacts from wash water discharges:
- All vehicle washing should be done in areas designed to collect and hold the wash and rinse water or effluent generated. Wash water effluent should be recycled, collected, or treated prior to discharge to the sanitary sewer system.
- Pressure cleaning and steam cleaning should be done off-site to avoid generating runoff with high pollutant concentrations. If done on-site, no pressure cleaning and steam cleaning should be done in areas designated as wellhead protection areas for Public Water Supply.
- On-site storm drain locations should be mapped to avoid discharges to the storm drain system or to wetland Resource Areas.
- Spills should be immediately contained and treated.

Effectiveness

The effectiveness of car washing management practices at reducing nonpoint source pollutant loads has yet to be measured accurately. Due to the diffuse nature of nonpoint source pollution, it is often difficult to determine the exact impact of a particular pollution prevention measure at reducing pollutant loading. While not much is known about the water quality of car wash water, it is clear that car washing is a common behavior.

Residents are typically not aware of the water quality consequences of car washing and do not understand the chemical content of the soaps and detergents they use. Car washing is a very difficult watershed behavior to change since it is often hard to define a better alternative. However, as with all pollution prevention measures, the reduction of pollutant loads from outdoor car washing activities are bound to have a positive effect on storm water quality.

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Road Salt Storage and Snow Disposal

This section addresses snow disposal and road salt storage. Snow dumps in or near Wetland Resource Areas or Buffer Zones, or plowing of snow directly into Wetland Resource Areas can alter wetlands. The application and storage of deicing materials, most commonly salts such as sodium chloride, can lead to water quality problems for surrounding areas. Salts, gravel, sand, and other materials are applied to highways and roads to reduce the amount of ice during winter storm events. Salts lower the melting point of ice, allowing roadways to stay free of ice buildup during cold winters. Sand and gravel increase traction on the road, making travel safer.

Snow Disposal

MassDEP has developed a guidance document for communities regarding snow disposal, available on the web at: https://www.mass.gov/guides/snow-disposal-guidance. The guidance applies to all federal agencies, state agencies, state authorities, municipal agencies and private businesses disposing of snow in the Commonwealth of Massachusetts.

Finding a place to dispose of collected snow poses a challenge to municipalities and businesses as they clear roads, parking lots, bridges, and sidewalks. While MassDEP is aware of the threats to public safety caused by snow, collected snow that is contaminated with road salt, sand, litter, and automotive pollutants such as oil also threatens public health and the environment.

As snow melts, road salt, sand, litter, and other pollutants are transported into Surface Water or through the soil where they may eventually reach the groundwater. Road salt and other pollutants can contaminate water supplies and are toxic to aquatic life at certain levels. Sand washed into waterbodies can create sand bars or fill in wetlands and ponds, impacting aquatic life, causing flooding, and affecting our use of these resources.

There are several steps that communities can take to minimize the impacts of snow disposal on public health and the environment. These steps will help communities avoid the costs of a contaminated water supply, degraded waterbodies, and flooding. Everything that occurs on the land has the potential to impact the Commonwealth's water resources.

The snow disposal guidelines address: (1) site selection; (2) site preparation and maintenance; and (3) emergency snow disposal.

Site Selection

The key to selecting effective snow disposal sites is to locate them adjacent to or on pervious surfaces in upland areas or upland locations on impervious surfaces away from water resources and drinking water wells. At these locations, the snow meltwater can filter into the soil, leaving behind sand and debris which can be removed in the spring. The following conditions should be followed:

- Within water supply Zone A and Zone II, avoid storage or disposal of snow and ice containing deicing chemicals that has been collected from streets located outside these zones. Municipalities may have a water supply protection land use control that prohibits the disposal of snow and ice containing deicing chemicals from outside the Zone A and Zone II, subject to the Massachusetts Drinking Water Regulations at 310 CMR 22.20C and 310 CMR 22.21(2).
- Avoid storage or disposal of snow or ice in Interim Wellhead Protection Areas (IWPA) of Public Water Supply wells, and within 75 feet of a private well, where road salt may contaminate water supplies.
- Avoid dumping snow into any waterbody, including rivers, the ocean, reservoirs, ponds, or wetlands. In addition to water quality impacts and flooding, snow disposed of in open water can cause navigational hazards when it freezes into ice blocks.
- Avoid dumping snow on MassDEP-designated high and medium-yield aquifers where it may contaminate groundwater.
- Avoid dumping snow in sanitary landfills and gravel pits. Snow meltwater will create more contaminated leachate in landfills posing a greater risk to groundwater, and in gravel pits, there is little opportunity for pollutants to be filtered out of meltwater because groundwater is close to the land surface.
- Avoid disposing snow on top of storm drain catch basins or in stormwater drainage systems including detention basins, swales or ditches. Snow combined with sand and debris may block a stormwater drainage system, causing localized flooding. A high volume of sand, sediment, and litter released from melting snow also may be quickly transported through the system into Surface Water.

Recommended Site Selection Procedures

It is important that the municipal Department of Public Works or Highway Department, Conservation Commission, and Board of Health work together to select appropriate snow disposal sites. The following steps should be taken:

- Estimate how much snow disposal capacity may be needed for the season so that an adequate number of disposal sites can be selected and prepared.
- Identify sites that could potentially be used for snow disposal, such as municipal open space (e.g., parking lots or parks).
- Select sites located in upland locations that are not likely to impact sensitive environmental resources first.
- If more storage space is still needed, prioritize the sites with the least environmental impact (using the site selection criteria, and local or MassGIS maps as a guide).

Snow Disposal Mapping Assistance

MassDEP has an online mapping tool to assist in identifying possible locations to potentially dispose of snow. MassDEP encourages municipalities to use this tool to identify possible snow disposal options. The tool identifies wetland Resource Areas, public drinking water supplies and other sensitive locations where snow should not be disposed. The tool may be accessed through the Internet at the following web address: https://maps.env.state.ma.us/dep/arcgis/js/templates/PSF/.

Site Preparation and Maintenance

In addition to carefully selecting disposal sites before the winter begins, it is important to prepare and maintain these sites to maximize their effectiveness. The following maintenance measures should be undertaken for all snow disposal sites:

- A silt fence or equivalent barrier should be placed securely on the downgradient side of the snow disposal site.
- Wherever possible maintain a 50-foot vegetated buffer between the disposal site and adjacent waterbodies to filter pollutants from the meltwater.
- Clear debris from the site prior to using the site for snow disposal.
- Clear debris from the site and properly dispose of it at the end of the snow season, and no later than May 15.

Snow Disposal Approvals

Proper snow disposal may be undertaken through one of the following approval procedures:

- **Routine snow disposal**: Minimal, if any, administrative review is required in these cases when upland and pervious snow disposal locations or upland locations on impervious surfaces that have functioning and maintained stormwater management systems have been identified, mapped, and used for snow disposal following ordinary snowfalls. Use of upland and pervious snow disposal sites avoids wetland Resource Areas and allows snow meltwater to recharge groundwater and will help filter pollutants, sand, and other debris. This process will address the majority of snow removal efforts until an entity exhausts all available upland snow disposal sites. The location and mapping of snow disposal sites will help facilitate each entity's routine snow management efforts.

- **Emergency Certifications:** If an entity demonstrates that there is no remaining capacity at upland snow disposal locations, local Conservation Commissions may issue an Emergency Certification under the Massachusetts Wetlands Protection regulations to authorize snow disposal in Buffer Zones to wetlands, certain open water areas, and certain wetland Resource Areas (i.e., within flood plains). Emergency Certifications can only be issued at the request of a public agency or by order of a public agency for the protection of the health or safety of citizens, and are limited to those activities necessary to abate the emergency. See 310 CMR 10.06(1)-(4). Use the following guidelines in these emergency situations:
    - Dispose of snow in open water with adequate flow and mixing to prevent ice dams from forming.
    - Do not dispose of snow in salt marshes, vegetated wetlands, certified vernal pools, shellfish beds, mudflats, drinking water reservoirs and their tributaries, Zone IIs or IWPAs of Public Water Supply wells, Outstanding Resource Waters, or Areas of Critical Environmental Concern.
    - Do not dispose of snow where trucks may cause shoreline damage or erosion.
    - Consult with the municipal Conservation Commission to ensure that snow disposal in open water complies with local ordinances and bylaws.

- **Severe Weather Emergency Declarations** – In the event of a large-scale severe weather event, MassDEP may issue a broader Emergency Declaration under the Wetlands Protection Act which allows federal agencies, state agencies, state authorities, municipalities, and businesses greater flexibility in snow disposal practices. Emergency Declarations typically authorize greater snow disposal options while protecting especially sensitive resources such as public drinking water supplies, vernal pools, land containing shellfish, FEMA designated floodways, coastal dunes, and salt marsh. In the event of severe winter storm emergencies, the snow disposal site maps created by municipalities will enable MassDEP and the Massachusetts Emergency Management Agency (MEMA) in helping communities identify appropriate snow disposal locations.

  If upland disposal sites have been exhausted, the Emergency Declaration issued by MassDEP allows for snow disposal near water bodies. In these situations, a buffer of at least 50 feet, preferably vegetated, should still be maintained between the site and the waterbody. Furthermore, it is essential that the other guidelines for preparing and maintaining snow disposal sites be followed to minimize the threat to adjacent waterbodies.

  Under extraordinary conditions, when all land-based snow disposal options are exhausted, the Emergency Declaration issued by MassDEP may allow disposal of snow in certain waterbodies under certain conditions. ***A federal agency, state agency, state authority, municipality or business seeking to dispose of snow in a waterbody should take the following steps***:

  - Call the emergency phone number [(888) 304-1133)] and notify the MEMA of the municipality's intent.
  - MEMA will ask for information about where the disposal will take place.
  - MEMA will confirm that disposal is consistent with MassDEP's Severe Weather Emergency Declaration and these guidelines and is therefore approved.

Deicer/Road Salt Storage

MassDEP has developed a guidance document for communities regarding storage of road salt or chemical deicing agents, available on the web at: https://www.mass.gov/guides/guidelines-on-road-salt-storage. The guidance applies to all parties storing road salt or other chemical deicing agents. This practice is applicable to areas that receive snowfall in winter months and require deicing materials. Municipalities in these areas must ensure proper storage and application for equipment and materials and identify appropriate areas for snow disposal.

Deicing Materials

To prevent increased pollutant concentrations in stormwater discharges, the amount of road salt applied should be reduced. Calibration devices for spreaders in trucks aid maintenance workers in the proper application of road salts. Many drinking water supply watersheds in Massachusetts use lower amounts of road salt to protect the resource. Reduced salt areas should be designated next to roads and wetlands. The amount of salt applied should be varied to reflect site-specific characteristics, such as road width and design, traffic concentration, and proximity to Surface Waters. Alternative materials, such as sand or gravel, calcium chloride, and calcium magnesium acetate may be used in especially sensitive areas. Information about road deicing materials can also be found at the American Association of State Highway and Transportation Officials web site at: http://www.transportation.org/.

Proper Storage of Deicing Materials

Proper snow management includes proper storage of deicing materials. Although covering stored road salts may be costly, the benefits are greater than the perceived costs. Correct road salt storage prevents salt from lumping together, which makes it easier to load and apply. Covering salt storage piles reduces salt loss from stormwater runoff and potential contamination to streams, aquifers, and estuarine areas. Salt storage piles should be located outside the 100-year floodplain for further protection against Surface Water contamination.

The Massachusetts General Laws, Chapter 85, Section 7A, forbid outside storage of salt in areas that would threaten groundwater and Surface Water sources for public water supplies or within 200 feet of an established river or estuary. Outside Zone IIs, Zone As and 200 feet of established rivers or estuaries, road salt and other deicing compounds must be stored on sheltered (protected from precipitation and wind), impervious pads. Internal flow within the shelter must be directed to a collection system and external flow directed around the shelter.

The Drinking Water Regulations require municipalities proposing new water sources to enact land use controls that prohibit the uncovered, uncontained storage of road deicing materials within:

- Wellhead Protection Areas (Zone I and Zone II) for Public Water Supply wells and
- Zone A for new public supply reservoirs

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Appendix B

EPA SCM Performance Removal Curves

Contents

Preface

Region 1 of the Environmental Protection Agency (EPA) developed pollutant removal performance curves ("EPA Performance Removal Curves", "EPA-PRC") for the Small MS4 Permit. The EPA-PRCs are located in version 2.0 of the BMP Accounting & Tracking Tool (BMP-BATT) published by EPA on June 30, 2021. The BATT is a spreadsheet-based tool that provides accounting, tracking, and reporting for pollutant load reductions from SCMs. The purpose of the tool is to provide permittees, developers, and watershed managers means to account for and track pollutant load reductions over time. Files are located at the below websites.

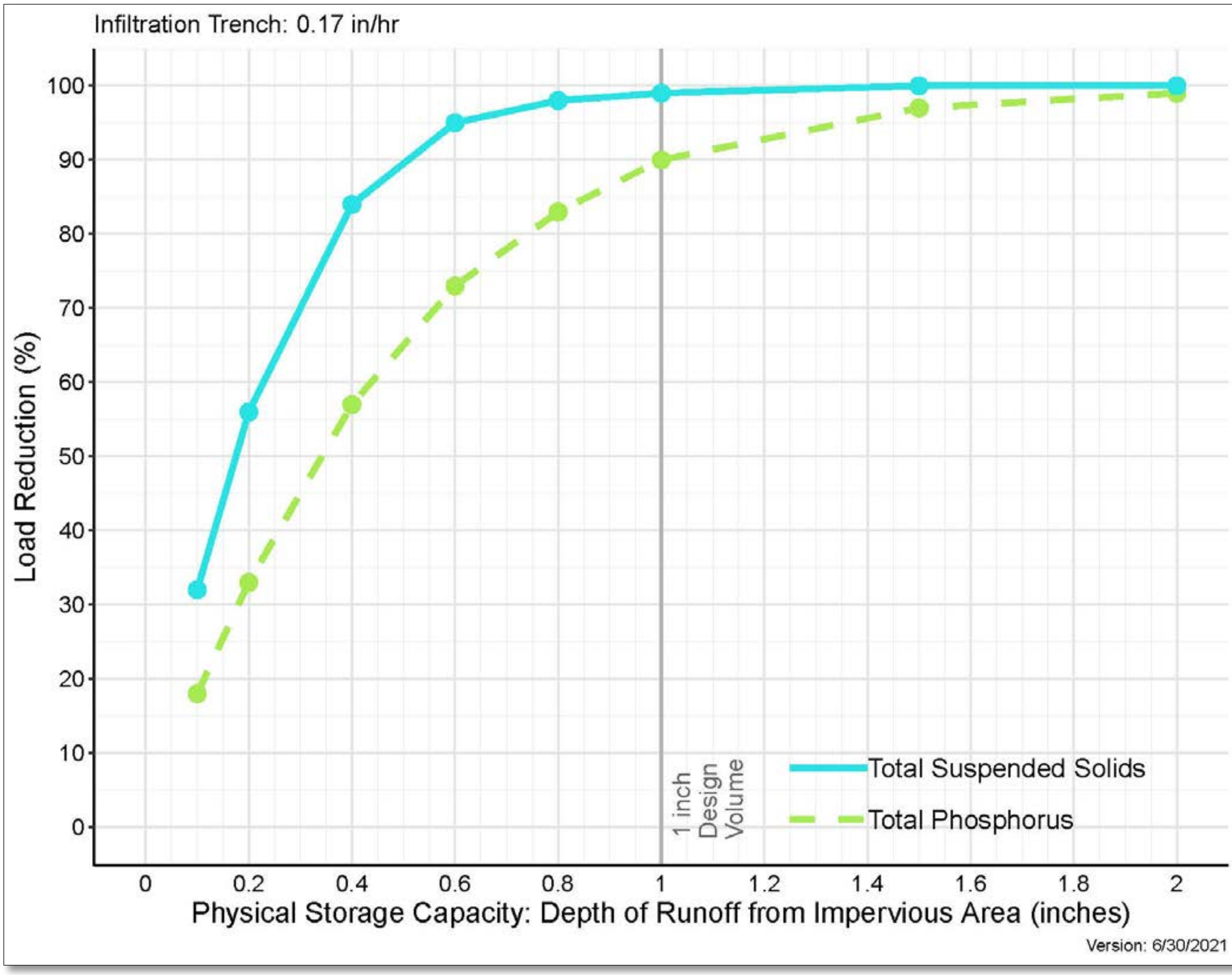
MassDEP has created this Appendix to memorialize tabular and graphical versions of the EPA-PRC's that are embedded in version 2.0 of the BMP-BATT. These PRC's may be used to perform pollutant removal calculations as required by Standard 4 and Standard 7 of 310 CMR 10.05(6)(k). As indicated in 310 CMR 10.04, MassDEP will presume that updated versions of the EPA-PRC meet the relevant pollutant removal standards. As such, Applicants are encouraged to use updated versions of the EPA-PRCs and the BMP-BATT as they become available. For SCMs not listed in this Appendix, pollutant removal is calculated using the MassDEP removal credits as shown in the MassDEP Crosswalk Table in **Section 2.3.4** of the Massachusetts Stormwater Handbook. Refer to the Massachusetts Stormwater Handbook and 310 CMR 10.05(6)(k) for more information on pollutant removal requirements and calculations.

EPA BMP-BATT Resources:

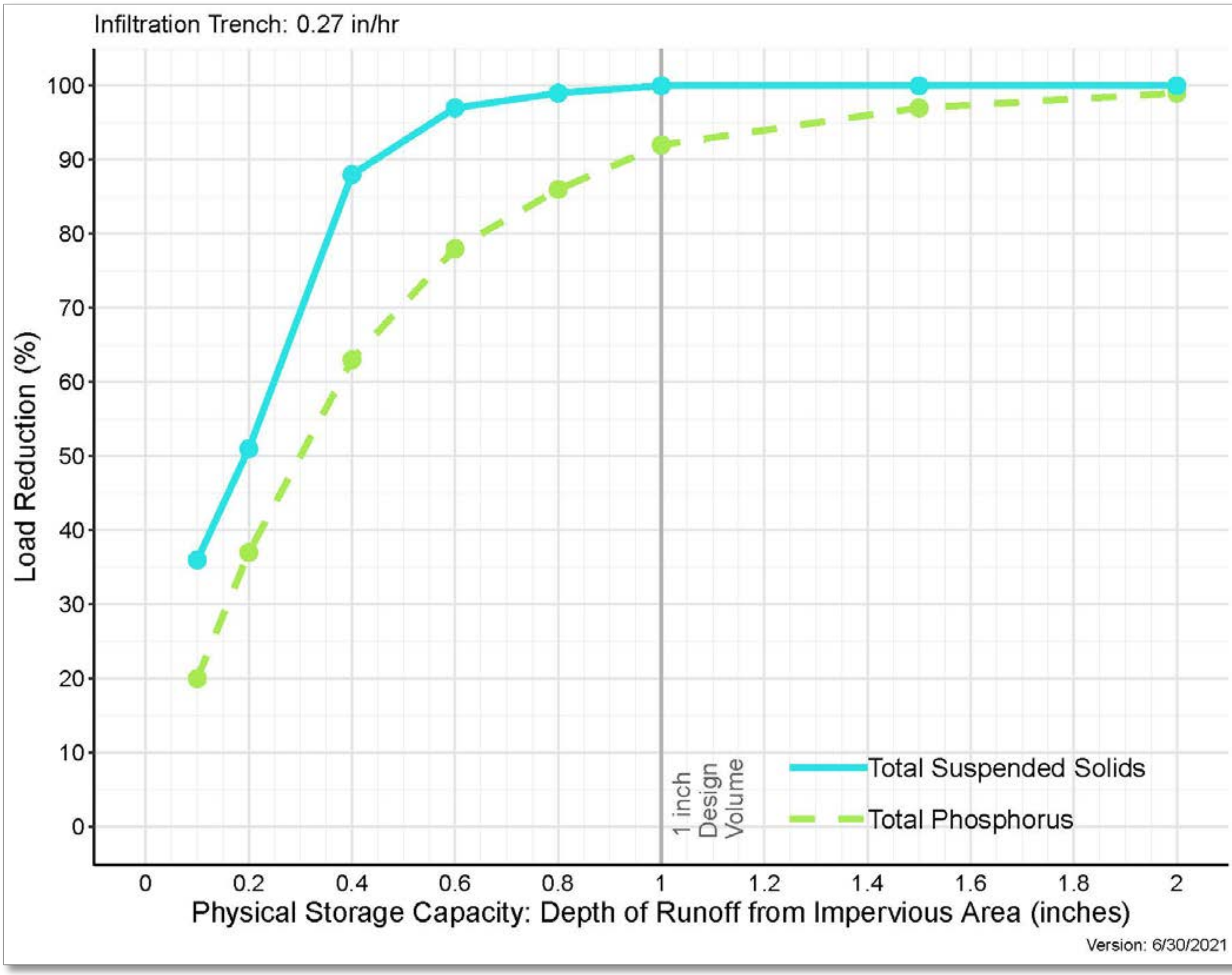
- BATT Tool Spreadsheet: https://www3.epa.gov/region1/npdes/stormwater/tools/batt-bmp-accounting-tracking-tool-v2-1.xlsm
- BATT Tool Version 2.1 User Guide: https://www3.epa.gov/region1/npdes/stormwater/tools/batt-users-guide-v2-1.pdf

Infiltration Trench Series

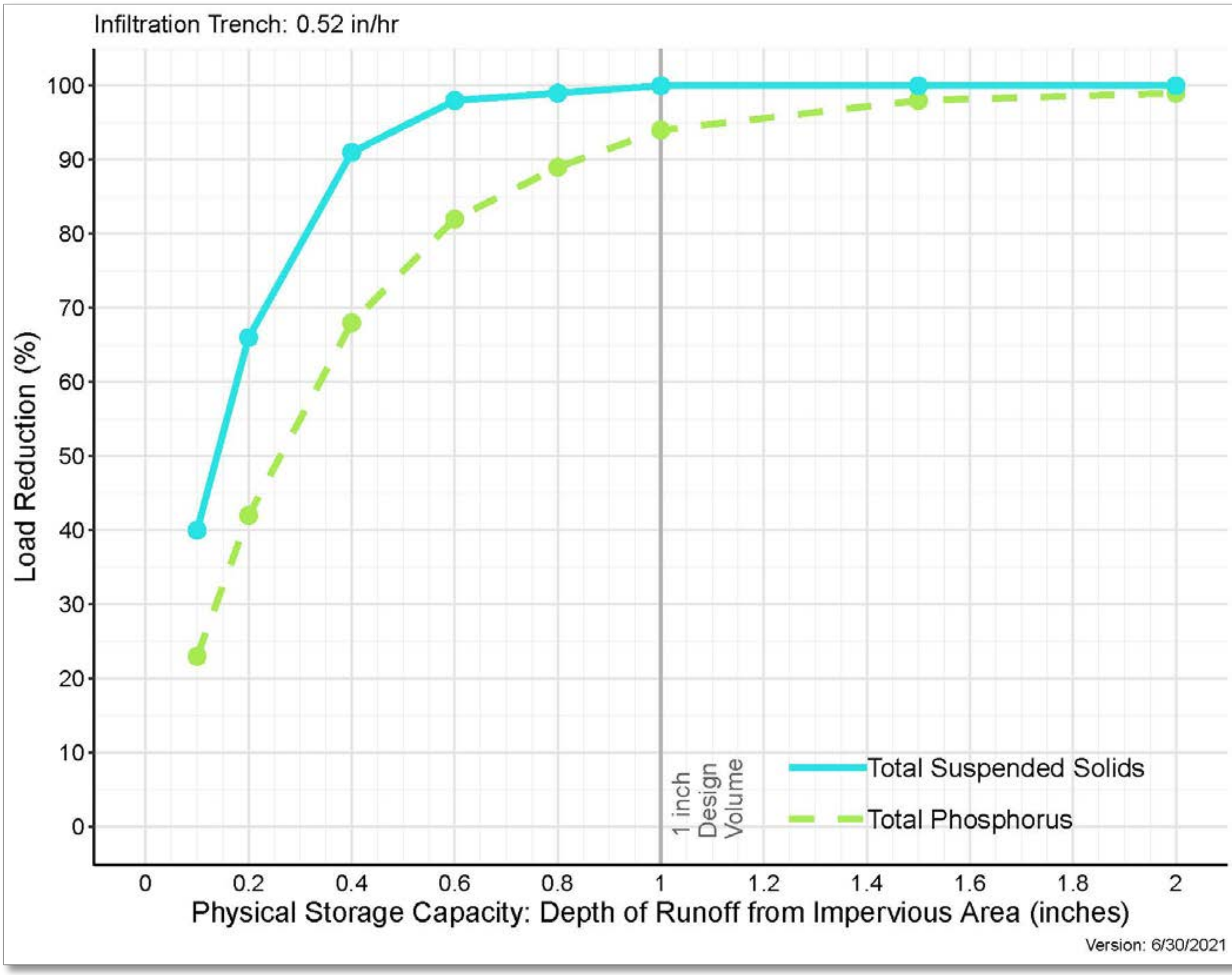
The Infiltration Trench Series includes an EPA-PRC for six different infiltration rates: 0.17, 0.27. 0.52, 1.02, 2.41, and 8.27 inches per hour.



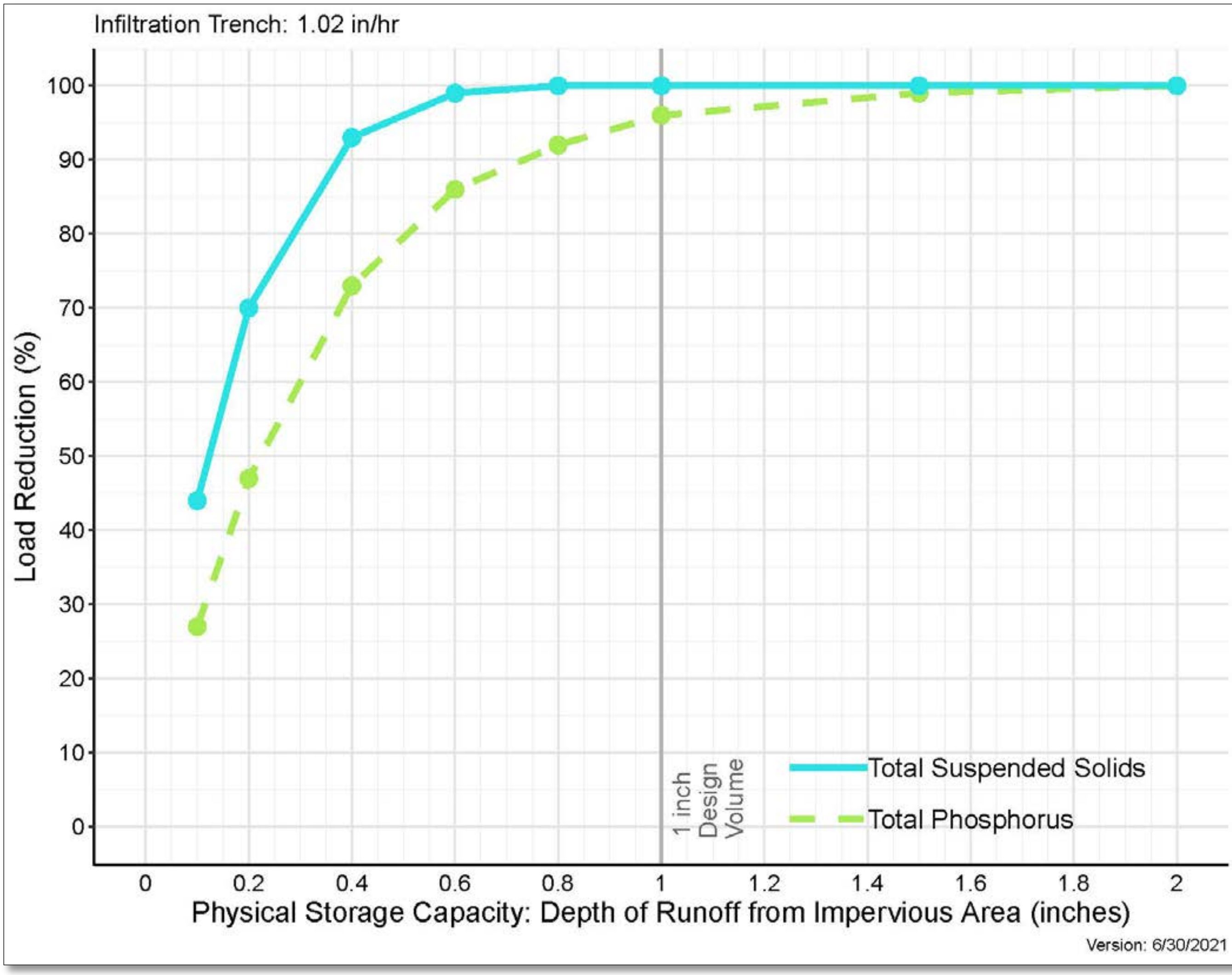
Infiltration Trench (0.17 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	18.0%	33.0%	57.0%	73.0%	83.0%	90.0%	97.0%	99.0%
Cumulative TSS Load Reduction	32.0%	56.0%	84.0%	95.0%	98.0%	99.0%	100.0%	100.0%



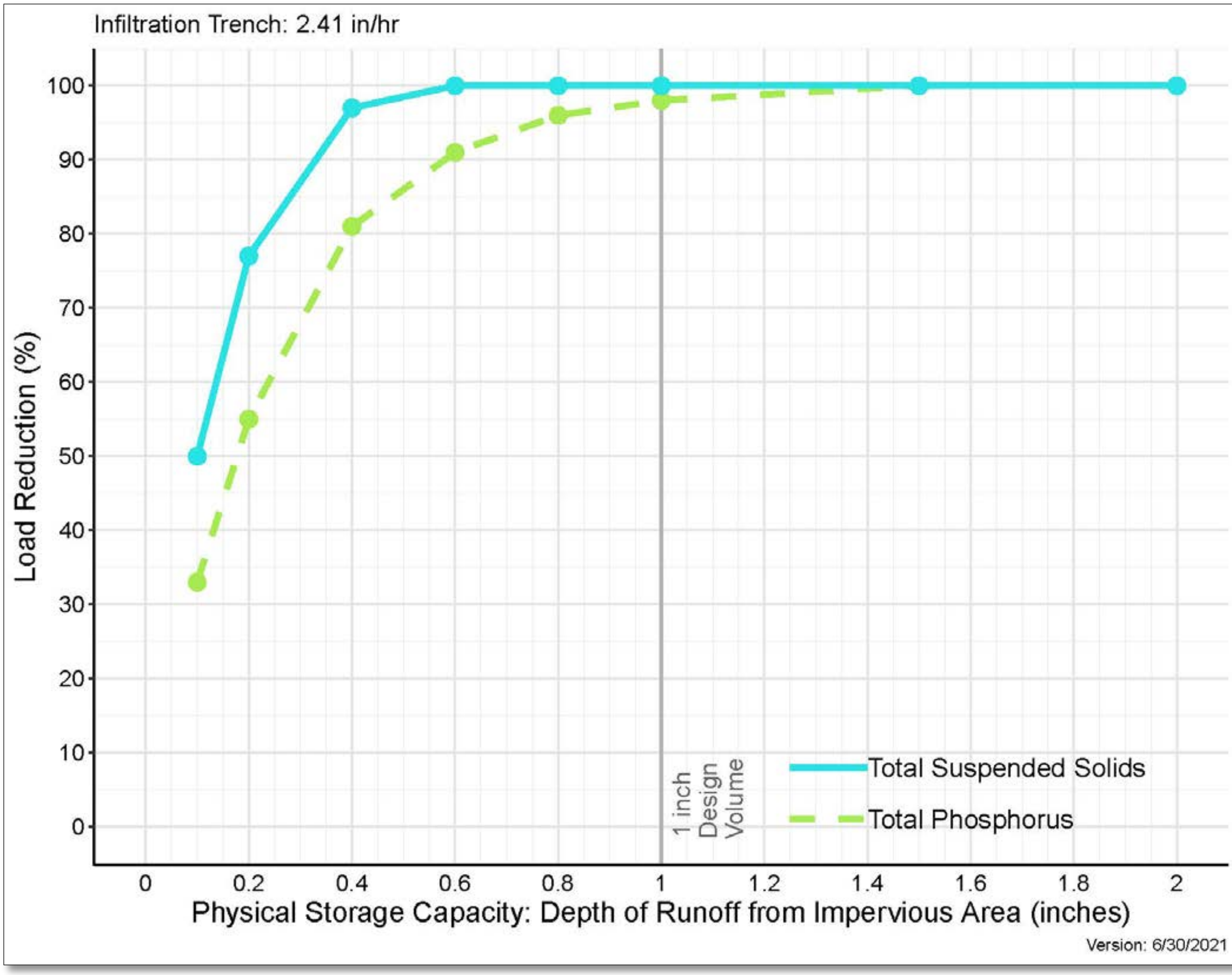
Infiltration Trench (0.27 in/hr) BMP Performance Table: Long-Term Load Reduction						
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1
Cumulative Phosphorus Load Reduction	20.0%	37.0%	63.0%	78.0%	86.0%	92.0%
Cumulative TSS Load Reduction	36.0%	51.0%	88.0%	97.0%	99.0%	100.0%



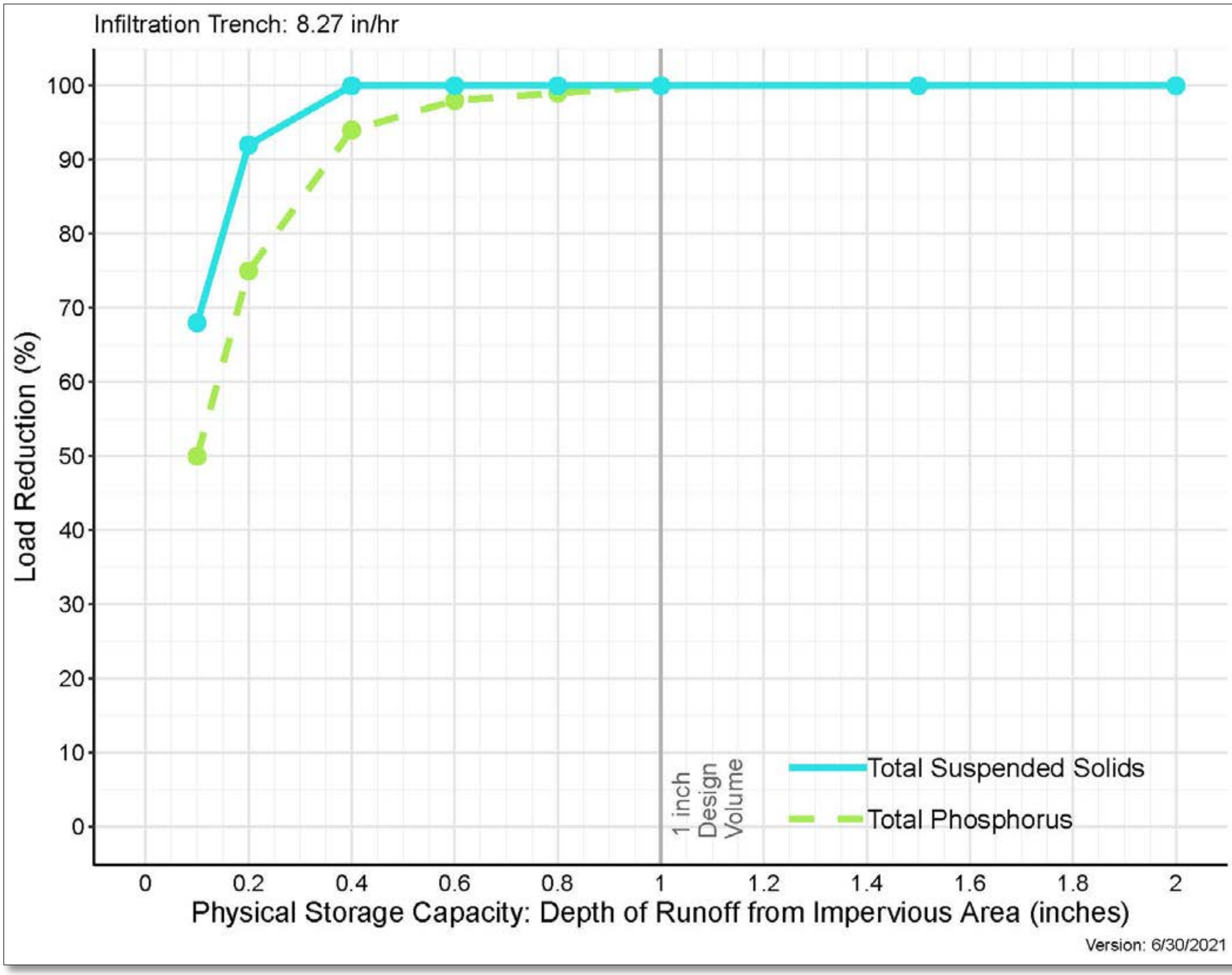
Infiltration Trench (0.52 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	23.0%	42.0%	68.0%	82.0%	89.0%	94.0%	98.0%	99.0%
Cumulative TSS Load Reduction	40.0%	66.0%	91.0%	98.0%	99.0%	100.0%	100.0%	100.0%



Infiltration Trench (1.02 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	27.0%	47.0%	73.0%	86.0%	92.0%	96.0%	99.0%	100.0%
Cumulative TSS Load Reduction	44.0%	70.0%	93.0%	99.0%	100.0%	100.0%	100.0%	100.0%



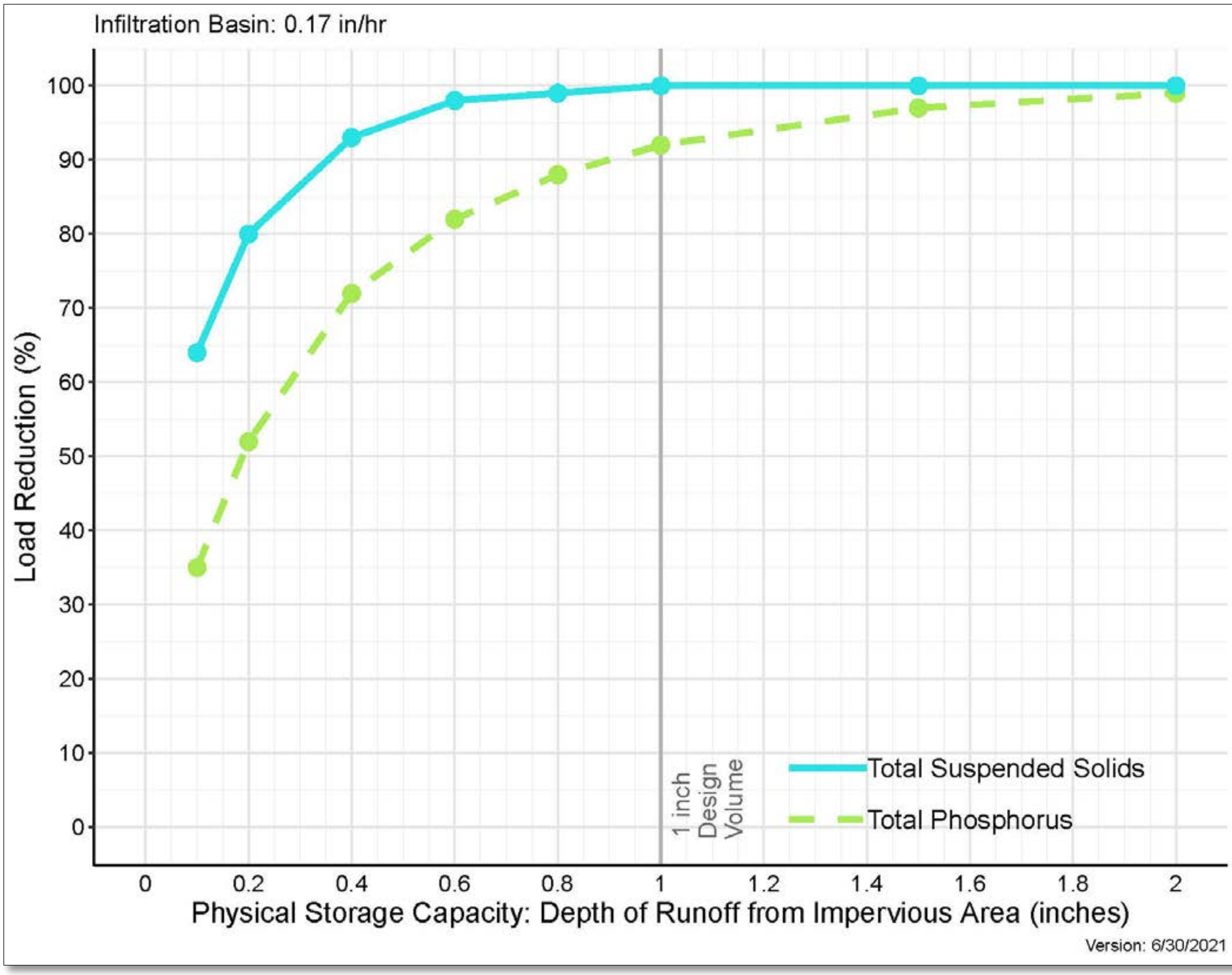
Infiltration Trench (2.41 in/hr) BMP Performance Table: Long-Term Phosphorus Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	33.0%	55.0%	81.0%	91.0%	96.0%	98.0%	100.0%	100.0%
Cumulative TSS Load Reduction	50.0%	77.0%	97.0%	100.0%	100.0%	100.0%	100.0%	100.0%



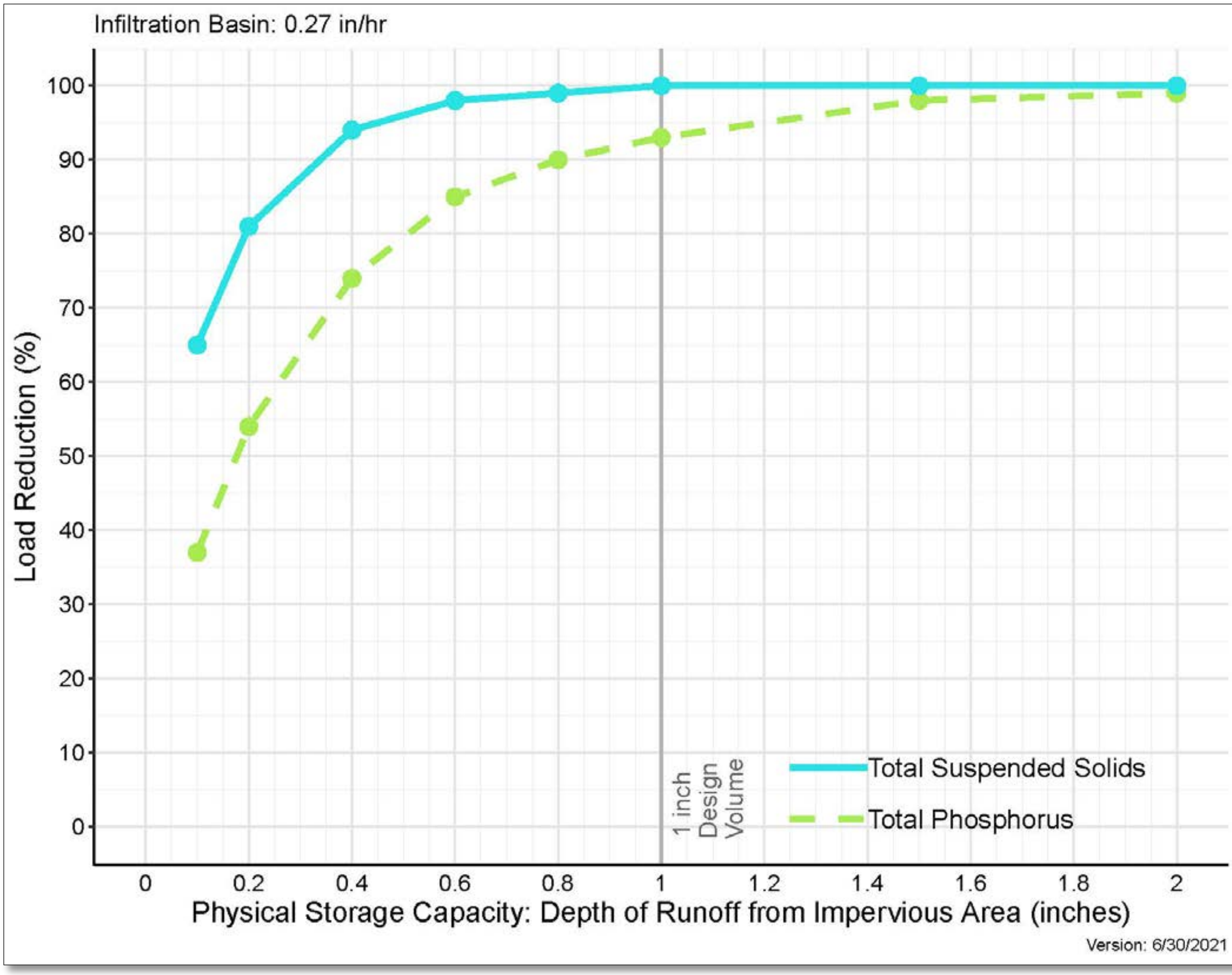
Infiltration Trench (8.27 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	50.0%	75.0%	94.0%	98.0%	99.0%	100.0%	100.0%	100.0%
Cumulative TSS Load Reduction	68.0%	92.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Infiltration Basin Series

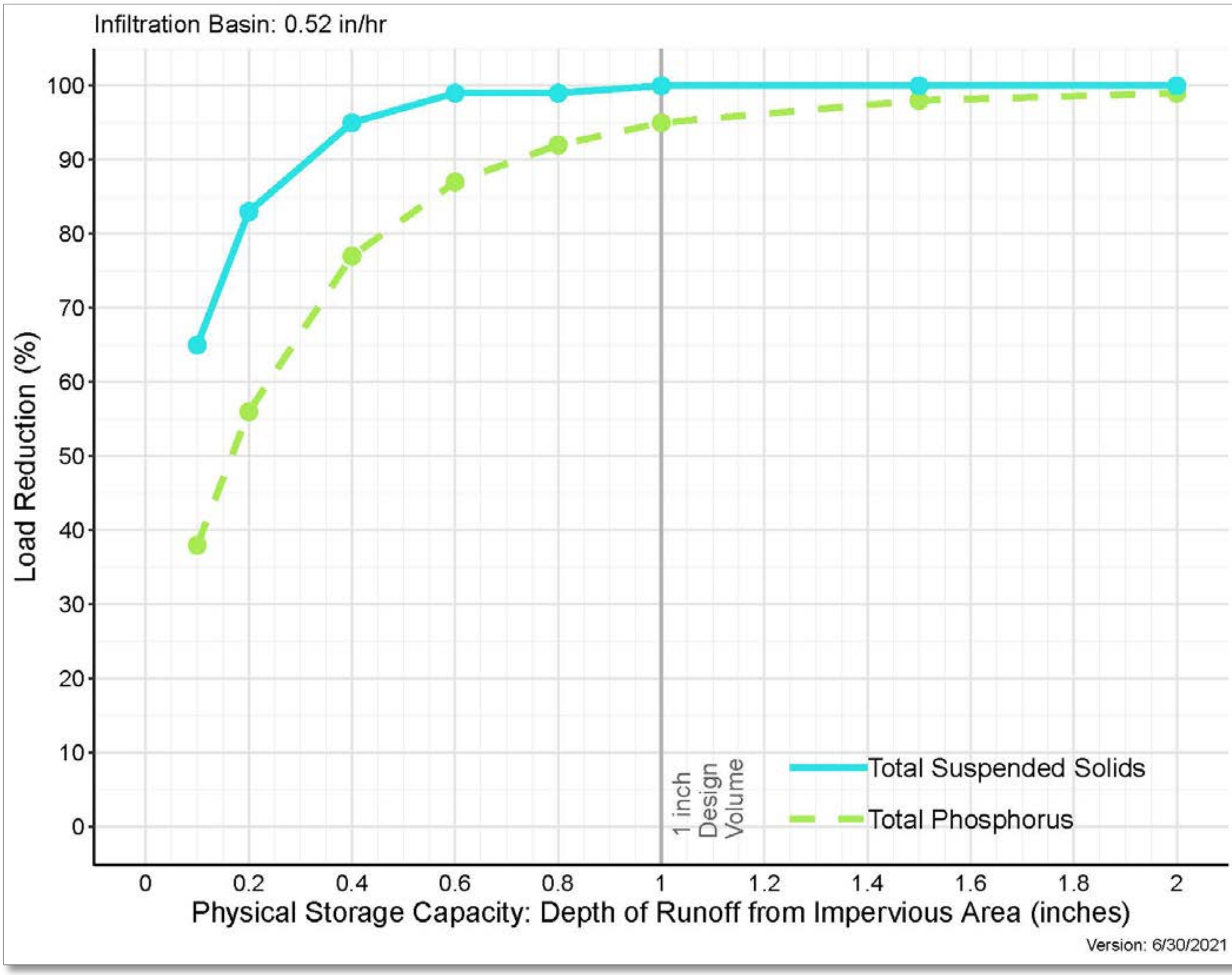
The Infiltration Basin Series includes an EPA-PRC for six different infiltration rates: 0.17, 0.27. 0.52, 1.02, 2.41, and 8.27 inches per hour.



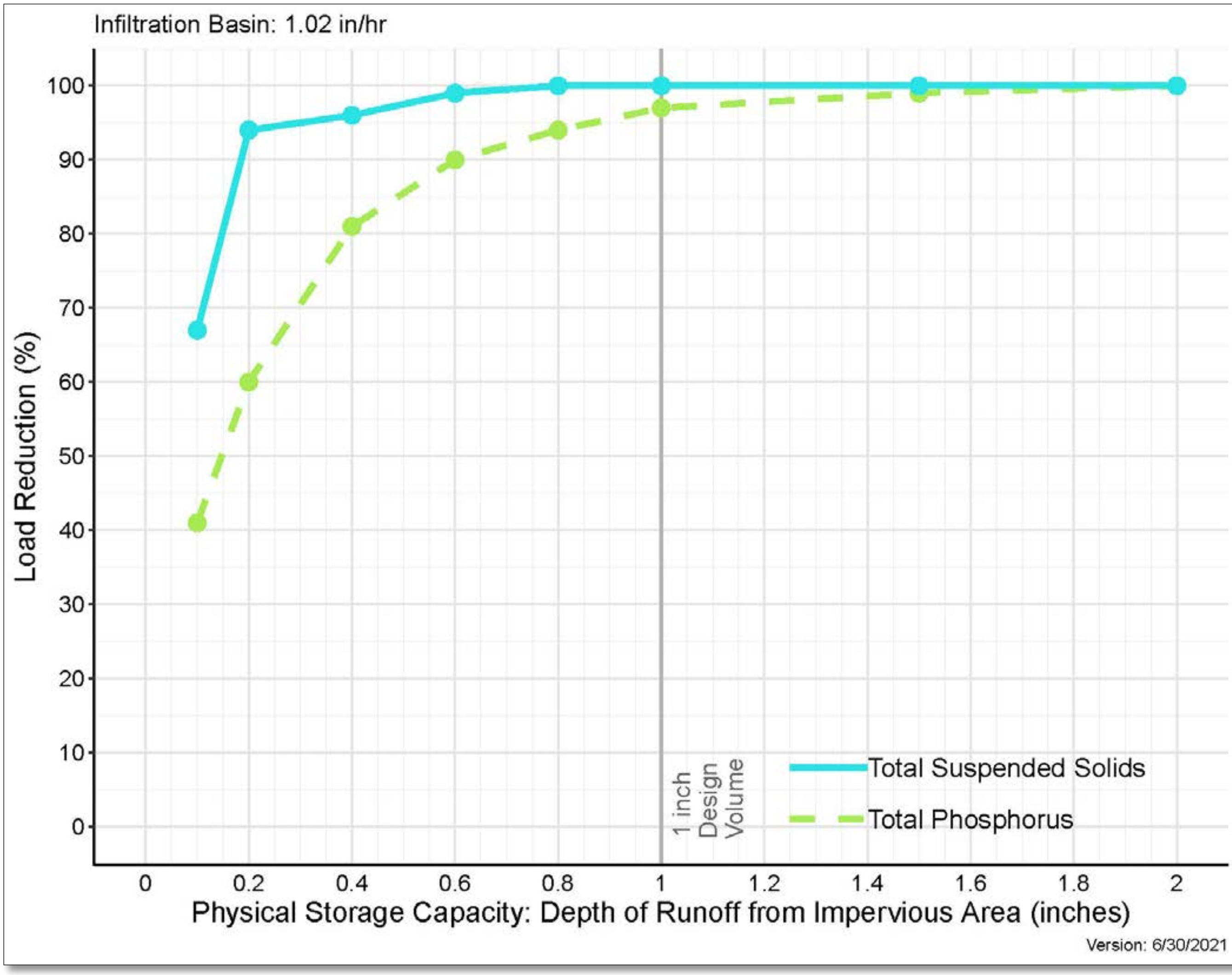
Infiltration Basin (0.17 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	35.0%	52.0%	72.0%	82.0%	88.0%	92.0%	97.0%	99.0%
Cumulative TSS Load Reduction	64.0%	80.0%	93.0%	98.0%	99.0%	100.0%	100.0%	100.0%



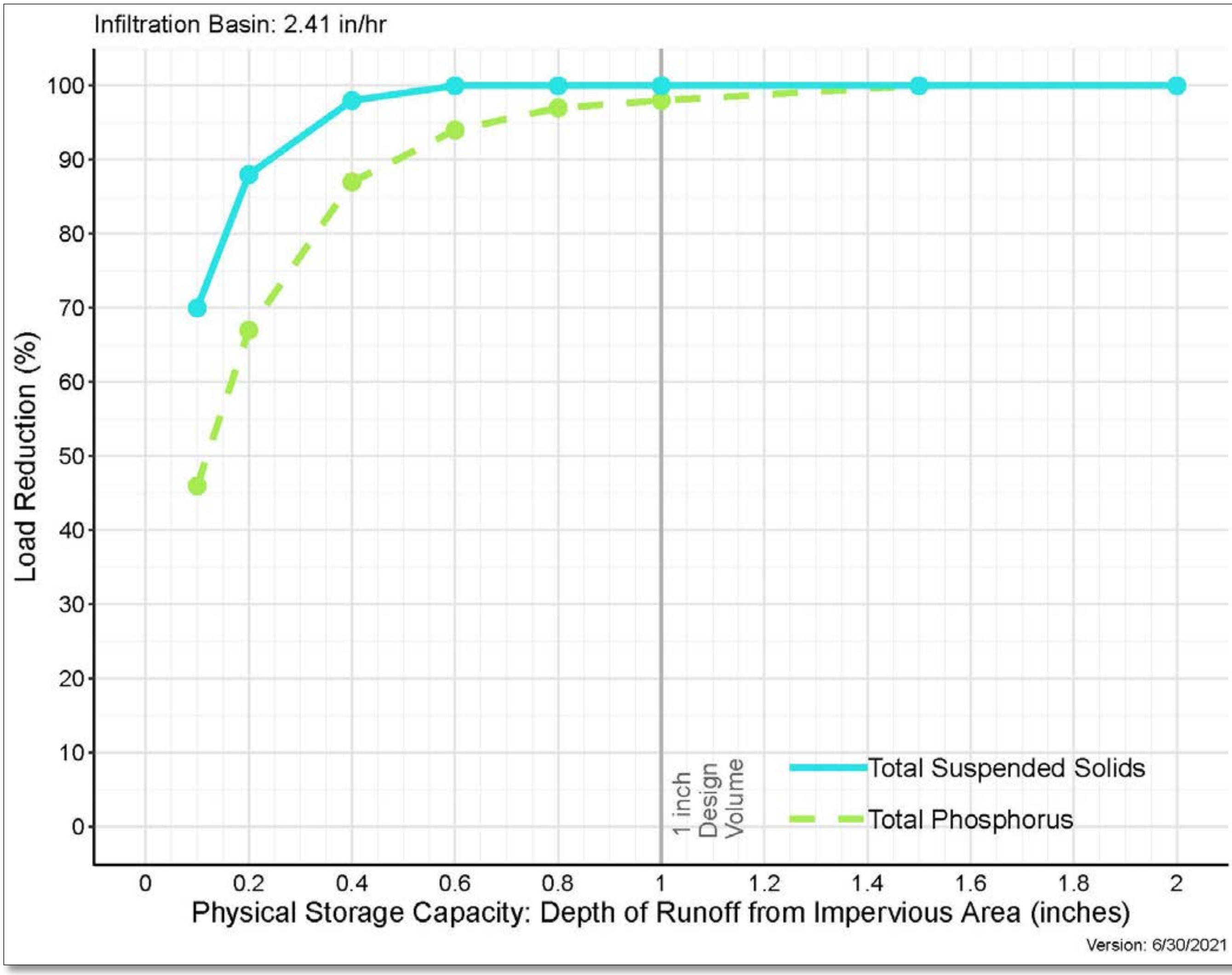
Infiltration Basin (0.27 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	37.0%	54.0%	74.0%	85.0%	90.0%	93.0%	98.0%	99.0%
Cumulative TSS Load Reduction	65.0%	81.0%	94.0%	98.0%	99.0%	100.0%	100.0%	100.0%



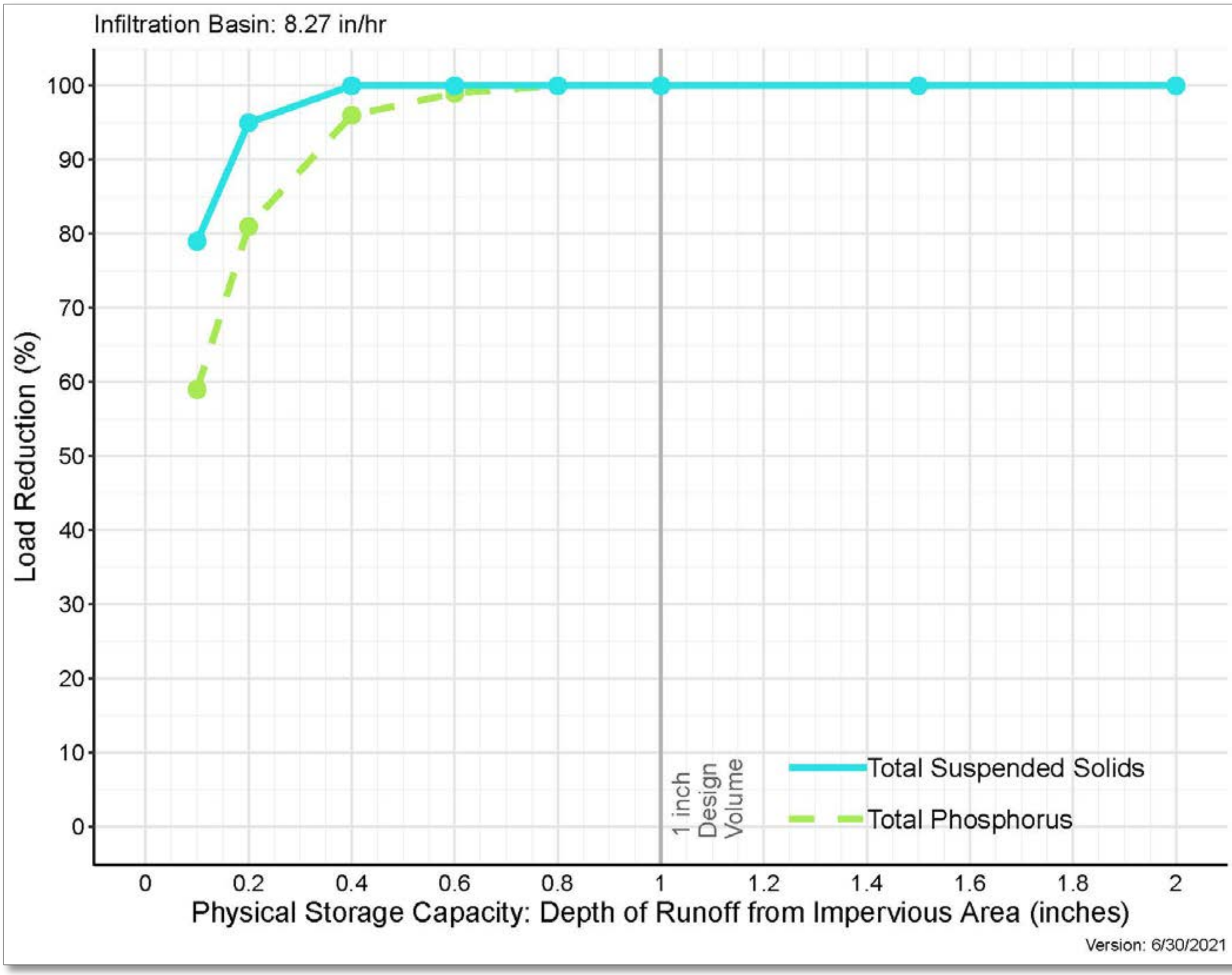
Infiltration Basin (0.52 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	38.0%	56.0%	77.0%	87.0%	92.0%	95.0%	98.0%	99.0%
Cumulative TSS Load Reduction	65.0%	83.0%	95.0%	99.0%	99.0%	100.0%	100.0%	100.0%



Infiltration Basin (1.02 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	41.0%	60.0%	81.0%	90.0%	94.0%	97.0%	99.0%	100.0%
Cumulative TSS Load Reduction	67.0%	94.0%	96.0%	99.0%	100.0%	100.0%	100.0%	100.0%

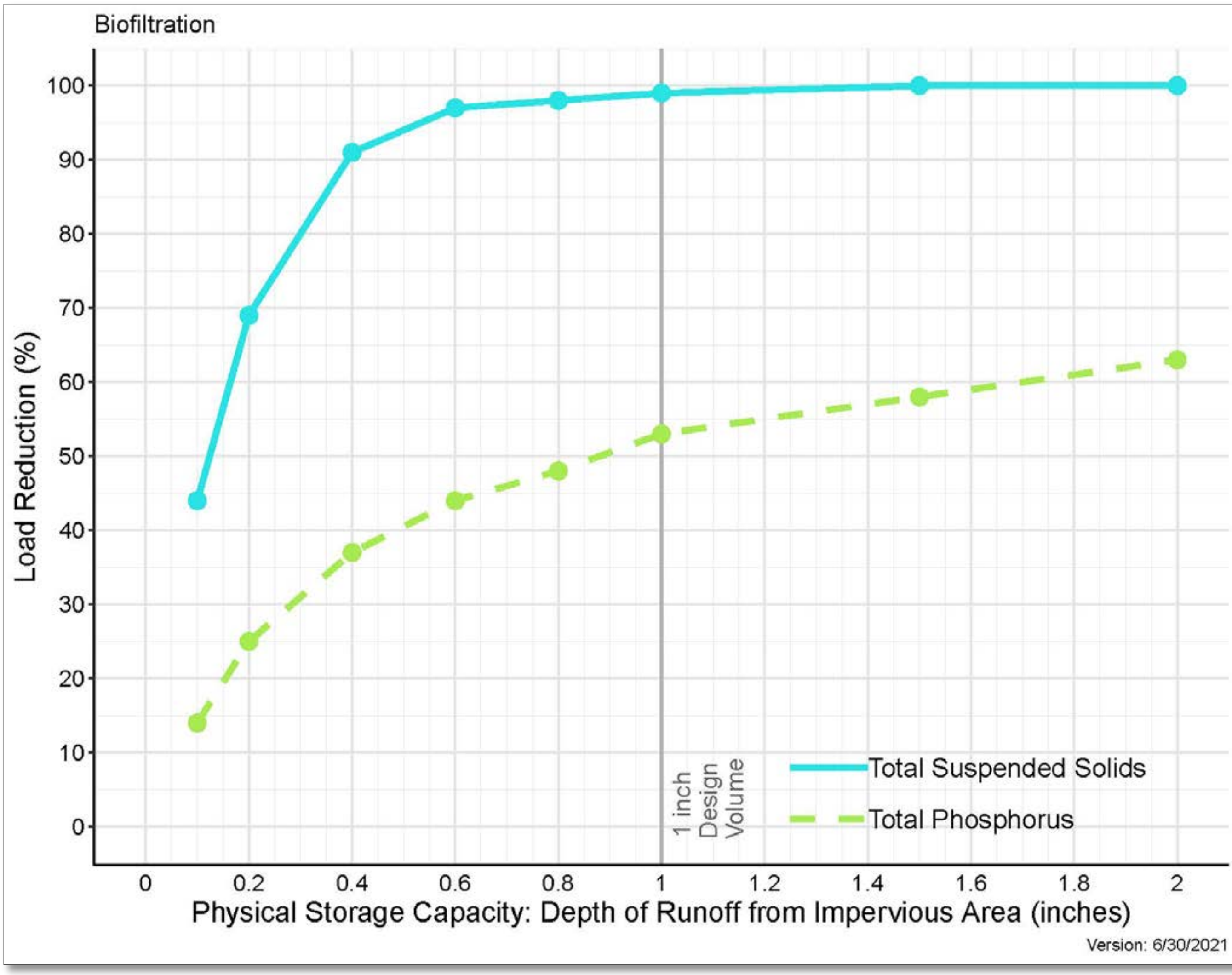


Infiltration Basin (2.41 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	46.0%	67.0%	87.0%	94.0%	97.0%	98.0%	100.0%	100.0%
Cumulative TSS Load Reduction	70.0%	88.0%	98.0%	100.0%	100.0%	100.0%	100.0%	100.0%



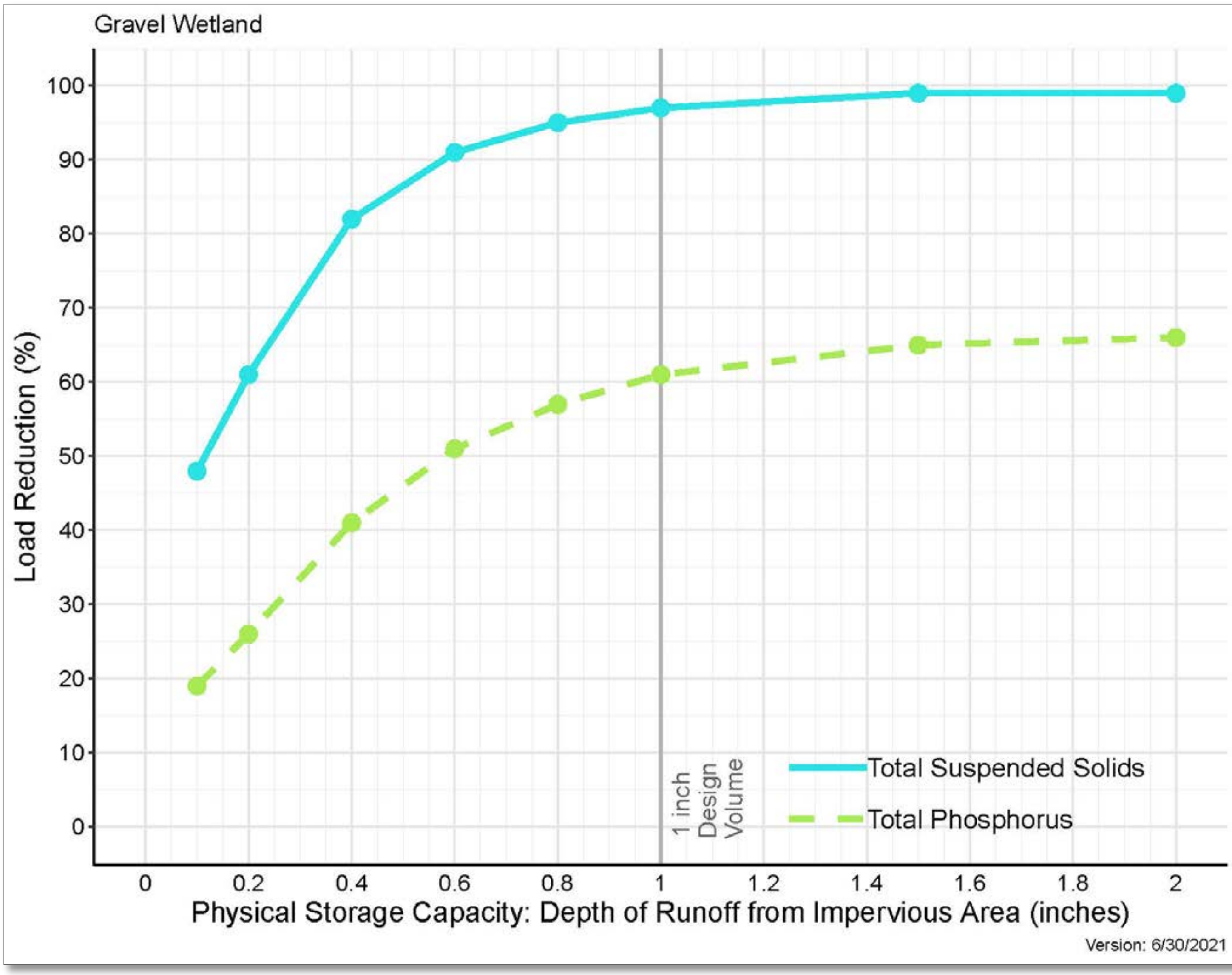
Infiltration Basin (8.27 in/hr) BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	59.0%	81.0%	96.0%	99.0%	100.0%	100.0%	100.0%	100.0%
Cumulative TSS Load Reduction	79.0%	95.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Biofiltration



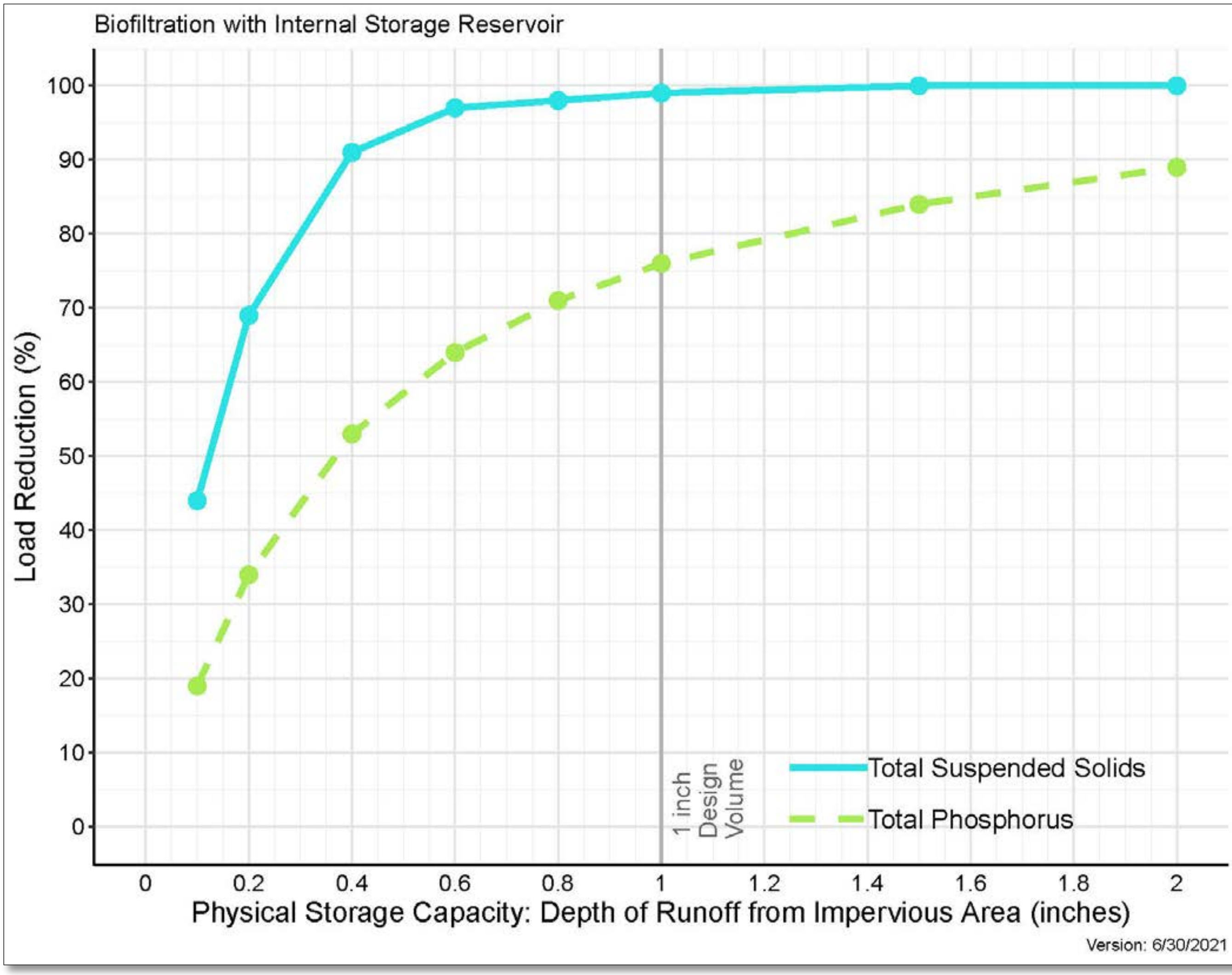
Biofiltration BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	14.0%	25.0%	37.0%	44.0%	48.0%	53.0%	58.0%	63.0%
Cumulative TSS Load Reduction	44.0%	69.0%	91.0%	97.0%	98.0%	99.0%	100.0%	100.0%

Gravel Wetlands



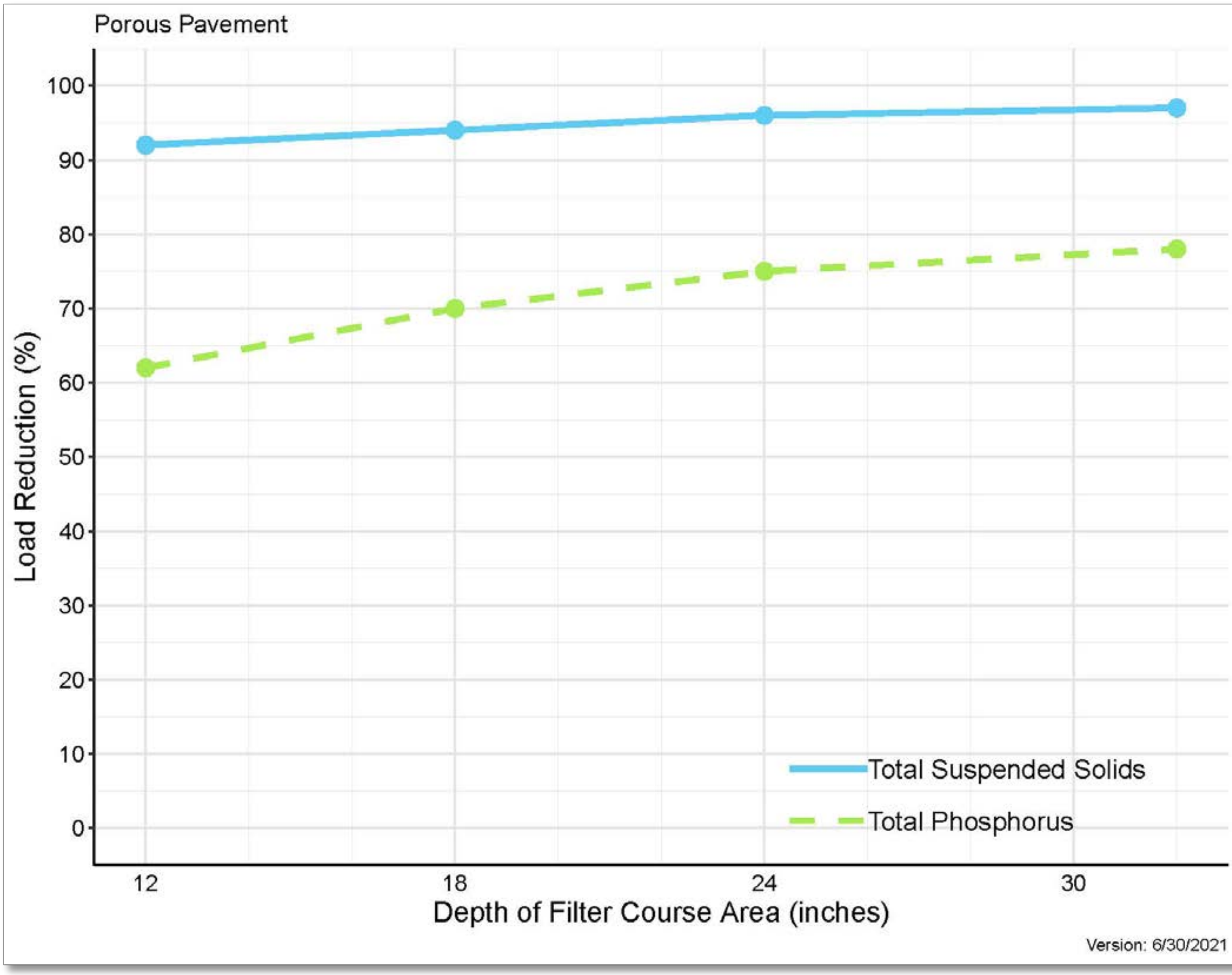
Gravel Wetland BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	19.0%	26.0%	41.0%	51.0%	57.0%	61.0%	65.0%	66.0%
Cumulative TSS Load Reduction	48.0%	61.0%	82.0%	91.0%	95.0%	97.0%	99.0%	99.0%

Enhanced Biofiltration with Internal Storage Reservoir



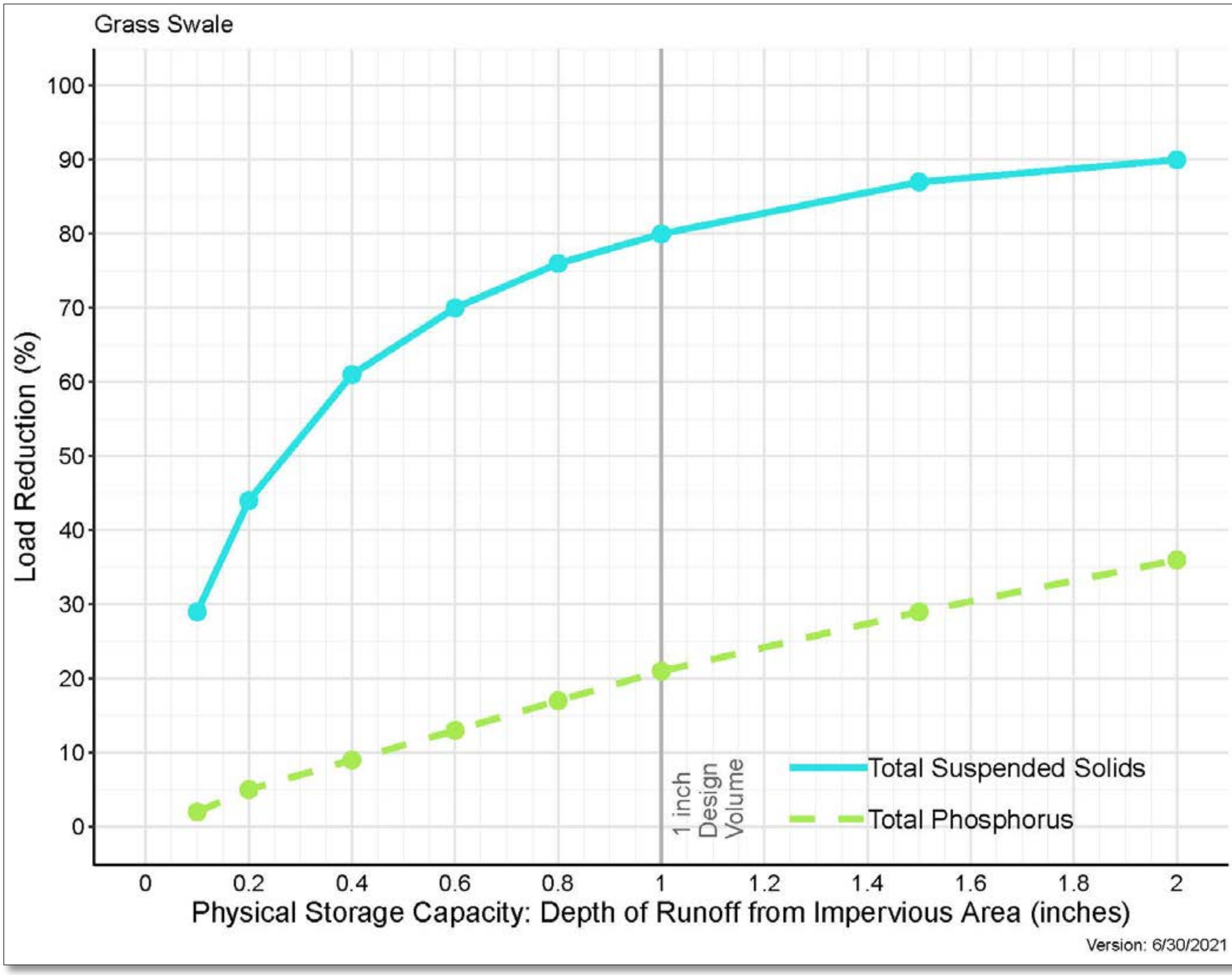
Biofiltration with Internal Storage Reservoir BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	19.0%	34.0%	53.0%	64.0%	71.0%	76.0%	84.0%	89.0%
Cumulative TSS Load Reduction	44.0%	69.0%	91.0%	97.0%	98.0%	99.0%	100.0%	100.0%

Porous Pavement



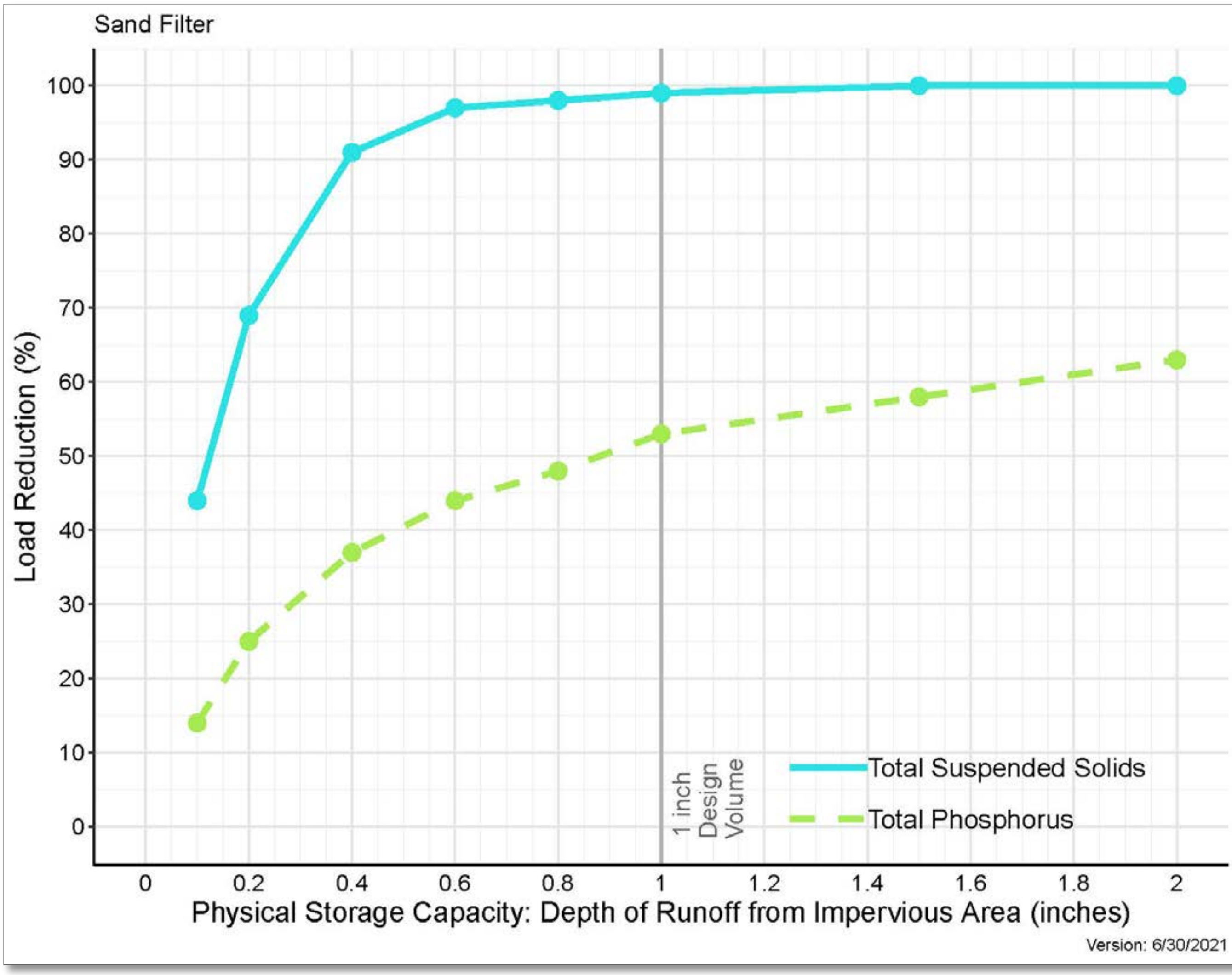
Porous Pavement BMP Performance Table: Long-Term Load Reduction				
Storage Capacity: Depth of Filter Course Area (inches)	12	18	24	32
Cumulative Phosphorus Load Reduction	62.0%	70.0%	75.0%	78.0%
Cumulative TSS Load Reduction	92.0%	94.0%	96.0%	97.0%

Grass Swale



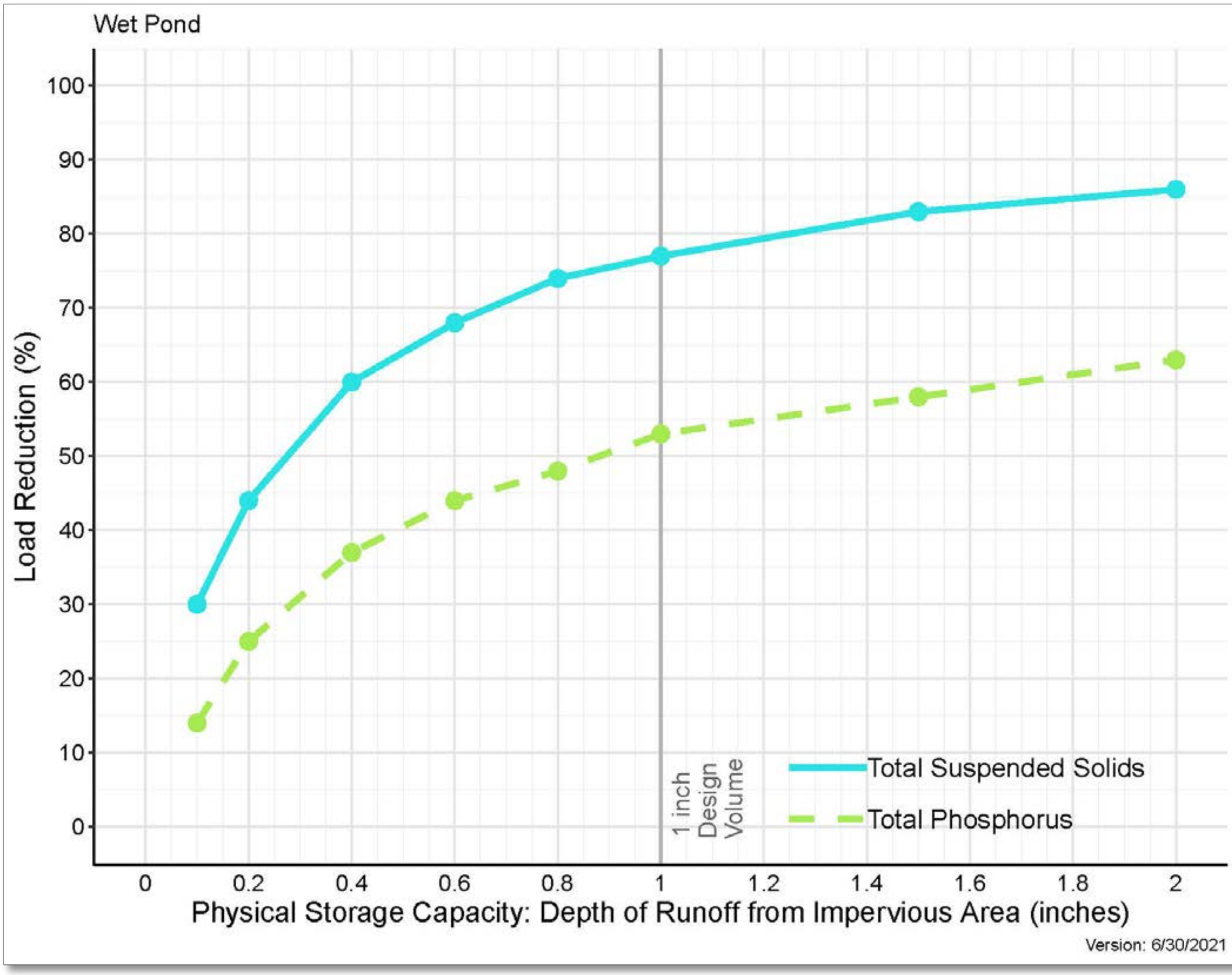
Grass Swale BMP Performance Table: Long-Term Load Reduction								
BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	2.0%	5.0%	9.0%	13.0%	17.0%	21.0%	29.0%	36.0%
Cumulative TSS Load Reduction	29.0%	44.0%	61.0%	70.0%	76.0%	80.0%	87.0%	90.0%

Sand Filter



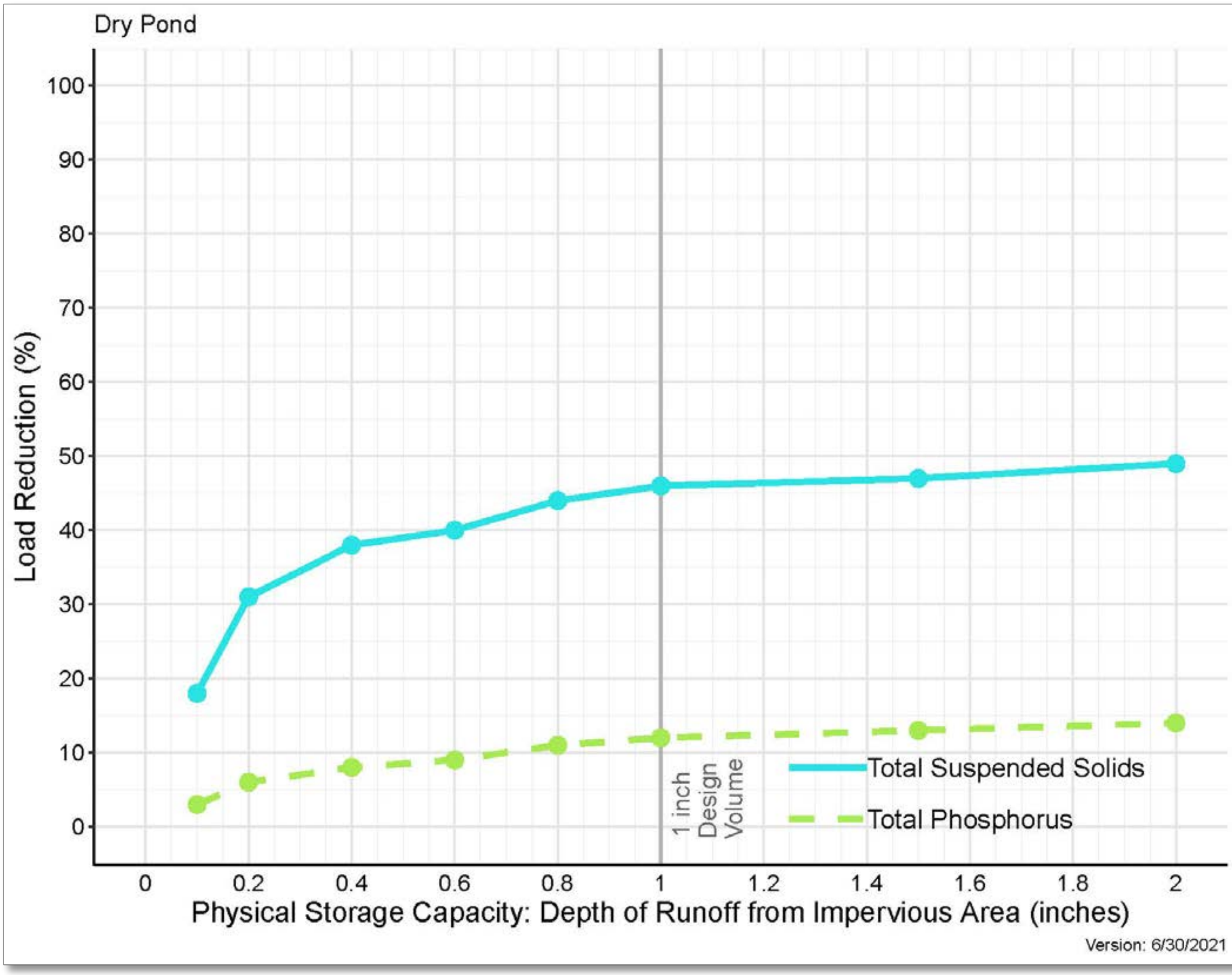
Sand Filter BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	14.0%	25.0%	37.0%	44.0%	48.0%	53.0%	58.0%	63.0%
Cumulative TSS Load Reduction	44.0%	69.0%	91.0%	97.0%	98.0%	99.0%	100.0%	100.0%

Wet Pond



Wet Pond BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	14.0%	25.0%	37.0%	44.0%	48.0%	53.0%	58.0%	63.0%
Cumulative TSS Load Reduction	30.0%	44.0%	60.0%	68.0%	74.0%	77.0%	83.0%	86.0%

Extended Dry Detention Basin



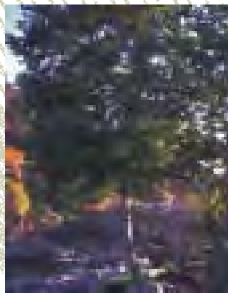
Dry Pond BMP Performance Table: Long-Term Load Reduction								
Storage Capacity: Depth of Runoff Treated from Impervious Area (inches)	0.1	0.2	0.4	0.6	0.8	1	1.5	2
Cumulative Phosphorus Load Reduction	3.0%	6.0%	8.0%	9.0%	11.0%	12.0%	13.0%	14.0%
Cumulative TSS Load Reduction	18.0%	31.0%	38.0%	40.0%	44.0%	46.0%	47.0%	49.0%

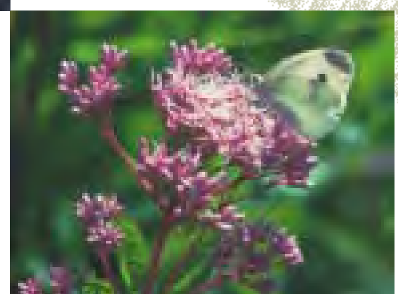
Appendix C

Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas

Massachusetts

Erosion and Sediment Control Guidelines for Urban and Suburban Areas





A Guide for Planners, Designers, and Municipal Officials

Department of Environmental Protection, Bureau of Resource Protection, One Winter Street 5th floor, Boston, MA 02108

MASSACHUSETTS EROSION AND SEDIMENT CONTROL GUIDELINES FOR URBAN AND SUBURBAN AREAS

A Guide for
Planners,
Designers and
Municipal Officials

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Massachusetts Department of Environmental Protection
Bureau of Resource Protection

U.S. Environmental Protection Agency
Region 1

Natural Resources Conservation Service
United States Department of Agriculture

originally prepared by:

Franklin, Hampden, Hampshire Conservation Districts

243 King Street - Room 39
Northampton, MA 01060

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Preface

In 1975, the Soil Conservation Service, USDA, in Massachusetts published the first edition of the ***Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts***. This was a 300+ page book dealing with a wide variety of conservation-related urban problems and situations encountered throughout the state of Massachusetts.

After the third printing and in 1982, the Soil Conservation Service began an update and revision to bring this volume up to date. At the same time, the format was changed from a single volume to a series of ***"Massachusetts Conservation Guides"*** - each keyed to a specific subject area. Only the first two of the proposed five guides were published: ***Volume I - Erosion & Sediment Control in Site Development and Volume II - Vegetative Practices in Site Development.***

In late 1993, realizing the need for a complete, up-to-date volume for persons undertaking to plan, install or review urban developments in the state, the State Commission for Conservation of Soil, Water and Related Resources took the lead to prepare a complete and comprehensive revision of this handbook. The Commission enlisted the aid of the Executive Office of Environmental Affairs, the Massachusetts Department of Environmental Protection, and the Natural Resources Conservation Services (formerly the Soil Conservation Service) of the U. S. Department of Agriculture. This group, working through the Franklin, Hampden, Hampshire Conservation Districts-Division V, undertook to update the original document and this volume is the culmination of their efforts.

There are numerous excellent references available to the general public covering the fields of erosion and sediment control, pollution control, and stormwater management. This guide draws upon many of those documents. It is meant to provide the lay person who is involved in projects which affect the land and water resources in Massachusetts with background information. Further details may be found in other documents, which are referenced as sources of information.

This guide deals primarily with conservation measures and conservation practices. These practices are generally referred to as ***"Best Management Practices"*** or ***"BMPs"*** and is intended to be a companion handbook with the recently prepared ***"Mega-Manual"*** prepared by the Massachusetts Department of Environmental Protection.

Only limited detail is included about the soils, engineering, hydrology, plant materials and other knowledge that is needed to plan and design a potential project. It is intended only as a guide and should be used as such. A professional planner should be engaged to prepare the proposal and a professional engineer for the detailed erosion and sediment control plan and designs, drawings, and specifications.

The contents of this guide are based on material almost entirely in the public domain, published by federal or state agencies or public educational institutions. It should not be interpreted as necessarily representing the policies or recommendations of other referenced agencies or organizations nor of the agencies who sponsored this revision. The mention of trade names, products, companies or publications does not constitute an endorsement, but are used for clarification.

In the fall of 1994, the USDA Soil Conservation Service was renamed the Natural Resources Conservation Service. Numerous references used herein were published as Soil Conservation Service documents and have not been renamed or revised at this date.

Acknowledgements

The following individuals were instrumental in guiding the development of this guide:

Thomas Anderson of the State Commission for Conservation of Soil, Water and Related Resources for his assistance in obtaining funds and coordinating the review of the draft documents with other state agencies.

William P. Annable, P. E., for collecting materials and related information, revising and updating the previously prepared editions of the handbook and updating and preparing this version of the Guidelines.

John Bennett of the Franklin Conservation District for his assistance in reviewing and commenting on the draft documents.

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Erosion and Sedimentation

As undeveloped areas are converted to urban uses, the natural vegetation is removed, land slopes may be excavated or filled, ground surfaces are paved over, and stream channels are modified. The result is an increase in runoff and a reduction in the ability of the land to provide natural treatment to the runoff.

Land is disturbed and exposed to erosion by wind and water during this period of conversion. Soil displaced by erosion contributes to both onsite and offsite damages. A portion of the soil reaches the state's streams, lakes, and coastal waters as sediment.

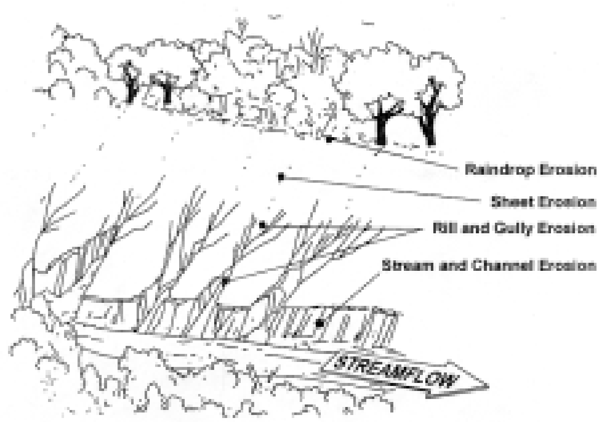
Erosion

Erosion is the wearing away of the land surface by running water, wind, ice, or other causes. Soil erosion is usually caused by the force of water falling as raindrops and by the force of water flowing in rills and streams. Raindrops falling on bare or sparsely vegetated soil detach soil particles. Water running along the surface of the ground picks up these particles and carries them along as it flows downhill towards a stream system.

As the runoff gains in velocity and concentration, it detaches more soil particles, cuts rills and gullies into the surface of the soil and adds to its sediment load. The merging rivulets produce larger channels which have a larger volume and usually higher velocity, and a greater capacity to remove sediment and transport it downstream.

The greater the distance the water runs uncontrolled, the greater its erosive force and the greater the resultant damage. Moreover, control becomes more difficult as the distance and volume increases.

Soil erosion is also caused by the force of wind blowing across unprotected ground. Open gravel pits and construction sites that have been stripped of vegetation are especially vulnerable to wind erosion. The wind-borne sediments land in streams, roads, and neighboring lots. Blowing dust is a nuisance, and can be a hazard on especially windy days. Wind erosion in areas undergoing development can be controlled best by keeping disturbed areas small and by stabilizing and protecting them as soon as possible.

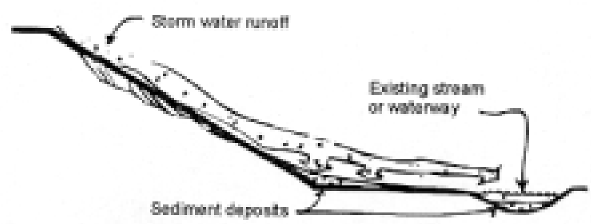


Types of Water Erosion

Sedimentation

Sedimentation is the deposition of soil particles that have been transported by water and wind. The quantity and size of the material transported increases with the velocity. Sedimentation occurs when the medium, air or water, in which the soil particles are carried is sufficiently slowed long enough to allow particles to settle out. Heavier particles, such as gravel and sand, settle out sooner than do finer particles, such as clay.

The length of time a particle stays in suspension increases as the particle size decreases. The coarsest, heaviest particles (gravel) are transported only a short distance, while water flow is at its maximum. Smaller, lighter particles (sand) move by rolling or bouncing along the surface, or stay in suspension over short distances while the water velocity is fairly high. Because of their slow settling rate, fine silt particles generally remain for several hours in suspension in the storm runoff that originally moved them. The still finer colloidal clays stay in suspension for very long periods and contribute significantly to water turbidity.



THE PROBLEM

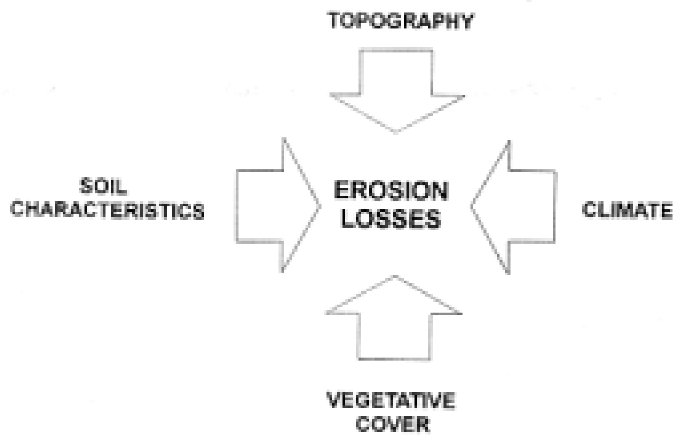
Factors that Influence Erosion

There are four principal factors that influence the potential for erosion: soils, surface cover, topography, and climate. These factors are interrelated in their effect on erosion potential.

Variability in terrain, soils, and vegetation makes erosion control unique to each development. Erosion and resulting sedimentation generally occur in Massachusetts only when the soil is disturbed. The seriousness of the problem is a function of the topography and size of the area disturbed, the characteristics of the soils, the climate, and the vegetative cover.

As a rule of thumb:

- The more fine-grained material there is in a soil, the greater the amount of material that will be picked up by water flowing across its surface;
- The steeper the slope, the faster the water will move, thus being able to carry more soil; and,
- The larger the unprotected surface, the larger the potential for problems.



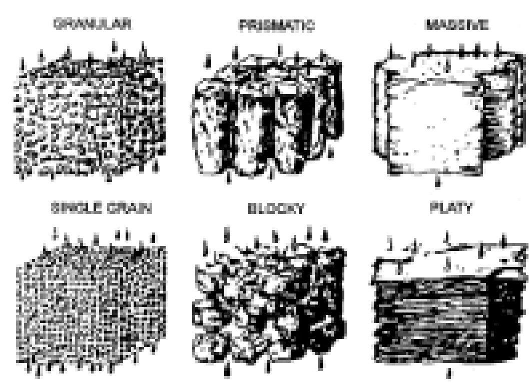
Soils

The vulnerability of a soil to erosion is known as its erodibility. Key factors that influence erodibility are:

- Soil texture (proportions of sand, silt, and clay)
- Organic matter content
- Soil structure (arrangement of soil particles)
- Soil permeability (the ease by which water passes through the soil)

Soil texture is described by the proportions of sand, silt, and clay in the soil. High sand content gives a coarse texture, which allows water to infiltrate readily, reducing runoff. A relatively high infiltration rate coupled with resistance to transport by runoff results in a low erosion potential. Soils containing high proportions of silt and very fine sand are most erodible. Clay particles and organic matter in the soil tend to bind it together into aggregates, thereby reducing erodibility. When clay erodes, however, the particles settle out very slowly.

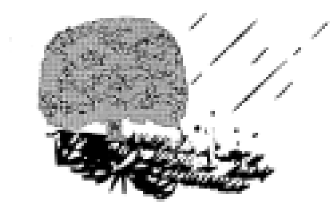
Organic matter, such as plant material, humus, or manure, improves soil structure, increases water-holding capacity, and may increase the infiltration rate. It reduces erodibility and the amount of runoff.

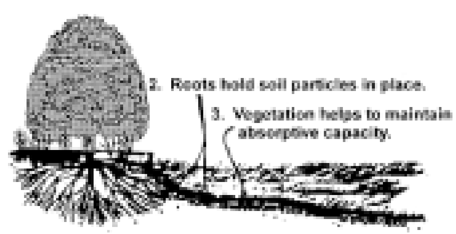


Soil structure is determined by the shape and arrangement of soil particle. A stable, sharp, granular structure absorbs water, readily, resists erosion by surface flow, and promotes plant growth. Clay soils or compacted soils have slow infiltration capacities that increase runoff rate and create severe erosion problems.

Soil permeability refers to a soil's ability to transmit air and water. Soils that are least subject to erosion from rainfall and shallow surface runoff are those with high permeability rates, such as well-graded gravels and gravel-sand mixtures. Loose, granular soils reduce runoff by absorbing water and by providing a favorable environment for plant growth. "Well-graded" soils are those which contain a wide range of particle sizes. Well-drained and well-graded gravels and gravels and mixtures with little or no silt have low erodibility to sheet flow, but wash easily under concentrated flow. Coarse, granular soils also have high permeabilities and a sufficiently good infiltration capacity to prevent or delay runoff.

Surface Cover


1. Vegetation absorbs the energy of falling rain.



4. Vegetation slows the velocity of runoff and acts as a filter to catch sediment.


Vegetative cover is extremely important in controlling erosion. It performs these functions:

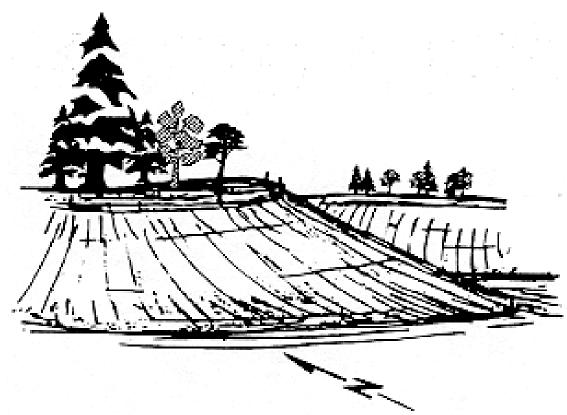
- Shields the soil surface from the impact of falling rain,
- Holds soil particles in place,
- Helps to maintain the soil's capacity to absorb water,
- Slows the velocity of runoff.

Soil erosion and sedimentation can be significantly reduced by scheduling construction activities to minimize the area of exposed soil and the time of exposure. Special consideration should be given to the maintenance of existing vegetative cover on areas of high erosion potential such as erodible soils, steep slopes, drainageways, and banks of streams.

Vegetation slows runoff velocity, disperses flow, and promotes infiltration and deposition of sediment. Plants remove water from the soil, increasing the capacity to absorb water. Plant roots help maintain soil structure.

The type and condition of ground cover influence the rate and volume of runoff. Impervious surfaces protect the area covered, but prevent infiltration and decrease the "time of concentration" for runoff, thereby increasing high peak flow and potential for stream and channel erosion. Covers such as mulches, paving, and stone aggregates also protect soils from erosion.

Topography



Topographic features distinctly influence erosion potential. Watershed size and shape, for example, affect runoff rates and volumes. Slope length and steepness are key elements in determining the volume and velocity of runoff and erosion risks. As both slope length and gradient increase, the rate of runoff increases and the potential for erosion is magnified. Swales and channels concentrate surface flow, which results in higher velocities. Exposed south-facing soils are hotter and drier, which makes vegetation more difficult to establish.

Climate

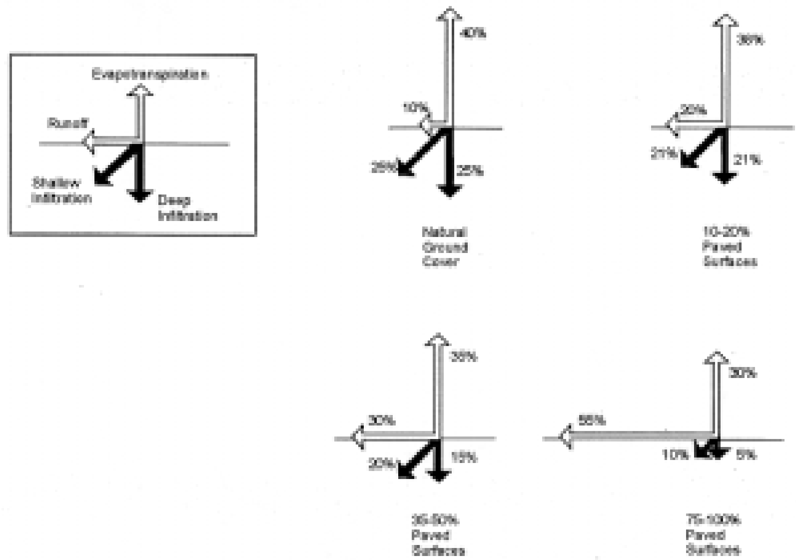
Where storms are frequent, intense, or of long duration, erosion risks increase. The high erosion risk period of the year results from seasonal changes in temperature, as well as variations in rainfall. When precipitation falls as snow, no erosion will take place immediately. In the spring, however, the hazards will be high. Most plants are still dormant. The existing vegetative cover is less able to buffer the raindrops. The ground is still partially frozen, or else saturated from melting snow, and its absorptive capacity is reduced.

Exposed areas should be well stabilized in the fall, before the period of high erosion risk in the spring.

The frequency, intensity, timing, and duration of rainfall are fundamental factors in determining the amounts of runoff produced. The ability of runoff to detach and transport soil particles also increases as both the volume and the velocity of runoff increase. Development should be scheduled to take place during the periods of low precipitation and low runoff.

In Massachusetts, soil erosion is caused primarily by runoff water from rainfall and snowmelt. Wind erosion is a problem for farmers on the broad plains adjoining the Connecticut River, and can be a problem for exposed soils at construction sites also.

Areas where the soil has been disturbed and left bare by construction activities should be revegetated early enough in the Fall so that a good cover is established before cold weather comes and growth stops until the spring. A good cover is defined as vegetation covering 75 percent or more of the ground surface. October is too late to seed and obtain a good cover for the winter. Where good cover has not been established, structural stabilization methods, such as hay bales, silt fences or anchored mulch, must be used.



Typical changes in runoff with increasing areas of impermeable surfaces such as roofs, paved surfaces:

Effects of Urbanization

Before colonial times, most of Massachusetts was forested. The forest system provided protection by intercepting rainfall in the tree canopy, reducing the possibility of erosion and the deposition of sediment in waterways. The trees and the forest duff layer absorbed large amounts of runoff, releasing it slowly to the streams by percolation through the soil.

As settlement occurred and the population grew, land was cleared for buildings, fields, pastures and roads. Low spots, often wetlands, were filled. Today, as areas are converted to urban uses, the natural vegetation is removed, land slopes are modified, areas are paved over.

After vegetated terrain is cleared, the additional area of compacted and impervious surfaces changes the hydrologic characteristics. Volume of surface runoff and the rate of flow increases. Ground water recharge decreases. Runoff that was previously slowly released to streams by filtering through the soil now runs quickly off the surface directly into the streams. This increases velocity and quantity of flow causing streambank erosion and general habitat destruction. Sediment from eroded and unstable streambanks and cleared areas is deposited downstream; filling ponds, streambeds and stormwater facilities. Summer base flows are reduced.

In addition to the increase in impervious surfaces, urbanization creates a significant amount of ground surface modification. Natural drainage patterns are modified and runoff is transported via road ditches, storm sewers, drainage swales, and constructed channels. These modifications increase the velocity of the runoff which in effect decreases the time that it takes for runoff to travel through the watershed. This decreased time creates higher peak discharges.

Vegetative cover on an undisturbed site protects the ground surface. Removal of that cover increases the site's susceptibility to erosion. Disturbed land may have an erosion rate 1,000 times greater than the preconstruction rate. Proper planning and use of control measures can reduce the impact of man-induced accelerated erosion.

The major problem associated with erosion on a construction site is the movement of soil off the site and its impact on water quality. Millions of tons of sediment are generated annually by construction activities in the United States. The rate of erosion on a construction site varies with site conditions and soil types but is typically 100 to 200 tons per acre and may be as high as 500 tons per acre.

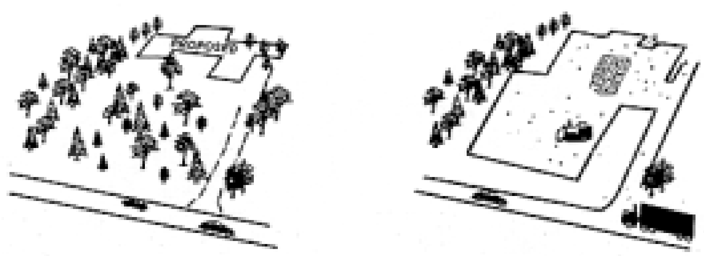
Under natural conditions, stream channels will normally handle, at bankfull, capacity the peak discharge from a storm that could be expected once every two years. The increased discharge caused by urbanization will cause out-of-bank flooding more frequently. The stream channel begins to widen and deepen to accommodate the increased flow and to change grade to handle the increased velocity. Eventually the increased sediment transport can lead to problems downstream.

Urbanization can be a significant cause of pollution problems due to sediment loads, with both short-term and long-term impacts. Short-term changes in water quality can restrict recreational activities, stress aquatic organisms, and damage shellfish beds. Long-term accumulation of pollutants into receiving waters can create particularly difficult to correct problems such as eutrophication, polluted groundwater, and contaminated sediments.

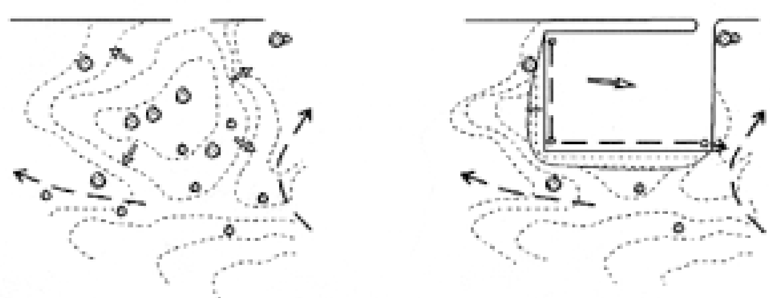
Erosion and Sediment Hazards Associated with Site Development

Hazards associated with site development include increased water runoff, soil movement, sediment accumulation, and higher peak flows caused by:

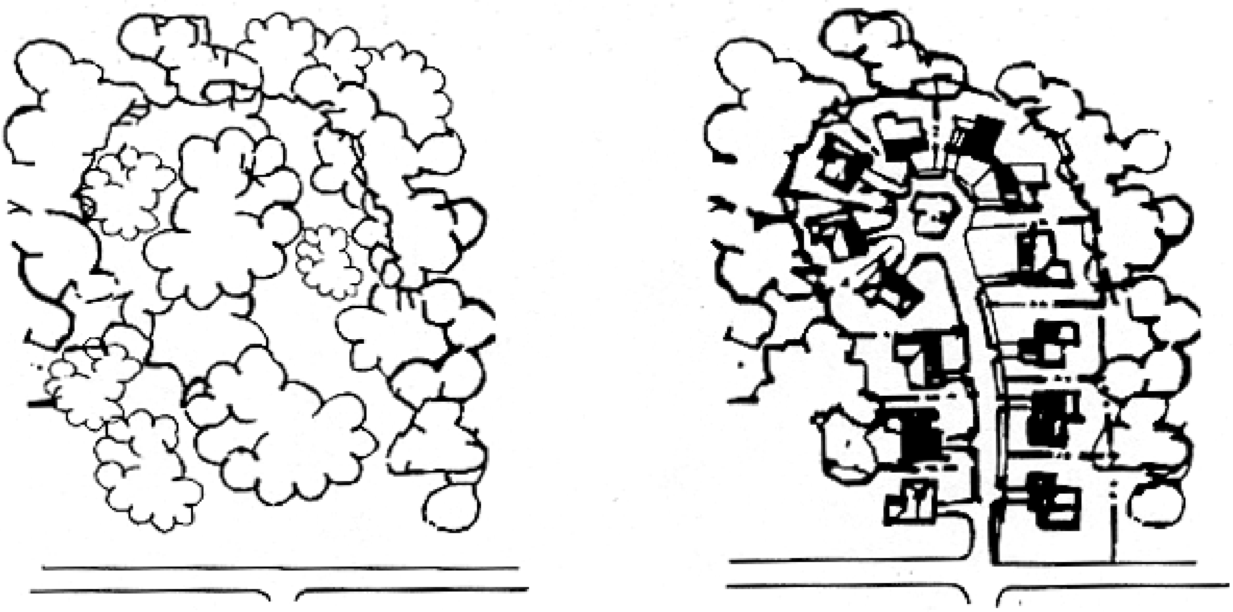
- **Removal of plant cover and a large increase of soil exposed to erosion by wind and water.**



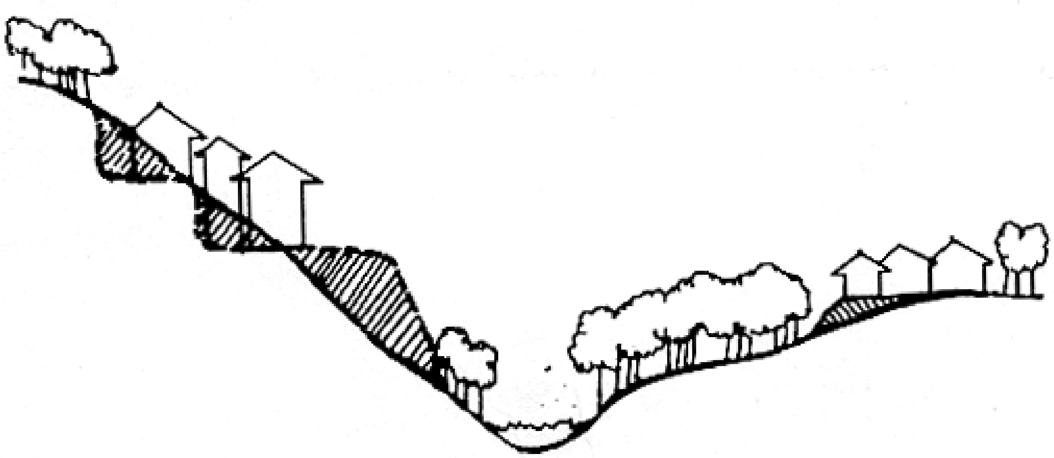
- **Changes in drainage areas caused by regrading the terrain, diversions, or road construction.**



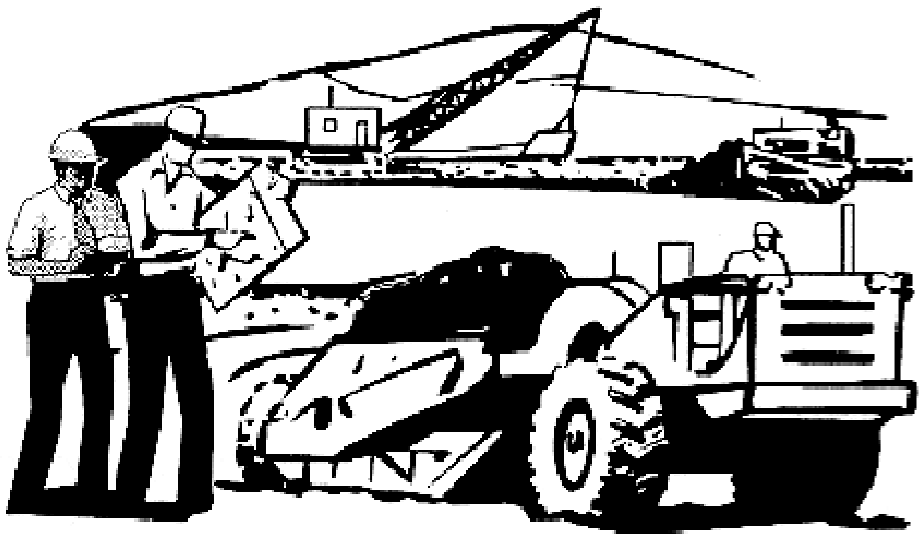
- A decrease in the area of soil which can absorb water because of construction of streets, buildings, sidewalks, or parking lots.



- Changes in volume and duration of water concentrations caused by altering steepness, distance and surface roughness.

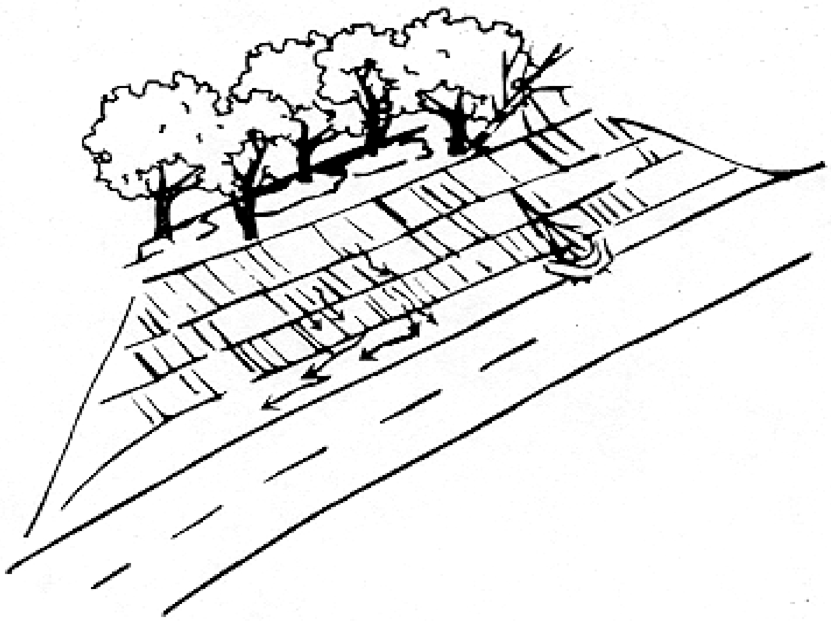


- Soil compaction by heavy equipment, which can reduce water intake of soils to 1/20 or less of the original rate.

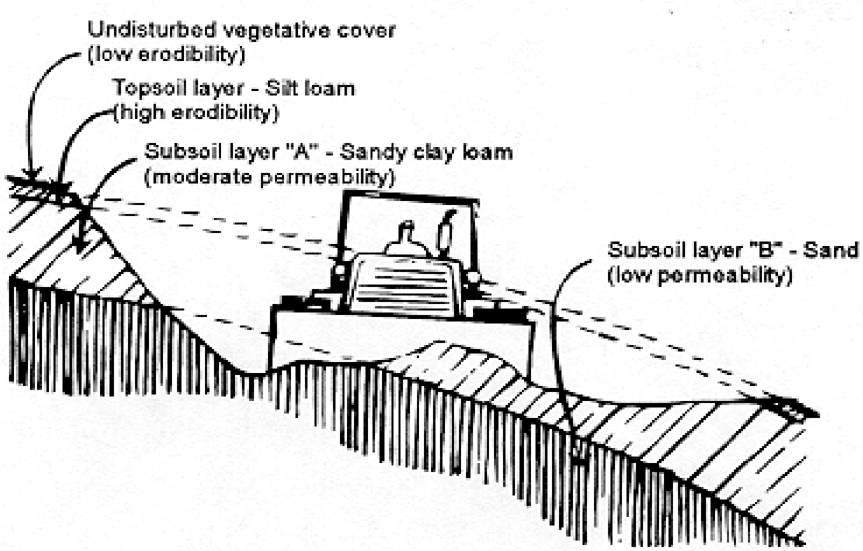


- Prolonged exposure of unprotected sites and service areas to poor weather conditions.

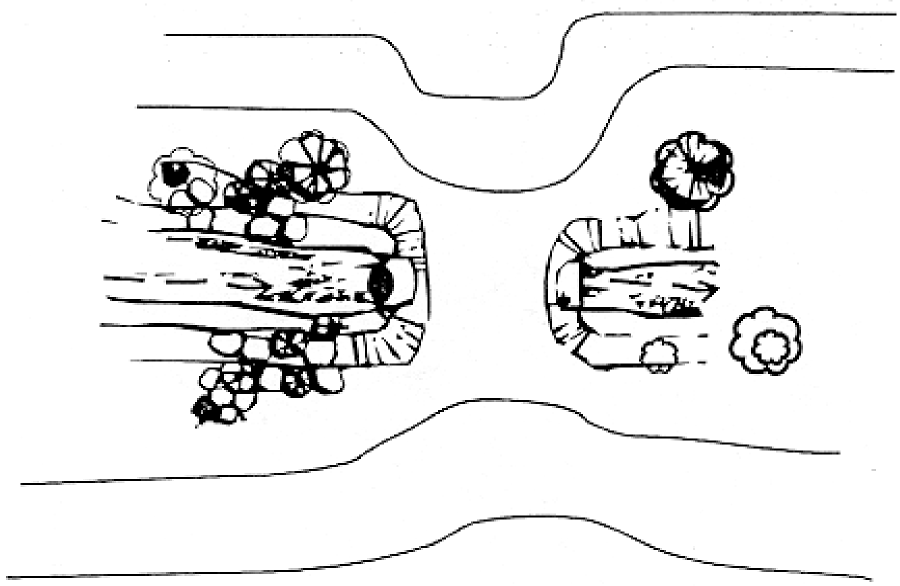
- **Altering the groundwater regime may adversely affect drainage systems, slope stability, survival of existing vegetation, and establishment of new plants.**



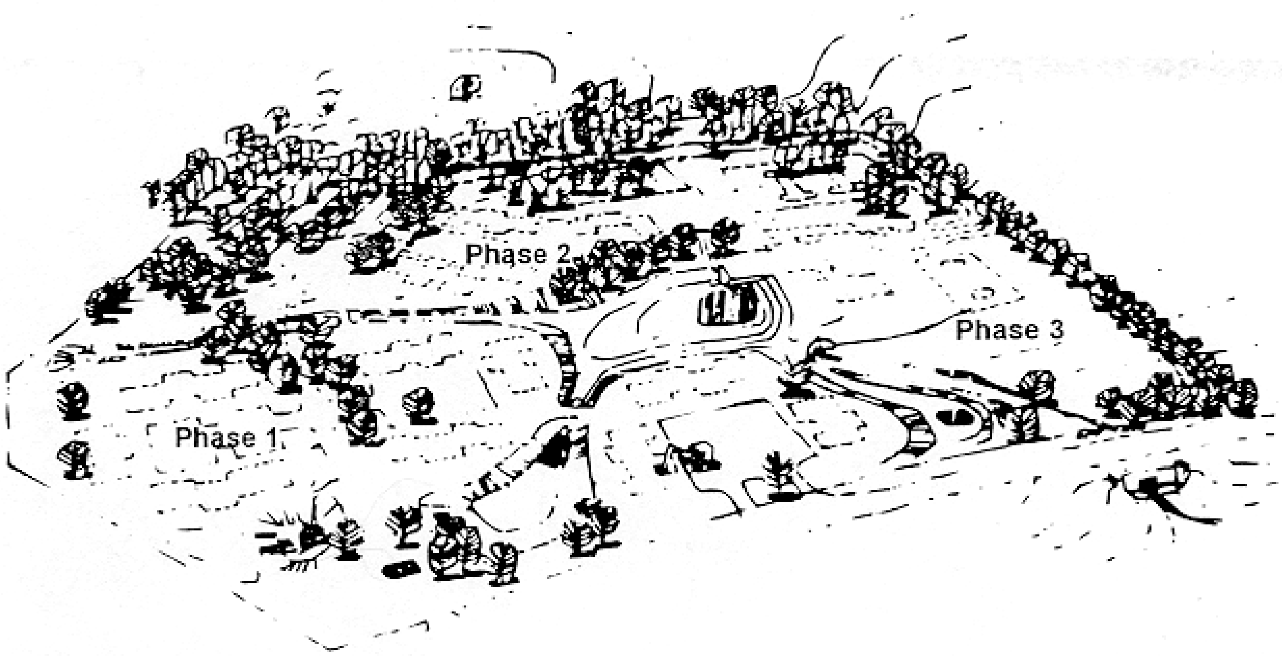
- **Exposing subsurface materials that are too rocky, too acid, or otherwise unfavorable for establishing plants.**



- Obstructing streamflow by new buildings, dikes, and landfills.



- Inappropriate timing and sequence of construction and development activities.

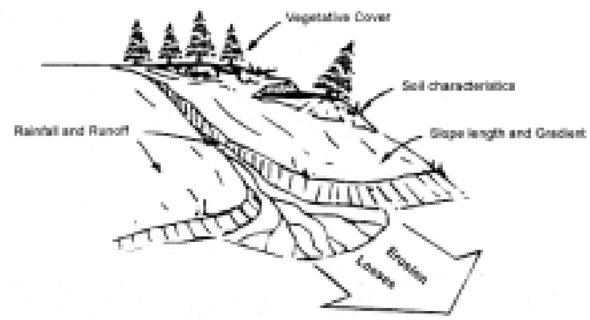


• **Abandonment of sites before construction is completed.**

Analyzing the Project Site

Most soil and water management problems encountered during land use change are caused by one or more of the following:

- Soil Limitations,
- Sloping Land,
- Drainage Problems
- Exposed Soil.



Soil Characteristics and Limitations

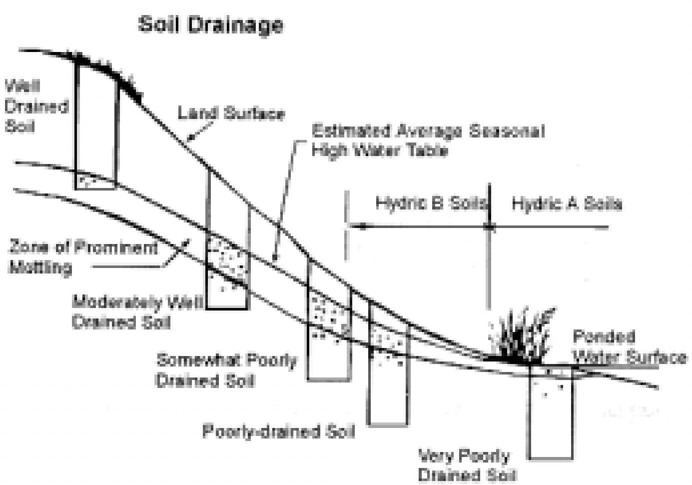
Soil characteristics have a major influence on how a proposed development site can best be utilized. Characteristics such as texture, permeability, and structure affect a soil's erodibility. Other characteristics that affect the potential, and the limitations, of a site include natural drainage, depth to seasonal water table, depth to bedrock, flood hazard potential, natural fertility, and engineering, physical, and chemical properties.

Significant differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are shallow to bedrock. Some are too unstable to be used as a foundation for buildings or roads. Finer-textured or wet soils have severe limitations for use as septic tank absorption fields. A site with a high water table is poorly suited to basements or underground installations. Depth to bedrock or to a cemented pan (cemented or hardened subsurface layers), large stones, slope, and the hazard of cutbanks caving affect the stability of ditch banks and the ability of construction equipment to perform excavation or grading work. Knowledge of the soil properties is of great value in deciding how to utilize the project site.

Drainage

Drainage is the removal of excess surface and subsurface water from the soil. How easily and effectively the soil is drained depends on the depth to bedrock, to a cemented pan, or to other layers that affect the rate of water movement; permeability; depth to water table (depth to standing water if the soil is subject to ponding): slope; susceptibility to flooding; subsidence of organic layers; and potential frost action.

Some soils are so wet that it would be difficult to use them for development. Two examples are the Scarboro soil series ("mucky fine sandy loam"), found on outwash plains and terraces; and the Whitman soil series (fine sandy loam) found in some upland areas. Poorly-drained soils such as Ridgebury and Walpole have severe limitations for houses, small commercial buildings, or lawns. Even moderately-well-drained soils such as the Woodbridge, Sudbury, or Deerfield series would present moderate to severe limitations for some development purposes.



Depth to seasonal high water table

Areas with a high water table should either be avoided or steps taken to control the condition. A high water table can cause malfunctioning septic systems, damp basements, and uneven foundation settlement.

Depth to bedrock

If the rock is soft or fractured, excavations can be made with trenching machines, backhoes, or small rippers. If the rock is hard or massive, blasting or special equipment generally is needed for excavation.

Flood hazard potential

Flooding, the temporary covering of the soil surface by flowing water, is caused by overflowing streams, by runoff from adjacent slopes, or by inflow from high tides.

Ability to support vegetation

"Tilth" (physical condition of the soil related to ease of tillage, fitness as a seedbed, and impedance to seedling emergence and root penetration) is important to the germination of seeds and the infiltration of water into the soil. Soils that have good tilth are generally granular and porous.

Fertility tends to be low for soils in their natural state. Most soils in the Northeast are acid. They require applications of lime to lower acidity sufficiently for lawns and other vegetation to do well. There are some exceptions; for example some shrubs prefer acid soils.

Soil Survey Reports

Soil survey reports offer detailed information on the soil characteristics. These reports contain soil maps, soil descriptions, and soil interpretation tables. They have been published for most areas of Massachusetts. Copies are available for review at the local Conservation District office.

Soil surveys maps are aerial photographs on which soil scientists have drawn boundaries of natural soil bodies, identifying each as a specific map unit. A map unit delineation on a soil map represents an area dominated by one major kind of soil or an area dominated by several kinds of soil, on the basis of soil series and soil phase. Map unit descriptions and accompanying tables provide detailed information on each, as well as interpretations on their use for numerous purposes.

Examples of two tables are shown in the accompanying figures.

A soil series is made up of soils that have horizons (soil layers) similar in arrangement and characteristics. Soils of one series can differ in texture, underlying material, slope, stoniness, wetness, etc. On the basis of such differences, a soil series is divided into soil phases. The smallest map unit that is practical to identify is three to five acres.

Every map unit generally has some soils that belong to other taxonomic classes. These soils are known as inclusions. The inclusion may be similar to the dominant soil and therefore may not affect the use or management of the soil. On the other hand, the inclusion may be contrasting and therefore require different management and may affect the potential use of the soil mapping unit. Inclusions could affect the site specific use of an area but may have little or no effect on broader land use determinations.

Soil survey reports are very useful to planners, contractors, engineers, and local officials. Planners can evaluate the effects of specific land uses in an area. Contractors can identify potential sources of sand and gravel, topsoil, and roadfill. They can use the survey to determine the areas where high water table, restrictive layers or bedrock may hinder excavation. Engineers and local officials may also use the survey to plan for waste disposal and site development.

The reports contain descriptions for each soil series, with information on the composition of each layer of the soil profile; to a depth of at least 60 inches. There are tables evaluating the limitations for use of each soil series. Other tables contain engineering, physical, and chemical properties.

Soil survey reports should be supplemented with onsite soil investigation for a specific land use.

TABLE 11.--BUILDING SITE DEVELOPMENT

(Some terms that describe restrictive soil features are defined in the Glossary. See text for definitions of "slight," "moderate," and "severe." Absence of an entry indicates that the soil was not rated. The information in this table indicates the dominant soil condition but does not eliminate the need for onsite investigation)

Soil name and map symbol	Shallow excavations	Dwellings without basements	Dwellings with basements	Small commercial buildings	Local roads and streets	Lawns and landscaping
BoB--------------- Brookfield	Slight---------	Slight---------	Slight---------	Moderate: slope.	Moderate: frost action.	Moderate: large stones.
BoC--------------- Brookfield	Moderate: slope.	Moderate: slope.	Moderate: slope.	Severe: slope.	Moderate: slope, frost action.	Moderate: large stones, slope.
BoD--------------- Brookfield	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.	Severe: slope.
BrC*:						
Brookfield--------	Moderate: slope.	Moderate: slope.	Moderate: slope.	Severe: slope.	Moderate: slope, frost action.	Moderate: large stones, slope.
Brimfield---------	Severe: depth to rock.	Severe: depth to rock.	Severe: depth to rock.	Severe: slope, depth to rock.	Severe: depth to rock.	Severe: thin layer.

TABLE 15.--ENGINEERING INDEX PROPERTIES

(The symbol < means less than; > means more than. Absence of an entry indicates that data were not estimated)

Soil name and map symbol	Depth	USDA texture	Classification		Frag-ments > 3 inches	Percentage passing sieve number--				Liquid limit	Plas-ticity index
			Unified	AASHTO		4	10	40	200		
	In				Pct					Pct	
BoB, BoC, BoD----- Brookfield	0-2	Fine sandy loam	SM, ML, GM	A-2, A-4	15-30	65-100	60-95	40-80	25-65	<25	NP-5
	2-65	Gravelly sandy loam, gravelly fine sandy loam, fine sandy loam.	SM, GM	A-2, A-4	0-15	65-100	60-95	40-70	25-85	---	NP
BrC*, BrE*:											
Brookfield------	0-2	Fine sandy loam	SM, ML, GM	A-2, A-4	15-30	65-100	60-95	40-80	25-65	<25	NP-5
	2-65	Gravelly sandy loam, gravelly fine sandy loam, fine sandy loam.	SM, GM	A-2, A-4	0-15	65-100	60-95	40-70	25-45	---	NP
Brimfield-------	0-2	Fine sandy loam	SM, ML, GM	A-2, A-4	15-30	65-100	60-95	40-85	20-65	<25	NP-5
	2-15	Gravelly fine sandy loam, sandy loam, loam.	SM, ML, GM	A-2, A-4	0-15	65-100	60-95	40-80	20-65	<25	NP-5
	15	Unweathered bedrock.	---	---	---	---	---	---	---	---	---

Excerpts from tables in typical Soil Survey report.

Status of Soil Survey Reports in Massachusetts, as of January 1996.

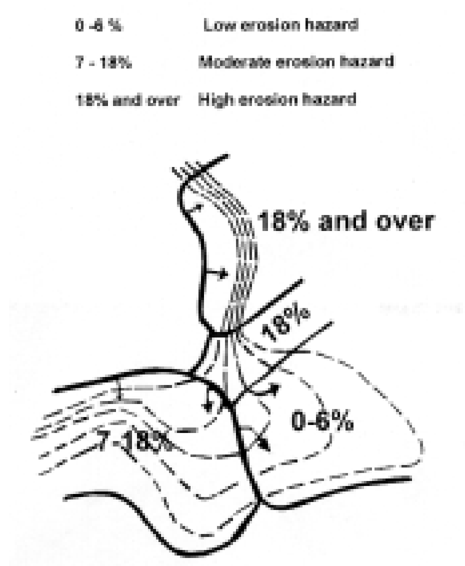
Berkshire County	Published
Franklin County	Report being updated
Hampden and Hampshire Counties, Western	Published
Hampshire County, Central	Published
Hampden County, Central	Published
Hampden and Hampshire Counties, Eastern	Published
Worcester County, Northwestern	Awaiting publication
Worcester County, Northeastern	Published
Worcester County, Southern	Awaiting publication
Middlesex County	Awaiting publication
Essex County, Northern	Published
Essex County, Southern	Published
Norfolk and Suffolk Counties	Published
Plymouth County	Report being updated
Bristol County, Northern	Published
Bristol County, Southern	Published
Barnstable County	Published
Dukes County	Published
Nantucket County	Published

Slopes

Runoff velocity increases as slope length and gradient increase. As the velocity increases, so does its capacity to detach and transport soil particles. In general, the flatter and shorter a slope, the slower the runoff velocity and the greater the infiltration rate on that slope.

Removal of existing vegetative cover from slopes increases the vulnerability of the slopes to erosion. Vegetation retards runoff velocity and root systems hold soil particles in place. Vegetation maintains the soils' capacity to absorb precipitation.

Soils are most vulnerable to erosion where highly erodible soils and steep or long slopes appear in combination, and where surface soils are low in fertility and ability to support vegetation.

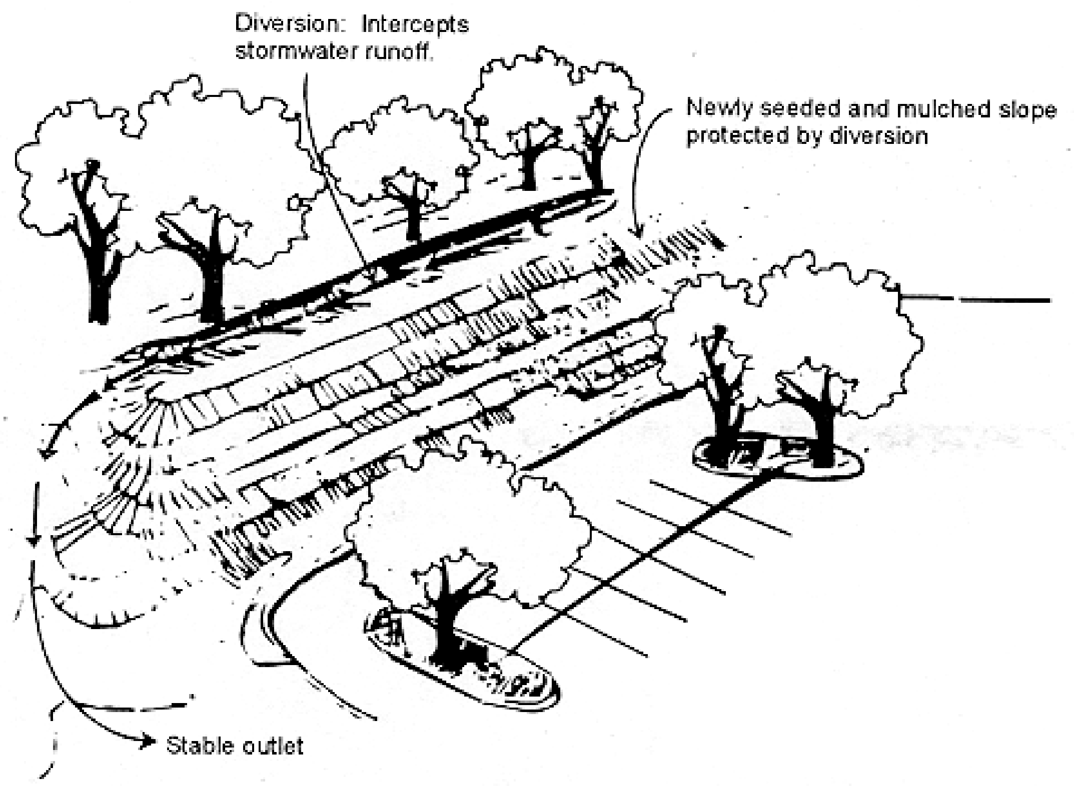


Practices to Divert Runoff

Runoff can be diverted from slopes that are exposed during development by using diversions to intercept runoff and keep it away from the slope face. A diversion extends across a slope, usually a combination of dike and ditch. Diversions can be used at intervals across the slope face to reduce slope length. Diversions are also used to collect runoff from a construction site and divert it to a sediment retention trap or pond.

Diversions can be bare channels, vegetatively stabilized channels, or lined channels (paving, erosion control fabric, etc.). Temporary diversions must remain in place until slopes have been permanently restabilized.

Diversions concentrate the volume of surface runoff. As a result, they also increase its erosive force. It is important to plan in advance for the disposal of runoff collected by diversions. Runoff must be released onto a stabilized area to reduce its erosion potential. In some cases this can be simply achieved by gradually reducing the gradient of the diversion channel.



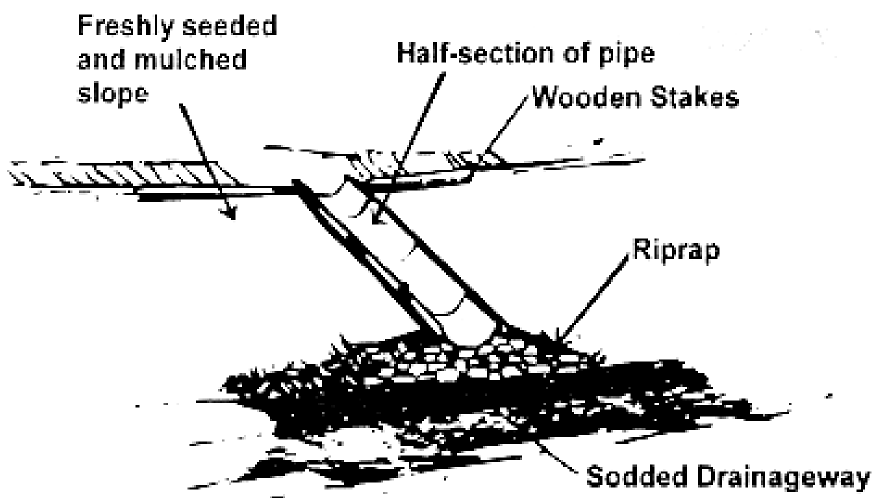
Slope Drains

If runoff cannot be satisfactorily disposed of by conveying across a slope, it can be drained over the face of the slope itself. Slope drains can run down the surface of the slope as a sectional downdrain, paved chute, or a pipe placed beneath the surface of the slope.

On-surface sectional downdrains are usually corrugated metal, or plastic pipe. These slope drains are temporary. For permanent installations; paved chutes with a surface of concrete or bituminous material, or subsurface pipes are used.

Compact the soil carefully at the mouth of the slope drain and anchor it adequately. Otherwise, undercutting can occur at the lip of the slope drain and under the drain.

At the slope drain outlet, energy dissipators are frequently necessary. Failure to utilize an "energy dissipater," such as rock riprap, can result in serious erosion problems at the outflow end of the slope drain. An energy dissipater breaks up the flow of water and reduces velocity to a non-erosive level.

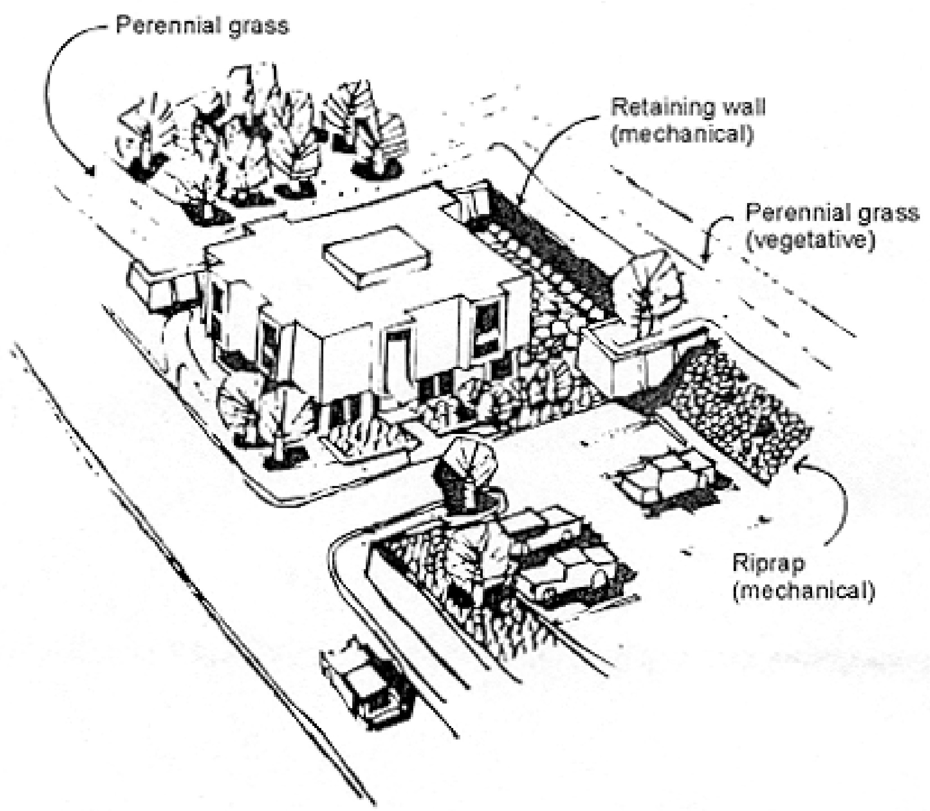


SECTIONAL DOWNDRAIN

Retaining Walls, Slope Protection

Retaining walls may be used to reduce extreme slope gradients, dividing a slope into a series of shorter, flatter segments and structural vertical walls. Retaining walls can be used in a situation where the builder is trying to keep existing mature vegetation. The cost of building retaining walls is often justified because of the maintenance costs that are saved on areas that would be difficult or impossible to stabilize otherwise.

Slope paving (e.g. asphalt or concrete paving, rock lining) may also be used to protect steep slopes that cannot be vegetated. If possible, use permeable materials.



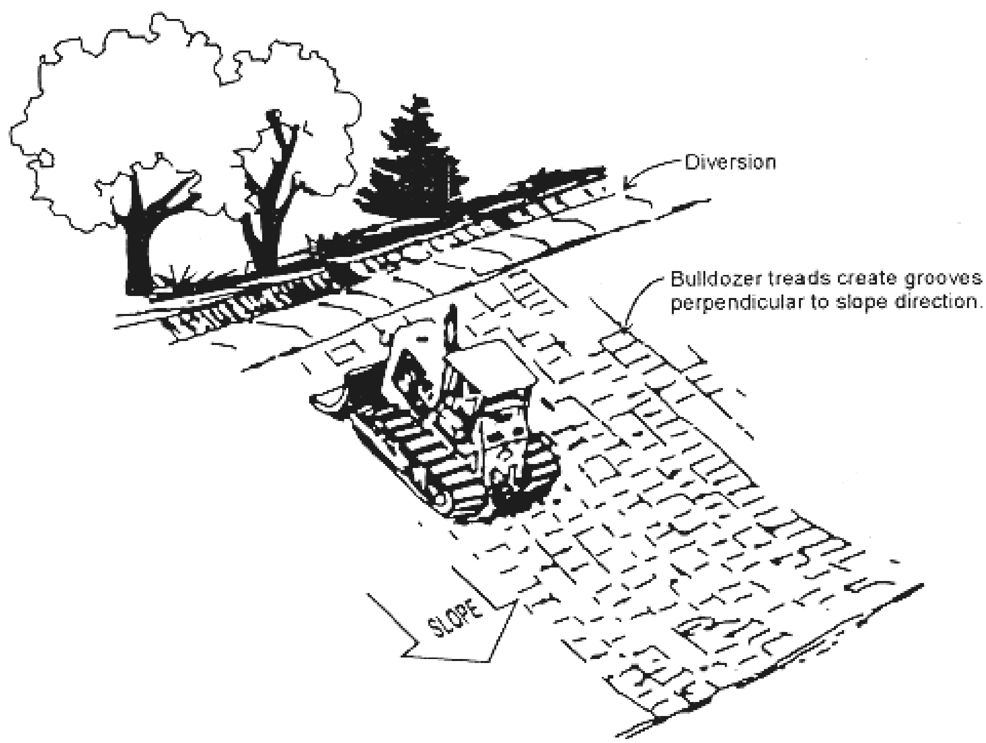
Examples of Vegetative and Mechanical Control Measures

Slope Stabilization Measures

Another way to stabilize slopes is to reduce their steepness. The selection of the appropriate grade for cut and fill slopes should be based on several considerations. The stability of the soil, its drainage characteristics, and its erodibility should be considered first.

If the slope gradient is flattened, the overall length of the slope increases, and this increases the amount of surface area subject to erosion. It is easier, however, to establish vegetation on a flatter slope.

Slope surfaces can be roughened by running wheeled construction equipment across the slopes, or tracked equipment up and down the slope face. This reduces the velocity of water flowing down the slope and increase infiltration rates. The rough surface holds water, seed, and mulch better than a smooth slope. The grooves created by the construction equipment should run across the slope horizontally, and not up and down the slope. Slopes can also be scarified (loosened with a harrow) to produce desired surface roughness.



Drainage

Protecting streams and waterways on or near sites undergoing development and protecting areas downstream from development involves three goals:

- The increased sediment loads carried by surface runoff from areas under construction must not be allowed to enter streams.
- Streambanks must be protected from erosion hazards caused by increases in runoff volume and velocity.
- The rates of release of increased volumes of runoff into streams and waterways and the velocity of flow in stream channels must be controlled.

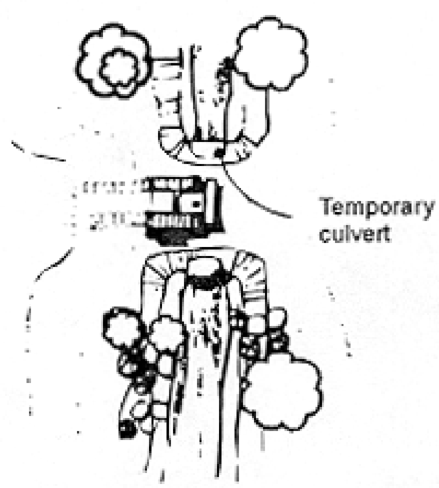
Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent."

There are several identifying characteristics for streams that are particularly vulnerable to erosion. Streams which have a small channel capacity and steep banks are very susceptible to erosion. Streams which flow through areas of erodible soil, and streams with sharp meanders or bends in the channel alignment are also prone to erosion.

Streambank Stabilization Measures

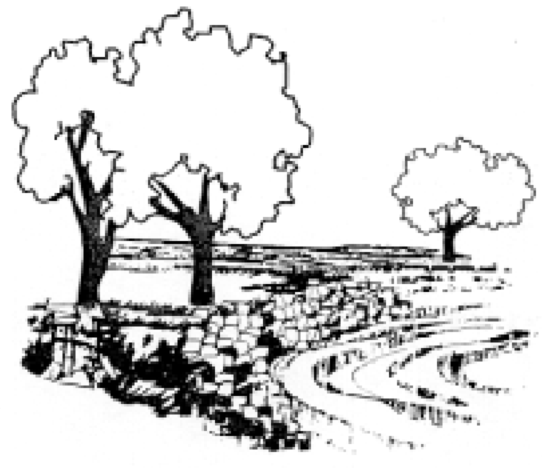
Maintain existing vegetation on streambanks. Streambank vegetation helps stabilize the soil, slows runoff and dissipates its erosive energy, and filters sediment from runoff.

To prevent the destruction of streambank vegetation, stream crossing and construction traffic along the banks must be controlled. Culverts and temporary bridges should be constructed only as a last alternative.



Control Stream Crossing Points

Vegetative Measures



When streambanks must be disturbed, or where existing vegetative cover is inadequate, grass or grass-legume mixtures may be established. Vegetative restabilization should be done immediately after streambank grading has been completed. Grass and legume vegetation is recommended for the protection of streambanks. Woody vegetation (shrubs) may be used if ice damage is a potential problem.

As soon as planting or seeding has been completed, banks should be mulched and the mulch securely anchored. Straw with a plastic-emulsion tacking agent, excelsior blanket, a netting over straw, or similar materials may be used. In recent years manufacturers have developed many new products for soil stabilization.

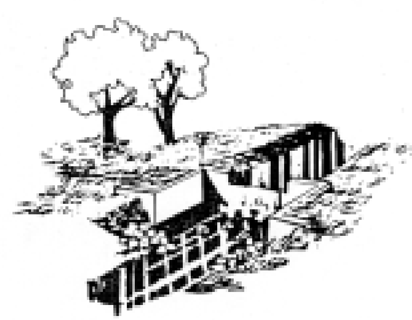
It is important to check periodically and repair areas where vegetation has failed.

Structural Measures

Streambanks can be protected from erosion by structural as well as vegetative measures. If vegetation will not provide sufficient protection, banks can be protected with revetments and deflectors.

Where sharp bends occur or where there are constrictions in the stream channel (such as culverts, bridges, or grade control structures), structural treatment may be necessary. Riprap, gabions, and concrete paving are often used to protect and reinforce a stream bank. Deflectors, consisting of jetties or pilings that angle outward from the bank in a downstream direction, may also be used to keep erosive currents away from vulnerable bank areas.

Grade Control Structures

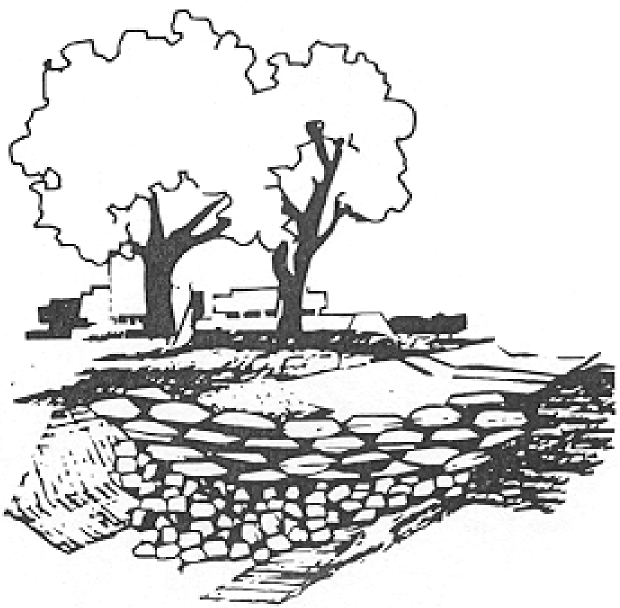


Grade control structures can be used to reduce the channel gradient, thereby reducing the velocity of flow in a channel. Check dams, weirs, and drop spillways, made of a variety of materials, both temporary and permanent, reduce channel grade and dissipate the energy of flowing water. These structures concentrate the volume of water and increase velocity of flow, therefore, special care must be taken to prevent undercutting at the toe of the structure and erosion of the banks.

Sediment Traps or Basins

The first step in preventing sediment from entering streams and waterways is to control erosion on construction sites. The second is to trap sediment transported by runoff before it reaches streams and waterways or leaves the construction site. Runoff must be detained for a sufficient period of time to allow the suspended soil particles to settle.

Vegetative filter strips between streams and development areas can slow runoff and filter out sediment.



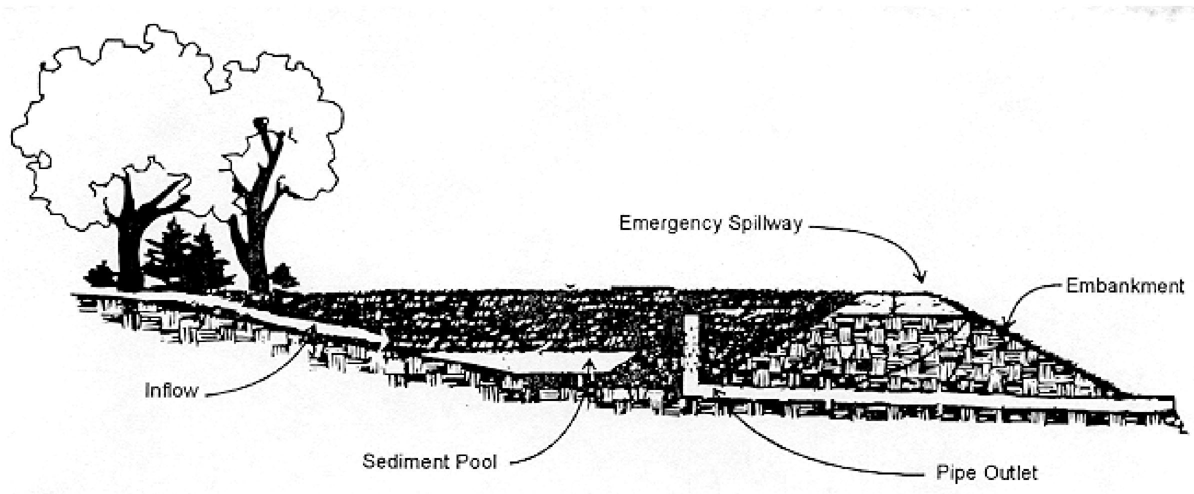
Sediment traps can be constructed in drainageways. Sandbags, straw bale barriers, and excavated sediment traps, placed at regular intervals within a drainage channel, are easy and economical to construct. Sandbag barrier sediment traps are constructed of bags filled with sand or crushed rock and stacked in an interlocking manner designed to trap sediment and reduce velocity of flow.

Straw bale barrier sediment traps are constructed of bales of hay or straw stacked and staked in place. Tying the bales to stakes with wire provides additional stability. Soil excavated from the drainage channel should be compacted along the upstream face of the barrier. Piping, or undercutting, can be reduced by setting the bales at least six inches into the bottom of the drainway and compacting excavated soil along the upstream side. Sediment traps require cleaning out periodically; and they should be checked after heavy rains to repair any damage and remove accumulated sediment.

Streams may also be protected from increased sediment loads by trapping runoff in sediment basins before it is released into stream channels. In addition to trapping sediment, these basins are designed to release runoff at nonerosive rates. Sediment basins usually consist of an earthen dam, a spillway to carry normal water flow, and an emergency spillway for storm flows. Construct sediment basins before clearing and grading of the main site begins. They are generally located at or near the low point of the site. Sediment basin outlets must be stabilized.

Surface runoff, and runoff intercepted by erosion control measures such as diversions, should be conveyed in erosion-resistant drainageways and released to stabilized areas, storm sewers, or sediment basins. The drainageways should be designed to insure that runoff is transported without risk of erosion or flooding.

The development should be planned to maintain and utilize the existing drainageways. Increases in runoff volume and velocity because of changes in soil and surface conditions during and after construction must be anticipated. Where the capacity of the natural site drainage channels is exceeded, additional capacity, stabilizing vegetation, or structural measures will be needed.



Bare Channels

Bare channels should be used with caution, and only in areas where the channel slope is quite flat. In areas where the soils have moderate to high erosion potential, stabilization techniques will need to be a part of the design.

Grassed Waterways

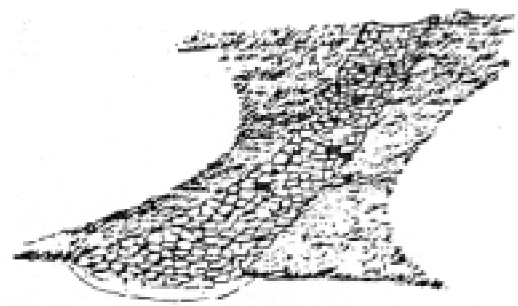
Waterways are designed to transport excess surface water from diversions or natural concentrations of flow in a stable channel. Grassed waterways are vegetatively stabilized channels. Jute netting, paper twine fabric, excelsior blankets, and various other mulching techniques are frequently used to protect channels until vegetation becomes well established. In some vegetatively lined channels, bank protection may also be necessary. Riprap is a commonly used material.

GRASSED WATERWAY

GRASSED WATERWAY WITH NETTING

Lined Channels

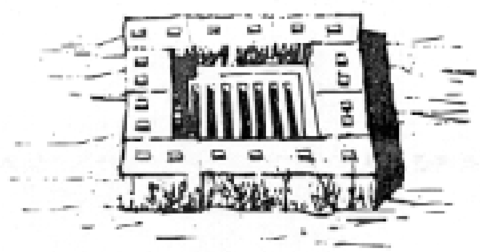
Linings are necessary in drainageways where: vegetation cannot be established because flow is of long duration in the channel, runoff velocities or concentrations are high, erodible soils exist or slopes are very steep. Concrete paving and riprap are commonly used channel linings. In general, vegetative stabilization and the use of permeable channel linings, such as riprap, are preferred to the use of impermeable linings, such as concrete or grouted riprap.



RIPRAP LINED DRAINAGEWAY

Inlet Protection

The capacity of the storm sewer system can be severely impaired by sediment deposits. Sediment should be prevented from entering an enclosed storm sewer by temporary sediment traps and filters at system inlets. Filters made of crushed rock, sod, or straw bales can be placed at inlets where sediment traps cannot be constructed. It is essential to check traps and filters regularly and remove accumulated sediment.



STRAW BALE DRAIN INLET
SEDIMENT BARRIER

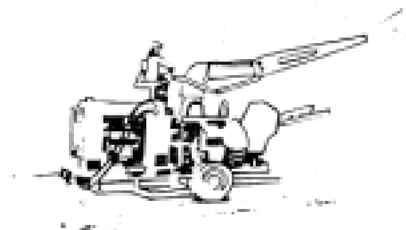
Enclosed Drainage

The capacity of vegetated drainage channels may be exceeded by the increases in runoff caused by earthchanging activities. As a result, vegetatively lined channels may scour and erode. If storm sewers will be needed, install them before major construction begins.

Ground Cover

Vegetative Stabilization Techniques

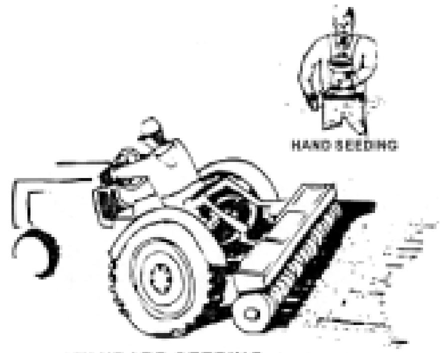
Grass and legumes are the most commonly used plant materials for stabilizing slopes. Vegetation is usually established in one of three ways.



HYDRO-SEEDING

Hydroseeding

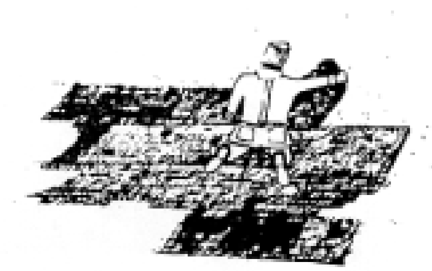
A mixture of seeds, fertilizer, and water is sprayed on the slope. A mulch and a mulch tacking agent should also be applied. Hydroseeding is effective on large areas.



STANDARD SEEDING

Standard seeding

Seed is drilled or broadcast either mechanically or by hand. A cultipacker or similar tool is used after seeding to compact the seedbed and cover the seed. The proper timing of seeding, mulching, and watering is important for areas seeded in this manner.



SODDING

Sodding

Sod strips are laid on the slope and in this way instant cover is provided. Sod should be placed on a prepared bed and pegged on steep slopes. Water and fertilizer are important. This method is effective and is often used on steep slopes and waterway channels.

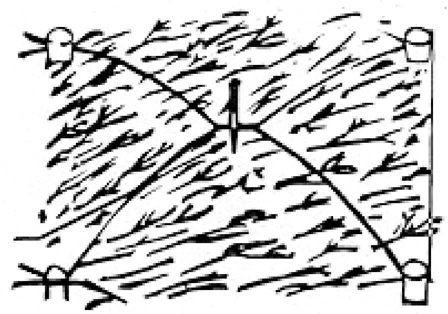
Suitable soil, good seedbed preparation, and adequate water, lime, and fertilizer are “musts” for all these methods.

Immediately after rough grading is completed, exposed slopes should be temporarily stabilized. If final grading will be delayed, temporary seeding and mulching may be used for short period of protection.

As soon as slopes are brought to final grade, permanent vegetation should be planted.

Maintenance will consist primarily of mowing, fertilizing, liming, and watering. It should be scheduled on a regular basis. Reseed bare areas as necessary.

Mulches

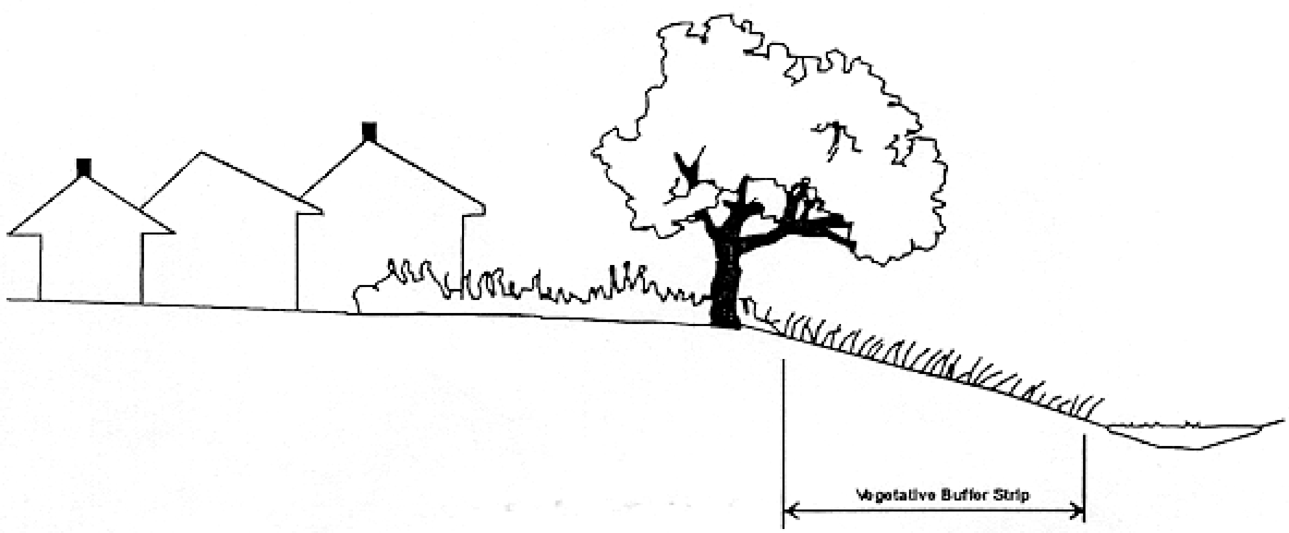


Mulch is usually used after permanent seeding, but may be used before seeding to protect exposed areas for short periods. Mulches protect the soil from the impact of falling rain, slow the velocity of runoff, and increase the capacity of the soil to absorb water. Mulches hold seed in place, preserve soil moisture, and insulate germinating seeds from the extremes of heat and cold.

Many types of mulch are available; such as straw, woodchips, and excelsior mats. Most mulches must be anchored, using plastic emulsions or jute, fiberglass, or plastic netting.

Vegetative Buffer Strips

Sediment can be reduced by maintaining a natural vegetative buffer or filter strip at the base of a slope and by placing sod strips at intervals across the face of the slope. These measures help to slow runoff and trap sediment.



Potential Problems

Some of the problems that arise when a site is developed are high watertable, flood-prone areas, seepage, or adverse soil conditions. If such problem areas are recognized early, site plans can be developed to accommodate, not aggravate, them.

Flood Plains

Is the proposed development located in a flood plain? A Soil Survey report can be used to locate areas subject to flooding by stream overflow. For example, soils such as those in the Hadley or Podunk series would be described as "subject to flooding." The maps in soil survey reports show the location of such soils.

If a Flood Hazard Analysis has been performed for the town, it may be used to locate flood hazard areas.

If neither of the above are available, a rough identification of flood hazard areas may be accomplished by interviewing local residents, checking town records. Field checks of vegetative cover types, soil moisture, or vertical distance above stream level help point out susceptible areas.

Effect of Development on Surface Runoff

Development usually results in the increase of hard-surfaced, impervious areas, which can increase flooding downstream. These effects may be reduced through:

Minimum lot sizes

For example, the runoff from a subdivision of one-quarter acre lots for a two-year frequency storm can be 50% greater than that from the same subdivision with one-acre lots.

Preservation of the natural drainage pattern

Development may disrupt drainage paths that have developed over hundreds of years. The existing, natural drainageways usually have sufficient capacity for the runoff from all except major, infrequent storm events; unless there has been significant change in the cover conditions upstream.

Stormwater Retarding Structures

Often it is not feasible to preserve enough of the natural drainage and vegetative cover to prevent an increase in runoff. A properly designed retarding structure temporarily stores runoff from a developed area and releases the water over a period of time, at a rate within the capacity of the channel downstream

Adverse Soil Conditions

Large Rocks and Ledge

If these are encountered, development costs rise significantly. Plan the development around these conditions and leave rocks and ledge undisturbed if possible.

Settlement Potential

Fills placed on soft organic soils or located in wet areas tend to settle unless care is taken to see that they are properly constructed. Foundations for larger buildings are usually designed by a soils or foundations engineer, but plans for houses, parking lots, driveways may not have been developed with sufficient concern for possible foundation settlement.

Water Table

Areas with a high water table should either be avoided or steps taken to drain or otherwise control the condition. High water table can cause malfunctioning septic systems, damp basements, uneven foundation settlement.

Seepage

Seepage may be encountered at the base of a hill (where the ground surface flattens out); or on a slope, where a roadside cut or an excavation for a foundation is made. Houses, driveways, roads, parking lots, etc., located in such areas usually require drainage measures.

Cuts and Fills

Constructed cuts and fills tend to change site characteristics (drainage, soil materials, stability, etc.). The earth-moving involved raises development costs. A comparison should be made of the cost of doing such work, and the subsequent drainage measures required vs. working with the natural ground contours to minimize cuts and fills. The comparison may show the latter to be more economical; as well as more pleasing to the eye.

Stabilization Principles for Site Development

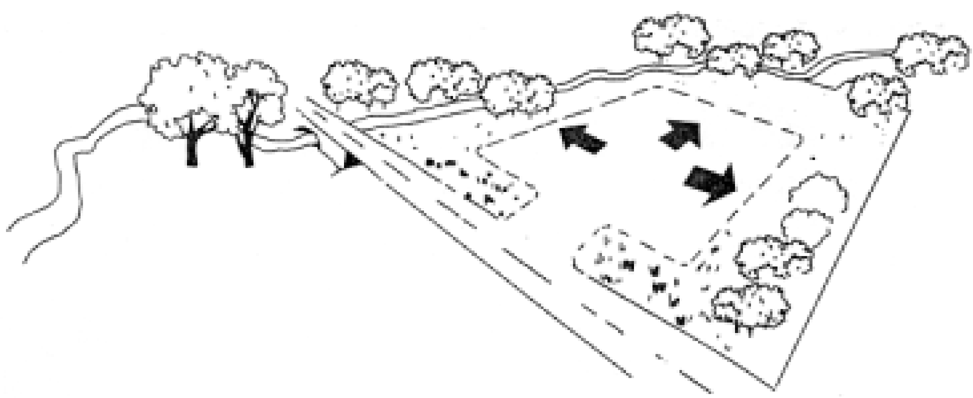
Review and consider all existing conditions in the initial site selection for the project. Select a site that is suitable rather than force the terrain to conform to development needs. Ensure that development features follow natural contours. Steep slopes, areas subject to flooding, and highly erodible soils severely limit a site's use, while level, well-drained areas offer few restrictions. Control seepage and high water table conditions. Any modification of a site's drainage features or topography requires protection from erosion and sedimentation.

Keep Disturbed Areas Small

Careful site selection will help on this point. The site, or corridor, should be able to accommodate the development with a minimum of grading.

The development plan should fit its topographic, soil, and vegetative characteristics with a minimum of clearing and grading. Natural cover should be retained and protected wherever possible. Critically erodible soil, steep slopes, streambanks, and drainageways should be identified. The development can then be planned to disturb these vulnerable areas as little as possible.

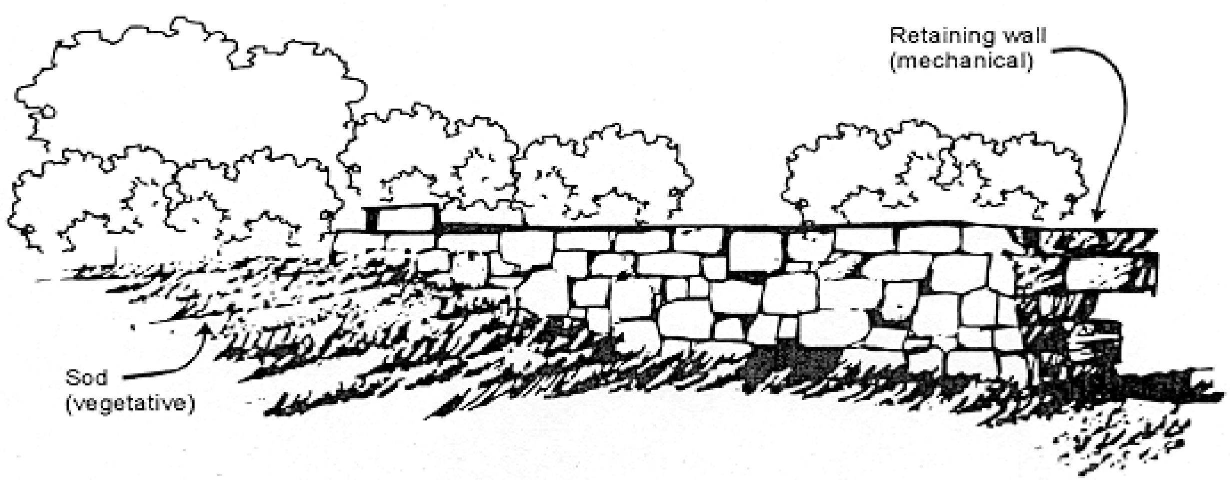
Where earth change and removal of vegetation are necessary, keep the area and duration of exposure to a minimum. Plan the phases of development so that only areas which are actively being developed are



exposed. All other areas should have a good cover of vegetation or mulch.

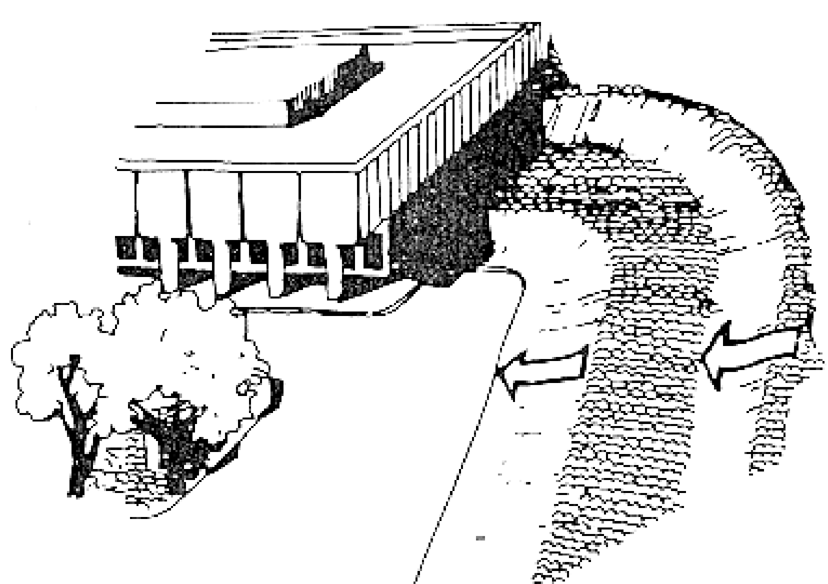
Stabilize and Protect Disturbed Areas as Soon as Possible

Two methods are available for stabilizing disturbed areas: mechanical (or structural) methods and vegetative methods. In some cases, both are combined in order to retard erosion.

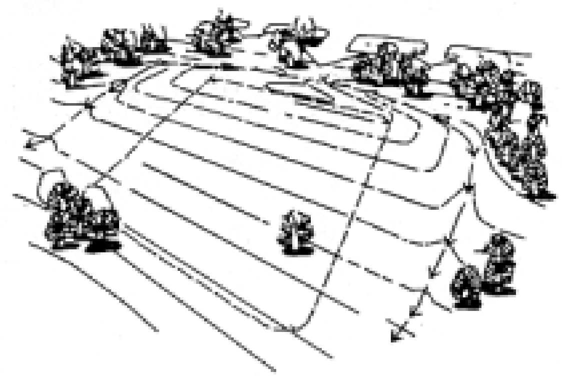


Keep Stormwater Runoff Velocities Low

The removal of existing vegetative cover during development and the resulting increase in impermeable surface area after development will increase both the volume and velocity of runoff. These increases must be taken into account when providing for erosion control.



Protect Disturbed Areas from Stormwater Runoff



Best management practices can be utilized to prevent water from entering and running over the disturbed area. Diversions and other control practices intercept runoff from higher watershed areas, store or divert it away from vulnerable areas, and direct it toward stabilized outlets.

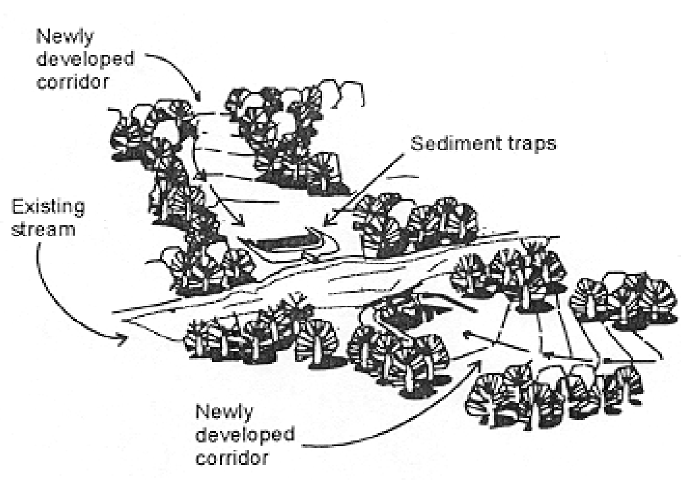
Retain Sediment within the Corridor or Site Area

Sediment can be retained by two methods: filtering runoff as it flows and detaining sediment-laden runoff for a period of time so that the soil particles settle out. The best way to control sediment, however, is to prevent erosion.

After construction is completed, inspection and maintenance are vital to the performance of erosion and sedimentation control measures. If not properly maintained, some practices may cause more damage than they prevent.

When considering which control measure to use, always evaluate the consequences of a measure failing. Failure of a practice may be hazardous or damaging to both people and property. For example, a large sediment basin failure can have disastrous results; low points in dikes can allow them to overflow and cause major gullies a fill slope.

It is essential to inspect all practices to determine that they are working properly and to ensure that problems are corrected as soon as they develop. Provide some means to see that routine checks of operating erosion and sedimentation control practices are carried out after construction is over.



Developing An Erosion and Sediment Control Plan

An erosion and sedimentation control plan should serve as a blueprint for the location, installation, and maintenance of practices to control all anticipated erosion, and prevent sediment from leaving the site.

Tracts of land vary in suitability for development. Knowledge of the soil type, topography, natural landscape values, drainage patterns, flooding potential, and other pertinent data helps identify both beneficial features and potential problems of a site. Developers and builders can minimize erosion, sedimentation, and other construction problems by selecting areas appropriate for the intended use.

The erosion and sedimentation control plan should be a part of the general construction contract. It should show location, design, and construction schedule for all erosion and sedimentation control practices. Also, developers and builders must abide by the local town bylaws.

Contents

An erosion and sedimentation control plan must contain sufficient information to describe the site development and the system intended to control erosion and prevent off-site damage from sedimentation. At a minimum, the plan should contain the following items:

- Brief narrative,
- Vicinity map,
- Site topography map,
- Site development plan,
- Erosion and sedimentation control plan drawing,
- Detail drawings and specifications,
- Vegetation plan,
- Supporting calculations,
- Construction sequence,
- Maintenance plan.

The narrative will clarify details of the plan as an aid for the inspector and the contractor. The narrative should be concise, but should describe:

- Nature and purpose of the proposed development,
- Pertinent conditions of the site and adjacent areas, and
- Proposed erosion and sedimentation control measures.

The narrative should also include how the developer has incorporated applicable regulations (e.g. filed wetlands NOI, applied for an NPDES Storm Water Permit, etc.)

The designer should assume that the plan reviewer has not seen the site and is unfamiliar with the project. Map scales and drawings should be appropriate for clear interpretation.

There is an example erosion and sedimentation control plan in Part 4.

Data Collection and Preliminary Analysis

The base map for the erosion control plan is prepared from a detailed topographic map. A soils map may be obtained from the local Conservation District office. Transferring soil survey information to the topographic map is helpful for site evaluation. Inspect the site to verify the base map with respect to natural drainage patterns, drainage areas, general soil characteristics, and off-site factors.

The base map should reflect such characteristics as:

- Soil type and existing contours,
- Natural drainage patterns,
- Unstable stream reaches and flood marks,
- Watershed areas,
- Existing vegetation,
- Critical areas such as steep slopes, eroding areas, rock out croppings, and seepage zones,
- Unique or noteworthy landscape values to protect,
- Adjacent land uses; especially areas sensitive to sedimentation or flooding, Critical or highly erodible soils that should be left undisturbed.

Base map should include:

Scale
North arrow
Benchmark
Property boundaries
Lot lines

Use the base map to locate:

- Buffer zones,
- Suitable stream crossing areas,
- Access routes for construction and maintenance of sedimentation control devices,
- Borrow and waste disposal areas, and
- The most practical sites for control practices.

Analysis of the topography, soils, vegetation, and hydrology will help the planners and designers to recognize the limitations of the site, and identify locations suitable for development.

Preparing the Plan

The erosion and sedimentation control plan should seek to protect the soil surface from erosion, control the amount and velocity of runoff, and capture sediment on-site during each phase of the construction project:

Schedule activities

Coordinate installation of erosion and sediment control practices with construction activities.

Sediment control practices should precede grading activities.

Protect the soil surface

Limit the extent of disturbance. Stabilize the soil surface immediately. Once the surface has been disturbed, it is vulnerable to erosion and should be protected with appropriate cover, such as mulch or vegetation.

Control surface runoff

Divert water from undisturbed areas to avoid disturbed areas. Break up long slopes with temporary diversions to reduce the velocity of runoff. Divert sediment-laden water to sediment impoundments. Make all outlets and channels stable for the intended flow.

Capture sediment on-site

Divert runoff that transports sediment to an adequate sediment-trapping device to capture sediment on the site.

Preparing the Plan - Step by Step

Runoff-Erosion Analysis

Landscape

Evaluate proposed changes in the landscape to determine their effect on runoff and erosion. Make a note of all physical barriers to surface runoff, such as roads, buildings, and berms. Check slope grades and lengths for potential erosion problems. Designate intended collection points for concentrated flow and specify controls to dissipate energy or stabilize the surface. Designate areas to be protected or used as buffer zones in this phase.

Runoff yield

Evaluate surface runoff for the entire contributing drainage area, both on-site and off-site. Delineate small subwatersheds on-site and estimate peak runoff rates and volumes at selected collection points. Base runoff determinations on site conditions during and after development, not preconstruction conditions.

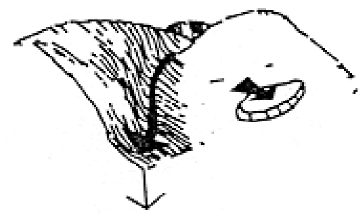
Sediment yield

Estimate sediment yield by subwatersheds. This aids in identifying preferred locations for sediment traps and barriers and can be used to estimate the expected cleanout frequency. An area that is subject to excessive erosion may need extra storage capacity in traps or additional precautions during construction.

Sediment Control

Erosion control practices reduce the amount of sediment generated, but they do not eliminate the need for sediment control devices such as barriers and traps. Sediment control practices operate by reducing flow velocity and creating shallow pools that reduce the carrying capacity of runoff. Thus sedimentation occurs on-site rather than off-site. Sediment is generally not controlled by filtering, but by deposition. The designer should locate all traps and barriers recognizing that they represent deposition points where access for maintenance will be necessary.

Sediment basins and traps

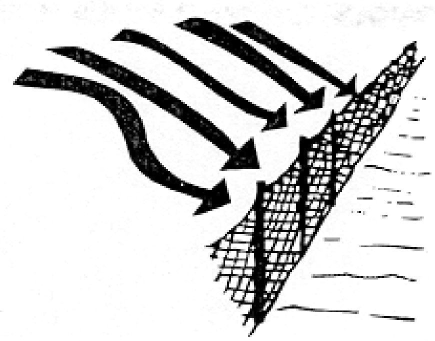


Select sites and install sediment basins and traps before other construction activities are started. Also, consider locations for diversions, open channels, and storm drains at this time so that all sediment-laden runoff can be directed to an impoundment structure before leaving the construction site.

Divert sediment-free water away from sediment basins and release it through stable outlets. This reduces construction costs and improves basin efficiency.

The plan should show access points for cleanout of all traps and basins and indicate sediment disposal areas. Maintenance of storage capacity is essential throughout the construction period.

Sediment fences



Sediment fences provide effective control of sediment carried in sheet flow. They are particularly useful where there is limited space to work such as near property lines, among trees, or near sidewalks or streets. Sediment fences should never be used across streams, ditches, channels, or gullies.

A sediment fence operates by reducing flow velocity and causing a shallow pool to form. If filtering action is required, the designer should assume that the barrier will clog rapidly so that all runoff must be retained behind the fence or released through a designated outlet. Any outlet points must be reinforced and stabilized and should be designated in the plan.

Place sediment fences on relatively flat ground with sufficient area for a pool to develop without putting unnecessary strain on the fence. If a level area is not available at the fence location, excavate a trench directly upslope from the fence.

Show sediment fences on the plan and indicate deposition areas and needed overflow or bypass outlet points. Also show access routes for maintenance.

Inlet protection

Inlet protection devices for storm sewers, conduits, slope drains, or other structures make effective, low-cost deposition areas for trapping and holding sediment. A shallow excavation in conjunction with a sediment barrier can be effective at many locations. Show where these measures will be located, what type of device will be used, and how these devices will be constructed and maintained.

Protection of Disturbed Areas

Once an area is disturbed, it is subject to accelerated erosion. In the plan, show how erosion will be controlled on these disturbed areas. Erosion control can be achieved by:

- Limiting the size of clearing and time of exposure by proper scheduling,
- Reducing the amount of runoff over the disturbed surface,
- Limiting grades and lengths of slopes, and
- Reestablishing protective cover immediately after land-disturbing activities are completed or when construction activities are delayed for 30 or more working days.

Cut-and-fill slopes

Steep cut or fill slopes are particularly vulnerable to erosion. Protect by installing temporary or permanent diversions just above the proposed slope before it is disturbed. Provide a stable channel, flume, or slope drain, where it is necessary to carry water down a slope. Flow channels may be either vegetated, lined with stone, or paved, or a combination - depending on slope and soil conditions.

Shorten long slopes by installing temporary diversions across the slope to reduce flow velocity and erosion potential. Install permanent diversions with slope drains and protected outlets on long steep slopes (over 20%) as the slopes are constructed.

Finish final slope grades without delay and apply surface stabilization measures as soon as possible. Roughen slope surfaces to improve the success of vegetative stabilization. Consider both the stabilization measures and how they will be maintained before planning the steepness of the finish slope. For example, if the finished slope is to have grass cover that will be mowed, it should be constructed on a grade of 3:1 or flatter.

Surface covers

Riprap, gravel, straw and other cover materials can provide immediate surface protection to disturbed soil areas. Riprap is especially useful where concentrated runoff occurs over steep slopes. Riprap should be installed on a gravel or filter fabric bed.

Construction traffic

Construction roads, parking areas, and construction access routes need to be carefully planned. Ensure that traffic patterns follow site contours and limit the length of routes up steeper slopes. Generally, road grades should not exceed 12%.

Controlling surface runoff is necessary to prevent serious roadside erosion. Proper grading of the road surface, stable channel design, and use of water bars, other diversions, and culverts help prevent erosive flows.

Where water tables are high, subsurface drainage may be needed to stabilize the subgrade. Storm drains should be considered for water disposal where channel grade exceeds 5%. Plans should show all stabilization measures needed to control surface runoff from all roads.

Borrow areas and disposal areas

Clear only as needed, and protect from surface runoff. Maintain berms as fill slopes are constructed to reduce slope length and control runoff. Slope all areas to provide positive drainage, and stabilize bare soil surfaces with permanent vegetation or mulch as soon as final grades are prepared. Direct all runoff that contains sediment to a sediment-trapping device. In large borrow and disposal sites, shape and deepen the lower end to form an in-place sediment trap, if site conditions warrant it.

Utilities

Use the spoil from utility trench excavations to divert flow from upslope areas (but use care in spoil placement to avoid blocking natural surface outlets). Diversions and water bars can reduce erosion when properly spaced across utility rights-of-way.

When utilities are located near a stream, maintain an undisturbed buffer zone wherever possible. If site dewatering is necessary, pump or divert muddy water to sediment traps or sump pits before discharging it to the stream. If streams must be crossed, make sure all necessary materials and equipment are on-site before construction begins, and complete work quickly. Finish all disturbed surfaces to design grade and immediately stabilize them with permanent vegetation or other suitable means. Where utilities cross the stream, specify measures to prevent sedimentation.

Perimeter protection

Consider diversion dikes for perimeter protection for all proposed developments and install them where appropriate before clearing the site. Exercise care not to create flooding or erosion by blocking the natural drainage pattern. Be sure to provide an adequate outlet.

Dust control

Exposed soil surfaces that are nearly level have little potential for runoff erosion but may be subject to severe wind erosion. Keeping the disturbed surface moist during windy periods is an effective control measure, especially for construction haul roads.

Preserving vegetation

Preserve existing vegetation on the site as long as possible as a cost-effective way to prevent on-site erosion and off-site sedimentation.

Runoff Conveyance

The safe conveyance of runoff water from a construction site is achieved by: utilizing and supplementing existing stable watercourses, designing and constructing stable open channels, or installing storm drains with stable outlets. The plan should indicate locations and designs for these facilities. Complete and stabilize outlets for channels, diversions, slope drains, or other structures before installing the conveyance measure.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent."

Existing watercourses

When using existing watercourses, either show that flow velocities are acceptable for increased runoff conditions or indicate how necessary stabilization will be achieved.

Excavated channels

When channels are to be excavated, the design should be prepared by a professional engineer. Include calculations in the plan documentation.

Wide, shallow channels with established grass linings are usually stable on slopes up to 5%. These channels must be protected with temporary liners until grass is established. If channel gradients are too steep to use vegetation, riprap or concrete linings may be required. In some instances grade stabilization structures may be needed.

Storm drains

Where the site plan calls for a system of storm drains, the drains may be used effectively in the erosion and sedimentation control plan. Build junction boxes or inlets early in the construction sequence, and grade the adjacent area to drain toward the inlet. Install an inlet protection device at all open pipe inlets and excavate a shallow basin in the approach to the inlet for sediment storage.

The storm drain flow from the protected inlets may be diverted to a sediment basin for additional sediment control. Restrict the drainage area for inlets to less than one acre. Inspect inlet protection devices frequently for needed maintenance.

Stream Protection

Streambanks, streambeds, and adjoining areas are susceptible to severe erosion if not protected. Include sufficient detail to show that streams are stable for the increased velocities expected from the development activity. At a minimum, all streams should be stable for flows from the peak runoff from the 10-year storm.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent."

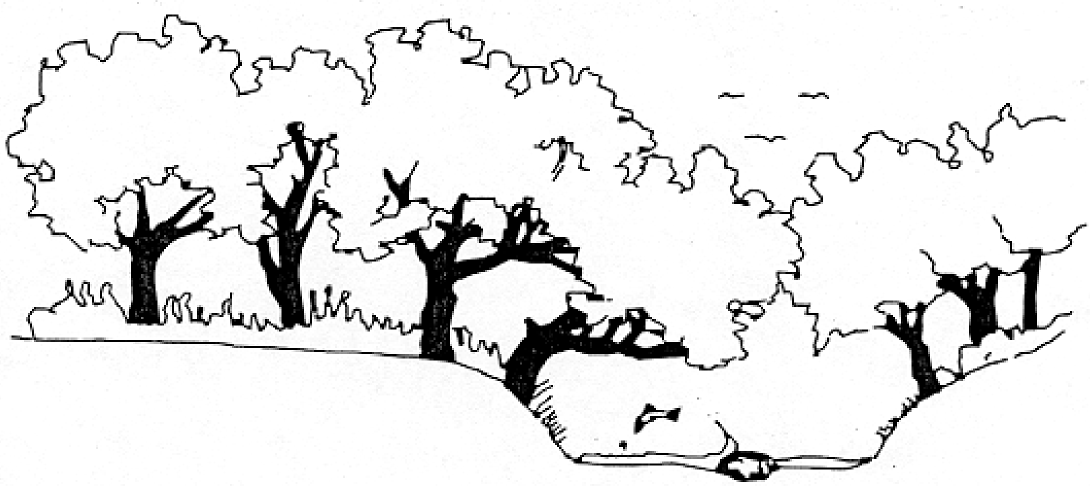
When stability analysis shows that the stream requires protection, vegetation is usually the preferred approach because it maintains the stream nearest to its natural state. When flow velocities approach 4-6 feet per second, or if frequent periods of bankful flows are expected; structural measures such as riprap lining or grade stabilization structures are usually necessary. In the plan, show where stream protection is needed and how it will be accomplished.

Runoff into stream

Only sediment-free runoff may be discharged from construction sites directly into streams. Ensure that all other flows enter from desilting pools formed by sediment traps or barriers.

Velocity control

Keep the velocity of flow discharged into a stream within acceptable limits for site conditions. Control velocity by installing an appropriate outlet structure.



Buffer zone

Areas adjoining streams should be left undisturbed as buffers. Existing vegetation, if dense and vigorous, will reduce flow velocities and trap sediment from sheet flow. However, the principal benefit of leaving natural buffer zones along streams is that they prevent excessive erosion in these sensitive areas. Maintaining stream canopies also protects fish and wildlife habitats; provides shade, windbreaks, and noise barriers, protects the bank from out-of-bank flood flows; and generally preserves natural site aesthetics.

Indicate stream buffer zones in plans that involve natural streams. The width is determined by site conditions but generally should not be less than 25 feet on each side of the stream. If natural buffers are not available, provide artificial buffers.

Off-site stream protection

Increased rate and volume of runoff from development activities may cause serious erosion at points some distance downstream. The developer should work with downstream property owners to stabilize sensitive downstream channel areas.

Stream crossing

Minimize the number of stream crossings. Construct crossings during dry periods. If necessary, divert water during construction. The plan should show the type of crossing to be used and the associated control measures to minimize erosion from surface runoff such as diversions, outlet structures, riprap stabilization, etc.

Construction Scheduling

Appropriate sequencing of construction activities is an effective means for controlling erosion and sedimentation. Use the construction schedule of the general contract as part of the erosion and sedimentation control plan. Install the primary erosion and sedimentation control practices for the site, i.e. sediment basins and traps, and a water conveyance system before undertaking major land-disturbing activities. Schedule work with an eye to the calendar, to minimize impacts due to seasonal changes.

Install sediment basins and primary sedimentation control practices as the first structural measures. Next install the overall water disposal outlet system for the site.

Stabilize all construction access routes, including construction entrances and exits, and the road drainage system, as the roads are constructed. Install storm drains early in the construction sequence and include them in the sedimentation control plan. Install inlet protection devices for efficient sediment control around the inlets. This allows early

Construction Scheduling - EPA Baseline General Permit Requirements for Site Stabilization:

Except as provided in the paragraphs below, stabilization measures shall be initiated as soon as practicable in portions of the site where construction activities have temporarily or permanently ceased, but in no case more than 14 days after the construction activity in that portion of the site has temporarily or permanently ceased.

(a) Where the initiation of stabilization measures by the 14th day after construction activity temporary or permanently cease is precluded by snow cover, stabilization measures shall be initiated as soon as practicable.

(b) Where construction activity will resume on a portion of the site within 21 days from when activities ceased (e.g. the total time period that construction activity is temporarily ceased is less than 21 days), then stabilization measures do not have to be initiated on that portion of site by the 14th day after construction activity temporarily ceased use of the inlets and the drain system.

Install diversions above areas to be disturbed and, where needed, along boundaries of areas to be graded before grading takes place.

After all principal erosion and sedimentation control measures are in place, perform the land clearing and rough grading. Clear areas only as needed and complete final grading and surface stabilization as soon as possible. Minimize the time of exposure and select temporary ground cover according to the location and season. Temporary surfaces should be stabilized as soon as active grading is suspended, regardless of the time of year. Disturbed areas should be revegetated early enough in the autumn that good cover is established before cold weather comes.

Inspection and Maintenance

In the erosion and sedimentation control plan, indicate who is responsible for maintenance and when it will be provided. The maintenance schedule should be based on site conditions, design safeguards, construction sequence and anticipated weather conditions. Specify the amount of allowable sediment accumulation, design cross-section, and, required freeboard for each practice and what will be done with the sediment removed. The plans should also state when temporary practices will be removed and how these areas and waste disposal areas will be stabilized.

Inspection Program

Essential parts of an inspection program include:

· Inspection during or immediately following initial installation of sediment controls.

· Inspection following severe rainstorms to check for damage to controls.

· Inspection prior to seeding deadlines, particularly in the fall.

· Final inspection of projects nearing completion to ensure that temporary controls have been removed, stabilization is complete, drainageways are in proper condition, and that the final contours agree with the proposed contours on the approved plan.

In addition, interim inspections should be made as manpower and workload permit, giving particular attention to the maintenance of installed controls.

All inspections should be documented by a written report or log. These reports should contain the date and time of inspections, dates when land-disturbing activities begin, comments concerning compliance or noncompliance and notes on any verbal communications concerning the project.

Before Construction

An on-site preconstruction meeting involving the owner, contractor, and erosion control personnel is recommended. This allows all parties to meet, review the plans and construction schedule, and agree on responsibility and degree of control expected. Discuss maintenance requirements, phasing of operations, and plan revisions. The preconstruction meeting is especially important for large, complex jobs or when the contractor and/or developer has had little experience in this type of work.

During Construction

The developer may be held responsible for off-site sediment damage resulting from construction activities even though an approved plan has been properly installed and maintained. Therefore, inspect the property boundary frequently for evidence of sedimentation.

It may be necessary to modify the erosion and sediment control plan during construction to account for unanticipated events or construction changes.

During Construction

In addition to the inspection and maintenance reports, the operator should keep records of the construction activity on the site, including:

· Dates when major grading activities occur in a particular area.
· Dates when construction activities cease in a particular area, temporarily or permanently.
· Dates when a particular area is stabilized, temporarily or permanently.

After Construction

Items to consider after construction is completed include permanent stabilization once activities have ceased, removal of temporary structural measures, final inspection, and maintenance of permanent structures.

References

Lobdell, Raymond, A Guide to Developing and Re-Developing Shoreland Property in New Hampshire, North Country Resource Conservation and Development Area, Inc., Meredith, NH, 1994.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts Nonpoint Source Management Manual, Boston, Massachusetts, June, 1993.

Minnesota Pollution Control Agency, Division of Water Quality, Protecting Water Quality in Urban Areas, Best Management Practices for Minnesota, ________ , MN, October, 1989.

Minnick, E. L., and H. T. Marshall, Stormwater Manageement and Erosion Control for Urban and Developing Areas in New Hampshire, Rockingham County Conservation District, August 1992.

North Carolina Sediment Control Commission, Erosion and Sediment Control Planning and Design Manual, Raleigh, NC, September, 1988.

Schueler, Thomas R., Controlling, Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, Metropolitan Washington Council of Governments, Washington, DC, July, 1987.

Southern New England Chapter, Soil Conservation Society of America, Recommendations for Erosion and Sediment Control During Land Use Change, January, 1978.

Tourbier, J., and R. Westmacott, Water Resources Center, University of Deleware, Water Resources Protection Measures in Land Development - A Handbook, Newark, Del., April, 1974.

U. S. Environmental Protection Agency, Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters, EPA-840-B-92-002, Washington, DC, January, 1993.

Washington State Department of Ecology, Stormwater Management Manual for the Puget Sound Basin, Olympia, WA, February, 1992.

Best Management Practice Selection

On any construction site the objective in erosion and sediment control is to prevent off-site sedimentation damage. Four basic methods are used to control erosion on construction sites: planning, soil stabilization, runoff control and sediment control. Careful site analysis, planning and scheduling can reduce the need to utilize stabilization and control practices, and, thereby, reduce the cost of implementing these measures.

Identify Control Problem

Controlling erosion should be the first line of defense. Controlling erosion is very effective for small disturbed areas such as single lots or small areas of a development that do not drain to a sediment-trapping facility. Where soil properties and topography of the site make the design of sediment trapping facilities impractical, runoff control and soil stabilization should be used.

Sediment trapping facilities should be used on large developments where mass grading is planned, where it is impossible or impractical to control erosion, and where sediment particles are relatively large. A combination of erosion control and sedimentation control measures is usually the least expensive way to accomplish erosion and sediment control.

Identify Problem Areas

Areas where erosion is to be controlled usually involve slopes, graded areas or drainage ways. Slopes include graded rights-of-way, stockpile areas, and all cut or fill slopes. Graded areas include all stripped areas other than slopes. Drainage ways are areas where concentrations of water flow naturally or artificially. Problem areas that need sediment control can be either large or small.

Identify Required Strategy

Select the strategy to solve the problem. Strategies can utilize an individual practice or a combination of practices. For example, if there is a cut slope to be protected from erosion, the strategies may be to protect the ground surface, divert water from the slope or shorten it. Any combination of the above can be used. If no rainfall except that which falls on the slope has the potential to cause erosion, and if the slope is relatively short, protecting the soil surface may be all that is required to solve the problem.

Select Specific Control Measures

The tables on the following pages are guides for selecting erosion and sediment control practices. This material can be used by either designers and developers or by plan review agencies.

The practices chosen for a site will often vary from one individual to another, depending on individual judgement and preference, past experience with a conservation practice, and the practices' suitability for a particular site. Persons reviewing an erosion and sedimentation control plan should not expect to find one set of "predetermined practices" used. The reviewer can, however, refer to these tables: (a) as an aid in recognizing potential problem areas that may exist at a site, and (b) for guidance to see if the developer and designer have addressed the potential problems.

SITE WORK: On-site Roads, Controlling Road Runoff

ITEM	RECOMMENDED PRACTICES
Site Preparation	Preserving Natural Vegetation Construction Entrance Construction Road Stabilization Filter Berm
Surface Stabilization	Temporary Seeding Mulching Riprap
Runoff Control	Temporary Diversions Water Bars Sump Pit
Runoff Conveyance	Grassed Waterway (Slopes up to 5%) Lined Waterway Temporary Slope Drain Paved Flume Vegetated Swale Inlet Protection Outlet Protection and Stabilization
Other	Dust Control

(Note: The structural practices listed above are suitable for slopes of up to 12%, except as noted. Steeper slopes usually need special consideration.)

Clearing and Grading

ITEM	RECOMMENDED PRACTICES
Site Preparation	Preserving Natural Vegetation Construction Entrance Land Grading
Surface Stabilization	Surface roughening Terrace Topsoiling Temporary Seeding Permanent Seeding Mulching Riprap
Runoff Control	Temporary Diversion Permanent Diversion Terrace Water Bar Sump Pit
Outlet Protection	Outlet Protection and Stabilization Level Spreader
Runoff Conveyance	See Storm Runoff sheet
Sediment Traps and Barriers	See Sediment Control sheet
Other	Dust Control

Excavations, Stockpiles, & Debris Disposal

ITEM	RECOMMENDED PRACTICES
Surface Stabilization	Surface roughening Topsoiling Temporary Seeding Permanent Seeding Trees and Shrub Planting Mulching
Runoff Control	Temporary Diversion
Sediment Traps and Barriers	Sediment Trap Sediment Fence
Other	Dust Control

Rill and Gully Erosion

ITEM	RECOMMENDED PRACTICES
Runoff Control	Temporary Diversion Permanent Diversion Water Bar Buffer Zone
Runoff Conveyance	Riprap-lined Channel Lined Waterway Temporary Slope Drain Paved Flume
Outlet Protection	Outlet Protection and Stabilization Level Spreader
Surface Stabilization	Slope Stabilization Topsoiling Surface Roughening Temporary Seeding Permanent Seeding Mulching Riprap Tree and Shrub Planting

Sediment Control

(Measures should be installed before major land disturbance begins)

ITEM	RECOMMENDED PRACTICES
Disturbed areas of less than 2 acres	Sediment Trap Sediment Fence Filter Berm Brush Barrier (Drainage area up to ¼ acre) Filter Strip Straw or Hay Bale Barrier Silt Curtain
Disturbed areas, 2-5 acres	Sediment Trap Sediment Basin Filter Strip Rock Dam Silt curtain
Disturbed areas of more than 5 acres	Sediment Basin Rock Dam Silt Curtain
Other	Dust Control

Storm Runoff

ITEM	RECOMMENDED PRACTICES
Drainage area less than 20 acres	
Runoff Control	Temporary Diversion Permanent Diversion Water Bar
Runoff Conveyance	Grassed Waterway (Slopes up to 5%) Vegetated Swale Lined waterway Riprap-lined Channel Temporary Slope Drain Paved Flume Inlet Protection
Outlet Protection	Level Spreader (Drainage up to 5 acres) Outlet Protection and Stabilization

Drainage area more than 20 acres

Same as above, except in addition, the designer would normally perform hydrologic and hydraulic calculations showing that runoff, during and after construction of the project, would comply with permitting agency requirements.

Streambank Protection and Stabilization

ITEM	RECOMMENDED PRACTICES
Design velocity less than 6 feet per second	Vegetative Methods Soil Bioengineering Methods Structural Methods
Design velocity more than 6 feet per second	Soil Bioengineering Methods Structural Methods

(Note: Contact the local Conservation Commission regarding any work conducted in what may be a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a “Request for Determination of Applicability” or “Notice of Intent.”)

Stream Crossings

ITEM	RECOMMENDED PRACTICES
Temporary	
To move equipment	Stream Crossing, Temporary
Surface Stabilization	Temporary Seeding Mulching Riprap
Permanent	
Vehicular traffic,To move Equipment	Permanent Stream Crossing; e.g. Bridge or Culvert
Surface Stabilization	Permanent Seeding Mulching Riprap

(Note: Contact the local Conservation Commission regarding any work conducted in what may be a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent.")

Building Construction, Utilities Installations

ITEM	RECOMMENDED PRACTICES
Surface Stabilization	Surface Roughening Topsoiling Temporary Seeding Permanent Seeding Mulching Tree and Shrub Planting
Runoff Control	Temporary Diversion Water Bar Sump Pit
Sediment Control	Sediment Trap Sediment Fence Filter Strip
Other	Construction Road Stabilization Dust Control

Special Site Problems

ITEM	RECOMMENDED PRACTICES
Seepage areas or high water table	Subsurface Drainage Sump Pit
Unstable temporary channels	Check Dam Riprap-lined Channel
Unstable permanent channels	Riprap-lined Channel Lined Waterway Grade Stabilization Structure
Blowing dust or sand	Dust Control Sand Fence
Dune reinforcement and stabilization	Sand Dune and Sandblow Stabilization Sand Fence

(Note: Contact the local Conservation Commission regarding any work conducted in what may be a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent.")

Final Site Stabilization

ITEM	RECOMMENDED PRACTICES
Surface Stabilization	Surface roughening Terrace Topsoiling Permanent Seeding Sodding Trees and Shrub Planting Mulching Riprap
Runoff Control	Permanent Diversion
Runoff Conveyance	Grassed Waterway Vegetated Swale Lined Waterway Riprap-lined Channel Paved Flume
Outlet Protection	Level Spreader Outlet Protection and Stabilization
Inlet Protection	Sod Drop Inlet Protection, or permanent paving

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

New York Guidelines for Urban Erosion and Sediment Control, March 1988.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual,*** Raleigh, NC, September, 1988.

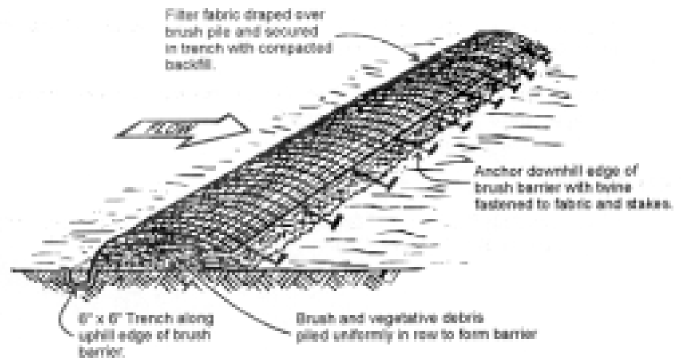
Practices

Brush Barrier
Buffer Zones, Stream Corridors, and Riparian Areas
Check Dam
Construction Entrance
Construction Road Stabilization
Diversion, Permanent
Diversion, Temporary
Dust Control
Filter Berm
Filter Strip, vegetated
Flume, paved
Gabions
Geotextiles
Grade Stabilization Structure
Inlet Protection
Land Grading
Level Spreader
Mulching & Netting
Outlet Protection & Stabilization

Brush Barrier

A temporary sediment barrier constructed at the perimeter of a disturbed area, using residue materials available from clearing and grubbing on-site.

Used to intercept and retain sediment from limited disturbed areas.



Where Practice Applies

Below disturbed areas of less than one quarter acre that are subject to sheet and rill erosion, where enough residue material is available for construction of such a barrier. Note: This does not replace a sediment trap or pond.

Advantages

- Brush barriers can often be constructed using materials found on-site.

Planning Considerations

Organic litter and spoil material from site clearing operations is usually hauled away to be disposed of elsewhere. Much of this material can be used effectively on the construction site itself. During clearing and grubbing operations, equipment can push or dump the mixture of limbs, small vegetation, and root mat along with minor amounts of soil and rock into windrows along the toe of a slope where erosion and accelerated runoff are expected.

Because brush barriers are fairly stable and composed of natural materials, maintenance requirements are small. Material containing large amounts of wood chips should not be used because of the potential for leaching from the chips.

Design Recommendations

Height - 3 feet maximum.

Width - 5 to 15 feet at base.

Filter fabric anchored over the berm will enhance its filtration capacity.

Practices

Preserving Natural Vegetation
Riprap
Rock Dam
Sand Dune & Sandblow Stabilization
Sand Fence
Sediment Basin
Sediment Fence
Sediment Trap
Seeding, permanent
Seeding, temporary
Silt Curtain
Slope Drain

Sodding
Staw or hay bale barrier
Stream Crossing
Streambank Protection & Stabilization
Subsurface Drain
Sump Pit
Surface Roughening
Topsoiling
Tree& Shrub Planting
Vegetated Swale
Water Bar
Waterway, grassed
Waterway, lined

Maintenance

Brush barriers generally require little maintenance. Heavy deposits of sediment may need removal. Occasionally, tearing of the filter fabric may occur.

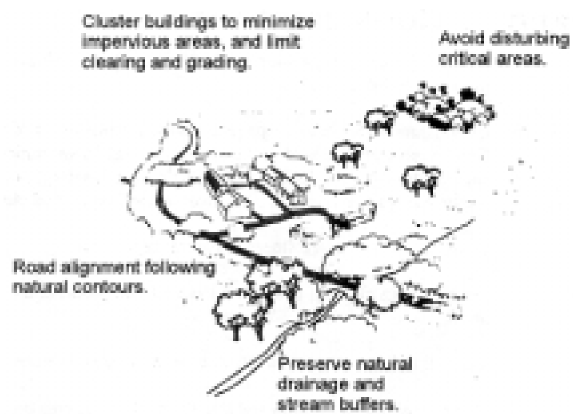
When the barrier is no longer needed the fabric can be removed to allow natural establishment of vegetation within the barrier. The barrier will rot over time.

References

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Buffer Zones, Stream Corridors, and Riparian Areas

An undisturbed area or strip of natural vegetation or an established suitable planting that will provide a living filter to reduce soil erosion and runoff velocities.



Where Practice Applies

Natural buffer zones are used along streams and other bodies of water that need protection from erosion and sedimentation. Vegetative buffer zones can be used to protect natural swales and incorporated into natural landscaping of an area.

Advantages

Buffer zones provide critical habitat adjacent to streams and wetlands, as well as assist in controlling erosion, especially on unstable steep slopes. Buffers along streams and other water bodies also provide wildlife corridors, a protected area where wildlife can move from one place to another.

- Buffer zones act as a visibility and noise screen, and provide aesthetic benefits.
- Low maintenance requirements.
- Low cost when using existing vegetation.

Disadvantages/Problems

Extensive buffers will increase development costs.

Planning Considerations

- Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.
- Establishing new buffer strips requires the establishment of a good dense turf, trees, and shrubs. Careful maintenance is important to ensure healthy vegetation. The need for routine maintenance such as mowing, fertilizing, liming, irrigating, pruning, and weed and pest control will depend on the species of plants and trees involved, soil types, and climatic conditions.
- Leave all unstable steep slopes in natural vegetation.
- Fence or flag clearing limits and keep all equipment and construction debris out of the natural areas.
- Keep all excavations outside the dripline of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage from burying and smothering.

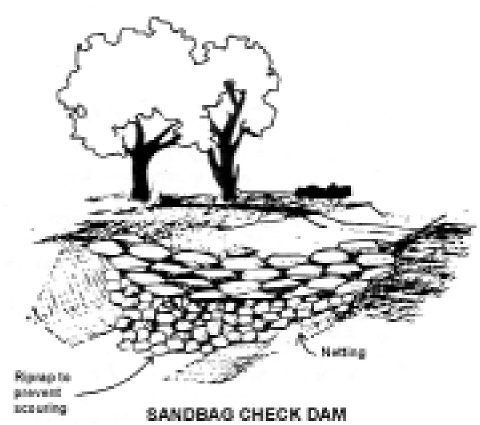
References

U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities,*** EPA-832-R- 92-005, Washington, DC, September, 1992.
Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin, Olympia***, WA, February, 1992.

Check Dam

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the speed of flow. Reduced runoff speed reduces erosion and gullying in the channel and allows sediments to settle out.

A check dam may be built from stone, sandbags filled with pea gravel, or logs.



Purpose

To reduce flow velocity: reducing erosion of the swale or ditch, and allowing retention of sediments.

Where Practice Applies

Where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible and velocity checks are required.

This practice may be used as a temporary or emergency measure to limit erosion by reducing flow in small open channels.

This practice should be used with drainage areas of 2 acres or less.

Check dams may be used:

- To reduce flow in small temporary channels that are presently undergoing degradation,
- Where permanent stabilization is impractical due to the temporary nature of the problem, and
- To reduce flow in small eroding channels where construction delays or weather conditions prevent timely installation of non-erosive liners.

Advantages

- Inexpensive and easy to install.
- Reduce velocity and may provide aeration of the water.
- Check dams not only prevent gully erosion from occurring before vegetation is established, but also cause a high proportion of the sediment load in runoff to settle out.
- In some cases, if carefully located and designed, these check dams can remain as permanent installations with very minor regrading, etc. They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to capture further sediment coming off that site.

Disadvantages/Problems

- Because of their temporary nature, many of these measures are unsightly, and they should be removed or converted to permanent check dams before dwelling units are rented or sold.
- Removal may be a significant cost depending on the type of check dam installed.
- Check dams are only suitable for a limited drainage area.
- May kill grass linings in channels if the water level remains high after rainstorms or if there is significant sedimentation.
- Reduce the hydraulic capacity of the channel.
- May create turbulence which erodes the channel banks.
- Clogging by leaves in the fall may be a problem.

Planning Considerations

Check dams are usually made of stone. The center section must be lower than the edges.

The dams should be spaced so that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

Ensure that overflow areas along the channel are resistant to erosion from out-of-bank flow caused by the check dams.

Check dams can also be constructed of logs, or pea gravel filled sandbags. Log check dams may be more economical from the standpoint of material costs, since logs can often be salvaged from clearing operations. However, log check dams require more time and hand labor to install. Stone for check dams must generally be purchased. This cost is offset somewhat by the ease of installation.

If stone check dams are used in grass-lined channels which will be mowed, care should be taken to remove all the stone from the channel when the dam is removed. This should include any stone which has washed downstream.

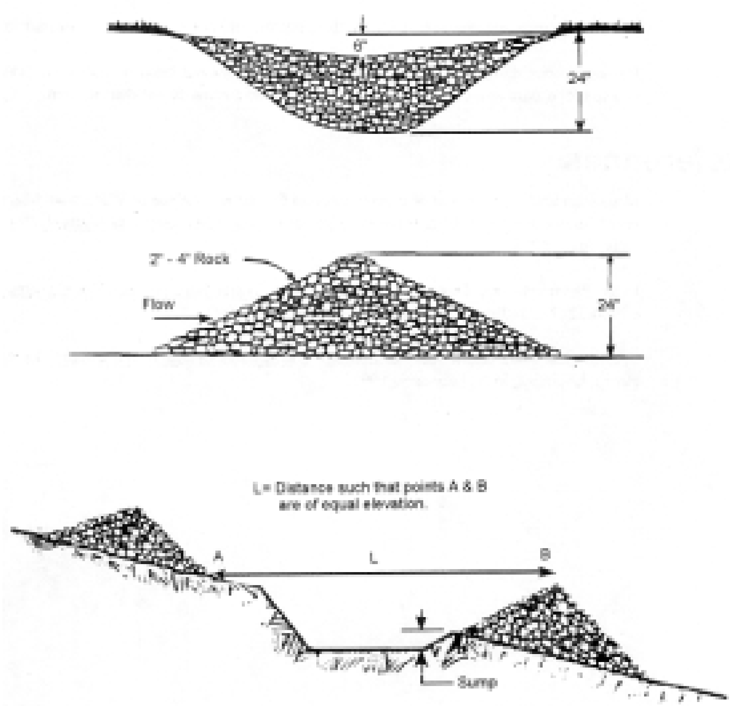
Since log check dams are embedded in the soil, their removal will result in more disturbance of the soil than will removal of stone check dams. Consequently, extra care should be taken to stabilize the area when log dams are used in permanent ditches or swales.

Design & Construction Recommendations

Check dams can be constructed of rock, sand bags filled with pea-gravel, or logs. Provide a sump immediately upstream.

The maximum spacing between the dams should be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.

The rock must be placed by hand or mechanical placement (do not dump rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges. The rock used must be large enough to stay in place given the expected design flow through the channel.



Log check dams should be constructed of 4 to 6-inch diameter logs embedded into the soil at least 18 inches.

In the case of grass-lined ditches and swales, check dams shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent. The area beneath the check dams shall be seeded and mulched immediately after dam removal.

Common Trouble Points

Stone displaced from face of dam
Stone size too small and/or face too steep.

Erosion downstream from dam
Provide stone-lined apron.

Erosion of abutments during high flow
Rock abutment height inadequate.

Sediment loss through dam
Inadequate layer of aggregate on inside face or aggregate too coarse to restrict flow through dam.

Maintenance

- Inspect after each rainfall event.
- Remove sediment accumulations.
- Check structure and abutments for erosion, piping, or rock displacement. Repair immediately.
- Remove check dam after the contributing drainage area has been permanently stabilized. Smooth site to blend with surrounding area and stabilize according to vegetation plan.

References

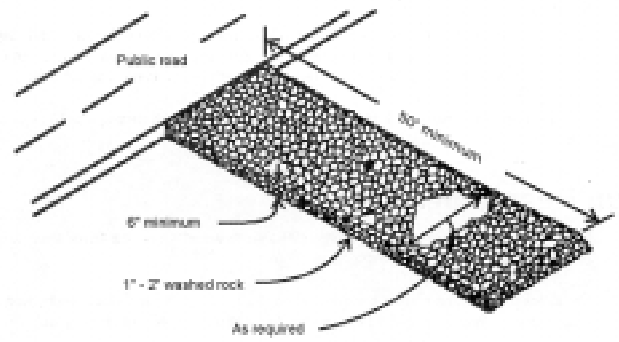
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Construction Entrance

A temporary stone-stabilized pad located at points of vehicular ingress and egress on a construction site.



Purpose

To provide a stable entrance and exit from a construction site and keep mud and sediment off public roads.

Where Practice Applies

Whenever traffic will be leaving a construction site and moving directly onto a public road or other paved areas.

Advantages

- Mud on vehicle tires is significantly reduced which avoids hazards caused by depositing mud on the public roadway.
- Sediment, which is otherwise contained on the construction site, does not enter stormwater runoff elsewhere.

Disadvantages

Effective only if installed at every location where traffic leaves and enters the site.

Planning Considerations

Avoid locating at curves in public roads or on steep slopes.

Construction entrances provide an area where mud can be removed from vehicle tires before they enter a public road. If the action of the vehicle traveling over the gravel pad is not sufficient to remove the majority of the mud, then the tires must be washed before the vehicle enters a public road.

If washing is used, provisions must be made to intercept the wash water and trap the sediment before it is carried off-site. Construction entrances should be used in conjunction with the stabilization of construction roads to reduce the amount of mud picked up by vehicles.

This practice will only be effective if sediment control is used throughout the rest of the construction site.

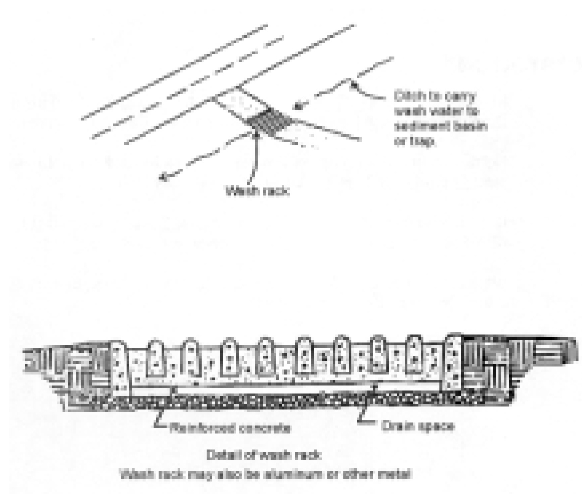
Design Recommendations

- Remove all vegetation and other objectionable material from the foundation area. Grade and crown foundation for positive drainage.
- Stone for a stabilized construction entrance shall be 1 to 3-inch stone, reclaimed stone, or recycled concrete equivalent placed on a stable foundation as specified in the plan.
- Pad dimensions: The minimum length of the gravel pad should be 50 feet, except for a single residential lot where a 30 foot minimum length may be used. Longer entrances will provide better cleaning action. The pad should extend the full width of the construction access road or 10 feet whichever is greater. The aggregate should be placed at least six inches thick.
- A geotextile filter fabric shall be placed between the stone fill and the earth surface below the pad to reduce the migration of soil particles from the underlying soil into the stone and vice versa. Filter cloth is not required for a single family residence lot.
- If the slope toward the road exceeds 2%, construct a ridge, 6 to 8 inches high with 3:1 side slopes, across the foundation approximately 15 ft from the entrance to divert runoff away from the public road.
- All surface water that is flowing to or diverted toward the construction entrance should be piped beneath the entrance. If piping is impractical, a berm with 5:1 slopes that can be crossed by vehicles may be substituted for the pipe.
- Washing: If the site conditions are such that the majority of mud is not removed from the vehicle tires by the gravel pad, then the tires should be washed before the vehicle enters the road or street. The wash area should be a level area with 3-inch washed stone minimum, or a commercial rack.
- Wash water should be directed into a sediment trap, a vegetated filter strip, or other approved sediment trapping device. Sediment should be prevented from entering any watercourses.
- A filter fabric fence should be installed down-gradient from the construction entrance in order to contain any sediment-laden runoff from the entrance.

Common Trouble Points

Inadequate runoff control
Sediment washes onto public road.

Stone too small, pad too thin, or geotextile fabric absent
Results in muddy condition as stone is pressed into soil.



Construction entrance with wash rack

Pad too short for heavy construction traffic
Extend pad beyond the minimum 50-ft length as necessary.
Pad not flared sufficiently at road entrance
Results in mud being tracked onto road and possible damage to road edge.
Unstable foundation
Use geotextile fabric under pad and/or improve foundation drainage.

Maintenance

- The entrance should be maintained in a condition that will prevent tracking or flowing of sediment onto public rights-of-way. This may require periodic topdressing with additional stone.
- Inspect entrance/exit pad and sediment disposal area weekly and after heavy rains or heavy use.
- Remove mud and sediment tracked or washed onto public road immediately.
- Mud and soil particles will eventually clog the voids in the gravel and the effectiveness of the gravel pad will not be satisfactory. When this occurs, the pad should be topdressed with new stone. Complete replacement of the pad may be necessary when the pad becomes completely clogged.
- If washing facilities are used, the sediment traps should be cleaned out as often as necessary to assure that adequate trapping efficiency and storage volume is available. Vegetative filter strips should be maintained to insure a vigorous stand of vegetation at all times.
- Reshape pad as needed for drainage and runoff control.
- Repair any broken road pavement immediately.
- All temporary erosion and sediment control measures shall be removed within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil areas resulting from removal shall be permanently stabilized.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

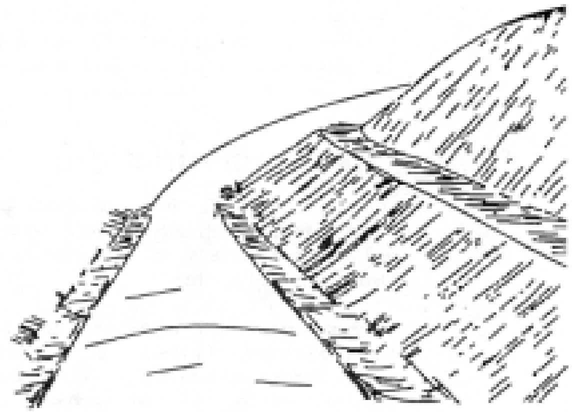
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities*** EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Construction Road Stabilization

Stabilization of temporary construction access routes, on-site vehicle transportation routes, and construction parking areas to control erosion



Where Practice Applies

All traffic routes and parking areas for temporary use by construction traffic.

Advantages

- Proper grading and stabilization of construction roads and parking areas reduces erosion and prevents dust problems.
- Road stabilization can significantly speed on-site work, avoid instances of immobilized machinery and delivery vehicles, and generally improve site efficiency and working conditions during adverse weather.

Disadvantages/Problems

- Measures on temporary roads must be cheap not only to install but also to demolish if they interfere with the eventual surface treatment of the area.
- May require maintenance to replace aggregate or repair ruts.

Planning Considerations

- Avoid steep slopes, excessively wet areas, and highly erodible soils.
- Controlling surface runoff from the road surface and adjoining area is a key erosion control consideration. Provide surface drainage and divert excess runoff to stable areas.
- Areas which are graded for construction vehicle transport and parking purposes are especially susceptible to erosion. The exposed soil surface is continually disturbed, leaving no opportunity for vegetative stabilization. Such areas also tend to collect and transport runoff waters along their surfaces. During wet weather, they often become muddy quagmires which generate significant quantities of sediment that may pollute nearby streams or be transported off-site on the wheels of construction vehicles. Dirt roads can become so unstable during wet weather that they are virtually unusable.

- Immediate stabilization of such areas with stone may cost money at the outset, but it may actually save money in the long run by increasing the usefulness of the road during wet weather.
- Permanent roads and parking areas should be paved as soon as possible after grading. As an alternative, the early application of stone may solve potential erosion and stability problems and eliminate later regrading costs. Some of the stone will also probably remain in place for use as part of the final base course of the road.

Design Recommendations

- A 6-inch course of 2 to 4-inch crushed rock, gavel base, or crushed surfacing base course should be applied immediately after grading or the completion of utility installation within the right-of-way. A 4-inch course of asphalt-treated base may be used in lieu of the crushed rock, or as advised by the local government.
- Temporary roads should follow the contour of the natural terrain to the maximum extent possible. Slope should not exceed 15 percent. Roadways should be carefully graded to drain transversely. Provide drainage swales on each side of the roadway in the case of a crowned section, or one side in the case of a super-elevated section.
- Drain inlets should be protected to prevent sediment-laden water entering.
- Areas adjacent to culvert crossings and steep slopes should be seeded and mulched.
- Dust control should be used when necessary.

Maintenance

- Inspect stabilized areas regularly, especially after large storm events. Add crushed rock if necessary and restabilize any areas found to be eroding.
- All temporary erosion and sediment control measures should be removed within 30 days after final site stabilization is achieved or after the temporary practices are no longer needed.
- Trapped sediment should be removed or stabilized on site. Disturbed soil areas resulting from removal should be permanently stabilized.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

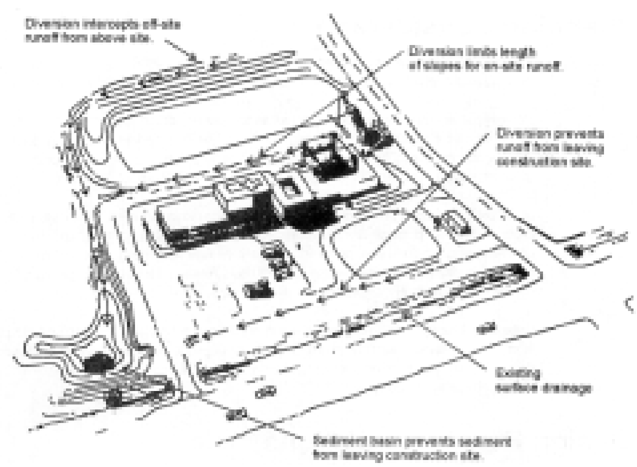
U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities*** EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin,*** Olympia, WA, February, 1992.

Diversion, Permanent

A permanent ridge or channel, or a combination ridge and channel, constructed: across sloping land; or at the top or bottom of a steep slope. Used to convey runoff water.

This practice is used to reduce slope lengths, break up concentration of runoff, and move water to stable outlets at a non-erosive velocity.



Where Practice Applies

This practice applies to sites where runoff can be diverted and used or disposed of safely to prevent flood damage or erosion and sediment damage, including:

- Above steep slopes to limit surface runoff onto the slope,
- Across long slopes to reduce slope length to prevent gully erosion,
- Below steep grades where flooding, seepage problems, or sediment deposition may occur,
- Around buildings or areas that are subject to damage from runoff.

Diversions must have stable outlets. The site, slopes, and soils must be such that the diversion can be maintained throughout its planned life.

Permanent diversions are not applicable below high sediment-producing areas unless land treatment practices, or structural measures, designed to prevent damaging accumulations of sediment in the channels, are installed with or before the diversions.

Advantages

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation.

Planning Considerations

Permanent diversions should be planned as a part of initial site development. They are principally runoff control measures that subdivide the site into specific drainage areas.

Permanent diversions can be installed as temporary diversions until the site is stabilized then completed as a permanent measure, or they can be installed in final form during the initial construction operation. The amount of sediment anticipated and the maintenance required as a result of construction operations will determine which approach should be used.

Stabilize permanent diversions with vegetation or materials such as riprap, paving stone, or concrete as soon as possible after installation. Base the location, type of stabilization, and diversion configuration on final site conditions. Evaluate function, need, velocity control, outlet stability, and site aesthetics. When properly located, land forms such as landscape islands, swales or ridges can be used effectively as permanent diversions.

Base the capacity of a diversion on the runoff characteristics of the site and the potential damage after development. Consider designing an emergency overflow section or bypass area to limit damage from storms that exceed the design storm. The overflow section may be designed as a weir with riprap protection.

Design Recommendations

Capacity

Peak runoff values should be determined by accepted methods. Recommended minimum design frequencies are shown below. In all cases, the design storm frequency should be chosen to provide protection compatible with the hazard or damage that would occur if the diversion should overtop.

Homes, schools, industrial buildings, etc.	**50-year design frequency**
Playfields, recreation areas, similar land areas	**25-year design frequency**

Permissible Flow Velocity

Soil Texture	Bare Channel	Vegetated Channel
Sand, silty sandy loam	1.5 feet/second	2.5 feet/second
Silty clay and sandy clay loam	2.0 feet/second	3.5 feet/second
Clay	2.5 feet/second	4.5 feet/second

Cross Section

The channel may be parabolic or trapezoidal. It should be designed to have stable side slopes.

Side slopes for permanent diversions should not be steeper than 3:1 for maintenance purposes and preferably 4:1. In no case should side slopes be steeper than 1:1.

Back slope of the ridge is not to be steeper than 2:1 and preferably 4:1.

The **ridge** should include a settlement factor equal to 5 percent of its height.

The minimum **top width** of the diversion ridge after settlement is to be 4.0 feet at the design elevation.

Freeboard equalling 0.5 foot minimum.

In determining the cross section on temporary diversions, consideration should be given to soil type and frequency and type of equipment that is anticipated to be crossing the diversion.

Grade

Channel grade for diversions may be uniform or variable. The permissible velocity for the soil type and vegetative cover will determine maximum grade. Level diversions with blocked ends may be used, provided pipes of sufficient size and spacing are placed in the embankment to drain the channel after runoff stops.

Outlets

Diversions are to have adequate outlets which will convey runoff without damaging erosion. The following types of outlets are acceptable:

Natural or constructed vegetated outlets capable of safely carrying the design discharge. The outlet should be established and well vegetated prior to construction of the diversion.

Properly designed and constructed **grade stabilization structures** or **storm sewers.**

Natural or constructed open channels which are stable and have adequate capacity and depth.

A **stable area** having a good sod cover or a woodland area with a deep erosion resistant litter. The outlet end of the diversion channel should be flared in a manner to spread the water over a wide area at a shallow depth.

Level Spreader

A level lip spreader should be used at diversion outlets discharging onto area already stabilized by vegetation. Spreaders shall be excavated at least 6 inches deep into undisturbed soil. The bottom of the excavation and the downstream lip of edge shall be level. Minimum spreader lengths shall be based on the peak rate of flow from a 10-year frequency storm.

Diversion Dikes

Diversion dikes should be used to divert runoff for temporary or permanent protection of cut or fill slopes. Diverted runoff must be discharged onto a stabilized area or through a slope-protection structure.

Recommended criteria:

- **Drainage area** - 5 acres or less.
- **Top width** - 2 feet minimum.
- **Height** (compacted fill) - 18 inches unless otherwise noted on the plans. (Height measured from the upslope toe to top of the dike.)
- **Side slopes** - 2:1 or flatter.
- **Grade** - dependent upon topography, but must have positive drainage to the outlet; may require vegetative or mechanical stabilization where grades are excessive.

Protection Against Sediment

Temporary diversions - None required.

Permanent diversions - As a minimum, a filter strip of close growing grass should be maintained above the channel. The width of the filter, measured from the center of the channel, should be one-half the channel width plus 15 feet.

The diversion ridge and channel should be vegetated to prevent erosion.

Small eroded areas and sediment-producing channels draining into the diversion should be shaped and seeded prior to or at the time the diversion is constructed.

Construction Recommendations

All trees, brush, stumps, and other objectionable material should be removed so they will not interfere with construction or proper functioning of the diversion.

All ditches or gullies which must be crossed should be filled and compacted prior to or as part of the construction.

Fence rows and other obstructions that will interfere with construction or the successful operation of the diversion should be removed.

The base for the diversion ridge should be prepared so that a good bond is obtained between the original ground and the placed fill. Vegetation should be removed and the base thoroughly disked before placement of the fill.

Vegetation

Diversions should be vegetated as soon after construction as practical. Give consideration to jute matting, excelsior matting, or sodding of channel to provide erosion protection.

Seeding, fertilizing, mulching, and sodding should be in accord with applicable vegetative standards for permanent cover. See Permanent Seeding.

One-half to one bushel of oats should be added to the basic mixture for quick cover and to help anchor the mulch.

Very moist channels are often best vegetated by working rootstocks of reed canarygrass into the seedbed.

When soil conditions are unfavorable for vegetation (such as very coarse-textured subsoil material), topsoil should be spread to a depth of 4 inches or more on at least the center half of parabolic shaped channels or on the entire bottom of trapezoidal shaped channels.

Seeded channels should be mulched. For critical sections of large channels, and for steep channels, the mulch should be anchored by cutting it lightly into the soil surface, or by covering with paper twine fabric or equivalent material; or jute netting should be used.

Maintenance

If no sediment protection is provided on temporary diversions, periodic cleanout will probably be required.

References

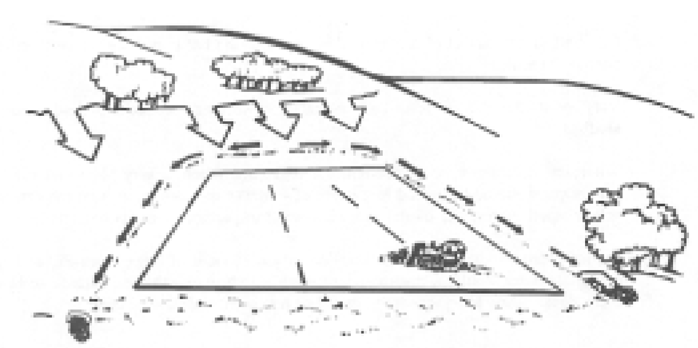
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

Diversion,Temporary

A permanent ridge or channel, or a combination ridge and channel, constructed: across sloping land; or at the top or bottom of a steep slope. Used to convey runoff water.



Purpose

- To reduce slope lengths, break up concentration of runoff, and move water to stable outlets at a non-erosive velocity.
- To protect work areas from upslope runoff.
- To divert sediment-laden water to an appropriate sediment-trapping facility.

Where Practice Applies

This practice applies to construction areas where runoff can be diverted and disposed of properly to control erosion, sedimentation, or flood damage. Specific locations and conditions include:

- Above disturbed existing slopes, and above cut or fill slopes to prevent runoff over the slope;

- Across unprotected slopes, as slope breaks, to reduce slope length;
- Below slopes to divert excess runoff to stabilized outlets;
- Where needed to divert sediment-laden water to sediment traps;
- At or near the perimeter of the construction area to keep sediment from leaving the site;
- Above disturbed areas before stabilization to prevent erosion and maintain acceptable working conditions.
- Where active construction activities make the use of a permanent diversion unfeasible.

Temporary diversions may also serve as sediment traps when the site has been overexcavated on a flat grade. They may also be used in conjunction with a sediment fence.

Advantages

Diversions are among the most effective and least costly practices for controlling erosion and sedimentation.

Planning Considerations

A temporary diversion is intended to divert overland sheet flow to a stabilized outlet or a sediment trapping facility during establishment of permanent stabilization on a sloping disturbed area. When used at the top of a slope, the structure protects exposed slopes by keeping upland runoff away. When used at the base of a slope, the structure protects adjacent and downstream areas by diverting sediment-laden runoff to a sediment trapping facility.

If the diversion is going to remain in place for longer than 15 days, it should be stabilized with temporary or permanent vegetation.

It is important that diversions are properly designed, constructed and maintained since they concentrate water flow and increase erosion potential. Particular care must be taken in planning diversion grades. Too much slope can result in erosion in the diversion channel or at the outlet. A change of slope from steeper grade to flatter may cause deposition to occur. The deposition reduces carrying capacity and may cause overtopping and failure.

Frequent inspection and timely maintenance are essential to proper functioning.

Sufficient area must be available to construct and properly maintain diversions. It is usually less costly to excavate a channel and form a ridge or dike on the downhill side with the spoil than to build diversions by other methods. Where space is limited, it may be necessary to build the ridge by hauling in dike fill material or using a sediment fence to divert the flow. Use gravel to form the diversion dike where vehicles must cross frequently.

Temporary diversions may be planned to function one year or more, or they may be constructed anew at the end of each days grading operation to protect new fill.

Temporary diversions may serve as in-place sediment traps if overexcavated 1 to 2 feet and placed on a nearly flat grade. The dike serves to divert water as the stage increases. A combination silt fence and channel in which fill from the channel is used to stabilize the fence can trap sediment and divert runoff simultaneously.

Wherever feasible, build and stabilize diversions and outlets before initiating other landdisturbing activities.

Design Criteria

Temporary diversions must be planned to be stable throughout their useful life and meet criteria given below. Otherwise, they should be designed as permanent diversions.

Drainage area
Not more than three acres.

Capacity
Peak runoff from 10-year storm.

Minimum cross section:

Top Width	Height	Side Slopes
0 ft.	1.5 ft.	4:1
4 ft	1.5 ft.	2:1

Grade

The grade may be variable depending upon the topography and must have a positive grade to the outlet. The maximum channel grade should be limited to 1.0 percent.

Spacing
The maximum spacing of diversions on side slopes or graded rights-of-way should be no greater than the following:

Land Slope (%)	Spacing (ft.)
1 or less	300
2	200
3-5	150
5 or greater	100

Diverted runoff should outlet onto a stabilized area, into a properly designed waterway, grade stabilization structure or sediment trapping facility.

Diversions that are to serve longer than 30 working days should be seeded and mulched as soon as they are constructed, in order to preserve dike height and reduce maintenance.

Maintenance

Inspect temporary diversions once a week and after every rainfall.

Damage caused by construction traffic or other activity should be repaired before the end of each working day.

Immediately remove sediment from the flow area and repair the diversion ridge.

Check outlets carefully and make timely repairs as needed.

When the area protected has been permanently stabilized, remove the ridge and the channel to blend with the natural ground level, and appropriately stabilize it.

References

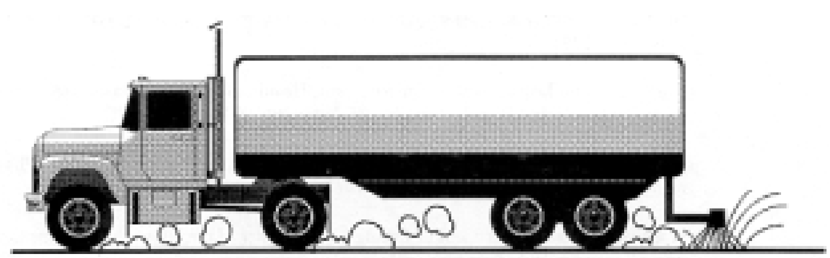
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Dust Control



Reducing surface and air movement of dust from exposed soil surfaces during land disturbing, demolition, and construction activities.

Where Practice Applies

On construction routes and other disturbed areas subject to surface dust movement and dust blowing where on-site and off-site damage is likely to occur if preventive measures are not taken.

Advantages

A decrease in the amount of dust in the air will decrease the potential for accidents and respiratory problems.

Disadvantages/Problems

Excessive use of water to control dust emissions, particularly in areas where the soil has been compacted, can cause a runoff problem.

Planning Considerations

Large quantities of dust can be generated during land grading activities for commercial, industrial, or subdivision development, especially during dry, windy weather. Research at construction sites has established an average dust emission rate of 1.2 tons/acre/month for active construction. Earthmoving activities comprise the major source of construction dust emissions, but traffic and general disturbance of the soil also generate significant dust emissions.

In planning for dust control, it is important to schedule construction activities so that the least area of disturbed soil is exposed at one time.

For disturbed areas not subject to traffic, vegetation provides the most practical and efficient means of dust control. For other areas control measures include mulching, sprinkling, spraying adhesive or calcium chloride, and wind barriers.

Maintain dust control measures properly through dry weather periods until all disturbed areas have been permanently stabilized.

Methods

Vegetative Cover - For disturbed areas not subject to traffic, vegetation provides the most practical method of dust control.
Mulch (including Gravel Mulch) - When properly applied, mulch offers a fast, effective means of controlling dust.
Spray-on Adhesive - Latex emulsions or resin in water can be sprayed onto mineral soil to prevent particles from blowing away.
Calcium Chloride - Calcium chloride may be applied by mechanical spreader as loose, dry granules or flakes at a rate that keeps the surface moist but not so high as to cause water pollution or plant damage.
Sprinkling - The site may be sprinkled until the surface is wet. Sprinkling is especially effective for dust control on haul roads and other traffic routes.
Stone - Used to stabilize construction roads; can also be effective for dust control.
Barriers - A board fence, wind fence, sediment fence, or similar barrier can control air currents and blowing soil. All of these fences are normally constructed of wood and they prevent erosion by obstructing the wind near the ground and preventing the soil from blowing offsite.

A wind barrier generally protects soil downward for a distance of 10 times the height of the barrier. Perennial grass and stands of existing trees may also serve as wind barriers.

Maintenance

Respray area as necessary to keep dust to a minimum.

References

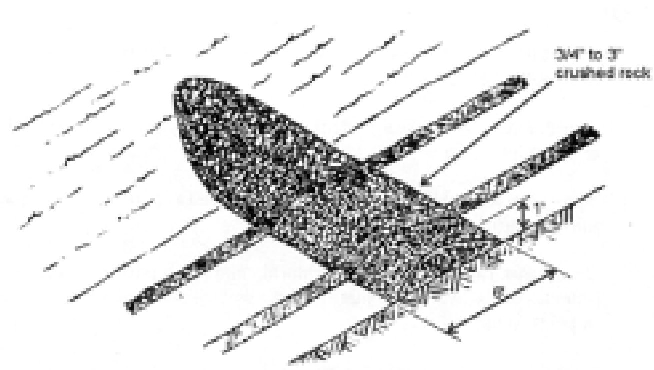
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Filter Berm

A filter berm is a temporary ridge constructed of loose gravel, stone, or crushed rock. It slows and filters flow, diverting it from an exposed traffic area. It is used to retain sediment from traffic areas.



Where Practice Applies

Where a temporary measure is needed to retain sediment from rights-of-way or in traffic areas on construction sites.

Advantages

This is an efficient method of sediment removal.
Reduces the speed of runoff flow.

Disadvantages/Problems

- A gravel filter berm is more expensive to install than other practices which use materials found on-site.
- Has a limited life span.
- Can be difficult to maintain because of clogging from mud and soil on vehicle tires.

Design Criteria

Berm material should be ¾ to 3 inches in size, washed, well-graded gravel or crushed rock with less than 5 percent fines.

Spacing of berms:

- Every 300 feet on slopes less than 5 percent.
- Every 200 feet on slopes between 5 and 10 percent.
- Every 100 feet on slopes greater than 10 percent.

Berm dimensions:

- 1 foot high with 3:1 side slopes.
- 8 linear feet per 1 cfs runoff based on the 10-year, 24-hour design storm.

Maintenance

Filter berms should be inspected regularly after each rainfall, or if damaged by construction traffic. All needed repairs should be performed immediately.

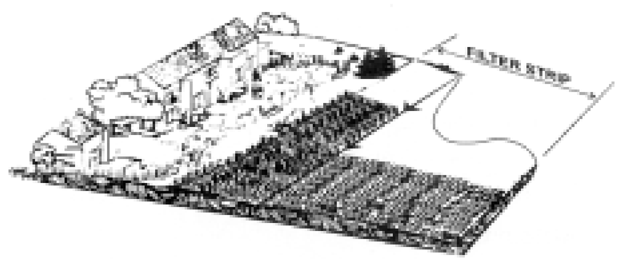
Accumulated sediment should be removed and properly disposed of and the filter material replaced, as necessary.

References

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Filter Strip, Vegetated



A vegetated filter strip is an area of vegetation for runoff to flow through before it leaves a disturbed site or enters into a designed drainage system. It improves water quality by removing sediment and other pollutants from runoff as it flows through the filter strip. Some of the sediment and pollutants are removed by filtering, absorption, adsorption and settling as the velocity of flow is reduced.

Where Practice Applies

This practice applies to any site where adequate vegetation can be established and maintained. Vegetative filter strips can be used effectively:

- Surrounding stormwater management infiltration practices to reduce the sediment load delivered to the structures;
- Adjacent to water courses such as waterways and diversions and water bodies such as streams, ponds, and lakes;
- At the outlets of stormwater management structures; or
- Along the top of and at the base of slopes.

A vegetative filter strip is designed to provide runoff treatment of conventional pollutants but not nutrients. This practice is not designed to provide streambank erosion control. A vegetative filter strip should not be used for conveyance of larger storms because of the need to maintain sheet flow conditions. Also, the filter strip would likely be prohibitively large for this application.

Planning Considerations

Filter strips may occur naturally or be constructed. It is important that filter strips be designed and constructed so that runoff flows uniformly across the filter strip as sheet flow. Once the flow becomes concentrated in rills, the effectiveness of the strip is greatly reduced. It is essential that some type of device such as a level spreader or shallow stone trench be used to distribute the runoff evenly across the strip.

Natural filter areas can provide excellent pollutant removal, particularly those areas left adjacent to natural water courses and bodies of water. It is also important to evenly distribute the runoff into these natural areas for best performance. These natural areas can provide excellent wildlife habitat and travel corridors.

To prevent soil compaction, no equipment should be allowed to operate within the filter strip area. Uncompacted soil encourages percolation and minimizes rapid surface runoff.

Design Recommendations

Drainage Area

Maximum recommended drainage area is 5 acres.

Entrance Conditions

Runoff must be introduced to the filter strip as uniform sheet flow. A level spreader can be used to distribute the runoff onto the filter strip by constructing the lip of the spreader and the top of the strip at the same elevation or contour. In some cases, a shallow stone trench can be used to intercept the runoff and allow the water to outlet evenly as long as the lower edge of the stone trench is constructed level. Make provisions to avoid flow bypassing the filter strip.

Length

Filter strip length (parallel to flow) should be designed to produce a water residence time of at least 20 minutes (the length should normally be in the range of 100-200 feet).

Vegetative filter strips should not receive concentrated flow discharges as their effectiveness will be destroyed plus the potential for erosion could cause filter strips to become sources of pollution.

Slope

Vegetative filter strips should not be used on slopes greater than about 15 percent because of the difficulty in maintaining the necessary sheet flow conditions.

Width of Strip

The minimum width of a filter strip should be 20 feet for slopes up to 1%. An additional 4 feet for each 1% of slope should be added. Experience has found that strips from 50 to 75 feet wide perform best.

Vegetation

A dense stand of vegetation is necessary for a well functioning filter strip. A temporary diversion should be used to divert runoff away from the filter strip until good vegetation is established; otherwise rills will develop and reduce the effectiveness of the strip.

Maintenance

Filter strips should be maintained as natural areas once the vegetation is established. The filter strip should be protected from damage by fire, grazing, traffic, and dense weed growth.

Fertilization needs should be determined by on-site inspections. Supplemental fertilizer is a key factor, as most species take two to three years to become fully established.

The filter strip should be inspected periodically and after every major rainstorm to determine if the entrance conditions are still uniform and level and to see if rills have formed. Any problem areas should be repaired promptly to prevent further deterioration.

References

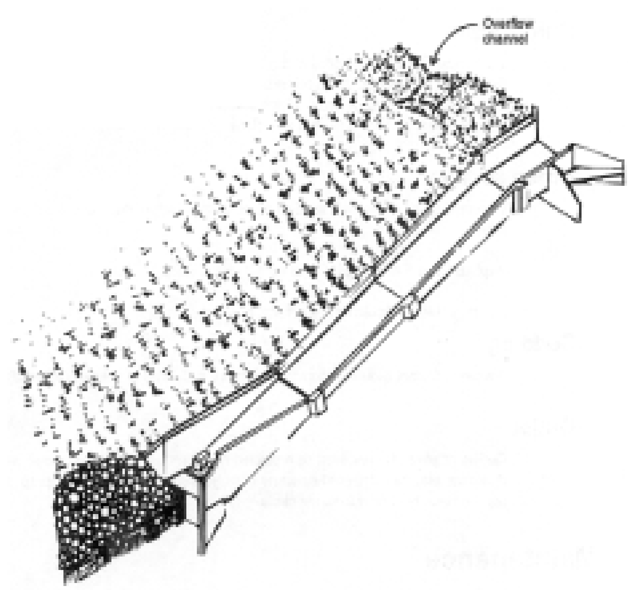
Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Flume, Paved

A paved flume is a permanent lined channel constructed on a slope. Paved flumes are used routinely on parking lot fills and highway cuts and fills to take runoff down the slope without causing erosion. The flumes may be constructed of concrete, asphalt, or masonry. The outlet of the flume should be protected to avoid erosion.



Where Practice Applies

This is a permanent practice that applies where stormwater runoff must be conveyed from the top of a cut or fill slope to the bottom.

Design Recommendations

This practice should be designed by a professional engineer.

Capacity
Paved flumes should be designed to pass the peak rate of flow expected from a 10 year frequency storm unless local regulations require a lower frequency higher discharge storm event.

Slope
The steepest slope of the structure shall be 1.5 horizontal to 1 vertical (1.5:1) where the flume is located in natural ground. The maximum slope shall be 2 horizontal to 1 vertical (2:1) on fill slopes.

Cutoff Walls
Cutoff walls shall be provided at the beginning and end of the flume. The wall should extend the full width of the flume and a minimum of 18 inches into the soil below the bottom of the flume. Cutoff wall should be at least 6 inches thick. Concrete walls should be reinforced with #4 bars spaced on 6 inch centers in both directions.

Cross section
Concrete flume walls will need to be at least 4 inches thick and reinforced with welded wire fabric.
Asphalt lined flumes should be at least 3 inches thick.
Masonry flumes should be a minimum of 4 inches thick.

Bedding
All paved flumes should be constructed on a 6 inch layer of sand-gravel bedding material.

Outlet
Outlets of paved flumes must be protected from erosion with some type of energy dissipater. The dissipater may be a designed structure or may be constructed of rock riprap capable of withstanding the velocity of flow from the chute.

Maintenance

Little maintenance is required for a paved flume, but the flume should be inspected periodically to see if cracks have developed in the lining. Any cracks should be repaired immediately. The energy dissipater should be checked to see that it is functioning properly. Any erosion below the dissipater should be repaired immediately.

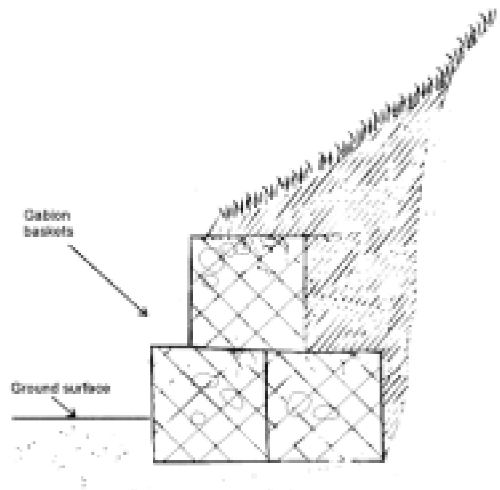
References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

Gabions

Gabions are rectangular baskets fabricated from a hexagonal mesh of heavily galvanized steel wire. The baskets are filled with stone and rock and stacked atop one another to form a gravity-type wall. Gabions depend mainly on the interlocking of the individual stones and rocks within the wire mesh for internal stability, and their mass or weight to resist hydraulic and earth forces. Gabions are a porous type of structure that can be vegetated.



Purpose

To slow the velocity of concentrated runoff or to stabilize slopes with seepage problems and/or noncohesive soils.

Where Practice Applies

Soil-water interfaces, where the soil conditions, water turbulence, water velocity, and expected vegetative cover, are such that the soil may erode under the design flow conditions. Gabions can be used on steeper slopes than riprap.

Advantages

Some advantages of gabion walls are:

- Ease of handling and transportation
- Speed of construction
- Flexibility (Gabions tolerate movement)
- Permeability to water (Good drainage)

Gabions offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion.

Disadvantages/Problems

Gabions are sometimes criticized as being unsightly. They can be made more attractive by use of attractive facing stone toward the front of the wall and by establishing vegetation in the spaces between the rocks.

Gabions are more expensive than either vegetated slopes or riprap.

The wire baskets used for gabions may be subject to heavy wear-and-tear due to wire abrasion by bedload movement in streams with high velocity flow.

Planning Considerations

For easy handling and shipping, gabions are supplied folded into a flat position and bundled together. Gabions are readily assembled by unfolding and binding together all vertical edges with lengths of connecting wire stitched around the vertical edges. The empty gabions are placed in position and wired to adjoining gabions. They are then filled with cobblestone-size rock (10-30 cm in diameter) to one-third their depth. Connecting wires, placed in each direction, brace opposing gabion walls together. The wires prevent the gabion baskets from "bulging" as they are filled. This operation is repeated until the gabion is filled. After filling, the top is folded shut and wired to the ends, sides, and diaphragms.

During the filling operation live rooting plant species, such as willow, may be placed among the rocks. If this is done, some soil should be placed in the gabions with the branches, and the basal ends of the plants should extend well into the backfill area behind the gabion breast wall.

Several different design configurations are possible with gabions. They may have either a battered (sloping) or a stepped-back front. The choice depends upon application, although the stepped-back type is generally easier to build when the wall is more than 10 ft high.

If large rocks are readily accessible, inexpensive, and near the proposed site, then their use in construction of a rock wall may be preferable. On the other hand, if rock must be imported or is only available in small sizes, a gabion wall may be preferable.

Sequence of Construction

Since gabions are used where erosion potential is high, construction must be sequenced so that they are put in place with the minimum possible delay. Disturbance of areas where gabions are to be placed should be undertaken only when final preparation and placement can follow immediately behind the initial disturbance.

Where gabions are used for outlet protection, they should be placed before or in conjunction with the construction of the pipe or channel so that they are in place when the pipe or channel begins to operate.

Maintenance

Gabions should be inspected on a regular basis and after every large storm event.

All temporary and permanent erosion and sediment control practices shall be maintained and repaired as needed to assure continued performance of their intended function. All maintenance and repair shall be conducted in accordance with an approved manual.

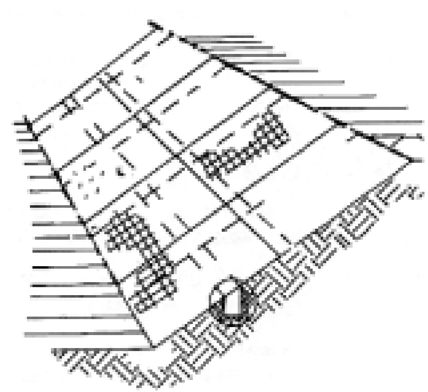
References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Gray, Donald H. and Leiser, A. T., ***Biotechnical Slope Protection and Erosion Control***, Leiser Van Reinhold Inc., 1982.

Pennsylvania, Commonwealth of, Bureau of Soil and Water Conservation, ***Erosion and Sediment Pollution Control Program Manual***, Harrisburg, PA, April, 1990.

Geotextiles



Geotextiles are porous fabrics known in the construction industry as filter fabrics, road rugs, synthetic fabrics, construction fabrics, or simply fabrics. Geotextiles are manufactured by weaving or bonding fibers made from synthetic materials such as polypropelene, polyester, polyethylene, nylon, polyvinyl chloride, glass and various mixtures of these.

Some geotextiles are also biodegradable materials such as mulch matting and netting. Mulch mattings are materials (jute or other wood fibers) that have been formed into sheets of mulch that are more stable than normal mulch. Netting is typically made from jute, other wood fiber, plastic, paper, or cotton and can be used to hold the mulching and matting to the ground.

Purpose

As a synthetic construction material, geotextiles are used for a variety of purposes in the United States and other countries. The uses of geotextiles include separators, reinforcement, filtration and drainage, and erosion control. Netting can also be used alone to stabilize soils while the plants are growing; however, it does not retain moisture or temperature well.

Where Practice Applies

Geotextiles, when used alone, can be used as matting. Mattings are used to stabilize the flow in channels and swales. Matting may also be used on recently planted slopes to protect seedlings until they become established and on tidal or stream banks where moving water is likely to wash out new plantings.

Geotextiles are also used as separators. An example of such a use is geotextile as a separator between riprap and soil. This 'sandwiching' prevents the soil from being eroded from beneath the riprap and maintaining the riprap's base.

Advantages

- Fabrics are relatively inexpensive for certain applications.
- A wide variety of geotextiles to match specific needs is available.

Disadvantages/Problems

If the fabric is not property selected, designed, or installed, the effectiveness may be reduced drastically.

Many synthetic geotextiles are sensitive to light and must be protected prior to installation.

Planning Considerations

There are numerous types of geotextiles available, therefore the selected fabric should match its purpose. In the field, important concerns include regular inspections to check for cracks, tears, or breaches in the fabric.

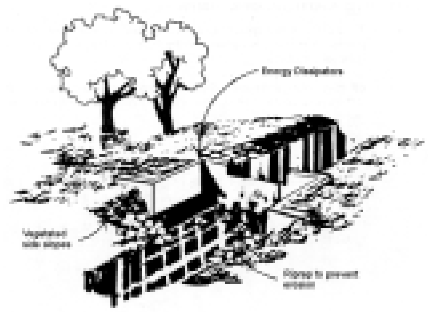
Effective netting and matting require firm, continuous contact between the materials and the soil. If there is no contact, the material will not hold the soil and erosion will occur underneath the material.

References

"Installing Erosion Control Blankets," ***Erosion Control, The Journal For Erosion & Sediment Control Professionals***, Vol. 1, No. 4, September/ October 1994.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Grade Stabilization Structure



A permanent structure used to drop water from a higher elevation to a lower elevation. Grade stabilization structures are used to reduce or prevent excessive erosion by reducing velocities in a watercourse or by providing channel linings or structures that can withstand high velocities.

Where Practice Applies

This practice applies to sites where earth and vegetation cannot safely handle water at permissible velocities, where excessive grades or overfall conditions are encountered, or where water is to be structurally lowered from one elevation to another. These structures should be planned and installed along with or as a part of other conservation practices in an overall surface water disposal system.

Planning Considerations

Permanent grade stabilization structures may be constructed of concrete, metal, rock riprap, timber, or other suitable material. The choice of material is dependent on the proposed life of the structure, availability of materials, site specification, and soil conditions where the structure will be installed.

Generally, concrete structures are more expensive and more complicated to build, however they are more durable. Prefabricated metal structures are available at a slightly lower cost and are not as complicated to install. Rock riprap is a less expensive alternative where an adequate supply of durable rock is available, but will require more maintenance. Timber structures are not as easily installed as rock riprap, nor are they as durable.

Permanent grade stabilization structures are dependent on adequate tailwater conditions for proper functioning. Without adequate tailwater, erosion at the toe of the structure will eventually cause failure.

Design Recommendations

Design and specifications should be prepared for each structure on an individual job basis by a qualified engineer.

Overfall structures of concrete, metal, rock riprap, or other suitable material may be used to lower water from one elevation to another. These structures are applicable where it is desirable to drop the watercourse elevation over a very short horizontal distance. Adequate protection should be provided to prevent erosion or scour problems at both the upstream and downstream ends of the structure as well as along sides of the structure.

Pipe drops of metal pipe may be used with suitable inlet and outlet structures. The inlet structure may consist of a vertical section of pipe, an embankment, or a combination of both. The outlet structure shall provide adequate protection against erosion or scour at the pipe outlet.

Capacity

Structures which are designed to operate in conjunction with other erosion control practices should have as a minimum sufficient capacity to handle the bankfull capacity of the channel delivering water to the structure.

The minimum design capacity for grade control structures that are not designed to perform in conjunction with other practices should be that required to handle a 25-year frequency 24-hour duration storm.

Runoff values should be computed using accepted methods.

Maintenance

Grade stabilization structures should be checked at least annually and after every major storm. Concrete structures should be checked for concrete deterioration, settlement, and joint integrity. Pipe structures should be checked for deterioration of the pipe, settlement, and joint integrity. The outlets of the structures should be checked to see if the outlet is stable and is not eroding. If repairs are necessary, they should be made immediately to avoid further damage to the structures.

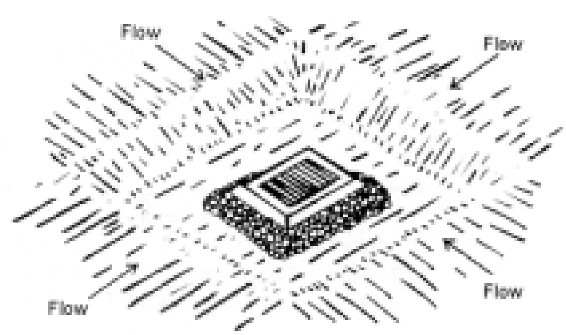
References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Inlet Protection

A sediment filter or an excavated impounding area around a storm drain, drop inlet, or curb inlet.

Used to prevent sediment from entering storm drainage systems prior to permanent stabilization of the disturbed area. This practice allows for early use of the drainage system.



Where Practice Applies

Where storm drains are to be made operational before permanent stabilization of the disturbed drainage area.

Inlet protection is a temporary measure used where the drainage area to the inlet or inlets of a storm drain system is disturbed and it is not possible to divert sediment laden water away from the system. Storm sewers which are put into use before their drainage area is stabilized can convey large amounts of sediment to natural drainageways. This practice should not be used to replace other sediment trapping devices, but it should be used in conjunction with these devices to help prevent sediment from being transported into the system and ultimately downstream or offsite.

Runoff from disturbed areas larger than one acre should be routed through a temporary sediment trap or basin.

Filter fabric is used for inlet protection when storm water flows are relatively small with low velocities.

Block and gravel filters can be used where velocities are higher.

Gravel and mesh filters can be used where flows are higher and subject to disturbance by site traffic.

Sod inlet filters may be used if sediment load in the storm water runoff is low.

Advantages

- Prevents clogging of storm drainage systems and siltation of receiving waters.
- Reduces the amount of sediment leaving the site.

Disadvantages/Problems

- May be difficult to remove collected sediment, especially under high flow conditions.
- May cause erosion elsewhere if clogging occurs.
- Practical only for low sediment, low volume flows.

Planning considerations

Installation of this measure should take place before any soil disturbance in the drainage area. Inlet protection should be used in combination with other measures, such as small impoundments or sediment traps, to provide more effective sediment removal.

The type of inlet protection device chosen depends on site conditions. Straw or hay bale barriers or sediment fences can be constructed around inlets. A small sediment basin can be excavated around the storm drain inlet. In other cases, gravel filters may be used around or directly over the storm sewer opening.

The major considerations in deciding the type of protection to be used must be based on the type of inlet, the conditions around the inlet, and the area adjacent to the inlet that may be damaged or inconvenienced because of temporary ponding of water.

Design Recommendations

- Grates and spaces of all inlets should be secured to prevent seepage of sediment-laden water.
- All inlet protection measures should include sediment sumps of 1 to 2 feet in depth, with 2:1 side slopes.
- The inlet protection device should be constructed so that any ponding resulting from the installation will not cause damage to adjacent areas or structures.
- The device must be constructed so that clean-out and disposal of trapped sediment and debris can be accomplished with little interference to construction activities.

Drainage Area

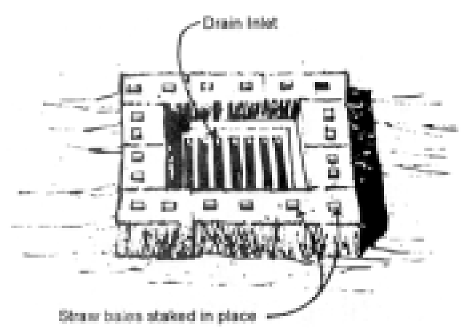
The drainage area normally should be no more than one acre.

Capacity

Runoff from 10-year storm must enter storm drain without bypass flow.

Types of Inlet Protection

Straw or Hay Bale Barriers



Straw or hay bale barriers can be constructed around the drain inlet.

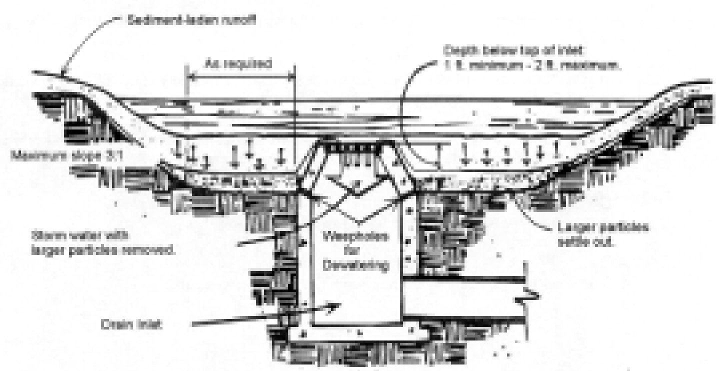
Permeability through bales is lower than for other types of inlet protection, such as sediment fences. Provide sufficient storage space for runoff or sufficient lineal footage of bales to allow storm flow to pass through the bales.

Excavated Drop Inlet Trap

This method of inlet protection is applicable where relatively heavy flows are expected and overflow capability is needed.

Applicable where the inlet drains a relatively small (less than one acre) flat area, on less than 5 percent slope. This practice works well for trapping coarse grained material. Do not place fabric under gate as the collected sediment may fall into the drain when the fabric is retrieved. This practice cannot easily be used where the area is paved because of the need for driving stakes to hold the material.

Excavated traps may be used to improve the effectiveness and reliability of other sediment traps and barriers such as fabric, or block and gravel inlet protection.



Installation:

The trap should be excavated around the inlet to provide 67 cubic feet of storage per acre of drainage area to the inlet. The trap should be no less than 1 foot deep or more than 2 feet deep when measured from the top of the inlet. Side slopes should be 3:1 or flatter.

Dimensions of the excavation should be based on the site conditions. Normally the traps are square. If there is concentrated flow being directed into the trap, however, then the trap should be rectangular with the long dimension oriented in the direction of the flow.

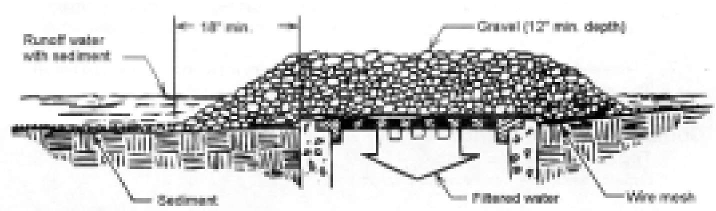
When necessary, spoil may be placed to form a dike on the downslope side of the excavation to prevent bypass flow.

Common Trouble Points

Sediment fills excavated basin and enters storm drain
Sediment-producing area too large for basin design or inlet not properly maintained.
Excessive ponding
Gravel over weep holes may be plugged with sediment. Remove debris, clear sediment, and replace gravel.
Flooding and erosion due to blockage of storm drain
Install trash guard.

Gravel and Wire Mesh Filter

Applicable where flows greater than 0.5 cfs are expected and construction traffic may occur over the inlet.



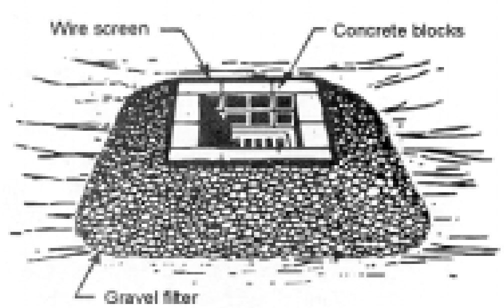
Installation

A wire mesh should be placed over the drop inlet or curb opening so that the entire opening and a minimum of 12 inches around the opening are covered by the mesh. The mesh may be ordinary hardware cloth or wire mesh with openings up to ½ inch. If more than one strip of mesh is necessary, overlap the strips. Place filter fabric over wire mesh.

Extend the filter fence/wire mesh beyond the inlet opening at least 18 inches on all sides. Place ¾ to 3-inch gravel over the filter fabric/wire mesh. The depth of the gravel should be at least 12 inches over the entire inlet opening.

Block and Gravel Inlet Protection

This method uses standard concrete block and gravel to provide a small, sturdy barrier to trap sediment at the entrance to a storm drain. It applies to both drop inlets and curb inlets where heavy flows are expected and an overflow capacity is necessary to prevent excessive ponding around the structure.



Concrete blocks are laid without mortar closely around the perimeter of the drain. Gravel is then placed around the outside of the blocks to restrict the flow and form a sediment pool. For slower drainage and therefore more settlement time, the concrete blocks could be eliminated and the device made entirely of gravel.

Pool depth should be limited to a maximum of 2 feet.

Frequent maintenance is a must for this practice.

Installation:

Place wire mesh over the drop inlet so that the wire extends a minimum of 1 foot beyond each side of the inlet structure. Use hardware cloth or comparable wire mesh with one-half inch openings. If more than one strip is necessary, overlap the strips. Place filter fabric over the wire mesh.

Place concrete blocks lengthwise on their sides in a single row around the perimeter of the inlet, so that the open ends face outward, not upward. The ends of adjacent blocks should abut. The height of the barrier can be varied, depending on design needs, by stacking combinations of blocks that are 4 inches, 8 inches, and 12 inches wide. The row of blocks should be at least 12 inches but no greater than 24 inches high.

Place wire mesh over the outside vertical face (open end) of the concrete blocks. Extend at least 12 inches around the opening to prevent aggregate from being transported through the openings in the block. Use hardware cloth or comparable wire mesh with ½ inch openings.

Pile gravel, 1-inch diameter or smaller, against the wire mesh to the top of the outside face of the blocks to control drainage rate.

Common Trouble Points

Top of structure too high

- Bypass storm flow causes severe erosion.

Blocks not placed firmly against storm drain inlet

- Scour holes develop.

Drainage area too large

- Poor trap efficiency and/or sediment overload.

Approach to drain too steep

- Causes high flow velocity and poor trap efficiency. Install excavated basin in the approach.

Sediment not removed following a storm

- Sediment enters storm drain.

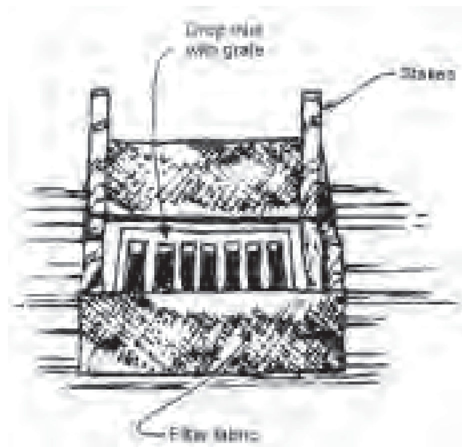
Stone in gravel donut not large enough or inside slope too steep

- Stone washes into inlet.

Maintenance

Remove and replace gravel over weep holes when drainage stops.

Fabric Drop Inlet Protection



A temporary device consisting of porous fabric supported by posts and placed around a drop inlet.

When properly braced and sealed at the bottom, the fabric restricts flow rate, forming a sedimentation pool at the approach to the inlet. The fabric allows the pool to drain slowly, protecting the storm drain from sediment.

This method of inlet protection is effective where the inlet drains a small, nearly level area with slopes generally less than 5 percent and where shallow sheet flows are expected.

The immediate land area around the inlet should be relatively flat (less than 1%) and located so that accumulated sediment can be easily removed.

This method cannot easily be used where the area is paved because of the need for driving stakes to hold the material.

Height of fabric
1.5 ft maximum, 1 foot minimum; measured from top of inlet.

Stability
Structure must withstand 1.5-foot head of water and sediment without collapsing or undercutting.

Support posts
Steel fence posts or 2 x 4-inch wood, length 3 foot minimum, spacing 3 foot maximum; top frame support recommended.

Fabric material
Synthetic, extra-strength fabric. Burlap is acceptable for short-term use only (60 days or less).

Installation:

Space support posts evenly against the perimeter of the inlet a maximum distance of 3 ft apart and drive them at least 8 inches into the ground. The stakes must be at least 3 feet long. Overflow must fall directly into the inlet and not on unprotected soil.

Build a supporting frame of 2 x 4-inch lumber, maximum height 1.5 ft above the drop inlet crest. The frame adds stability and serves as a weir to control storm overflow into the drop inlet. Alternatively, use wire fence (14 gauge minimum, with a maximum mesh spacing of 6 inches) to support fabric. Stretch fence with top level to provide uniform overflow. Extend wire 6 inches below ground.

Excavate a trench approximately 8 inches wide and 12 inches deep around the outside perimeter of the stakes.

Cut fabric from a single roll to eliminate joints. Place bottom 12 inches of fabric in trench adjacent to the drop inlet.

Fasten fabric securely to the posts and frame or support fence, if used. Overlap joints to the next post.

Backfill the trench with ¾ inch or less washed gravel all the way around.

Do not place fabric under grate as the collected sediment may fall into the drain when the fabric is retrieved.

Stabilize disturbed areas immediately after construction.

Common Trouble Points:

Posts and fabric not supported at the top
- Results in collapse of the structure.

Fabric not properly buried at bottom
- Results in undercutting.

Top of fabric barrier set too high
- Results in flow bypassing the storm inlet or collapsing structure.

Temporary dike below the drop inlet not maintained
- Results in flow bypassing storm inlet

Sediment not removed from pool
- Results in inadequate storage volume for next storm.

Fence not erected against drop inlet
- Results in erosion and undercutting.

Land slope at storm drain too steep
- Results in high flow velocity, poor trapping efficiency, and inadequate storage volume. Excavation of sediment storage area may be necessary.

Sod Drop Inlet Protection

A permanent grass sod filter area around a storm drain drop inlet in a stabilized, well vegetated area.

Where Practice Applies:

- Where the drainage area of the drop inlet has been permanently seeded and mulched and the immediate surrounding area is to remain in dense vegetation.
- This practice is well suited for lawns adjacent to large buildings.
- The drainage area should not exceed 2 acres,
- The entrance flow velocity must be low, and
- The general area around the inlet should be planned for vegetation.

Other Inlet Protection Practices

There are several types of manufactured inlet filters and traps which have different applications dependent upon site conditions and type of inlet. One is a catchbasin filter that prevents sediments and other contaminants from entering storm drainage systems. The catchbasin filter is inserted in the catchbasin just below the grating. The catchbasin filter is equipped with a sediment trap and up to three layers of a fiberglass filter material.

This is a changing field. New products are being developed and brought to the market. For the most recent information see a trade journal such as Erosion Control or Land and Water.

Maintenance

All trapping devices and the structures they protect should be inspected after every rain storm and repairs made as necessary.

Sediment should be removed from the trapping devices after the sediment has reached a maximum of one half the depth of the trap.

Sediment should be disposed of in a suitable area and protected from erosion by either structural or vegetative means.

Temporary traps should be removed and the area repaired as soon as the contributing drainage area to the inlet has been completely stabilized.

Systems using filter fabric

Inspections should be made on a regular basis, especially after large storm events. If the fabric becomes clogged, it should be replaced.

Systems using stone filters

If the stone filter becomes clogged with sediment, the stones must be pulled away from the inlet and cleaned or replaced. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

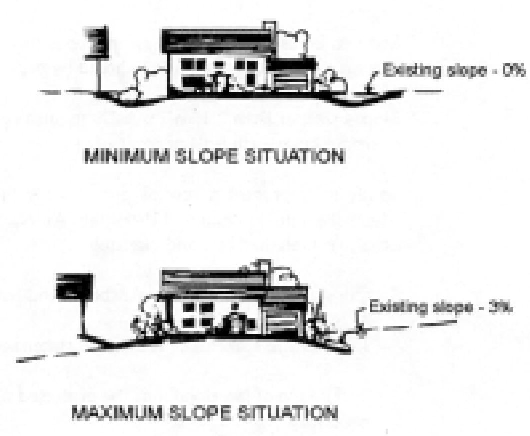
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Land Grading and Stabilization

Using engineering techniques or vegetative practices, or a combination of both, to provide surface drainage and control erosion and sedimentation while reshaping and stabilizing the ground surface to provide more suitable sites for buildings and other facilities, or maintain temporary stockpiles.



Where Practice Applies

This practice applies where the existing ground surface is regraded, new cut or fill slopes are created, or existing slopes or ground surfaces would otherwise be unstable or subject to erosion.

Planning Considerations

Provisions should be made to safely conduct surface runoff to storm drains, protected outlets, or to a stable watercourse to insure that the runoff will not damage slopes or other graded areas.

Wherever possible runoff water should be diverted away from the top of cut and fill slopes to stable outlets or grade control structures.

Waterways, diversions, grade stabilization structures, terraces, pipe drains, flumes, subsurface drains, or rock fills are some of the practices that may find use in slope stabilization. Bioengineering practices, combining vegetative and mechanical practices, also have a place.

Cuts, Fills, and Slopes

Compaction can be a major factor in erosion control for fill slopes. In addition to other compaction controls required by the nature of the project, the minimum criterion recommended for successful erosion control on fill slopes is to compact the uppermost one foot of fill to at least 85 percent of the maximum unit weight (based on the modified AASHTO compaction test). This is usually accomplished by running heavy equipment over the fill.

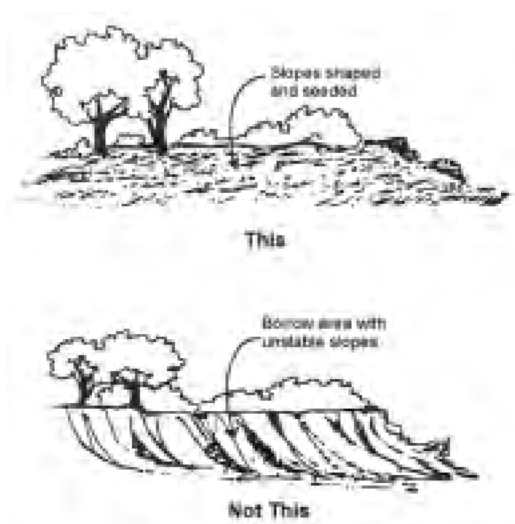
On cut slopes ground water seepage causes undercutting and soil slippage. Subsurface drains, a layer of crushed rock, or other measures may be necessary.

Slope gradient is an important factor in the success of vegetative restabilization measures. Normal tillage equipment cannot be used to prepare a seedbed on slopes 2:1 or steeper. Storm water runoff will result in the loss of seeds, fertilizer, and soil.

Sod can be used to stabilize steep slopes instead of seeding where grades are not more than 2:1. Sod on slopes steeper than 3:1 should be pegged.

Slopes steeper than 2:1 will usually require special stabilization measures such as a crushed rock or riprap layer, crib wall or revetment.

Sandy soils present a special problem for the establishment of vegetation, especially in areas where the sand is deep and droughty. American beachgrass is one solution to this problem. It is usually established by hand planting.



Borrow areas should be left stable.

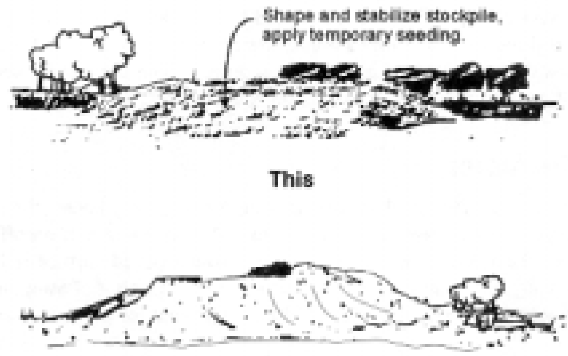
Steeply sloped areas such as lakeshores and road banks involve three special considerations:

- To insure reasonable success in stabilization, bank slopes should be 2:1 or flatter.
- The toe of the slope must be protected from undercutting by mechanical means where necessary.
- Water seeping from the face of the slope should be intercepted by a drainage system.

Borrow and Stockpile Areas

Borrow areas, especially those that are located off the development site, must be considered in erosion and sedimentation control planning. Borrow areas, as well as stockpile and spoil areas, must be stabilized.

Borrow and stockpile areas present the same set of problems for the control of erosion and sedimentation as exposed cut and fill slopes. Runoff should be diverted from the face of the slopes which are exposed in the excavation process. The runoff must then be conveyed in stabilized channels to stable disposal points.



Leave stockpiles in stable condition.

The measures used to control erosion on slopes should also be used in borrow areas. Only those sections of the borrow area which are currently needed to supply fill should be stripped. Immediately after the required fill has been taken, the exposed area should be stabilized.

If final grading is delayed, temporary seeding should be used. By properly timing the disturbance of the natural cover in the borrow area in carefully planned phases, the area of exposed soil and the duration of exposure is reduced and, therefore, erosion losses are reduced.

Topsoil from borrow areas is usually stripped and stockpiled for later redistribution on the disturbed area. These stockpiles should be located on the uphill side of the excavated area wherever possible so that they can act as diversions. Stockpiles should be shaped and seeded with temporary cover.

Where borrow areas are off the development site, a separate system for trapping sediment from the area is needed.

After the excavation is complete, borrow areas should be regraded to insure proper drainage and to blend the borrow area with the surrounding topography. Stockpiled topsoil is then redistributed and permanent vegetative cover established.

Exposed Surfaces

Although erosion rates on steep exposed slopes are higher than on flat or gently sloping areas, all areas of exposed soil are vulnerable to erosion. If erosion control is ignored on larger areas of nearly flat or gently sloping land, it will be possible for significant amounts of soil to be eroded. Clearing, grading, and vegetative restabilization in these areas can be timed so that the extent of exposed area and the duration of exposure is minimized. These areas require prompt vegetative restabilization. Temporary seeding or mulching is required where larger areas will not be permanently stabilized within recommended time limits. Diversions, sediment barriers, or traps constructed on the lower side of large disturbed areas should be used to intercept and collect sediment.

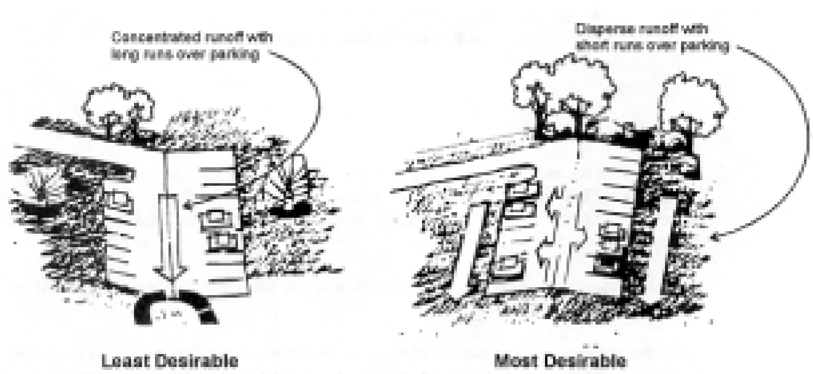
Right-of-ways and parking areas that are being prepared for paving must be protected from rainfall and runoff. Diversions should be constructed to protect these areas from runoff before clearing and grading begin.

Areas that are being prepared for paving should be properly compacted because compaction makes the exposed surface area less vulnerable to erosion. Cleared right-of-ways may be covered with crushed aggregate to reduce erosion. If right-of-ways will not be used for construction traffic, they can be seeded with temporary cover.

Gravel or stone filter berms should be used at intervals along a right-of-way to intercept runoff and direct it to stabilized areas, drainageways, or enclosed drainage system inlets. Filter berms slow runoff, filter it, and collect sediment. The berms will need some continuing maintenance, but can be crossed by construction equipment.

Paved Surfaces

An increase in paved surface area on a site greatly boosts the rate of site runoff. For example, a 20 percent increase in paved area can double the rate of runoff during a heavy rainfall. In addition, the velocity of runoff moving across a paved surface is higher than the velocity of runoff moving across an area of exposed earth of vegetation. Pavement provides very little resistance to flow and does not allow any infiltration (except for porous pavement).



Construction Areas and Eroding Areas

Types of plantings

When erosion or sediment control is of primary and immediate concern, these areas are usually initially stabilized by seeding grass cover. When necessary, the site should be prepared by seeding temporary vegetative cover. Jute netting or anchored mulch should be used in conjunction with seeding at critical locations where water concentrates.

Seeding mixtures

When dense plant cover is needed for erosion and sediment control, or for appearances, seedings of enduring herbaceous species should be used. See the Permanent Seeding and Temporary Seeding practices. One-half to one bushel of oats, or 1 to 1 ½ bushels of rye should usually be added to the basic mixture for quick cover.

Mulching

Where plantings are on areas subject to mulch removal by wind or water flows, the mulch should be anchored. Mulched areas should be checked periodically and immediately after severe storms for damage until the desired purpose of the mulching is achieved. Any damaged areas should be repaired as soon as discovered.

Design Recommendations

Cut or fill slopes which are to be vegetated should not be steeper than 2 horizontal to 1 vertical. If a slope is to be mowed, it should be 3:1 or flatter. Slopes of materials not to be vegetated should be at the safe angle of repose for the materials encountered.

Provisions should be made to safely conduct surface water to storm drains or suitable natural water courses and to prevent surface runoff from damaging cut faces and fill slopes.

Terraces or diversions should be provided whenever the height of the cut or fill exceeds 20 feet. The "benches" should divide the slope face as equally as possible and should convey the water into stable outlets. Benches should be kept free of sediment during all phases of development.

Seeps or springs encountered during construction should be controlled by subsurface drains or other appropriate methods.

Subsurface drainage should be provided in areas having a high water table, to intercept seepage that would affect slope stability, building foundations, or create undesirable wetness.

Excavations should not be made so close to property lines as to endanger adjoining property without supporting and protecting such property from erosion, sliding, settling, or cracking.

No fill should be placed where it will slide or wash onto the premises of another or be placed adjacent to the bank of a channel so as to create bank failure or reduce the natural capacity of the stream.

Fills should consist of material from cut areas, borrow pits, or other approved sources.

Protective slopes around buildings should be planned to slope away from foundations and water supply wells to lower areas, drainage channels, or waterways. The minimum horizontal length should be 10 feet, except where restricted by property lines.

The minimum vertical fall of protective slopes should be 6 inches, except that the vertical fall at the high point at the upper end of a swale may be reduced to 3 inches, if a long slope toward a building or from a nearby high bank will not exist.

Minimum gradients should be 1/16 inch per foot (1/2 percent) for concrete or other impervious surfaces and ¼ inch per foot (2 percent) for pervious surfaces.

Maximum gradient of protective slopes should be 2 ½ inches per foot (21 percent) for a minimum of 4 feet away from all building walls, except where restricted by property lines.

All graded areas should be permanently stabilized immediately following final grading.

Site plans should show the location, slope, cut, fill, and finish elevation of the surfaces to be graded and the auxiliary practices for safe disposal of runoff water, slope stabilization, erosion control, and drainage such as waterways, lined, ditches, diversions, grade stabilization structures, retaining walls, and surface and subsurface drains.

Construction Recommendations

Areas to be graded should be cleared and grubbed of all timber, logs, brush, rubbish, and vegetable matter that will interfere with the grading operation. Topsoil should be stripped and stockpiled for use on critical disturbed areas for establishment of vegetation. Cut slopes to be topsoiled should be thoroughly scarified to a minimum depth of 3 inches prior to placement of topsoil.

Fill materials should be generally free of brush, rubbish, rocks, and stumps. Frozen materials or soft and easily compressible materials should not be used in fills intended to support buildings, parking lots, roads, conduits, or other structures.

Earth fill intended to support structural measures should to be compacted to a minimum of 90 percent of standard Proctor test density with proper moisture control, or as otherwise specified by the engineer responsible for design. Compaction of other fills should be to the density required to control sloughing, erosion or excessive moisture content.

Maximum thickness of fill layers prior to compaction should not exceed 9 inches.

Grading should generally be done to a tolerance of within 0.2 foot of planned grades and elevations. Allowances may be made for topsoil, paving, or other surface installations.

All disturbed areas should be free draining, left with a neat and finished appearance, and should be protected from erosion. (See applicable vegetative standards.)

Maintenance

All slopes should be checked periodically to see that vegetation is in good condition. Any rills or damage from erosion and animal burrowing should be repaired immediately to avoid further damage.

If seeps develop on the slopes, the area should be evaluated to determine if the seep will cause an unstable condition. Subsurface drains or a gravel mulch may be required to solve seep problems.

Diversions, berms, and waterways should be checked to see that they are functioning properly. Problems found during the inspections should be repaired promptly.

Areas requiring revegetation should be repaired immediately.

Slopes should be limed and fertilized as necessary to keep vegetation healthy.

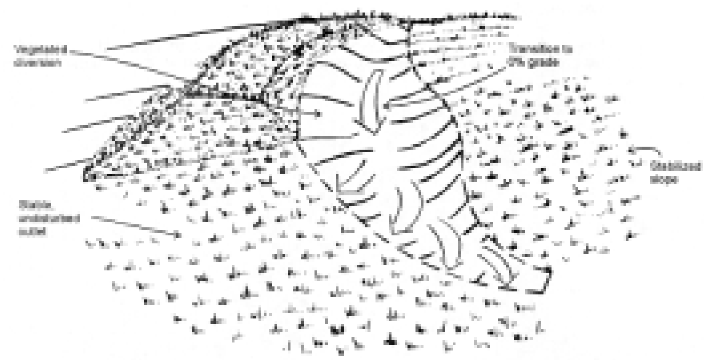
Control undesirable vegetation such as weeds and woody growth to avoid bank stability problems in the future.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Level Spreader



A level spreader is an excavated depression constructed at zero percent grade across a slope. The level spreader changes concentrated flow into sheet flow and then outlets it onto stable areas without causing erosion. It allows concentrated runoff to be discharged at non-erosive velocities onto natural or man-made areas that have existing vegetation capable of preventing erosion. An example would be at the outlet of a diversion or a waterway.

Where Practice Applies

- Where it can be constructed on undisturbed soils and a level lip can be installed without filling.
- Where the area directly below the spreader is stabilized by existing vegetation
- Where water will not re-concentrate immediately below the spreader, and water can be released in sheet flow down a stabilized slope without causing erosion.
- Where there is at least 100 feet of vegetated area between the spreader and surface waters.
- Where the area below the spreader lip is uniform with a slope of 10 percent or less and is stable for anticipated flow conditions.
- Where there will be no traffic over the spreader.

Advantages

- Level spreaders are relatively low cost structures designed to release small volumes of water safely.
- Level spreaders disperse the energy of concentrated flows, reducing erosion potential and encouraging sedimentation.

Disadvantages/Problems

If the level spreader has any low points, flow tends to concentrate there. This concentrated flow can create channels and cause erosion. If the spreader serves as an entrance to a water quality treatment system, short-circuiting of the forebay may happen and the system will be less effective in removing sediment and particulate pollutants.

Planning Considerations

Diversions and waterways need a stable outlet for concentrated stormwater flows. The level spreader can be used for this purpose if the runoff is relatively free of sediment. If properly constructed, the level spreader will significantly reduce the velocity of concentrated stormwater and spread it uniformly over a stable undisturbed area.

Placement of the level spreader must allow the water flowing over the level section to leave the structure as a uniform, thin film of water. The structure should outflow onto naturally vegetated areas whenever possible. The creation of a uniform level lip for the water to spread over is critical.

Particular care must be taken during construction to ensure that the lower lip of the structure is level. If there are any depressions in the lip, flow will tend to concentrate at these points and erosion will occur, resulting in failure of the outlet. This problem may be avoided by using a grade board or a gavel lip over which the runoff must flow when exiting the spreader. Regular maintenance is essential for this practice.

Water containing high sediment loads should enter a sediment trap before release in a level spreader.

Design Recommendations

Drainage area should be limited to five acres.

The grade of the channel for the last 20 feet of the conservation practice entering the level spreader should be no steeper than 1 percent.

The level spreader should be flat (“0 percent” grade) to ensure uniform spreading of storm runoff.

The design length for a level spreader should be no more than 0.5 cfs per foot of level section, based on the peak rate of flow from the contributing erosion control or stormwater management practice. The minimum length of the spreader should be 5 feet and the maximum length 50 feet.

The width of the spreader should be at least 6 feet.

The depth of the spreader as measured from the lip should be at least 6 inches and it should be uniform across the entire length.

The spreader shall be stabilized with an appropriate grass mixture. The spreader should be mulched if necessary for the establishment of good quality vegetation.

The level lip may be protected with an erosion stop and jute or excelsior matting. The erosion stop should be placed vertically a minimum of six inches deep in a slit trench one foot back from the crest of the level lip and parallel to the lip. The erosion stop should extend the entire length of the level lip. Two strips of jute or excelsior matting can be placed along the lip. Each strip should overlap the erosion stop by at least six inches.

The area downslope should have a complete vegetative cover sufficiently established to be erosion resistant.

Maintenance

- The level spreader should be checked periodically and after every major storm.
- Any detrimental sediment accumulation should be removed.
- If rilling has taken place on the lip, the damage should be repaired and re-vegetated.
- Vegetation should be mowed occasionally to control weeds and encroachment of woody vegetation. Clippings should be removed and disposed of outside the spreader and away from the outlet area.
- Fertilization should be done as necessary to keep the vegetation healthy and dense.
- The spreader should be inspected after every runoff event to ensure that it is functioning correctly.

References

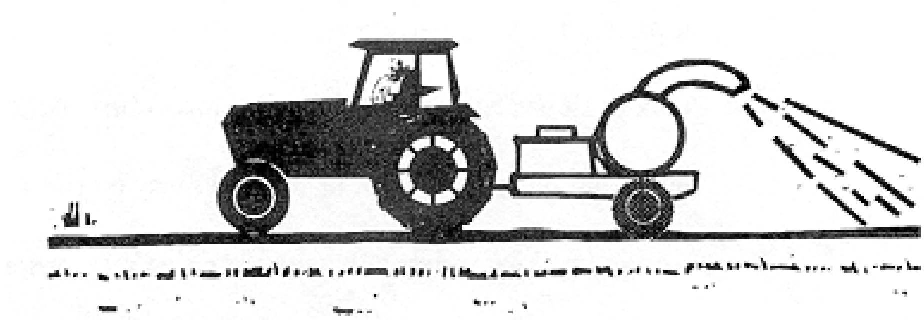
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Mulch and Netting

Application of a protective blanket of straw or other plant residue, gravel or synthetic material to the soil surface.



Purpose

To provide immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas.

Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface.

In addition to stabilizing soils, mulching can reduce the speed of storm water runoff over an area.

Where Practice Applies

- In areas which have been seeded either for temporary or permanent cover, mulching should immediately follow seeding.
- Areas which cannot be seeded because of the season, or are otherwise unfavorable for plant growth.
- Mulch around plantings of trees, shrubs, or ground covers to stabilize the soil between plants.
- In an area of greater than 2:1 slope, mulching should immediately follow seeding.

Advantages

- Mulching offers instant protection to exposed areas.
- Mulches conserve moisture and reduce the need for irrigation.
- Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings.
- This is one of the most important, effective, and economical erosion-control practices.

Disadvantages/Problems

- Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting.
- Thick mulches can reduce the soil temperature, delaying seed germination.
- Mulch can be easily blown or washed away by runoff if not secured.
- Some mulch materials such as wood chips may absorb nutrients necessary for plant growth.
- Mulches such as straw, which are often applied to areas after grading must then be removed and either composted or landfilled.

Planning Considerations

Mulches are applied to the soil surface to conserve a desirable soil property or to promote plant growth. A surface mulch is one of the most effective means of controlling runoff and erosion on disturbed land.

Mulches can increase the infiltration rate of the soil, reduce soil moisture loss by evaporation, prevent crusting and sealing of the soil surface, modify soil temperatures, and provide a suitable microclimate for seed germination.

Organic mulch materials, such as straw, wood chips, bark and wood fiber, have been found to be the most effective, although straw is preferred.

Wood chips and bark are effective for use around trees and shrubs.

It is important to properly anchor grass or straw mulch materials so they are not blown away by wind or washed away by flowing water.

On steep slopes and critical areas such as waterways, use netting or anchoring with mulch to hold it in place.

“Mechanical mulches” such as gravel may be used in critical areas where conditions preclude the use of vegetation for permanent stabilization.

The choice of materials for mulching will be based on the type of soil to be protected, site conditions, season, and economics. It is especially important to mulch liberally in mid-summer and prior to winter, and at locations on cut slopes and southern slope exposures.

Materials and Installation

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Sawdust - green or composted	Free from objectinable coarse material	83-500 cu.ft.	- - -	1-7"	Most effective as a mulch around ornamentals, small fruits& other nursery stock. Requires 30-35 lbs. N/ton to prevent N deficiency while decaying mulch. One cu. ft. weighs 25 lbs.
Wood Chips or Shavings	Green or airdried. Free of objectionable material	500-900 lbs	10-20 tons	2-7 "	Has about the same use and application as sawdust, but requires less N/ton (10-12 lbs). Resistant to wind blowing. Decomposes slowly.
Wood Excelsior	Green or air-dried burred wood fibers	90 lbs (one bale)	2 tons	- - -	Decomposes slowly. Subject to some wind blowing. Packaged in 80-90 lb. bales.
Wood Fiber Cellulose (partially digested wood fibers)	Made form natural wood, usually with green dye & dispersing agent added	50 lbs	2000 lbs	- - -	Apply with hydromulcher. No tie-down required. Less erosion control provided than 2t hay or straw.
Compost or Manure	Well shredded, free of excessive coarse materials	400-600 lbs	8-10 tons	- - -	Use straw manure where erosion control is needed. May create problem with weeds. Excellent moisture conserver. Resistant to wind blowing.
Cornstalks, shredded or chopped	Airdried, shredded into 8-12" lengths	150-300 lbs	4-6 tons	- - -	Effective for erosion control,relatively slow to decompose. Excellent for mulch on crop fields. Resistant to wind blowing.

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Gravel, crushed stone or slag	Washed, 1 1/2" max.	9 cu. yds	- - -	3'	Excellent mulch for short slopes and around woody plants and ornamentals. Frequently used over black plastic for better weed control.
Hay or Straw	Air-dried, free of undesirable seeds & materials	90-100 lbs. (2-3 bales)	2 tons (100-120 bales)	Cover about 90% of surface	Use straw where mulch is maintained for more than 3 months. Subject to wind blowing unless anchored. Most commonly used mulching material. Best microenvironment for germinating seeds.
Peat Moss	Dried, compressed free of coarse materials	200-400 cu. ft	---------	2"-4"	Most effective as a mulch around ornamentals. Subject to wind blowing unless kept wet. 100 lbs. bales (6 cu.ft.). Excellent moisture holding capacity.
Jute Twisted Yarn	Undyed, unbleached plain weave. Warp: 78 ends/yd. Weft: 41 ends/yd 60-90 lbs/roll	48"x50 yds or 48"x75 yds.	-------	-----	Use without additional mulch. Tie down as per manufacturing specification.
Excelsior Wood Fiber Mats	Interlocking web of excelsior fibers with photodegradable plastic netting	48"x100" 2-sided plastic; 48"x180" 1-sided plastic	------	-----	Use without additional mulch. Excellent for seeding establishment. Tie down as per manufacturers specs. Appox. 72 lbs/roll for Excelsior with plastic on both sides. Use 2-sided plastic for center, plastic for centerline of waterways.

Mulch Material	Quality Standards	Application Rate / 1,000 sq. ft.	Application Rate /Acre	Depth of Application	Remarks
Glass Fiber	1/4" thick, 7/16" dia. holes on 1" centers: 56 lb rolls	72'x30 yds.	----	----	Use without additional mulch. Tie down with T-bars as per manufacturers specifications.
Plastic	2-4 mils	variable	-----	-----	Use black for weed control. Effective moisture conservation and weed control for small fruits and ornamentals
Filter Fabrics	Woven or Spun	variable	------	------	------
Straw or coconut fiber or combination	Photodegradable plastic net on one or two sides	Most are 6.5'x83.5'	81 rolls	-----	Designed to tolerate higher velocity water flow, centerlines of waterways. 60 sq. yds. per roll.

Mulch Anchoring Guide

Anchoring Method or Material	Kind of Mulch To Be Anchored	How To Apply
Manual		
Peg & Twine	Hay or straw	After mulching, divide areas into blocks approximately 1 sq. yd. in size. Drive 4-6 pegs per block to within 2" to 3" soil surface. Secure mulch to surface by stretching twine between pegs in criss-cross pattern on each block. Secure twine around each peg with 2 or more turns. Drive pegs flush with soil where mowing and maintenance is plannned.
Mulch Netting	Hay or straw	Staple the light-weight paper, jute, wood fiber, or plastic nettings to soil surface according to manufacturers recommendations. Should be biodegradable. Most products not suitable for foot traffic.
Soil & Stone	Plastic	Plow a single furrow along edge of area to be covered with plastic, fold about 6" of plastic into the furrow and plow furrow slice back over plastic. Use stones to hold plastic down in other places as needed.
Cut-in	Hay or straw	Cut mulch into soil surface with square edged spade. Make cuts in contour rows spaced 18" apart. Most sucessful on contour in sandy soils

Anchoring Method or Material	Kind of Mulch To Be Anchored	How To Apply
Mechanical		
Asphalt Spray (emulsion)	Compost, wood chips, wood shavings, hay or straw	Apply with suitable spray equipment using the following rates; Asphalt emulsion: on slopes use 200 gal/acre, on level, use 150 gal/acre Liquid asphalt: (rapid, medium, or slow setting) 0.10 gal per square yd. 400 gal/acre
Wood Cellulose Fiber	Hay or straw	Apply with hydroseeder immediately after mulching. Use 750 lbs. wood fiber per acre. Some products contain an adhesive material.
Pick Chain	Hay or straw, manure compost	Use on slopes steeper than 3:1. Pull across slopes with suitable power equipment.
Mulch Anchoring tool or Disk	Hay or straw, manure/mostly straw	Apply mulch and use a mulch anchoring tool. When a disk (smooth) is used, set in straight position and pull across slope with suitable power equipment. Mulch material should be tucked into soil surface about 3".
Chemical	Hay or straw	Apply Terra Tack AR at 120 lbs/acre in 480 gal. of water or Aerospray 70 (60 gal/acre) according to manufacturer's instructions. A 24 hr. curing period and a soil temp higher than 45 degrees F. are required.

Common Trouble Points

Inadequate Coverage
Results in erosion, washout, and poor plant establishment

Appropriate tacking agent not applied, or applied in insufficient amount
Mulch is lost to wind and runoff.

Channel grade and liner not appropriate for amount of runoff
Results in erosion of channel bottom. Plan modification may be required.

Hydromulch applied in winter
Results in deterioration of mulch before plants can become established.

Maintenance

Inspect after rainstorms to check for movement of mulch or erosion. If washout, breakage, or erosion occurs, repair surface, reseed, remulch, and install new netting.

Straw or grass mulches that blow or wash away should be repaired promptly.

Blanket mulch that is displaced by flowing water should be repaired as soon as possible.

If plastic netting is used to anchor mulch, care should be taken during initial mowings to keep the mower height high. Otherwise, the netting can wrap up on the mower blade shafts. After a period of time, the netting degrades and becomes less of a problem.

Continue inspections until vegetation is well established.

References

Gaffney, F.B., Dickerson, J.A., Myers, R.E., Hoyt, D.K., Moonen, H.F., Smith, R.E., ***A Guide To: Conservation Plantings on Critical Areas for New York***, U.S. Department of Agriculture, Soil Conservation Service, Syracuse, NY, June, 1991.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire,*** Rockingham County Conservation District, August 1992.

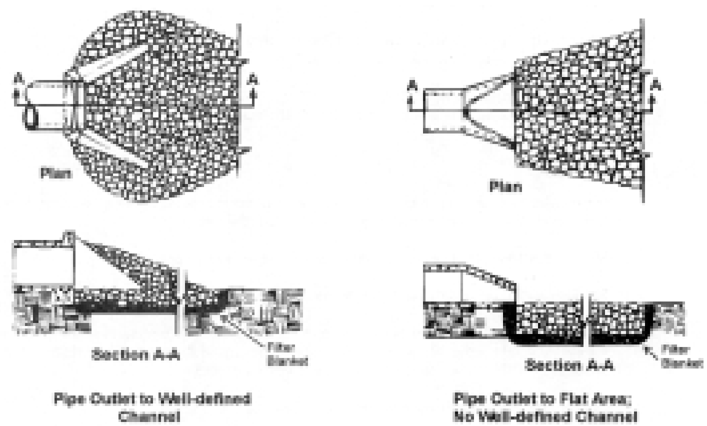
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R-92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Outlet Protection and Stabilization

A structure designed to control erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy.



Where Practice Applies

- Outlet protection should be installed at all pipe, culverts, swales, diversions, or other water conveyances where the velocity of flow may cause erosion at the pipe outlet and in the receiving channel.
- Outlet protection should also be used at outlets where the velocity of flow at the design capacity may result in plunge pools.
- Outlet protection should be installed early during construction activities, but may be added at any time, as necessary.

Advantages

- Plunge pools, which can develop unless outlet protection is provided, may severely weaken the embankment and thus threaten its stability.
- Protection can prevent scouring at a culvert mouth and thus prevent gully erosion which may gradually extend upstream.

Disadvantages/Problems

- Some types of structures may be unsightly.
- Sediment removal may be difficult.

Planning Considerations

Erosion at the outlet of channels, culverts, and other structures is common and can cause structural failure with serious downstream problems.

A riprap lined apron is the most commonly used structure for this purpose, because it has relatively low cost and can be installed easily on most sites.

Other types of outlet stabilization structures include riprap stilling basins, concrete impact basins, and paved outlets.

Design Criteria

Capacity - Peak runoff from 10-year storm.
Apron - As shown in plans, set on zero grade, aligned straight, with sufficient length to dissipate energy.
Foundation - Extra-strength filter fabric or well-graded gravel filter layer, 6 inches thick, minimum.
Material - Hard, angular, and highly weather-resistant stone (riprap) with specific gravity at least 2.5. Stone size as specified in plans.
Thickness - At least 1.5 times the maximum stone diameter.

Installation

Excavate subgrade below design elevation to allow for thickness of filter and riprap. Install riprap to minimum thickness of 1.5 times maximum stone diameter. Final structure should be to lines and elevations shown in plans.

Construct apron on zero grade. If there is no well-defined channel, cross section may be level or slightly depressed in the middle. In a well-defined channel, extend riprap and filter to the top of the bank or as shown on plans. Blend riprap smoothly to the surrounding land.

Apron should be straight and properly aligned with the receiving stream. If a curve is necessary to fit site conditions, curve the apron near the upstream end.

Compact any fill used in the subgrade to the density of the surrounding undisturbed material.

Subgrade should be smooth enough to protect fabric from tearing.

Install a continuous section of extra-strength filter fabric on smooth, compacted foundation.

Protect filter fabric from tearing while placing riprap with machinery. Repair any damage immediately by removing riprap and installing another section of filter fabric. Upstream section of fabric should overlap downstream section a minimum of one foot.

Make sure top of riprap apron is level with receiving stream or slightly below it. Riprap should not restrict the channel or produce an overfall.

Immediately following installation, stabilize all disturbed areas with vegetation as shown in plans.

Common Trouble Points

Foundation not excavated deep enough or wide enough
Riprap restricts flow cross section, resulting in erosion around apron and scour holes at outlet.

Riprap apron not on zero grade
Causes erosion downstream.

Stones too small or not properly graded
Results in movement of stone and downstream erosion.

Riprap not extended far enough to reach a stable section of channel
Results in downstream erosion.

Appropriate filter not installed under riprap
Results in stone displacement and erosion of foundation.

Maintenance

Inspect riprap outlet structures after heavy rains for erosion at sides and ends of apron and for stone displacement.

Rock may need to be added if sediment builds up in the pore spaces of the outlet pad.

Make repairs immediately using appropriate stone sizes. Do not place stones above finished grade.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual Boston***, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

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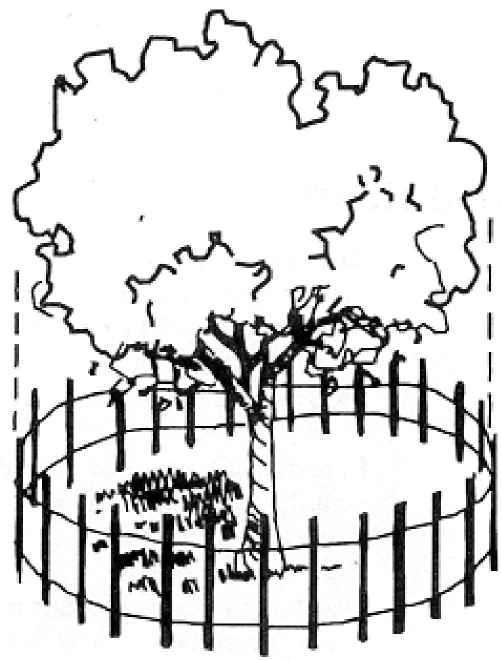
Preserving Natural Vegetation

Minimizing exposed soils and consequent erosion by clearing only where construction will occur.

Where Practice Applies



Natural vegetation should be preserved whenever possible, but especially on steep slopes, near perennial and intermittent watercourses or swales, and on building sites in wooded areas.

Advantages

Preserving natural vegetation will:

- Save money on site stabilization
- Help reduce soil erosion.
- Beautify an area.
- Save money on landscaping costs.
- Provide areas for wildlife.
- Possibly increase the value of the land.
- Provide buffers and screens against noise.

Preserving natural vegetation also moderates temperature changes and provides shade and cover habitat for surface waters and land. Increases in stream water temperature tend to lower the dissolved oxygen available for aquatic life.

Disadvantages/Problems

Saving individual trees can be difficult, and older trees may become a safety hazard.

Planning Considerations

New development often takes place on tracts of forested land. Building sites are often selected because of the presence of mature trees. Unless sufficient care is taken and planning done, however, much of this resource is likely to be destroyed in the interval between buying the property and completing construction. It takes 20 to 30 years for newly planted trees to provide the benefits for which we value trees so highly.

Natural vegetation can be preserved in natural clumps or as individual trees, shrubs and vines.

Selection

Examine the area to identify trees to be saved: trees with unique or unusual form, trees which may be uncommon in the area, desirable shade trees and trees for screening purposes. Look for healthy trees with full green crowns. The length of the annual twig growth gives an indication of the general vigor of the tree. Trees with broken tops or with many dead branches are usually not good risks. Badly scarred trees are also unsuitable.

In selecting trees to be retained, care must also be used to make certain they will not interfere with the installation and maintenance of utilities such as electric and telephone lines, water and sewer lines and driveways.

Preserving individual plants is more difficult because equipment is generally used to remove unwanted vegetation. Points to consider when attempting to save individual plants are:

Value

Is the plant worth saving? Consider the location, species, size, age, vigor, and the work involved. Local governments may also have ordinances to save natural vegetation and trees.

Desirability

Is the tree or shrub a desirable plant? Is it shallow-rooted, do the roots seek water, or are insects and disease a problem? Shallow-rooted plants can cause problems in the establishment of lawns or ornamental plants. Water-seeking roots can block sewer and tile lines. Insects and diseases can make the plant undesirable. This is especially true with aphids on alder and maple.

Age and size

Old or large plants do not generally adapt to changes in environment as readily as young plants of the same species. Usually, it is best to leave trees which are less than 40 years of age. Some hardwoods mature at approximately 50 years of age. After maturity they rapidly decline in vigor. Conifers, after 40 years of age, may become a safety hazard due to the possibility of breakage or blowdown, especially where construction has left only a few scattered trees in an area that was formerly dense woods.

While old large trees are sometimes desirable, the problem of later removal should be considered. Local governments, however, may have requirements to preserve older, larger specimen trees. It is expensive to cut a large tree and to remove the tree and stump from a developed area. Thinning some branches from trees can provide avenues for wind and hence lessen the “sail” effect.

Tree Preservation

Clearly flag or mark areas around trees that are to be saved. It is preferable to keep ground disturbance away from the trees at least as far out as the dripline.

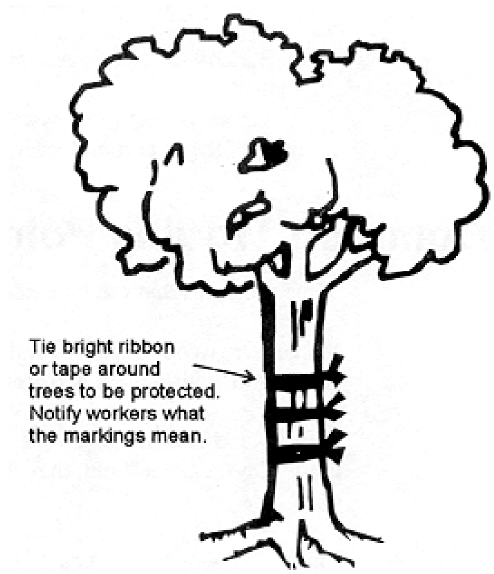
Barriers

If possible, place a barrier around the trees. Bulldozers are notorious for damaging trees. Besides skinning bark from tree trunks, their tracks severely damage tree roots which are close to the surface.

Place a simple wooden fence around the tree. Inexpensive or scrap lumber will do. Snow fencing, although more expensive, is easy to install. The fence should enclose an area at least five feet out from the tree trunk. Erect the fence before the bulldozer arrives and leave it up until the last piece of equipment has left the area.

Marking

If erecting a barrier around the trees is impractical, marking the trees may help save them from damage, if equipment operators are forewarned and reliable. A band of bright colored cloth, ribbon, or tape may be used to identify trees to be protected. The band should be placed around the trunk high enough to be seen from a distance and from all angles. It is important that all people involved be informed of the meaning of the marking.



Grade Changes

Filling

Tree roots need air water and minerals to survive. Few trees can survive with more than six inches of earth fill over the roots. The tree roots are literally suffocated with more earth fill than this coarser the fill material, the better the chance for survival.

Construction of a dry well around the tree trunk will provide some air circulation for the trees. Installation of a drain system in conjunction with the dry well is even better. Four inch drain pipe is placed in a spoke-like fashion to drain water away from the tree before filling takes place.

The dry well may be built of stones, brick, tile, concrete blocks or other material. It should be built at least 12 to 18 inches away from the trunk of a large, slow-growing tree and up to 36 inches for younger fast-growing trees.

Lowering

Lowering the natural ground level can seriously damage trees and shrubs. Most of the plant roots are in the upper 12 inches of the soil and cuts of only 2-3 inches can cause serious injury. To protect the roots it may be necessary to terrace the immediate area around the plants to be saved. If roots are exposed, construction of retaining walls may be needed to keep the soil in place. Plants can also be preserved by leaving them on an undisturbed, gently sloping mound. To increase the chances for survival, it is best to limit grade changes and other soil disturbances to areas outside the dripline of the plant.

Excavations

Protect trees and other plants when excavating for tile, water, and sewer lines. Where possible, the trenches should be routed around trees and large shrubs. When this is not possible, it is best to tunnel under them. This can be done with hand tools or with power augers.

If it is not possible to route the trench around plants to be saved, then the following should be observed:

- Cut as few roots as possible. When you have to cut - cut clean. Paint cut root ends with a wood dressing like asphalt base paint.
- Backfill the trench as soon as possible.
- Tunnel beneath root systems as close to the center of the main trunk as possible to preserve most of the important feeder roots.

Common Trouble Points

Some problems that can be encountered with trees are:

- Maple, Dogwood, Eastern hemlock, Eastern red cedar and Douglas fir do not readily adjust to changes in environment and special care should be taken to protect these trees.
- Maples, and willows have water-seeking roots. These can cause trouble in sewer lines and filter fields. On the other hand, they thrive in high moisture conditions that other trees would succumb to.
- Thinning operations can cause serious disease problems. Disease can become established through damaged limbs, trunks, roots, and freshly cut stumps. Diseased and weakened trees are also susceptible to insect attack.

Maintenance

Inspect flagged areas regularly to make sure flagging has not been removed. If tree roots have been exposed or injured, re-cover and/or seal them.

References

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

U.S. Department of Agriculture, Soil Conservation Service, Amherst, MA, ***Guidelines for Soil and Water Conservation in Urbanizing Areas of Massachusetts***, October, 1977.

Riprap

A permanent, erosion-resistant ground cover of large, loose, angular stone.

RIPRAPPED STREAMBANK

Purpose

- To protect slopes, streambanks, channels, or areas subject to erosion by wave action.
- Rock riprap protects soil from erosion due to concentrated runoff. It is used to stabilize slopes that are unstable due to seepage. It is also used to slow the velocity of concentrated runoff which in turn increases the potential for infiltration.

Where Practice Applies

- Cut or fill slopes subject to seepage or weathering, particularly where conditions prohibit establishment of vegetation,
- Channel side slopes and bottom,
- Inlets and outlets for culverts, bridges, slope drains, grade stabilization structures, and storm drains; where the velocity of flow from these structures exceeds the capacity of the downstream area to resist erosion.
- Stream banks and stream grades,
- Shorelines subject to wave action.

Advantages

- Riprap offers an easy-to-use method for decreasing water velocity and protecting slopes from erosion. It is simple to install and maintain.
- Riprap provides some water quality benefits by increasing roughness and decreasing the velocity of the flow, inducing settling.

Disadvantages/Problems

- Riprap is more expensive than vegetated slopes.
- There can be increased scour at the toe and ends of the riprap.
- Riprap does not provide the habitat enhancement that vegetative practices do.

Planning Considerations

Well graded riprap forms a dense, flexible, self-healing cover that will adapt well to uneven surfaces.

Care must be exercised in the design so that stones are of good quality, sized correctly, and placed to proper thickness.

Riprap should be placed on a proper filter material of sand, gravel, or fabric to prevent soil from "piping" through the stone.

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Determination of Applicability" or "Notice of Intent."

Rock riprap is used where erosion potential is often high. The rock should be placed as soon as possible after disturbing the site, before additional water is concentrated into the drainage system. Properly sized bedding or geotextile fabric is needed to prevent erosion or undermining of the natural underlying material.

Riprap is classified as either graded or uniform. A sample of graded riprap would contain a mixture of stones which vary in size from small to large. A sample of uniform riprap would contain stones which are all fairly close in size.

For most applications, graded riprap is preferred to uniform riprap. Graded riprap forms a flexible self-healing cover, while uniform riprap is more rigid and cannot withstand movement of the stones. Graded riprap is cheaper to install, requiring only that the stones be dumped so that they remain in a well-graded mass. Hand or mechanical placement of individual stones is limited to that necessary to achieve the proper thickness and line. Uniform riprap requires placement in a more or less uniform pattern, requiring more hand or mechanical labor.

Design Recommendations

As graded riprap consists of a variety of stone sizes, a method is needed to specify the size range of the mixture of stone. This is done by specifying a diameter of stone in mixture for which some percentage, by weight, will be smaller. For example, d 85 refers to a mixture of stones in which 85 percent of the stone by weight would be smaller than the diameter specified. Most designs are based on "d." The design, therefore, is based on the median size of stone in the mixture.

A well graded mixture of rock sizes should be used for riprap rather than rocks of a uniform size. Rock riprap sizes are specified by either weight or diameter.

Stone should be hard, angular, weather-resistant; specific gravity at least 2.5.

Gradation: well-graded stone, 50% by weight larger than the specified "150" The largest stones should not exceed 1.5 times the "d5O" specified.

Stones should be shaped so that the least dimension of the stone fragment is not less than one-third of the greatest dimension of the fragment. Flat rocks should not be used for riprap.

Filter: heavy-duty filter fabric or aggregate layer should be used under all permanent riprap installations.

Thickness: 1.5 times the maximum stone diameter, minimum, or as specified in the plan.

Construction Recommendations

Subgrade for the filter material, geotextile fabric or riprap should be cleared and grubbed to remove all roots, vegetation, and debris and prepared to the lines and grades shown on the plans.

Excavate deep enough for both filter and riprap. Compact any fill material to the density of surrounding undisturbed soil.

Excavate a keyway in stable material at base of slope to reinforce the toe. Keyway depth should be 1.5 times the design thickness of riprap and should "extend a horizontal distance equal to the design thickness.

Rock and/or gravel used for filter and riprap shall conform to the specified gradation.

Voids in the rock riprap should be filled with spalls and smaller rocks.

Filter

Install synthetic filter fabric or a sand/gravel filter on subgrade.

Synthetic filter fabric

Place filter fabric on a smooth foundation. Overlap edges at least 12 inches, with anchor pins spaced every 3 ft along overlap. For large stones, a 4-inch layer of sand may be needed to protect filtercloth.

Geotextile fabrics should be protected from puncture or tearing during placement of the rock riprap by placing a cushion of sand and gravel over the fabric. Damaged areas in the fabric should be repaired by placing a piece of fabric over the damaged area or by complete replacement of the fabric. All overlaps required for repairs or joining two pieces of fabric should be a minimum of 12 inches.

Sand/gravel filter

Spread well-graded aggregate in a uniform layer to the required thickness (6 inches minimum). If two or more layers are specified, place the layer of smaller stones first and avoid mixing the layers.

Stone Placement

Place riprap immediately after installing filter.

Install riprap to full thickness in one operation. Do not dump through chutes or use any method that causes segregation of stone sizes. Avoid dislodging or damaging underlying filter material when placing stone.

If fabric is damaged, remove riprap and repair fabric by adding another layer, overlapping the damaged area by 12 inches.

Place smaller stones in voids to form a dense, uniform, well-graded mass. Selective loading at the quarry and some hand placement may be necessary to obtain an even distribution of stone sizes.

Blend the stone surface smoothly with the surrounding area allowing no protrusions or overfall.

Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay. Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance.

Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.

Common Trouble Points

Excavation not deep enough
Riprap blocks channel, resulting in erosion along edges.

Slope too steep
Results in stone displacement. Do not use riprap as a retaining wall.

Foundation not properly smoothed for filter placement
Results in damage to filter.

Filter omitted or damaged
Results in piping or slumping.

Riprap not properly graded
Results in stone movement and erosion of foundation.

Foundation toe not properly reinforced
Results in undercut riprap slope or slumping.

Fill slopes not properly compacted before placing riprap
Results in stone displacement.

Maintenance

Riprap should be checked at least annually and after every major storm for displaced stones, slumping, and erosion at edges, especially downstream or downslope. If the riprap has been damaged, it should be repaired immediately before further damage can take place.

Woody vegetation should be removed from the rock riprap annually because tree roots will eventually dislodge the riprap.

If the riprap is on a channel bank, the stream should be kept clear of obstructions such as fallen trees, debris, and sediment bars that may change flow patterns which could damage or displace the riprap.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

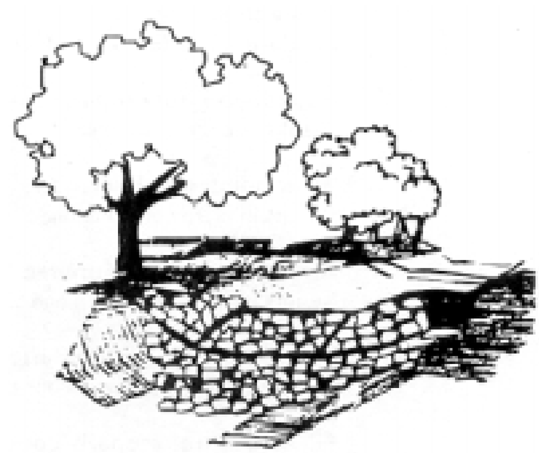
Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire*** , Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Rock Dam

A rock embankment constructed across a drainageway or other suitable location to create a temporary basin for collecting sediment.



Purpose

To trap sediment on the construction site and prevent off-site sedimentation. Useful where earth fill material is not readily available.

Where Practice Applies

Where a temporary measure is needed to retain sediment from a construction area - but not in a natural stream.

Design Criteria

Drainage area: limited to 50 acres.
Design life: limited to 3 years.
Sediment storage: 1800 cubic feet per acre disturbed, as a minimum. Measured one foot below spillway crest.
Dam crest height: limited to 8 feet.
Basin area and shape: The largest surface area gives the greatest trapping efficiency. Basin length-to-width ratio should be 2:1 minimum.
Spillway capacity: 10-year peak runoff, at maximum flow depth of one foot and minimum freeboard of one foot. Entire length of dam between rock abutments may serve as spillway.
Rock embankment:

Top width 5 ft minimum

Side slopes Upstream, 2:1 or flatter; Downstream, 3:1 or flatter

Earth abutments Smooth, stable slopes, 2:1 or flatter.

Rock abutments Must protect earth abutments and extend along downstream face to toe of dam. Abutments must be at least one foot higher than the spillway face at all points.

Height	2 ft minimum above spillway crest
Width	2 ft thick, minimum
Side slopes	2:1 or flatter

Outlet protection: Rock apron, 1.5 ft thick, minimum, zero grade, length equal to height of dam or extended to stable grade, whichever is greater.
Rock material: Well-graded, hard, angular, weather-resistant stone with a “d50” of 9 inches minimum.
Protection from piping: Extra-strength filter fabric covering entire foundation including earth abutments and apron.
Basin dewatering: Through one-foot thick minimum layer of ½- to ¾-inch aggregate on upstream face of dam.

Installation

Divert runoff from undisturbed areas away from the basin. Delay clearing pond area until dam is in place.

Excavate foundation for apron and use it as a temporary sediment basin during construction of dam.

Clear and grub area under darn, removing all root mat and other objectionable material. Grade earth abutments no steeper than 1:1. Dispose of material in approved location.

If cutoff trench is required, excavate at center line of dam, extending all the way up earth abutments.

Protection from Piping

The entire foundation including both earth abutments must be covered by filter fabric. Overlap one foot at all joints, upstream strip over downstream strip.

Smooth the foundation area before placing filter fabric. Be careful placing rock on fabric. It may be helpful to place a 4-inch layer of sand over fabric before placing rock.

Embankment and pool

Construct embankment to dimensions shown on plans. Use well-graded, hard, angular, weather-resistant rock. Rock abutments must be at least 2 feet higher than the spillway crest and at least 1 foot higher than the downstream face of dam at all points.

Divert sediment-laden flow to upper end of basin.

Set marker stake to indicate clean out elevation where sediment pool is 50% full.

Establish vegetation to stabilize all disturbed areas except the lower one-half of sediment pool as shown in the plan.

Safety

Sediment basins that impound water are hazardous. Basin should be dewatered between storms. Avoid steep side slopes. Fences with warning signs may be necessary if trespassing is likely. State and local requirements must be followed.

Common Trouble Points

Failure from piping along abutments
Filter material not properly installed, or earth abutments too steep.

Stone displaced from face of dam
Stone size too small and/or face too steep.

Erosion below dam
Apron not extended to stable grade.

Erosion of abutments during spillway flow
Rock abutment height inadequate.

Sediment carried through spillway
Drainage area too large. Divert runoff from undisturbed area away from basin.

Sediment loss through dam
Inadequate layer of aggregate on inside face or aggregate too coarse to restrict flow through dam.

Maintenance

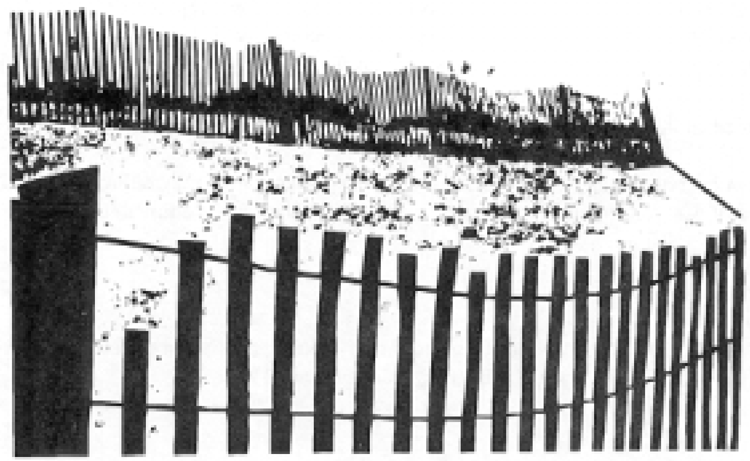
- Inspect rock dam and pool after each rainfall event.
- Remove sediment when it accumulates to one-half design volume (marked by stakes).
- Check structure and abutments for erosion, piping, or rock displacement. Repair immediately.
- Replace aggregate on inside face of structure when sediment pool does not drain between storms.
- Add fine gravel to upstream face of dam if sediment pool drains too rapidly (less than 6 hours) following a storm.
- Remove rock dam after the contributing drainage area has been permanently stabilized, inspected, and approved. Remove all water and sediment prior to removing dam. Dispose of waste materials in designated disposal areas. Smooth site to blend with surrounding area and stabilize according to vegetation plan.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

Sand Dune and Sandblow Stabilization



Planning Considerations

Active sand areas may be stabilized by establishing temporary control measures, followed by tree or shrub planting within five years. In situations where trees or shrubs are not desired or practical, such as the seaface of a beach frontal dune, American beachgrass may be maintained as a long-term means of stabilization.

Methods of Stabilization

Mechanical - This is usually done with brush matting or with sand fencing. It is usually limited to small areas where beachgrass is not available for planting, or where immediate stabilization is desired.

Place brush matting (preferably coniferous) with butts to windward. Start placing on leeward side, working towards windward side. Overlap butts with tops to provide a shingling effect. Sand fencing placed at right angles to the prevailing wind will also give temporary stabilization but is expensive and more prone to vandalism.

Beachgrass - Beachgrass may be a temporary or long-term measure. American beachgrass is planted in culms. Culms should consist of two or more healthy stems, 2 to 3 feet tall. The ideal time to plant dormant beachgrass culms is in early spring, March 15 to May 1. Culms should be planted 8 to 9 inches deep. Culms may be dug anytime during the planting season. The stems should be cut back to 12 to 15 inches before or after digging. They may be stored by heeling-in, or storing at 28 to 32 degrees F.

Culm plantings should be planted at 18 inch spacings, with center staggered in alternate rows. Five hundred to 1,000 pounds per acre of 10-5-5, or equivalent analysis, should be applied soon after planting, or in the case of a fall planting, the fertilizer should be applied early the following spring.

An alternative, less expensive method, is to plant the beachgrass in bands. These bands should be spaced 20 to 40 feet apart. The bands should consist of at least 2 rows spaced approximately 18 inches apart, with culms approximately 18 inches apart in the rows and centers staggered in alternate rows. The closer band spacing should be used on the windward side. Fertilizer should be applied to the planted bands as indicated above.

When beachgass is to be used for long-term protection, it may be maintained by annual applications of 300-500 pounds per acre of a 10-5-5 fertilizer or its equivalent.

References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Tree Plantings for Enduring Cover Species

Inland Areas	**Coastal Areas**
Eastern red cedar*	Pitch pine

Density and Arrangement:
400-1,000 plants per acre uniformly spaced. Trees should be planted where existing vegetation is least competitive.

Shrub Plantings for Enduring Cover Species

Inland Areas	**Coastal Areas**
Bayberry	Beach plum
Eastern red cedar*	Bayberry
Rugosa rose	Rugosa rose

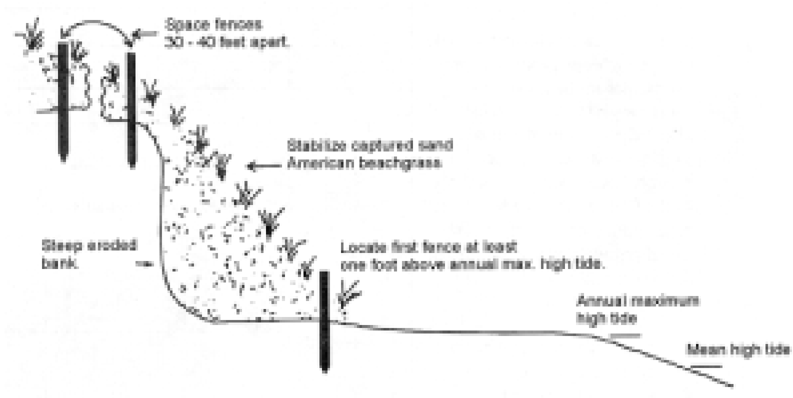
Density and Arrangement
Plant in rows or uniform spacing with 4 to 6 feet between plants.

**Caution to users who may be near orchards: Eastern red cedar is an alternate host to apple rust.*

Sand Fence

An artificial barrier of evenly spaced wooden slats or synthetic fabric erected perpendicular to the prevailing wind and supported by posts.

Sand fences are usually made commercially of light wooden slats wired together with spaces between the slats. The distance between slats is approximately equal to the slat width (about 1 ½ inches). Synthetic fencing fabric is available for this use. The fences are erected 2 to 4 feet high in parallel rows spaced 30 to 40 feet apart over the area to be protected. Fences are supported by wooden or metal posts.



Purpose

To reduce wind velocity at the ground surface and trap blowing sand. Typically used for rebuilding frontal dunes along coastal areas.

Where Practice Applies

- Across open bare, sandy soil areas subject to frequent winds, where the trapping of blowing sand is desired.
- Wind fences are used primarily to build frontal ocean dunes (to control erosion from wave overwash and flooding).
- Sand fences can also be used to prevent sand from blowing off disturbed areas onto roads or adjacent property.

Planning Considerations

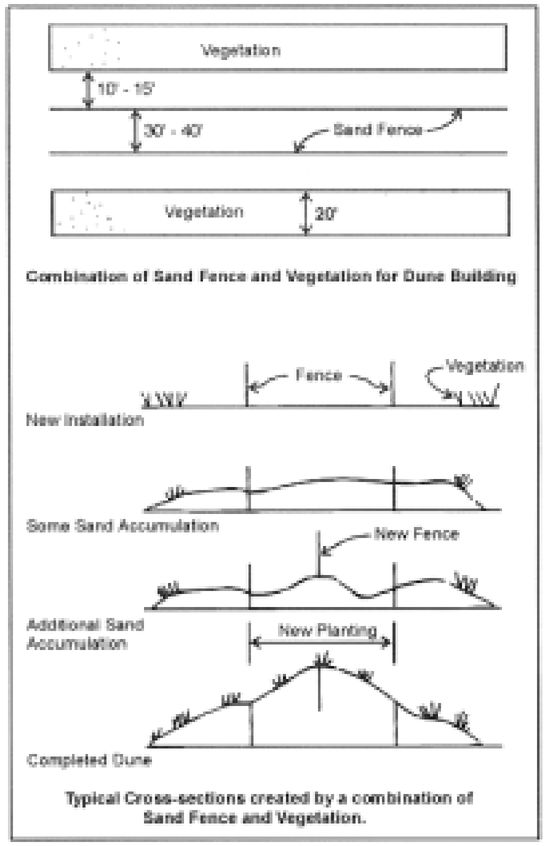
When wind fences are approximately two-thirds full, another series of fences is erected. In this manner, dunes can be built 2 to 6 feet high or more during a single season. When the dune has reached the approximate height of other mature dunes or when the building process slows significantly, stabilize with appropriate vegetation.

Installation

Install sand fences in spring or early summer and seed selected permanent vegetation in the fall or the following spring.

Erect a windward fence parallel to existing dune (generally perpendicular to the prevailing onshore wind), at least one foot above the maximum annual high water elevation. Locate a second fence generally parallel to the first at the top edge of the eroded dune bank. Space additional parallel fences 30 - 40 feet apart as needed over the area to be built up).

A second set of fences may be erected perpendicular to the first to protect captured dune sand from cross winds. Space perpendicular fences a greater distance apart (50-75 feet).



Combination of Sand Fence and Vegetation for Dune Building

Typical Cross-sections created by a combination of Sand Fence and Vegetation.

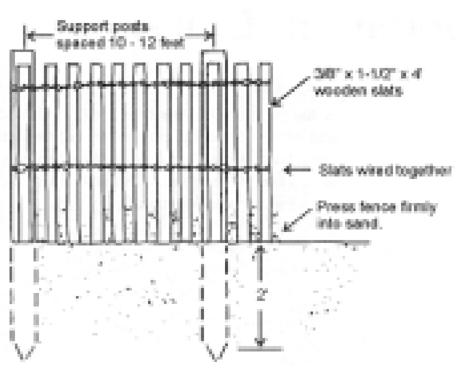
Support fencing material with 2 x 4-inch or 3-inch round posts, 6 feet long minimum, driven firmly into the ground at least 2 feet and spaced approximately 12 feet apart. Alter spacing so that posts are placed at all low points. Secure fencing to windward side of posts by tying or nailing. Press bottom of fencing material firmly into the ground at all points.

Raising the Dune

When the fence system is approximately two-thirds filled with sand, erect another series of fences until desired dune height is reached.

Final Stabilization

When the dune-building process slows significantly, the dune must be permanently stabilized. Planting should begin in November and be completed the following spring even if the dune has not reached the desired height. Vegetation hastens the building process. Maintain fences until vegetation is well established.



Common Trouble Points

Bottom fence located too low
Fence washes out.

Fences not maintained long enough
Some seasons provide little opportunity for dune building and fences may have to be maintained for longer periods.

Dune not adequately stabilized with permanent vegetation
Dune is subject to erosion during storms, even with sand fences in place.

Fencing material placed on leeward side of posts or not adequately secured
Sections of fence collapse.

Posts not driven deep enough
Fence collapses.

Fence system located too near the ocean
Not enough sand source for dune building.

Maintenance

Inspect sand fences periodically, and immediately following storms. Repair damaged sections of fence promptly.

Maintain fences until vegetation is well established.

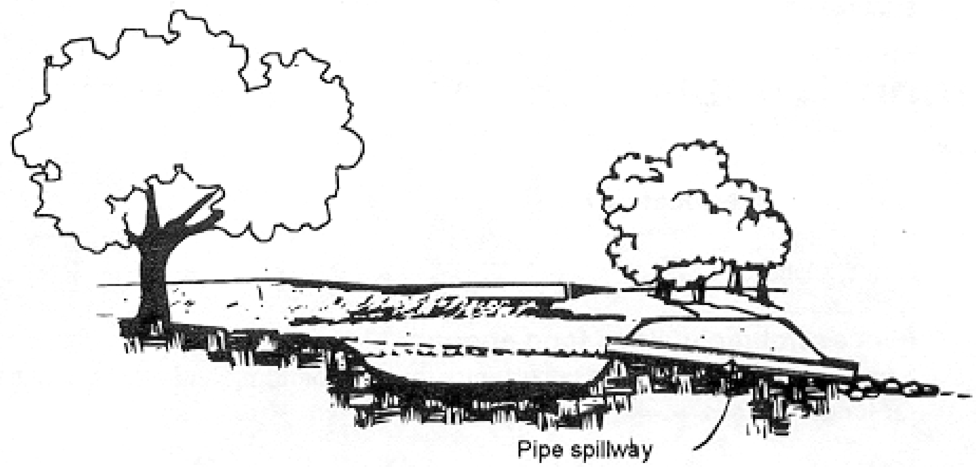
References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual Boston***, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Sediment Basin

A sediment basin is a settling pond with a controlled storm water release structure used to collect and store sediment produced by construction activities. A sediment basin can be constructed by excavation or by placing an earthen embankment across a low area or drainage swale. Sediment basins can be designed to maintain a permanent pool or to drain completely dry. The basin detains sediment-laden runoff long enough to allow most of the sediment to settle out.



Purpose

- To collect and store sediment from sites cleared and/or graded during construction or for extended periods of time before reestablishment of permanent vegetation or construction of structures.
- To retain sediment on the construction site and prevent off-site sedimentation.

Where Practice Applies

Sediment basins are needed where other erosion control measures are not adequate to prevent offsite sedimentation.

A sediment basin should be used only where is sufficient space and appropriate topography. The basin should be made large enough to handle the maximum expected amount of site drainage.

Fencing around the basin may be necessary for safety or vandalism reasons.

A sediment basin used in combination with other control measures, such as seeding or mulching, is especially effective for removing sediments.

Dam Safety Regulations must be followed where applicable.

Advantages

Protects downstream areas from clogging or damage due to sediment deposits generated during construction activities.

Because of additional detention time, sediment ponds may be capable of trapping smaller-sized sediment particles than other practices. They are most effective, however, when used in conjunction with other practices such as seeding or mulching.

Disadvantages/Problems

Ponds may become an “attractive nuisance” and a safety hazard.

Sediment ponds are only effective in removing sediment down to about the medium silt size fraction. Sediment-laden runoff with smaller-size fractions (fine silt and clay) will pass through untreated; emphasizing the need control erosion to the maximum extent first.

Planning Considerations

Sediment basins are usually constructed by building a low earthen dam across a drainageway to form a temporary sediment storage pool. A properly designed spillway outlet with adequate freeboard is essential.

A sediment basin may be created by excavation, construction of a compacted embankment, or a combination of both. It may have one or more inflow points carrying polluted runoff.

Basins should be installed before clearing and grading begin.

To improve trap efficiency the basin should have the maximum surface area possible, and sediment should enter the basin as far from the outlet as possible.

Sediment basin life should be limited to 3 years, unless it is designed as a permanent structure.

Effectiveness

Sediment basins are at best only 70-80 percent effective in trapping sediment which flows into them. Therefore, they should be used in conjunction with erosion control practices such as temporary seeding, mulching, diversion dikes, etc. to reduce the amount of sediment flowing into the basin. Sediment basins are most effective when designed with a series of chambers.

Location

Locate sediment basins only in upland areas, not wetlands.

Ensure that basin location provides a convenient concentration point for sediment laden flows from the area served.

To improve the effectiveness of the basin, it should be located so as to intercept the largest possible amount of runoff from the disturbed area. The best locations are generally on relatively flat terrain downstream from disturbed areas.

Drainage into the basin can be improved by the use of diversion dikes and ditches.

The basin must not be located in a stream but should be located to trap sediment-laden runoff before it enters the stream.

The basin should not be located where its failure would result in the loss of life or interruption of the use or service of public utilities or roads.

Diversions

Divert sediment-laden water to upper end of sediment pool to improve trap effectiveness. Bring all water into the basin at low velocity to prevent erosion.

Divert runoff from undisturbed areas away from basin.

Multiple Use

Sediment basins may be designed as permanent structures to remain in place after construction is completed for use as stormwater detention ponds. Sediment must be removed from the pond when construction is complete to prepare the pond for permanent use.

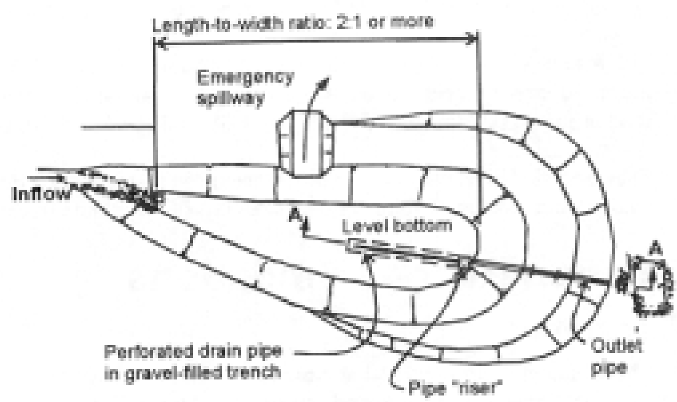
Design Recommendations

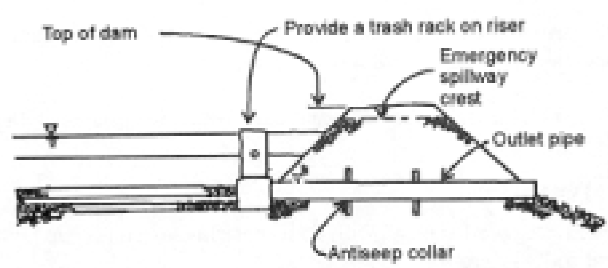
Drainage area - Not more than 100 acres.
Sediment storage - The sediment basin should have a minimum volume based on ½ inch of storage for each acre of drainage area. This volume equates to 1800 cubic feet of storage or 67 cubic yards for each acre of drainage area.
Trap efficiency - Length-to-width ratio should be 2:1 or greater; divert inflow to upper end of basin to avoid short-circuiting flow. Length is defined as the average distance from the inlet to the outlet of the trap. Baffles to spread the flow throughout the basin should be included.
Dewatering - Perforate riser and cover holes with gravel.
Total spillway capacity -10-year peak flow with 1 foot freeboard.

Principal Spillway

Riser and barrel - Usually vertical pipe riser with horizontal pipe barrel; must withstand the maximum external loading without yielding, buckling, or cracking. Pipe connections must be watertight.
Capacity Minimum of 0.2 cfs/acre of drainage.
Barrel diameter - 8-inch corrugated pipe minimum, or 6-inch smooth-wall pipe minimum.
Riser cross-sectional area - 1.5 x barrel area, minimum.
Dewatering - Perforate lower half of riser in each outside valley with ½-inch holes spaced approximately 3 inches. If corrugated pipe is used, locate holes along each outside valley. Cover with 2 ft of ½- to ¾-inch aggregate.
Crest of principal spillway - One foot minimum below elevation of emergency spillway crest.

Seepage prevention - At least one watertight antiseep collar with a minimum projection of 2 feet is required around barrel of pipes 8 inches in diameter or larger. The antiseep collar(s) shall increase by 15 percent the seepage path along the pipe from the riser to downstream toe of dam.
Anti-flotation block - Riser must be held in place with an anchor having buoyant weight greater than 1.1 times the weight of water displaced by riser and any exposed portion of barrel.
Trash guard - Required at top of riser.
Outlet - Must be stable for design pipe discharge. Install riprap outlet apron unless foundation is rock.





Section A-A

Emergency Spillway

Capacity - 10-year peak flow, minus flow in principal spillway.
Location - Construct in undisturbed soil - not fill.
Cross section - Trapezoidal with side slopes 3:1 or flatter.
Control section - Level and straight, at least 20 feet long. Outlet section must be straight.
Embankment - Top width 8 feet minimum for dam height less than 10 feet. 10 feet minimum for dam height of 10 to 15 feet.
Side slopes - 2.5:1 or flatter.
Settlement allowance - 10% of design height.

Cutoff trench - Required tinder centerline of dam, depth 2 feet minimum into undisturbed firm mineral soil. Extend trench up each abutment to elevation of emergency spillway crest. The bottom width should be wide enough to permit operation of excavation and compaction equipment, but not less than 4 feet wide. Side slopes should be no steeper than 1:1.

Fill material - The fill material should be clean mineral soil free of roots, woody vegetation, oversized stones, rocks, or other objectionable material. Relatively pervious materials such as sand or gravel (Unified Soil Classification GW, GP, SW, and SP) should not be used in the fill.

Freeboard - "Freeboard" is the difference between the design flow elevation in the emergency spillway and the top elevation of the embankment. Minimum freeboard should be one foot.

Construction Recommendations

Site Preparation

The sediment basin should be as close to the sediment source as site conditions allow considering soils, pool area, dam length, and spillway conditions. Delay clearing pool until dam is complete to reduce erosion and off-site sedimentation.

Clear, grub, and strip dam location. Excavate area for the outlet apron.

Remove surface soil containing high amounts of organic matter and stockpile for later use. Clear sediment pool to facilitate sediment cleanout.

Dispose of trees, limbs, logs, and other debris in designated disposal areas.

Cutoff Trench

Excavate cutoff trench along dam centerline extending up both abutments to elevation of principal spillway crest.

Cut trench into stable soil material, at least 2 ft wide and at least 2 ft deep with side slopes 1H: 1V or flatter.

Backfill with clayey soil if available. Compaction requirements: same as those for embankment. The trench should be de-watered during the backfilling and compaction operations.

Principal Spillway

Use only approved watertight assemblies as shown in the plans for all pipe connections. Rod and lug connector bands with gaskets are recommended for corrugated pipe. Do not use dimple (universal) connector bands. Connection between pipe and anti-seep collar must be watertight.

Place barrel and riser on firm, even foundation. Install anti-seep collar(s) slightly downstream of dam centerline.

Place moist, clayey, workable soil around pipe and anti-seep collars. Do not use pervious material such as sand, gravel, or silt. Compact 4-inch layers of soil, by hand, under and around pipe and collars to at least the density of foundation soil. Avoid raising pipe from firm contact with foundation while compacting material under pipe haunches.

Cover pipe to a depth of 2 feet minimum of hand-compacted backfill before crossing it with construction equipment.

Anchor riser in place with concrete to prevent flotation. Embed riser at least 6 inches into concrete.

Install trash guard with bars spaced 2-3 inches apart.

Install riprap apron at pipe outlet, width 5 ft minimum. Extend apron to stable grade (length 10 ft minimum). Use well-graded stone with “d50” of 9 inches minimum.

Embankment

Scarify base of dam before placing fill.

Fill material should be placed in 6- to 8-inch continuous layers over the entire length of the fill and compacted. Save the least permeable soil for center portion of dam. Place the most permeable soil in downstream toe.

Compaction may be obtained by routing the hauling equipment over the fill so that the entire surface of each layer of the fill is traversed by at least one wheel or tread track of the equipment. If compaction is obtained with hauling equipment, an elevation 10 percent higher than the design height is required to allow for settlement. If compactors are used for compaction, the overbuild may be reduced to not less than 5 percent.

Fill material must contain sufficient moisture that it can be formed by hand into a ball without crumbling. If water can be squeezed out of the ball, it is too wet for proper compaction.

Construct dam to lines and grades shown in plan. Side slopes must be 2.5:1 or flatter.

Compact fill material in 6- to 8-inch continuous layers over length of dam. Compaction may be obtained by routing construction equipment over fill so that the entire surface of each layer is traversed by at least one wheel of compacting equipment. Protect spillway barrel with 2 ft of hand-compacted fill before traversing with equipment

Construct embankment 10% higher than design height to allow for settlement.

Emergency Spillway

Cut emergency spillway in undisturbed soil to lines and grade shown in the approved plan. Side slopes must be 3:1 or flatter.

Control section must be level and straight, 20 ft long minimum. Exit section must be straight.

Vegetate spillway as soon as grading is complete, following all requirements in vegetation plan. Anchor mulch in spillway with netting.

Install paving material to finished grade if spillway is not to be vegetated.

Cleanout

Place reference stake at sediment cleanout elevation (50% of design volume).

Erosion Control

Minimize the area disturbed and time of exposure.

Excavate the outlet apron area first, to use as a sediment trap during construction of dam.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Construct embankment before clearing the sediment pool.

Stabilize all disturbed areas except lower one-half of sediment basin immediately after construction.

Safety

Sediment basins should be installed only on sites where failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities.

Sediment basins are attractive to children and can be very dangerous.

Keep sediment pool dewatered between storms.

Construct side slopes 2:1 or flatter in pool area.

Fence area if trespassing is likely. Post signs warning the public of hazards of soft sediment and floodwater.

Follow all state and local requirements.

Common Trouble Points

Piping failure along conduit

Due to lack of proper compaction, omission of anti-seep collar, or leaking pipe joints.

Erosion of spillway or embankment slopes

Due to inadequate vegetation or improper grading and sloping.

Slumping and/or settling of embankment

Due to inadequate compaction and/or use of poor-quality fill material.

Slumping failure

Due to steep side slopes.

Erosion and caving below pipe

Due to inadequate outlet protection.

Basin not located properly for access

Makes maintenance difficult and costly.

Sediment not properly removed

Leaves inadequate storage capacity.

Lack of anti-flotation pipe

Damage from uplift.

Lack of trash rack

Barrel and riser blocked with debris.

Elevations of principal spillway and emergency spillway too high relative to top of dam
Potential failure from overtopping.

Maintenance

Sediment basins should be readily accessible for maintenance and sediment removal. The sediment basin should remain in operation and be properly maintained until the site area is permanently stabilized by vegetation and/or when permanent structures are in place.

Inspect sediment basins after each significant rainfall.

Remove and properly dispose of sediment when it accumulates to one-half design volume (level marked by reference stake). The effectiveness of a sediment pond is based less on its size than on regular sediment removal.

Check embankment, emergency spillway, and outlet for erosion damage.

Check embankment for: settlement, seepage, or slumping along the toe or around pipe. Look for signs of piping. Repair immediately. Remove trash and other debris from principal spillway, emergency spillway, and pool area.

Clean or replace gravel when sediment pool does not drain properly.

Remove basin after drainage area has been permanently stabilized, inspected, and approved. Before removing dam, drain water and remove sediment; place waste material in designated disposal areas. Smooth site to blend with surrounding area and stabilize.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

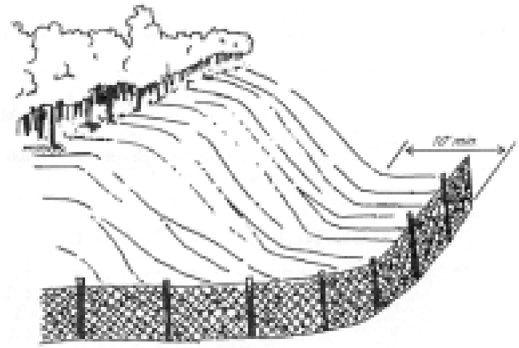
Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sediment Fence



A temporary sediment barrier consisting of a filter fabric stretched across and attached to supporting posts and entrenched. The sediment fence is constructed of stakes and synthetic filter fabric with a rigid wire fence backing where necessary for support.

Sediment fence can be purchased with pockets presewn to accept use of steel fence posts.

Purpose

A sediment fence intercepts and detains small amounts of sediment from disturbed areas during construction operations and reduces runoff velocity down a slope.

Sediment fences may also be used to catch wind-blown sand and to create an anchor for sand dune creation.

Where Practice Applies

- Below small disturbed areas of less than ¼ acre per 100 feet of fence, where runoff may occur in the form of sheet and rill erosion.
- Where there is no concentration of water in a channel or other drainageway above the fence, and drainage area is usually not more than 1-½ acres.
- Where runoff can be stored behind the sediment fence without damaging the fence, or the submerged area behind the fence.
- Where erosion would occur only in the form of sheet erosion.
- Do not install sediment fences across streams, ditches, or waterways.

Advantages

- Removes sediments and prevents downstream damage from sediment deposits
- Reduces the speed of runoff flow
- Minimal clearing and grubbing required for installation
- Sediment fences trap a much higher percentage of suspended sediments than straw bales.

Disadvantages/Problems

Sediment fences are not practical where large flows of water are involved. Their use is recommended only for small drainage areas, and flow rates of less than 0.5 cfs.

Flow should not be concentrated; it should be spread out over many linear feet of sediment fence.

Problems may arise from incorrect selection of filter fabric or from improper installation.

Sediment fences are not an adequate method of runoff control for anything deeper than sheet or overland flow.

Planning Considerations

Sediment fences should be located where they will trap sediment; that is, where there will be contributing runoff. A sediment fence, located along the top of a ridge serves no useful purpose, except as it may be used to mark limits of a construction area. A sediment fence located at the upper end of a drainage area performs no sediment-collecting function.

Sediment fences are preferable to straw barriers in many cases. While the failure rate is lower than that of straw barriers there are, however, many cases in which sediment fences have been improperly installed.

Sediment fences have a low permeability to enhance sediment trapping. This will create ponding behind the fence, so they should not be located where ponding will cause property damage or a safety hazard.

The sedimentation pool behind the fence is very effective and may reduce the need for sediment basins and traps.

Sediment fences may be designed to store all the runoff from the design storm or located to allow bypass flow when the temporary sediment pool reaches a predetermined level.

The drainage area must be restricted and the fence located so that water depth does not exceed 1.5 feet at any point.

The expected life of a sediment fence is generally six months.

To use sediment fences effectively, provide access to the locations where sediment accumulates and provide reinforced, stabilized outlets for emergency overflow.

Sediment fence is most effective when used in conjunction with other practices such as perimeter dikes or diversions.

Allow for safe bypass of storm flow to prevent overtopping failure of fence.

Do not install sediment fence across intermittent or permanent streams, channels, or any location where concentrated flow is anticipated.

It is not necessary to use straw or hay bales together with a sediment fence.

Design Recommendations

Depth of impounded water should not exceed 1.5 feet at any point along the fence.

Drainage area

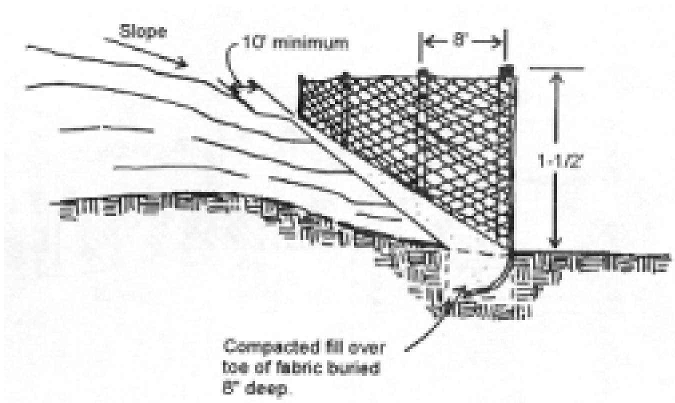
Limited to ¼ acre per 100 ft of fence, and no more than 1.5 acres in total; or in combination with a sediment basin on a larger site. Area is further restricted by slope steepness as shown in the following table.

Land Slope (%)	Maximum Slope Distance Above Fence (feet)
2	250
5	180
10	100
20	50
30	30

Location

Locate the fence at least 10 feet from the toe of steep slopes to provide sediment storage and access for cleanout.

The fence line should be nearly level through most of its length to impound a broad, temporary pool. The last 10 to 20 feet at each end of the fence should be swung slightly uphill (approximately 0.5 feet in elevation) to provide stroage capacity.



Stabilized outlets are required for bypass flow, unless the fence is designed to retain all runoff from the 10-year storm.

The fence line may run slightly off level (grade less than 1%) if it terminates in a level section with a stabilized outlet, diversion, basin, or sediment trap. There must be no gullying along the fence or at the ends. A sediment fence should not be used as a diversion.

Materials and Use

Filter Fabric

The filter fabric used in a sediment fence must have sufficient strength to withstand various stress conditions. It also must have the ability to allow passage of water while retaining soil particles. Filter fabric for a sediment fence is available commercially.

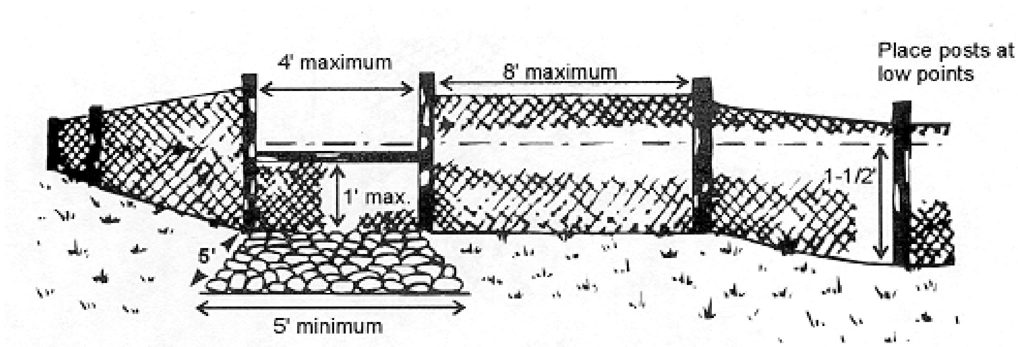
Support posts
Four-inch diameter pine, 1.33 lb./linear ft. steel, or sound quality hardwood with a minimum cross sectional area of 3.0 square inches. Steel posts should have projections for fastening fabric.
Drive posts securely, at least 16 inches into the ground, on the downslope side of the trench. Space posts a maximum of 8 feet if fence is supported by wire, 6 feet if extra-strength fabric is used without support wire. Adjust spacing to place posts at low points along the fenceline.
Support wire
Wire fence (14 gauge with 6-inch mesh) is required to support standard-strength fabric.

Reinforced, stabilized outlets

Any outlet where storm flow bypass occurs must be stabilized against erosion.

Set outlet elevation so that water depth cannot exceed 1.5 feet at the lowest point along the fenceline.

Set fabric height at 1 foot maximum between support posts spaced no more than 4 feet apart. Install a horizontal brace between the support posts to serve as an overflow weir and to support top of fabric. Provide a riprap splash pad a minimum 5 feet wide, 1 foot deep, and 5 feet long on level grade. The finished surface of the riprap should blend with surrounding area, allowing no overfall. The area around the pad must be stable.



Construction Recommendations

Dig a trench approximately 8 inches deep and 4 inches wide, or a V-trench; along the line of the fence, upslope side.

Fasten support wire fence securely to the upslope side of fence posts with wire ties or staples. Wire should extend 6 inches into the trench.

Attach continuous length of fabric to upslope side of fence posts. Avoid joints, particularly at low points in the fence line. Where joints are necessary, fasten fabric securely to support posts and overlap to the next post.

Place the bottom one foot of fabric in the trench. Backfill with compacted earth or gravel.

Filter cloth shall be fastened securely to the woven wire fence with ties spaced every 24 inches at the top, mid-section, and bottom.

To reduce maintenance, a shallow sediment storage area may be excavated on the upslope side of fence where sedimentation is expected.

Provide good access to deposition areas for cleanout and maintenance.

Sediment fences should be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized. Retained sediment must be removed and properly disposed of, or mulched and seeded.

Common Trouble Points

Fence sags or collapses:

- Drainage area too large,
- Too much sediment accumulation allowed before cleanout,
- Approach too steep, or
- Fence not adequately supported.

Fence fails from undercutting:

- Bottom of fence not buried at least 8 inches at all points,
- Trench not backfilled with compacted earth or gravel,
- Fence installed on excessive slope, or
- Fence located across drainage way.

Fence is overtopped:

- Storage capacity inadequate, or
- No provision made for safe bypass of storm flow, or
- Fence located across drainage way.

Erosion occurs around end of fence:

- Fence terminates at elevation below the top of the temporary pool.
- Fence terminates at unstabilized area, or
- Fence located on excessive slope.

Maintenance

A sediment fence requires a great deal of maintenance. Silt fences should be inspected immediately after each rainfall and at least daily during prolonged rainfall. Repair as necessary.

Remove sediment deposits promptly to provide adequate storage volume for the next rain and to reduce pressure on fence. Take care to avoid undermining fence during cleanout.

If the fabric tears, decomposes, or in any way becomes ineffective, replace it immediately.

Replace burlap used in sediment fences after no more than 60 days.

Remove all fencing materials after the contributing drainage area has been properly stabilized. Sediment deposits remaining after the fabric has been removed should be graded to conform with the existing topography and vegetated.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, S***tormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manua***l, Raleigh, NC, February 1991.

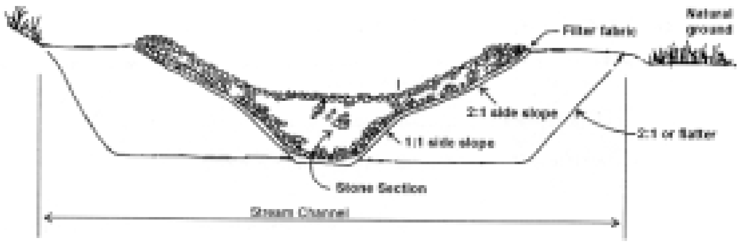
"Proper Silt Fence Performance," ***Erosion Control, The Journal For Erosion & Sediment Control Professionals***, Vol. 1, No. 3, July/August 1994.

U. S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sediment Trap

A sediment trap is formed by excavating a pond or by placing an earthen embankment across a low area or drainage swale. An outlet or spillway is constructed using large stones or aggregate to slow the release of runoff. The trap retains the runoff long enough to allow most of the silt to settle out.



Purpose

A sediment trap intercepts sediment-laden runoff from small disturbed areas and detains it long enough for the majority of the sediment to settle out.

Where Practice Applies

A sediment trap is installed:

- As close to the disturbed area or source of sediment as physically possible;
- Where the drainage area is less than 5 acres; and
- Where runoff from undisturbed areas can be excluded from the structure.

A sediment trap may be used in conjunction with other temporary measures, such as gravel construction entrances, vehicle wash areas, slope drains, diversion dikes and swales, or diversion channels.

Advantages

- Reduced sediment deposits downstream.
- Is inexpensive and simple to install.
- Can simplify the design process by trapping sediment at specific spots onsite.
- Disadvantages/Problems
- Effective only if properly maintained.
- Will not remove very fine silts and clays.
- Serves only limited areas.

Planning Considerations

Temporary sediment traps are usually installed in drainage ways with small watersheds. They may be used at a storm drain inlet or outlet.

Locate sediment trap as near the sediment source as topography allows.

Divert runoff from all undisturbed areas away from sediment trap.

Sediment traps should be installed before any land disturbance takes place in the drainage area.

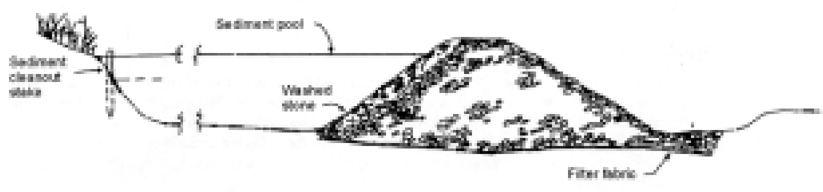
Design Recommendations

Drainage area - Not more than 5 acres.
Sediment storage - The sediment trap should have a minimum volume based on ½ inch of storage for each acre of drainage area. This volume equates to 1800 cubic feet of storage or 67 cubic yards for each acre of drainage area.
Trap efficiency - Length-to-width ratio should be 2:1 or greater; divert inflow to upper end of basin to avoid short-circuiting flow. Length is defined as the average distance from the inlet to the outlet of the trap.
Structure life - Limited to 2 years.
Embankment - The maximum height of the sediment trap embankment should be 5 feet when measured from the lowest point of natural ground on the downstream side of the embankment. The minimum top width of the embankment should be 5 feet. The side slopes of the embankment should be 2:1, horizontal to vertical, or flatter.
Excavations - When excavation is necessary to obtain the required storage, the side slopes should be no steeper than 2:1, horizontal to vertical, in the excavated portion of the basin.
Outlets - The outlet should be designed so that sediment does not leave the trap and erosion does not take place below the outlet. The outlets must empty onto undisturbed ground, into a water course, stabilized channel or a storm sewer system.
Capacity - 10-yr peak storm.
Stone - Hard, angular, well-graded mixture with “d50” of 9 inches minimum. Inside facing lined with a 1-foot thick layer of ½- to ¾-inch washed aggregate.
Side slopes - Spillway and excavated basin, 2:1 or flatter.
Protection from “piping” - Filter fabric or a cut-off trench is required between the stone spillway outlet section and the compacted embankment.
Spillway depth - 1.5 ft minimum below designed, settled top of embankment. Freeboard - 0.5 foot minimum.

Spillway width

Drainage Area (acres)	Minimum Bottom Width (feet)
1	4.0
2	6.0
3	8.0
4	10.0
5	12.0

Outlet apron - 5-ft long, minimum, on level grade with filter fabric foundation.



CROSS-SECTION

Construction Recommendations

Embankment

- Clear, grub, and strip all vegetation and root mat from area of embankment. Use stable mineral soil free of roots, rocks, debris, organic material, and other objectionable material.
- Place embankment fill in 9-inch lifts, maximum. The fill should be compacted by routing construction equipment so that the entire area of the fill is transversed by at least one wheel or tread track of the equipment. Construct side slopes 2:1 or flatter (3:1 recommended for backslope to improve stability of stone spillway).
- Overfill embankment to 6 inches above design elevation to allow for settlement.
- Outlet crest elevations should be at least one foot below the top of the embankment.

Outlet Section

- Excavate trapezoidal stone outlet section from compacted embankment. Allow for thickness of stone side slopes (21 inches minimum).
- Install filter fabric under riprap. Extend fabric up the sides to top of embankment.

A Place specified stone to lines and grades shown on plans, working the smaller stones into the voids to achieve a dense mass. Spillway crest must be level with minimum inside dimension specified in plan. Measure spillway depth from the highest stones in the spillway to the design elevation of dam. Minimum depth is 1.5 foot.

- Keep sides of the stone outlet section at least 21 inches thick through the level section and the downstream face of dam.
- Extend outlet apron below toe of dam on level grade until stable conditions are reached (5 feet minimum). Edges and end of the stone apron section must be flush with surrounding ground. No overfall should exist.
- Cover inside face of stone outlet section with a 1-foot thick layer of ½- to ¾-inch aggregate.

Vegetation

All embankments, earth spillways, and disturbed areas downstream from the structure should be vegetated within 3 days of completion of the construction of the structure. If the structure is not planned for more than one vegetative growing season, the structure may be vegetated using in **Temporary Seeding** recommendations. Basins that will be carried over the winter and into the next vegetative growing season should be vegetated using **Permanent Seeding** recommendations.

Common Trouble Points

Inadequate spillway size
Results in overtopping of dam, poor trap efficiency and possible failure of the structure. Modification of the plan may be required.

Omission of or improper installation of filter fabric
Results in washout under sides or bottom of the stone outlet section (piping).

Low point in embankment caused by inadequate compaction and settling
Results in overtopping and possible failure.

Stone outlet apron does not extend to stable grade
Results in erosion below the dam.

Stone size too small or backslope too steep
Results in stone displacement.

Inadequate vegetative protection
Results in erosion of embankment.

Inadequate storage capacity
Sediment not removed from basin frequently enough.

Contact slope between stone spillway and earth embankment too steep
Piping failure is likely.

Maintenance

The effective life of a sediment trap depends upon adequate maintenance. The trap should be readily accessible for periodic maintenance and sediment removal.

Set a stake at one-half the design depth. This will be the “cleanout level.” Remove sediment when it has accumulated to one-half the design depth.

Inspect sediment traps after each significant rainfall event. Repair any erosion and piping holes immediately.

Clean or replace spillway gravel facing if clogged.

Promptly replace any displaced riprap, being careful that no stones in the spillway are above design grade.

Inspect vegetation; reseed and remulch if necessary.

Check spillway depth periodically to ensure minimum of 1.5 ft depth from lowest point of the settled embankment to highest point of spillway crest. Fill any low areas of the embankment to maintain design elevation.

After all sediment-producing areas have been stabilized, inspected, and approved, remove the structure and all unstable sediment. Smooth site to blend with adjoining areas and stabilize in accordance with vegetation plan.

References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

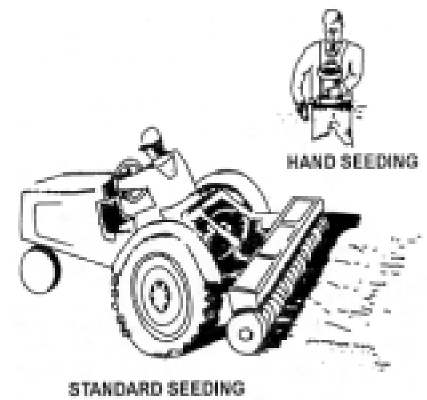
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Seeding, Permanent

The establishment of perennial vegetative cover on disturbed areas.



Purpose

Permanent seeding of grass and planting trees and shrubs provides stabilization to the soil by holding soil particles in place.

Vegetation reduces sediments and runoff to downstream areas by slowing the velocity of runoff and permitting greater infiltration of the runoff.

Vegetation also filters sediments, helps the soil absorb water, improves wildlife habitats, and enhances the aesthetics of a site.

Where Practice Applies

- Permanent seeding and planting is appropriate for any graded or cleared area where long-lived plant cover is needed to stabilize the soil.
- Areas which will not be brought to final grade for a year or more.
- Some areas where permanent seeding is especially important are filter strips, buffer areas, vegetated swales, steep slopes, and stream banks.
- This practice is effective on areas where soils are unstable because of their texture or structure, high water table, winds, or steep slope.

Advantages

Advantages of seeding over other means of establishing plants include the small initial establishment cost, the wide variety of grasses and legumes available, low labor requirement, and ease of establishment in difficult areas.

Seeding is usually the most economical way to stabilize large areas.

Well established grass and ground covers can give an aesthetically pleasing, finished look to a development.

Once established, the vegetation will serve to prevent erosion and retard the velocity of runoff.

Disadvantages/Problems

Disadvantages which must be dealt with are the potential for erosion during the establishment stage, a need to reseed areas that fail to establish, limited periods during the year suitable for seeding, and a need for water and appropriate climatic conditions during germination. Vegetation and mulch cannot prevent soil slippage and erosion if soil is not inherently stable.

Coarse, high grasses that are not mowed can create a fire hazard in some locales. Very short mowed grass, however, provides less stability and sediment filtering capacity.

Grass planted to the edge of a watercourse may encourage fertilizing and mowing near the water's edge and increase nutrient and pesticide contamination.

Depends initially on climate and weather for success.

May require regular irrigation to establish and maintain.

Planning considerations

Selection of the right plant materials for the site, good seedbed preparation, timing, and conscientious maintenance are important. Whenever possible, native species of plants should be used for landscaping. These plants are already adapted to the locale and survivability should be higher than with "introduced" species.

Native species are also less likely to require irrigation, which can be a large maintenance burden and is neither cost-effective nor ecologically sound.

If non-native plant species are used, they should be tolerant of a large range of growing conditions, as low-maintenance as possible, and not invasive.

Consider the microclimate within the development area. Low areas may be frost pockets and require hardier vegetation since cold air tends to sink and flow towards low spots. South-facing slopes may be more difficult to re-vegetate because they tend to be sunnier and drier.

Divert as much surface water as possible from the area to be planted.

Remove seepage water that would continue to have adverse effects on soil stability or the protecting vegetation. Subsurface drainage or other engineering practices may be needed. In this situation, a permit may be needed from the local Conservation Commission: check ahead of time to avoid construction delays.

Provide protection from equipment, trampling and other destructive agents.

Vegetation cannot be expected to supply an erosion control cover and prevent slippage on a soil that is not stable due to its texture, structure, water movement, or excessive slope.

Seeding Grasses and Legumes

Install needed surface runoff control measures such as gradient terraces, berms, dikes, level spreaders, waterways, and sediment basins prior to seeding or planting.

Seedbed Preparation

If infertile or coarse-textured subsoil will be exposed during land shaping, it is best to stockpile topsoil and respread it over the finished slope at a minimum 2- to 6-inch depth and roll it to provide a firm seedbed. If construction fill operations have left soil exposed with a loose, rough, or irregular surface, smooth with blade and roll.

Loosen the soil to a depth of 3-5 inches with suitable agricultural or construction equipment.

Areas not to receive top soil shall be treated to firm the seedbed after incorporation of the lime and fertilizer so that it is depressed no more than ½ - 1 inch when stepped on with a shoe. Areas to receive topsoil shall not be firmed until after topsoiling and lime and fertilizer is applied and incorporated, at which time it shall be treated to firm the seedbed as described above. This can be done by rolling or cultipacking.

Cool Season Grasses

Cool Season Grasses grow rapidly in the cool weather of spring and fall, and set seed in June and July. Cool season grasses become dormant when summer temperatures persist above 85 degrees and moisture is scarce.

Lime and Fertilizer

Apply lime and fertilizer according to soil test and current Extension Service recommendations. In absence of a soil test, apply lime (a pH of 5.5 - 6.0 is desired) at a rate of 2.5 tons per acre and 10-20-20 analysis fertilizer at a rate of 500 pounds per acre (40 % of N to be in an organic or slow release form). Incorporate lime and fertilizer into the top 2-3 inches of soil.

Seeding Dates

Seeding operations should be performed within one of the following periods:

- April 1 - May 31,
- August 1 - September 10,
- November 1 - December 15 as a dormant seeding (seeding rates shall be increased by 50% for dormant seedings).

Seeding Methods

Seeding should be performed by one of the following methods. Seed should be planted to a depth of ¼ to ½ inches.

- Drill seedings,
- Broadcast and rolled, cultipacked or tracked with a small track piece of construction equipment,
- Hydroseeding, with subsequent tracking.

Mulch

Mulch the seedings with straw applied at the rate of ½ tons per acre. Anchor the mulch with erosion control netting or fabric on sloping areas.

Warm Season Grasses

Warm Season Grasses begin growth slowly in the spring, grow rapidly in the hot summer months and set seed in the fall. Many warm season grasses are sensitive to frost in the fall, and the top growth may die back. Growth begins from the plant base the following spring.

Lime and Fertilizer

Lime to attain a pH of at least 5.5. Apply a 0-10-10 analysis fertilizer at the rate of 600 lbs./acre.

Incorporate both into the top 2-3 inches of soil. (30 lbs. of slow release nitrogen should be applied after emergence of grass in the late spring.)

Seeding Dates

Seeding operations should be performed as an early spring seeding (April 1-May 15) with the use of cold treated seed. A late fall early winter dormant seeding (November 1 - December 15) can also be made, however the seeding rate will need to be increased by 50%.

Seeding Methods

Seeding should be performed by one of the following methods:

- Drill seedings (de-awned or de-bearded seed should be used unless the drill is equipped with special features to accept awned seed).
- Broadcast seeding with subsequent rolling, cultipacking or tracking the seeding with small track construction equipment. Tracking should be oriented up and down the slope.
- Hydroseeding with subsequent tracking. If wood fiber mulch is used, it should be applied as a separate operation after seeding and tracking to assure good seed to soil contact.

Mulch

Mulch the seedings with straw applied at the rate of ½ tons per acre. Anchor the mulch with erosion control netting or fabric on sloping areas.

Seed Mixtures for Permanent Cover

Recommended mixtures for permanent seeding are provided on the following pages. Select plant species which are suited to the site conditions and planned use. Soil moisture conditions, often the major limiting site factor, are usually classified as follows:

Dry - Sands and gravels to sandy loams. No effective moisture supply from seepage or a high water table.

Moist - Well drained to moderately well drained sandy loams, loams, and finer; or coarser textured material with moderate influence on root zone from seepage or a high water table.

Wet - All textures with a water table at or very near the soil surface, or with enduring seepage.

When other factors strongly influence site conditions, the plants selected must also be tolerant of these conditions.

Permanent Seeding Mixtures

Mix	Site	Seed Mixture	Seed, Pounds per: Acre	Seed, Pounds per: 1,000 sf	Remarks
1	Dry	Little Bluestem or Broomsedge	10	0.25	* Use Warm Season planting procedure. * Roadsides
		Tumble Lovegrass*	1	0.10	* Sand and Gravel Stabilization
		Switchgrass	10	0.25	* Clover requires inoculation with nitrogen-fixing bacteria
		Bush Clover*	2	0.10	
		Red Top	1	0.10	* Rates for this mix are for PLS.
2	Dry	Deertongue	15	0.35	* Use Warm Season planting procedures.
		Broomsedge	10	0.25	* Acid sites/Mine spoil
		Bush Clover*	2	0.10	* Clover requires inoculation with nitrogen-fixing bacteria.
		Red Top	1	0.10	*Rates for this mix are for PLS.
3	Dry	Big Bluestem	10	0.25	* Use Warm Season planting procedures.
		Indian Grass	10	0.25	* Eastern Prairie appearance
		Switchgrass	10	0.25	* Sand and Gravel pits.
		Little Bluestem	10	0.25	* Golf Course Wild Areas
		Red Top or	1	0.10	* Sanitary Landfill Cover seeding
		Perennial Ryegrass	10	0.25	* Wildlife Areas *OK to substitute Poverty Dropseed in place of Red Top/Ryegrass. *Rates for this mix are for PLS.
4	Dry	Flat Pea	25	0.60	* Use Cool Season planting procedures
		Red Top or	2	0.10	* Utility Rights-of-Ways (tends to suppress woody growth)
		Perennial Ryegrass	15	0.35	
5	Dry	Little Bluestem	5	0.10	* Use Warm Season planting procedures.
		Switchgrass	10	0.25	* Coastal sites
		Beach Pea*	20	0.45	* Rates for Bluestein and Switchgrass are for PLS.
		Perennial Ryegrass	10	0.25	
6	Dry - Moist	Red Fescue	10	0.25	* Use Cool Season planting procedure.
		Canada Bluegrass	10	0.25	* Provides quick cover but is non-aggressive; will tend to allow indigenous plant colonization.
		Perennial Ryegrass	10	0.25	
		Red Top	1	0.10	* General erosion control on variety of sites, including forest roads, skid trails and landings.
7	Moist-Wet	Switchgrass	10	0.25	* Use Warm Season planting procedure.
		Virginia Wild Rye	5	0.10	* Coastal plain/flood plain
		Big Bluestem	15	0.35	* Rates for Bluestem and Switchgrass are for PLS.
		Red Top	1	0.10	

Permanent Seeding Mixtures

Mix	Site	Seed Mixture	Seed, Pounds per: Acre	Seed, Pounds per: 1,000 sf	Remarks
8	Moist Wet	Creeping Bentgrass	5	0.10	* Use Cool Season planting procedures.
		Fringed Bromegrass	5	0.10	* Pond Banks
		Fowl Meadowgrass	5	0.10	* Waterways/ditch banks
		Bluejoint Reedgrass or Rice Cutgrass	2	0.10	
		Perennial Ryegrass	10	0.25	
9	Moist Wet	Red Fescue	5	0.10	*Salt Tolerant
		Creeping Bentgrass	2	0.10	* Fescue and Bentgrass provide low growing appearance, while Switchgrass provides tall cover for wildlife.
		Switchgrass	8	0.20	
		Perennial Ryegrass	10	0.25	
10	Moist Wet	Red Fescue	5	0.10	* Use Cool Season planting procedure.
		Creeping Bentgrass	5	0.10	* Trefoil requires inoculation with nitrogen fixing bacteria.
		Virginia Wild Rye	8	0.20	
		Wood Reed Grass*	1	0.10	* Suitable for forest access roads, skid trails and other partial shade situations.
		Showy Tick Trefoil*	1	0.10	
11	Moist Wet	Creeping Bentgrass	5	0.10	* Use Cool Season planting procedure.
		Bluejoint Reed Grass	1	0.10	* Suitable for waterways, pond or ditch banks.
		Virginia Wild Rye	3	0.10	* Trefoil requires inoculation with nitrogen fixing bacteria.
		Fowl Meadow Grass	10	0.25	
		Showy Tick Trefoil*	1	0.10	
		Red Top	1	0.10	
12	Wet	Blue Joint Reed Grass	1	0.10	* Use Cool Season planting procedure.
		Canada Manna Grass	1	0.10	* OK to seed in saturated soil conditions, but not in standing water.
		Rice Cut Grass	1	0.10	
		Creeping Bent Grass	5	0.10	* Suitable as stabilization seeding for created wetland.
		Fowl Meadow Grass	5	0.10	* All species in this mix are native to Massachusetts.
13	Dry - Moist	American Beachgrass	18” centers	18’ centers	*Vegetative planting with dormant culms, 3-5 culms per planting
14	Inter-Tidal	Smooth Cordgrass Saltmeadow Cordgrass	12-18” centers	12-18” centers	* Vegetative planting with transplants.

Notes:
* Species such as Tumble Lovegrass, Fringed Bromegrass, Wood Reedgrass, Bush Clover and Beach Pea, while known to be commercially available from specific seed suppliers, may not always be available from your particular seed suppliers. The local Natural Resources Conservation Service office may be able to help with a source of supply. In the event a particular species listed in a mix can not be obtained, however, it may be possible to substitute another species.

Seed mixtures by courtesy of Natural Resources Conservation Service, Amherst, MA.

(PLS) Pure Live Seed

Warm Season grass seed is sold and planted on the basis of pure live seed. An adjustment is made to the bulk rate of the seed to compensate for inert material and non-viable seed. Percent of pure live seed is calculated by multiplying the percent purity by the percent germination; **(% purity) x (% germination) = percent PLS.**

For example, if the seeding rate calls for 10 lbs./acre PLS and the seed lot has a purity of 70% and germination of 75%, the PLS factor is:

(.70 x .75) =.53

10 lbs. divided by .53 = approx. 19 lbs.

Therefore, 19 lbs of seed from the particular lot will need to be applied to obtain 10 lbs. of pure live seed.

Special Note

Tall Fescue, Reed Canary Grass, Crownvetch and Birdsfoot Trefoil are no longer recommended for general erosion control use in Massachusetts due to the invasive characteristics of each. If these species are used, it is recommended that the ecosystem of the site be analyzed for the effects species invasiveness may impose. The mixes listed in the above mixtures include either species native to Massachusetts or non-native species that are not perceived to be invasive, as per the Massachusetts Native Plant Advisory Committee.

Wetlands Seed Mixtures

For newly created wetlands, a wetlands specialist should design plantings to provide the best chance of success. Do not use introduced, invasive plants like reed canarygrass (Phalaris arundinacea) or purple loosestrife (Lythrum salicaria). Using plants such as these will cause many more problems than they will solve.

The following grasses all thrive in wetland situations:

- Fresh Water Cordgrass (*Spartina pectinata*)
- Marsh/Creeping Bentgrass (*Agrostis stolonifera, var. Palustric*)
- Broomsedge (*Andropogon virginicus*)
- Fringed Bromegrass (*Bromus ciliatus*)
- Blue Joint Reed Grass (*Calamagrostis cavedensis*)
- Fowl Meadow Grass (*Glyceria striata*)
- Riverbank Wild Rye (*Elymus riparius*)
- Rice Cutgrass (*Leersia oryzoides*)
- Stout Wood Reed (*Cinna arundinacea*)
- Canada Manna Grass (*Glyceria canadensis*)

A sample wetlands seed mix developed by The New England Environmental Wetland Plant Nursery is shown on the following page.

Wetland Seed Mixture

The New England Environmental Wetland Plant Nursery has developed a seed mixture which is specifically designed to be used in wetland replication projects and stormwater detention basins. It is composed of seeds from a variety of indigenous wetland species. Establishing a native wetland plant understory in these areas provides quick erosion control, wildlife food and cover, and helps to reduce the establishment of undesirable invasive species such as Phragmites and purple loosestrife (Lythrum salicaria). The species have been selected to represent varying degrees of drought tolerance, and will establish themselves based upon microtopography and the resulting variation in soil moisture.

Common Name (*Scientific Name*)	**% in Mix**	**Comments**
Lurid Sedge (*Carex lurida*)	30	A low ground cover that tolerates mesic sites in addition to saturated areas; prolific seeder in second growing season.
Fowl Meadow Grass (*Glyceria Canadensis*)	25	Prolific seed producer that is a valuable wildlife food source.
Fringed Sedge (*Carex crinita*)	10	A medium to large sedge that tolerates saturated areas; good seed producer.
Joe-Pye Weed (*Eupatoriadelphus maculatus*)	10	Flowering plant that is valuable for wildlife cover. Grows to 4 feet.
Brook Sedge (*Carex spp., Ovales group*)	10	Tolerates a wide range of hydrologic conditions.
Woolgrass (*Scirpus cyperinus*)	5	Tolerates fluctuating hydrology.
Boneset (*Eupatorium perfoliatum*)	5	Flowering Plant that is valuable for wildlife cover. Grows to 3 feet.
Tussock Sedge (*Carex stricta*)	<5	Grows in elevated hummocks on wet sites, may grow rhizomonously on drier sites.
Blue Vervain (*Verbena hastata*)	<5	A native plant that bears attractive, blue flowers.

The recommended application rate is one pound per 5,000 square feet when used as an understory cover. This rate should be increased to one pound per 2,500 square feet for detention basins and other sites which require a very dense cover. For best results, a late fall application is recommended. This mix is not recommended for standing water.

Maintenance

Inspect seeded areas for failure and make necessary repairs and reseed immediately. Conduct or follow-up survey after one year and replace failed plants where necessary.

If vegetative cover is inadequate to prevent rill erosion, overseed and fertilize in accordance with soil test results.

If a stand has less than 40% cover, reevaluate choice of plant materials and quantities of lime and fertilizer. Re-establish the stand following seedbed preparation and seeding recommendations, omitting lime and fertilizer in the absence of soil test results. If the season prevents resowing, mulch or jute netting is an effective temporary cover.

Seeded areas should be fertilized during the second growing season. Lime and fertilize thereafter at periodic intervals, as needed.

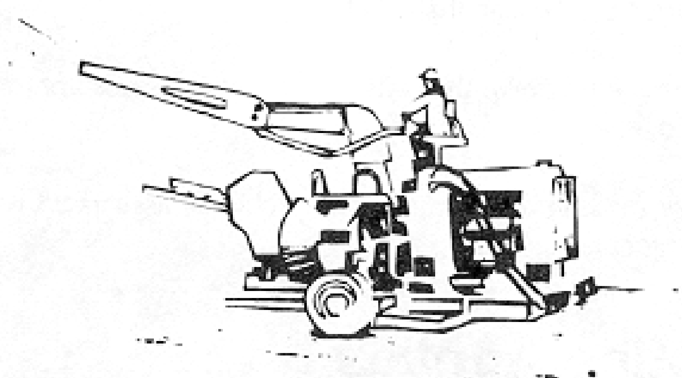
References

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Personal communication, Richard J. DeVergilio, USDA, Natural Resources Conservation Service, Amherst, MA.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

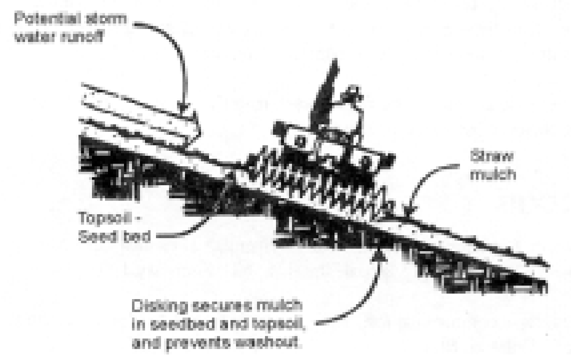


HYDRO-SEEDING

Seeding, Temporary

Planting rapid-growing annual grasses, small grains, or legumes to provide initial, temporary cover for erosion control on disturbed areas.

Purpose



To temporarily stabilize areas that will not be brought to final grade for a period of more than 30 working days.
To stabilize disturbed areas before final grading or in a season not suitable for permanent seeding.
Temporary seeding controls runoff and erosion until permanent vegetation or other erosion control measures can be established.
Root systems hold down the soils so that they are less apt to be carried offsite by storm water runoff or wind.
Temporary seeding also reduces the problems associated with mud and dust from bare soil surfaces during construction.

Where Practice Applies

On any cleared, unvegetated, or sparsely vegetated soil surface where vegetative cover is needed for less than one year. Applications of this practice include diversions, dams, temporary sediment basins, temporary road banks, and topsoil stockpiles.

Where permanent structures are to be installed or extensive re-grading of the area will occur prior to the establishment of permanent vegetation.

Areas which will not be subjected to heavy wear by construction traffic.

Areas sloping up to 10% for 100 feet or less, where temporary seeding is the only practice used.

Advantages

This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used.

Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site.

Temporary seeding offers fairly rapid protection to exposed areas.

Disadvantages/Problems

Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. It depends heavily on the season and rainfall rate for success.

If sown on subsoil, growth will be poor unless heavily fertilized and limed. Because overfertilization can cause pollution of stormwater runoff, other practices such as mulching alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems.

Once seeded, areas should not be travelled over.

Irrigation may be needed for successful growth. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected.

Planning Considerations

Temporary seedings provide protective cover for less than one year. Areas must be reseeded annual or planted with perennial vegetation.

Temporary seeding is used to protect earthen sediment control practices and to stabilize denuded areas that will not be brought into final grade for several weeks or months. Temporary seeding can provide a nurse crop for permanent vegetation, provide residue for soil protection and seedbed preparation, and help prevent dust production during construction.

Use low-maintenance native species wherever possible.

Planting should be timed to minimize the need for irrigation.

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. Annual plants which sprout rapidly and survive for only one growing season are suitable for establishing temporary vegetative cover. Temporary seeding is effective when combined with construction phasing so bare areas of the site are minimized at all times.

Temporary seeding may prevent costly maintenance operations on other erosion control systems. For example, sediment basin clean-outs will be reduced if the drainage area of the basin is seeded where grading and construction are not taking place. Perimeter dikes will be more effective if not choked with sediment.

Proper seedbed preparation and the use of quality seed are important in this practice just as in permanent seeding. Failure to carefully follow sound agronomic recommendations will often result in an inadequate stand of vegetation that provides little or no erosion control.

Soil that has been compacted by heavy traffic or machinery may need to be loosened. Successful growth usually requires that the soil be tilled before the seed is applied. Topsoiling is not necessary for temporary seeding; however, it may improve the chances of establishing temporary vegetation in an area.

Planting Procedures

Time of Planting

Planting should preferably be done between April 1 and June 30, and September 1 through September 30. If planting is done in the months of July and August, irrigation may be required. If planting is done between October 1 and March 31, mulching should be applied immediately after planting. If seeding is done during the summer months, irrigation of some sort will probably be necessary.

Site Preparation

Before seeding, install needed surface runoff control measures such as gradient terraces, interceptor dike/swales, level spreaders, and sediment basins.

Seedbed Preparation

The seedbed should be firm with a fairly fine surface.

Perform all cultural operations across or at right angles to the slope. See **Topsoiling** and **Surface Roughening** for more information on seedbed preparation. A minimum of 2 to 4 inches of tilled topsoil is required.

Liming and Fertilization

Apply uniformly 2 tons of ground limestone per acre (100 lbs. per 1,000 Sq. Ft.) or according to soil test.

Apply uniformly 10-10-10 analysis fertilizer at the rate of 400 lbs. per acre (14 lbs. per 1,000 Sq. Ft.) or as indicated by soil test. Forty percent of the nitrogen should be in organic form.

Work in lime and fertilizer to a depth of 4 inches using any suitable equipment.

Seedings for Temporary Cover

Species	**Seeding Rates lbs/sq.ft.** 1,000 Sq.Ft.	Acre	**Recommended Seeding Dates**
Annual Ryegrass	1	40	April 1 to June 1 Aug. 15 to Sept. 15
Foxtail Millet	0.7	30	May 1 to June 30
Oats	2	80	April 1 to July 1 August 15 to Sept. 15
Winter Rye	3	120	Aug. 15 to Oct. 15

"Hydro-seeding" applications with appropriate seed-mulch-fertilizer mixtures may also be used.

Seeding

Select adapted species from the accompanying table.
Apply seed uniformly according to the rate indicated in the table by broadcasting, drilling or hydraulic application.
Cover seeds with suitable equipment as follows:

Rye grass	¼ inch
Millet	½ to ¾ inch
Oats	1 to 1-1/2 inches
Winter rye	1 to 1-1/2 inches.

Mulch

Use an effective mulch, such as clean grain straw; tacked and/or tied down with netting to protect seedbed and encourage plant growth.

Common Trouble Points

Lime and fertilizer not incorporated to at least 4 inches
May be lost to runoff or remain concentrated near the surface where they may inhibit germination.

Mulch rate inadequate or straw mulch not tacked down
Results in poor germination or failure, and erosion damage. Repair damaged areas, reseed and mulch.

Annual ryegrass used for temporary seeding
Ryegrass reseeds itself and makes it difficult to establish a good cover of permanent vegetation.

Seed not broadcast evenly or rate too low
Results in patchy growth and erosion.

Maintenance

Inspect within 6 weeks of planting to see if stands are adequate. Check for damage after heavy rains. Stands should be uniform and dense. Fertilize, reseed, and mulch damaged and sparse areas immediately. Tack or tie down mulch as necessary.

Seeds should be supplied with adequate moisture. Furnish water as needed, especially in abnormally hot or dry weather or on adverse sites. Water application rates should be controlled to prevent runoff.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

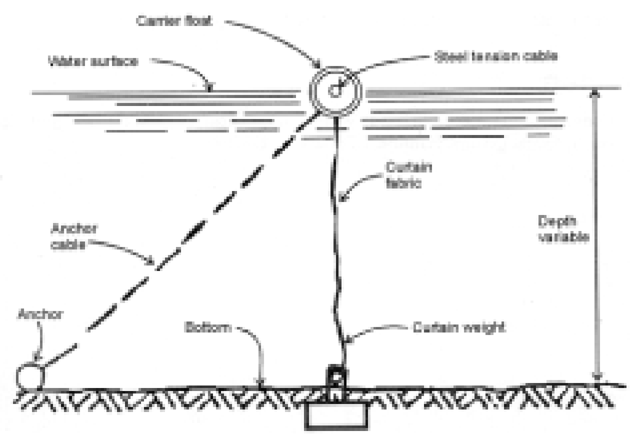
North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Silt Curtain

A temporary sediment barrier installed parallel to the bank of a stream or lake. Used to contain the sediment produced by construction operations on the bank of a stream or lake and allow for its removal.



Where Practice Applies

The silt curtain is used along the banks of streams or lakes where sediment could pollute or degrade the stream or lake.

Planning Considerations

A silt curtain is useful where construction is on the bank of a stream or lake and coarse sediment is a major concern. A silt curtain will not keep the water from being muddy during construction operations, but it will contain the coarse sediment to the construction area. The curtain should obstruct the flow as little as possible to reduce the chance of failure.

Installation Recommendations

The silt curtain should be a filter fabric recommended by the manufacturer for use as a silt curtain. Both ends of the silt curtain should be tied into the bank. The silt curtain should be placed as close as possible to the bank, allowing room for construction operations inside the protected area. In a flowing stream, remove trapped sediment before removing the silt curtain.

The curtain should be anchored to the bottom so sediment cannot go beneath the curtain. It should extend above normal water level. It can be supported by either stakes or floats of adequate strength.

Maintenance

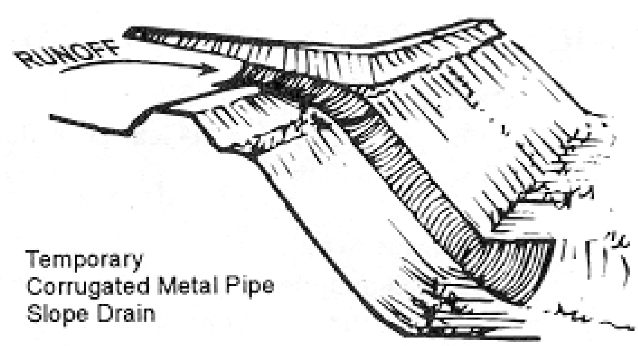
Accumulated sediment must be removed periodically. The curtain must be inspected often and after each storm. Any damage must be immediately repaired.

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Slope Drain, Temporary

A pipe extending from the top to the bottom of a cut or fill slope and discharging into a stabilized water course or a sediment trapping device or onto a stabilization area. Used to carry concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of slide-prone soils until permanent water disposal measures can be installed.



Where Practice Applies

This practice applies to construction areas where storm water runoff above a cut or fill will cause erosion if allowed to flow over the slope.

Advantages

Slope drains provide a potentially effective method of conveying water safely down steep slopes.

Disadvantages/Problems

Care must be taken to correctly site drains and not underdesign them. Also, when clearing takes place prior to installing these drains, care must be taken to revegetate the entire easement area, otherwise erosion tends to occur beneath the pipeline, resulting in gully formation.

Planning Considerations

Temporary slope drains are generally used in conjunction with diversions to convey runoff down a slope until permanent water disposal measures can be installed.

There is often a significant lag between the time a cut or fill slope is completed and the time a permanent drainage system can be installed. During this period, the slope is particularly vulnerable to erosion. This situation also occurs on slope construction which is temporarily delayed before final grade is reached.

When used in conjunction with diversion dikes, temporary slope drains can be used to convey stormwater from the entire drainage area above a slope to the base of the slope without erosion.

Slope drains must extend downslope to stable outlets, or special outlet protection must be provided.

It is very important that these temporary structures be sized, installed, and maintained properly since their failure will often result in severe gully erosion. The entrance section must be securely entrenched, all connections must be watertight, and the conduit must be staked securely.

Temporary slope drains should be replaced with more permanent structures as soon as construction activities permit.

Design Recommendations

Capacity

Sufficient to handle a 10-year peak flow. Permanent pipe slope drains should be sized for the 25-year peak flow.

Drainage Area

The maximum drainage area recommended per pipe is ten acres. For larger areas, a rock-lined channel or more than one pipe should be installed.

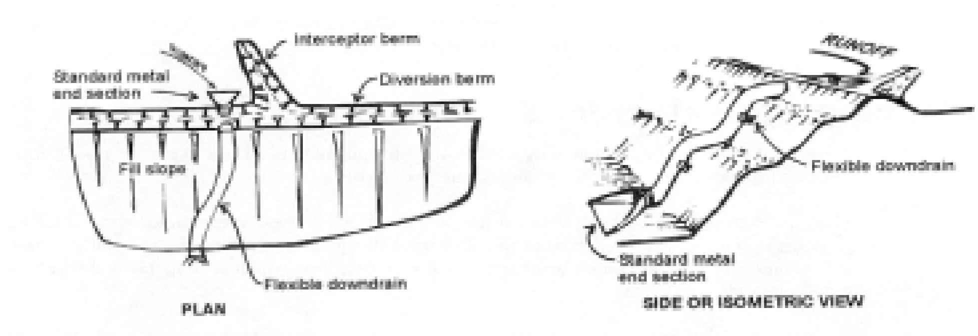
Material

Strong, flexible pipe such as heavy duty, non-perforated, corrugated plastic.

Pipe size

Based on drainage area:

Maximum Drainage Area Per Pipe (Acres)	Minimum Pipe Diameter (Inches)
0.5	12
0.75	15
1.0	18
>1.0	Individually designed



Entrance

The entrance should consist of a standard flared-end section with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance should be at least 3 percent.

Connection to diversion ridge at top of slope: compacted fill over pipe with minimum dimensions 1.5-foot depth, 4-foot top width, and 0.5 foot higher than diversion ridge.

The soil around and under the pipe and entrance section should be thoroughly compacted to prevent undercutting.

The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.

Slope drain sections shall be securely fastened together and have gasketed watertight fittings, and be securely anchored into the soil.

Interceptor dikes

Interceptor dikes should be used as needed to direct runoff into a slope drain. The height of the dike should be at least 1 foot higher at all points than the top of the inlet pipe.

Outlet

The area below the outlet must be stabilized with a riprap apron.

If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.

Common Trouble Points

Washout along the pipe due to seepage and piping
inadequate compaction, insufficient fill, or installation too close to edge of slope.

Overtopping of diversion caused by undersized or blocked pipe
Drainage area may be too large.
Overtopping of diversion caused by improper grade of channel and ridge Maintain positive grade.
Overtopping due to poor entrance conditions and trash build up at pipe inlet Deepen and widen channel at pipe entrance; inspect and clear inlet frequently.
Erosion at outlet
Pipe not extended to stable grade or outlet stabilization structure needed.
Displacement or separation of pipe
Tie pipe down and secure joints.
CAUTION!!
Do not divert more water to the slope drain than it was designed to carry.

Maintenance

Failure of a temporary slope drain can cause severe erosion damage. This practice requires intensive maintenance. Inspect slope drains and supporting diversions once a week and after every rainfall event.

Check inlet for sediment or trash accumulation. Clear inlet and restore proper entrance condition. The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, the headwall should be reinforced with compacted earth or sand bags.

Check fill over pipe for settlement, cracking, or piping holes. Repair immediately.

Check for seepage holes at point where pipe emerges from dike. Repair immediately.

Check conduit for evidence of leaks or inadequate lateral support. Repair immediately.

Check outlet for erosion or sedimentation. Clean, repair, or extend as needed.

When slopes have been stabilized, inspected, and approved, remove temporary diversions and slope drains and stabilize all disturbed areas.

References

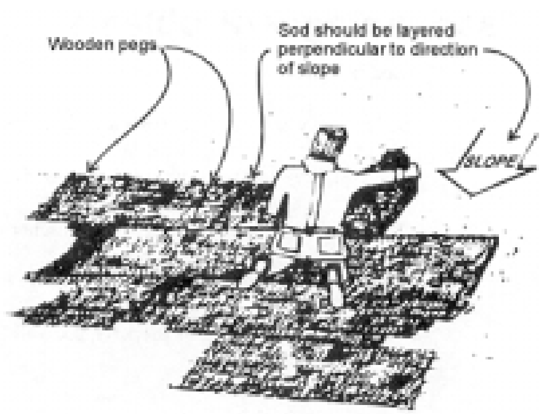
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sodding

Stabilizing fine-graded disturbed areas by establishing permanent grass stands with sod. To provide immediate erosion protection or to stabilize drainageways where concentrated overland flow will occur.



Where Practice Applies

- Disturbed areas which require immediate vegetative cover.
- Waterways carrying intermittent flow: where immediate stabilization or aesthetics are factors; where velocities will not exceed that specified for a grass lining; and other locations which are particularly suited to stabilization with sod.
- Disturbed areas requiring immediate and permanent vegetative cover.

Locations best suited to stabilization with sod are:

- Areas around drop inlets, when the drainage area has been stabilized.
- Steep critical areas.
- If mowing is required, do not use grass sod on slopes steeper than 3:1. (Use minimum maintenance ground covers.)

Advantages

- Sod gives an immediate vegetative cover, which is both effective in checking erosion and is aesthetically pleasing.
- Provides more stabilizing protection than initial seeding through dense cover formed by sod.
- Produces lower weed growth than seeded vegetation.
- Can be used for site activities within a shorter time than can seeded vegetation.
- Can be placed at any time of the year as long as moisture conditions in the soil are favorable and the ground is not frozen.

Disadvantages/Problems

- Sod is expensive.
- Sod is heavy and handling costs are high.
- Good quality sod, free from weed species, may be difficult to obtain.
- If laid in an unfavorable season, midsummer irrigation may be required.
- Grass species in the sod may not be suitable for site conditions.
- If not anchored or drained properly, sod will "roll up" in grassed waterways.

Planning Considerations

Sod requires careful handling and is sensitive to transport and storage conditions. Soil preparation, installation, and proper maintenance are as important with sod as with seed.

Choosing the appropriate type of sod for site conditions and intended use is of the utmost importance.

Installation

Sod should be free of weeds and be of uniform thickness (approximately 1 inch) and should have a dense root mat for mechanical strength. Sodding is a very expensive method of establishing a grass-type cover but it has the benefit of giving "instant" protection for critical areas. This value may be well worth the higher expense.

Site Preparation

Rake or harrow to achieve a smooth, final grade. Roll or cultipack to create a smooth, firm surface on which to lay the sod. Do not install on compacted clay or pesticide-treated soil. Apply topsoil if needed.

Lime and Fertilizer

Lime according to soil test to pH 6.5, or in the absence of a soil test, apply lime at the rate of 2 to 3 tons of ground limestone per acre (10-15 lbs. per 100 sq. feet).

Fertilize according to soil test or at the rate of 500-1,000 lbs. per acre (1 ¼ to 2 ½ pounds per 100 sq. feet) of 10-5-5 or similar fertilizer. Fertilizer with 40% or more of the nitrogen in organic form is preferred.

Work the lime and fertilizer into the soil 1 or 2 inches deep, and smooth.

Sod

Select high-quality, healthy, vigorous certified-class sod which is at least one year old but not older than three years. It should be a variety that is well-adapted to the region and expected level of maintenance. Common sod types include: Kentucky bluegrass blends, Kentucky bluegrass/Fine fescue mixes and Tall fescue/Kentucky bluegrass mixture.

Sod should be machine cut to a uniform thickness of ¾ inch, plus or minus ¼ inch, at the time of cutting. Measurement of thickness should exclude top growth or thatch.

Standard size sections of sod should be strong enough to support their own weight and retain their size and shape when suspended vertically with a firm grasp of the upper 10% of the section.

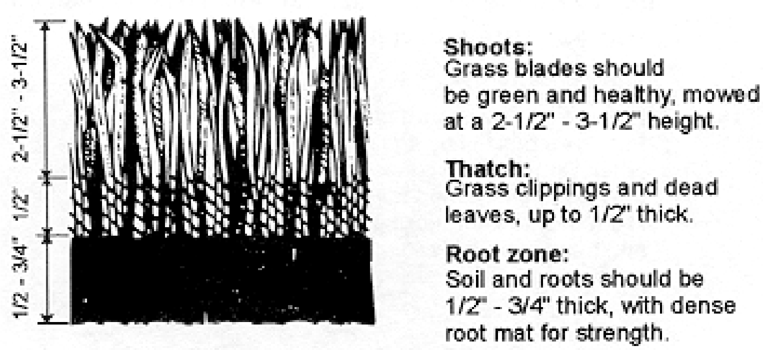
Individual pieces of sod should be cut to suppliers width and length. Maximum allowable deviation from the standard widths and lengths should be 5 percent. Broken pads or torn or uneven ends will not be accepted.

If sod is not purchased and local sod is used, cut the sod in strips 12 to 24 inches wide, 6 to 10 feet long, and approximately 1- ¼ inches thick. Roll with roots out to facilitate handling.

Sod should not be harvested or transplanted when the moisture content (excessively wet or dry) may adversely affect its survival.

Sod should be harvested, delivered, and installed within a period of 36 hours. Store rolls of sod in shade during installation. Sod not transplanted within this period should be inspected and approved prior to its installation.

Sod labels should be made available to the job foreman or inspector.



Appearance of Good Sod

Sod Placement

Rake soil surface to break crust just before laying sod. During periods of high temperature, lightly irrigate the soil immediately prior to placement. Do not install on hot, dry soil, compacted clay, frozen soil, gravel, or soil that has been treated with pesticides.

Sod strips should be laid on the contour, never up and down the slope, starting at the bottom of the slope and working up. Install strips of sod with their longest dimension perpendicular to the slope, and stagger in a brick-like pattern with snug even joints. Do not stretch or overlap. All joints should be butted tightly in order to prevent voids which would cause drying of the roots. Also, open spaces invite erosion.

On slopes greater than 3 to 1, secure sod to surface soil with wood pegs, wire staples, or split shingles (8 to 10 inches long by ¾ inch wide). The use of ladders will facilitate work on steep slopes, and prevent damage to the sod.

Wedge strips securely into place. Square the ends of each strip to provide for a close tight bond. Stagger joints at least 12 inches.

Match angled ends correctly to prevent voids. Use a knife or mason's trowel to trim and fit irregularly shaped areas.

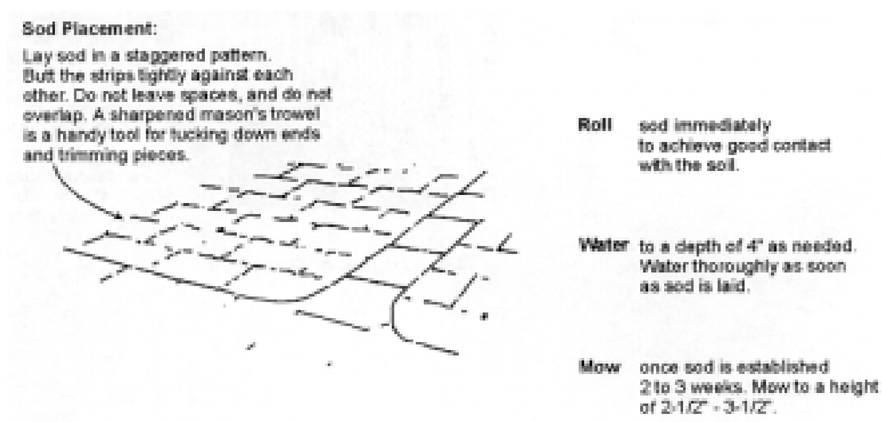
Trim all areas where water enters or leaves the sodded area so that a smooth, flush joint is secured.

Roll or tamp sod immediately following placement to insure solid contact of root mat and soil surface.

Immediately following installation, sod should be watered until moisture penetrates the soil layer beneath sod to a depth of 4 inches. Maintain optimum moisture for at least two weeks.

When sodding is carried out in alternating strips, or other patterns the areas between the sod should be seeded as soon after the sodding as possible.

Surface water cannot always be diverted from flowing over the face of the slope, but a capping strip of heavy jute or plastic netting, properly secured, along the crown of the slope and edges will provide extra protection against lifting and undercutting of sod. The same technique can be used to anchor sod in water-carrying channels and other critical areas. Wire staples must be used to anchor netting in channel work.

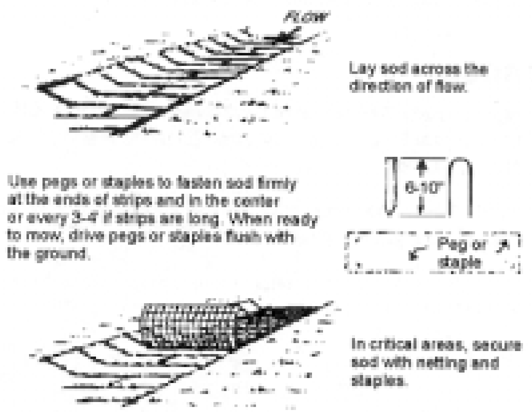


Sodded Waterways

Sod provides quicker protection than seeding and may reduce the risk of early washout.

When installing sod in waterways, use the type of sod specified in the channel design.

Lay sod strips perpendicular to the direction of waterflow and stagger in a brick-like pattern. Staple firmly at the corners and middle of each strip. Jute or plastic netting may be pegged over the sod for further protection against washout during establishment.



Common Trouble Points

Sod laid on poorly prepared soil or unsuitable surface.
Grass dies because it is unable to root.
Sod not adequately irrigated after installation.
May cause root dieback; grass does not root rapidly and is subject to drying out.
Sod not anchored properly.
May be loosened by runoff.

Maintenance

Keep sod moist until it is fully rooted.
Inspect sodded areas regularly, especially after large storm events. Re-tack, re-sod, or re-seed as necessary.
Mow to a height of 2-3 inches after sod is well-rooted. Do not remove more than one-third of the shoot in any mowing.
Permanent, fine turf areas require yearly maintenance fertilization.
Fertilize warm-season grass in late spring to early summer, cool-season grass in late winter and again in early fall.

References

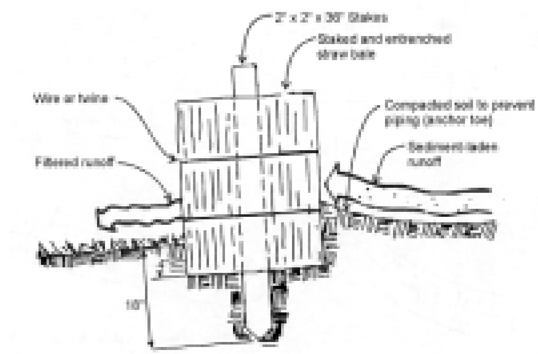
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual,*** Raleigh, NC, February 1991.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Straw or Hay Bale Barrier

A temporary sediment barrier consisting of a row of entrenched and anchored straw bales. Used to intercept and detain small amounts of sediment from disturbed areas of limited extent to prevent sediment from leaving the site. Decreases the velocity of sheet flows and low-to-moderate level channel flows.



Where Practice Applies

- Downslope from disturbed areas subject to sheet and rill erosion.
- In minor swales where the maximum contributing drainage area is not more than one acre.
- Where effectiveness is required for less than 3 months.

Advantages

When properly used, straw bale barriers are an inexpensive method of sediment control.

Disadvantages/Problems

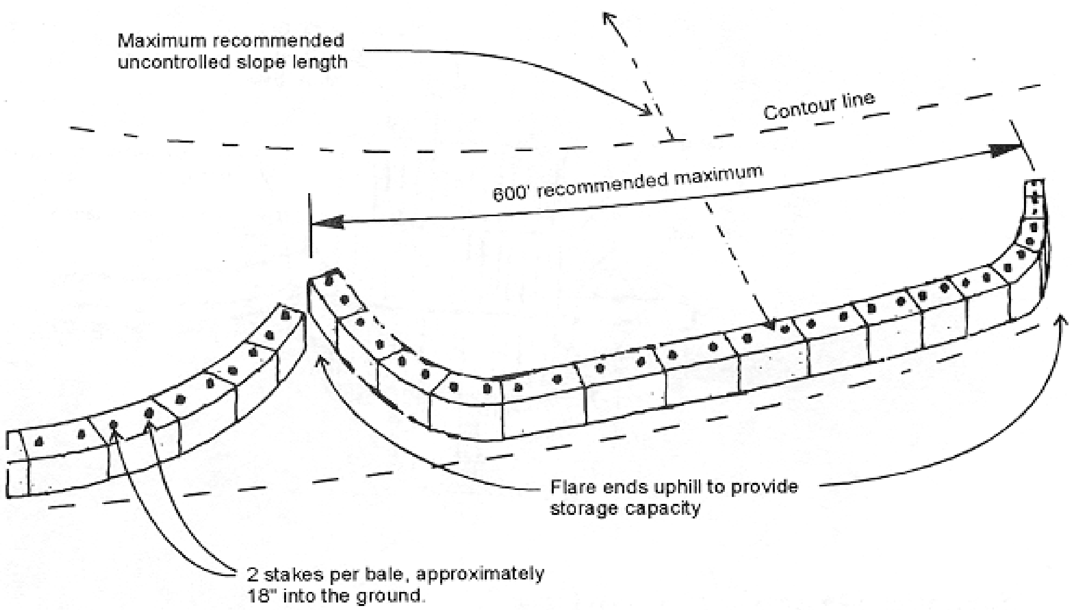
Straw bale barriers are easy to misuse. They can become contributors to a sediment problem instead of a solution unless properly located and maintained.

It is difficult to tell if bales are securely seated and snug against each other.

Planning Considerations

Straw or hay bale barriers are used similarly to sediment fence barriers; specifically where the area below the barrier is undisturbed and vegetated. Bale barriers require more maintenance than silt fence barriers and permeability through the bales is slower than sediment fence.

Bales should be located where they will trap sediment; that is, where there will be contributing runoff. Bales located along the top of a ridge serve no useful purpose, except to mark limits of a construction area. Straw or hay bales located at the upper end of a drainage area perform no sediment-collecting function.



Installation

Maximum recommended slope lengths upslope from straw or hay bale barriers are as follows:

Percent Slope	Maximum slope length, feet
1	180
4	100
9	60
14	40
18	30
30	20

(Based on providing storage for 1.0 inch of runoff.)

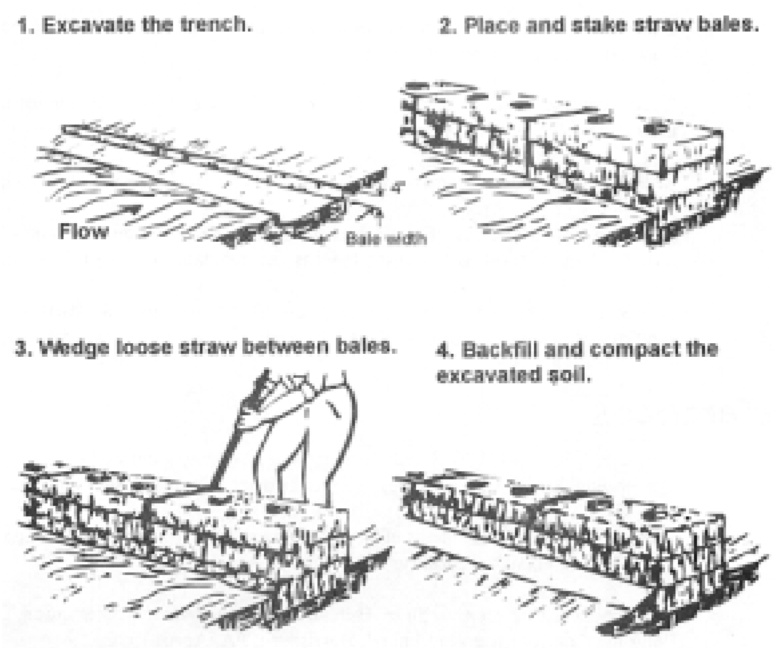
Bales should be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.

All bales should be either wire-bound or string-tied. Straw bales should be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales in order to prevent deterioration of the bindings.

The barrier should be entrenched and backfilled. A trench should be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. The trench must be deep enough to remove all grass and other material which might allow underflow. After the bales are staked and chinked (filled by wedging), the excavated soil should be backfilled against the barrier. Backfill soil should conform to the ground level on the downhill side and should be built up to 4 inches against the uphill side of the barrier.

Each bale should be securely anchored by at least 2 stakes or re-bars driven through the bale. The first stake in each bale should be driven toward the previously laid bale to force the bales together. Stakes or re-bars should be driven deep enough into the ground to securely anchor the bales. For safety reasons, stakes should not extend above the bales but should be driven in flush with the top of the bale.

The gaps between the bales should be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency. Wedging must be done carefully in order not to separate the bales.



Straw bale barriers should be removed when they have served their usefulness, but not before the upslope areas have been permanently stabilized.

When used in a swale, the barrier should be extended to such a length that the bottoms of the end bales are higher in elevation than the top of the lowest middle bale to assure that sediment-laden runoff will flow either through or over the barrier but not around it.

Common Trouble Points

Improper use

Straw bale barriers have been used in streams and drainageways where high water velocities and volumes have destroyed or impaired their effectiveness.

Improper placement and installation

Staking the bales directly to the ground with no soil seal or entrenchment allows undercutting and end flow. This has resulted in additions to, rather than removal of, sediment from runoff waters.

Inadequate maintenance

Trapping efficiencies of carefully installed straw bale barriers on one project dropped from 57 percent to 16 percent in one month due to lack of maintenance.

Maintenance

Straw bale barriers should be inspected immediately after each runoff-producing rainfall and at least daily during prolonged rainfall.

Close attention should be paid to the repair of damaged bales, undercutting beneath bales, and flow around the ends of the bales.

Necessary repairs to barriers or replacement of bales should be accomplished promptly.

Sediment deposits should be checked after each runoff-producing rainfall. They must be removed when the level of deposition reaches approximately one-half the height of the barrier.

Any sediment deposits remaining in place after the straw bale barrier is no longer required should be dressed to conform to the existing grade, prepared and seeded.

References

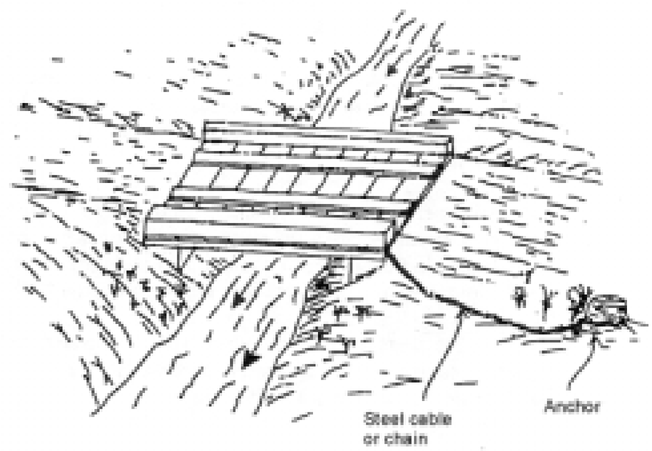
Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Pennsylvania, Commonwealth of, Bureau of Soil and Water Conservation, ***Erosion and Sediment Pollution Control Program Manual***, Harrisburg, PA, April, 1990.

Stream Crossing, Temporary

A bridge, ford or temporary structure installed across a stream or watercourse for short-term use by construction vehicles or heavy equipment. To provide a means for construction vehicles to cross streams or watercourses without moving sediment into streams, damaging the streambed or channel, or causing flooding.



Where Practice Applies

Where heavy equipment must be moved from one side of a stream channel to another, or where light-duty construction vehicles must cross the stream channel frequently for a short period of time.

Planning Considerations

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Request for Determination of Applicability” or a “Notice of Intent” with the Conservation Commission.

Careful planning can minimize the need for stream crossings. Try to avoid crossing streams, whenever possible, complete the development separately on each side and leave a natural buffer zone along the stream.

Temporary stream crossings are necessary to prevent damage to stream banks and stream channels by construction vehicles crossing the stream. This reduces the sediment and other pollutants continually being tracked into the stream by vehicles. These are temporary crossings that represent channel constrictions which may cause obstruction to flow or erosion during periods of high flow. They should be in service for the shortest practical period of time and should be removed as soon as their function is complete.

Select locations for stream crossings where erosion potential is low. Evaluate stream channel conditions, overflow areas, and surface runoff control at the site before choosing the type of crossing. When practical, locate and design temporary stream crossings to serve as permanent crossings to keep stream disturbance to a minimum.

Plan stream crossings in advance of need, and when possible, construct them during dry periods to minimize stream disturbance and reduce cost. Ensure that all necessary materials and equipment are onsite before any work is begun. Complete construction in an expedient manner and stabilize the area immediately.

When construction requires dewatering of the site, construct a bypass channel before undertaking other work. If stream velocity exceeds that allowed for the inplace soil material, stabilize the bypass channel with riprap or other suitable material. After the bypass is completed and stable, the stream may be diverted.

Unlike permanent stream crossings, temporary stream crossings may be allowed to overtop during peak storm periods. The structure and approaches should, however, remain stable. Keep any fill needed in floodplains to a minimum to prevent upstream flooding and reduce erosion potential. Use riprap to protect locations subject to erosion from overflow.

Stream crossings are of three types: bridges, culverts, and fords. In selecting a stream crossing practice consider: frequency and kind of use, stream channel conditions; overflow areas; potential flood damage; and surface runoff control.

Culvert crossings

Culverts are the most common stream crossings. In many cases, they are the least costly to install, can safely support heavy loads, and are adaptable to most site conditions. Construction materials are readily available and can be salvaged. The installation and removal of culverts, however, causes considerable disturbance to the stream and surrounding area. Culverts also offer the greatest obstruction to flood flows and, therefore, are subject to blockage and washout.

Bridges

Where available materials and designs are adequate to bear the expected loadings, bridges are preferred for temporary stream crossing.

Bridges usually cause the least disturbance to the stream bed, banks, and surrounding area. They provide the least obstruction to flow and fish migration. They generally require little or no maintenance, can be designed to fit most site conditions, and can be easily removed and materials salvaged. Bridges, however, are generally the most expensive to design and construct. Also, they present a safety hazard if not adequately designed, installed, and maintained. If washed out, they cause a longer construction delay and are more costly to repair.

In steep watersheds it is recommended to tie a cable or chain to one corner of the bridge frame with the other end secured to a large tree or other substantial object. This will prevent flood flows from carrying the bridge downstream where it may cause damage to property.

Fords

Fords should only be used where crossings are infrequent.

Fords made of stabilizing material such as rock are sometimes used in steep areas subject to flash flooding, where normal flow is shallow (less than 3 inches deep) or intermittent. Fords are especially adapted for crossing wide, shallow watercourses.

When properly installed, fords offer little or no obstruction to flow, can safely handle heavy loadings, are relatively easy to install and maintain, and, in most cases, may be left in place at the end of construction.

Potential problems include:

Approach sections are subject to erosion. Do not use fords where bank height exceeds 5 feet.

Excavation for the installation of the riprap-gravel bottom and filter material causes major stream disturbance. In some cases, fords may be adequately constructed by shallow filling without excavation.

The stabilizing material is subject to washing out during storm flows and may require replacement.

Mud and other contaminants are brought directly into the stream on vehicles unless crossings are limited to no-flow conditions.

Design and Construction Recommendations

A stream crossing must be non-erosive and structurally stable, and must not introduce any flooding or safety hazard. Bridge design in particular should be undertaken only by a qualified engineer. The following standards apply only to erosion and sediment control aspects of bridges, culverts, and fords.

The anticipated life of a temporary stream crossing structure is usually considered to be 1 year or less. Remove the structure immediately after it is no longer needed.

As a minimum, design the structure to pass bank-full flow or peak flow, whichever is less, from a 2-year frequency, 24-hour duration storm without over topping. Ensure that no erosion will result from the 10-year peak storm.

Ensure that design flow velocity at the outlet of the crossing structure is nonerosive for the stream channel.

Consider overflow for storms larger than the design storm and provide a protected overflow area.

Planning and Site Preparation

Construct crossing when stream flow is low. Have all necessary materials and equipment on site before work begins.

Minimize clearing and excavation of streambanks, bed, and approach sections. Plan work to minimize crossing the stream with equipment. If possible, complete all work on one side of the stream before crossing to work on other side.

Location

The temporary crossing should be located where there will be the least disturbance to the stream channel, the stream banks, the flood plain adjacent to the channel, and adjacent wetlands.

Width

The minimum road width of a temporary crossing should be 12 feet.

Alignment

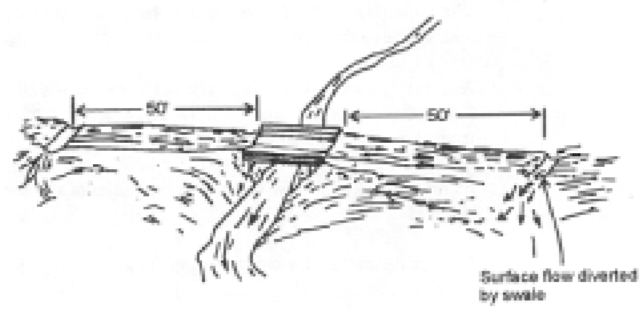
The temporary crossing should be at right angles to the stream whenever possible. If the approach conditions to the crossing are such that a perpendicular crossing is not possible, then a variation of up to 15 degrees is allowable.

Approaches

The centerline of the roadway approaches to the crossing should coincide with the crossing alignment for a distance of 30 feet in either direction. The maximum height of fill associated with the approaches should not exceed 2 feet. Limit surface runoff by installing diversions.

Surface Water and High Flow Diversion

A water diversion structure such as a swale should be constructed across the roadway at the end of both approaches to the crossing to allow stream flow exceeding the design storm to pass safely around the structure. These swales will also prevent surface water from flowing along the roadway and directly into the stream.



Locate swales not more than 50 feet from the waterway crossing. This will prevent roadway surface runoff from directly entering the waterway. The 50 feet is measured from the top of the waterway bank. If the roadway approach is constructed with a reverse grade away from the waterway, a separate diverting structure is not required.

Temporary Stream Diversion

Avoid diverting stream out of its natural channel by working on one-half of the installation at a time. If stream must be diverted, select most appropriate location considering extent of clearing, channel grade, amount of cut, and spoil disposal.

Excavate diversion channel starting at the lower end. If stream velocity exceeds that allowable for the temporary channel, stabilize with riprap. Temporary bypass channel must be stable for flows up to and including the 10-year storm.

The crossing site should be built in the dry streambed and stabilized before the stream is redirected to its normal course.

Sediment Traps

Where appropriate, install instream sediment traps immediately below stream crossings to reduce downstream sedimentation. Install before excavating or grading the approaches to a ford.

Excavate trap at least 2 feet below stream bottom and approximately twice the channel width for a minimum distance equal to one-half the length of crossing. Remove all spoil to an area outside the flood plain. Stabilize spoil appropriately.

Ensure that the flow velocity through the basin does not exceed the allowable flow velocity for the inplace soil material; otherwise it should not be excavated. In locations where trees or other vegetation must be removed, the sediment trap may be more damaging to the stream than if it were not installed.

Bridges and Culverts

Elevate bridge abutments or culvert fill 1 foot minimum above the adjoining streambank to allow storm overflow to bypass structure without damage. Culvert pipe should extend well beyond fill side slopes.

Protect disturbed streambanks, fill slopes and overflow areas with riprap or other suitable methods. Stabilize other disturbed areas as specified in the vegetation plan. Good surface stabilization is especially important at stream crossings as all eroded material directly enters the stream.

Earth fill for approaches should be free of roots, woody vegetation, oversized stones, organic material or other objectionable materials. The fill should be compacted by routing construction equipment over the fill so that the entire area of the fill is transversed by at least one wheel track or tread track of the equipment.

Bridges

A temporary bridge should be constructed at or above the stream bank elevation. Excavation of the stream bank should not be allowed for construction of this practice.

Span

Bridges should be constructed to span the entire width of the channel. If the width of the channel as measured from top of bank to top of bank exceeds 8 feet, then a footing, pier, or bridge support may be constructed in the stream bed. An additional footing or support will be allowed for each additional 8 feet of channel width. No footing, pier, or bridge support should be used in the stream bed for channel widths less than 8 feet.

Materials

Materials should be of sufficient strength to support the anticipated design loads. Stringers may be logs, sawn timber, prestressed concrete beams, or other appropriate materials. Decking materials must be butted tightly and securely fastened to the stringers to prevent soil, and other construction materials from falling into the stream channel below.

Bridge Anchors

The bridge should be anchored at only one end with either a steel cable or chain to prevent the bridge from floating away during flood events. The anchoring should be sufficient to prevent the bridge from floating downstream and possibly causing an obstruction in the stream channel below. Acceptable anchors are large trees, large boulders, or driven steel anchors.

Culverts

The minimum size for a culvert should be 18 inches. The maximum size for a culvert should be the largest pipe diameter that will fit into the existing channel without a significant amount of excavation required for its placement. Culverts may be circular or elliptical depending on the site requirements. Culverts should extend a minimum of one foot beyond the upstream and downstream toe of backfill placed around the culvert. Length should not exceed 40 feet.

Filter Cloth

Place filter cloth on the stream bed and the stream banks before installing the culvert and backfill. The filter cloth should extend a minimum of six inches and a maximum of one foot past the toe of the backfill.

Culvert Placement

The culvert should be installed on the natural stream bed grade. No overfall should be permitted at the downstream invert.

Backfill

No earth or fine-grained soil backfill should be used for temporary culvert crossings. Backfill should be clean, coarse aggregate. The backfill should be placed in maximum 6 inch lifts and compacted using a vibrating plate compactor. Material should be hand compacted around the haunches of the pipe, using particular care to assure that the line and grade of the pipe is maintained. The minimum allowable backfill over the pipe should be 12 inches or one-half pipe diameter which ever is greater. If multiple culverts are used they should be separated by a minimum of 12 inches of compacted aggregate backfill.

Appropriate headwalls or large rock should be placed on the upstream and downstream ends of the temporary fill crossing to protect against erosion during large flood flows.

Fords

Install geotextile fabric in channel to stabilize foundation, then apply well-graded, weather-resistant stone (3 to 6 inch) over fabric. Use only stabilization fabric, not filter fabric.

Stabilization

All areas disturbed by the installation of the temporary crossing should be stabilized using either rock, gravel, or vegetation as appropriate.

Removal

Remove temporary stream crossings as soon as they are no longer needed. Restore stream channel to original cross section and stabilize all disturbed areas. Appropriate measures should be taken to minimize effects on water quality when removing the crossing. Fords may be left in place if site conditions allow.

Temporary bypass channels should be permanently stabilized or removed. If removed, overfill by at least 10%, compact, and stabilize appropriately.

Leave in-stream sediment traps in place.

Common Trouble Points

Inadequate flow capacity and/or lack of overflow area around structure
Results in washout of culverts or bridge abutments.

Inadequate stabilization of overflow area
Results in severe erosion around bridges and culverts.

Exit velocity from culvert or bridges too high
Causes stream channel erosion and may eventually cause erosion of bridge or culvert fill.

Debris not removed after a storm
Clogging may cause washout of culverts or bridges.

Inadequate compaction under or around culvert pipes
Culverts wash out due to seepage and piping.

Stone size too small
Ford washes out.

Culvert pipes too short
Results in a crossing supported by steep, unstable fill slopes.

Maintenance

Inspect temporary crossing after each rainfall event for accumulation of debris, blockage, erosion of abutments and overflow areas, channel scour, riprap displacement, or piping along culverts.

Remove debris; repair and reinforce damaged areas immediately to prevent further damage to the installation.

Remove temporary stream crossings immediately when they are no longer needed. Restore the stream channel to its original cross-section, and smooth and stabilize all disturbed areas.

Leave in-stream sediment traps in place to continue capturing sediment.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

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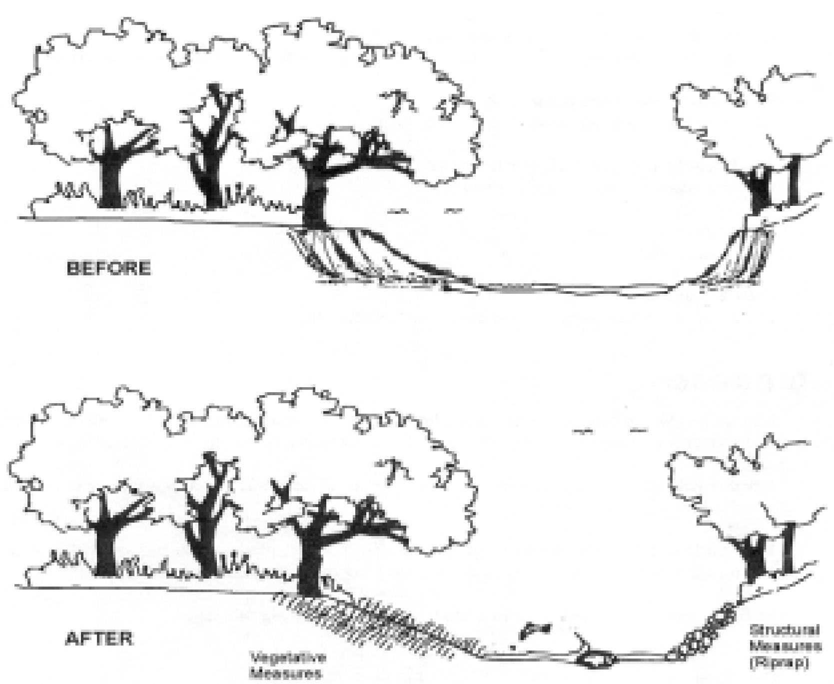
North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual,*** Raleigh, NC, September, 1988.

Streambank Protection and Stabilization

Protecting and stabilizing banks of streams or excavated channels against scour and erosion. This practice may be accomplished by structural or vegetative means, or by a combination of both.



Purpose

- To protect streambanks from the erosive forces of moving water.
- To prevent the loss of land or damage to utilities, roads, buildings, or other adjacent facilities.
- To maintain the capacity of the channel.
- To control channel meander which would adversely affect downstream facilities.
- To reduce sediment loads causing downstream damages and pollution.
- To improve the stream for recreational use or as a habitat for fish and wildlife.

Where Practice Applies

This practice applies to natural or excavated channels where the streambanks are susceptible to erosion from the action of water, ice, or debris; excessive runoff from construction activities; or to damage from vehicular traffic.

This practice also applies to controlling erosion on shorelines where the problem can be solved with relatively simple structural measures, vegetation, or upland erosion control practices.

Advantages

Structural Methods

- Streambank protection can break wave action and reduce the velocity of flood flows.
- The reduction of velocity can lead to the deposit of water-borne soil particles.
- Water quality benefits of reduced erosion and downstream siltation.

Vegetative and Bioengineering Methods

Vegetative and bioengineering stabilization methods have additional advantages:

- Vegetative techniques are generally less costly and more compatible with natural stream characteristics.
- Roots and rhizomes stabilize streambanks.
- Certain reeds and bulrushes have the capability of improving water quality by absorbing certain pollutants such as heavy metals, detergents, etc.
- Plants regenerate themselves and adapt to changing natural situations, thus offering a distinct economic advantage over mechanical stabilization.
- Mechanical materials provide for interim and immediate stabilization until vegetation takes over.
- Once established, vegetation can outlast mechanical structures and requires little maintenance while regenerating itself
- Aesthetic benefits and improved wildlife and fisheries habitat.

Disadvantages/Problems

Structural Methods

- Cost of structural practices.
- Aesthetics.

Vegetative Methods

- Native plants may not be carried by regular nurseries and may need to be collected by hand, or obtained from specialty nurseries. Nurseries which carry these plants may require a long lead time for large orders.
- Flow retarding aspects of vegetated waterways need to be taken into account.
- Structural practices can be installed on steeper slopes than vegetative methods.
- Will not withstand as high flow velocities as structural methods.

Planning Considerations

Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Determination of Applicability” or a “Notice of Intent” with the Conservation Commission.

Stream channel erosion problems vary widely in type and scale, and there is no one measure that works in all cases. Stabilization structures should be planned and designed by an engineer with experience in this field. Many of the practices involve the use of manufactured products and should be installed in accordance with the manufacturers specifications. Where long reaches of stream channels require stabilization, make detailed strewn studies.

Before selecting a structural stabilization technique, the designer should carefully evaluate the possibility of using vegetative stabilization in conjunction with structural measures to achieve the desired protection. Vegetative techniques are generally less costly and more compatible with natural stream characteristics.

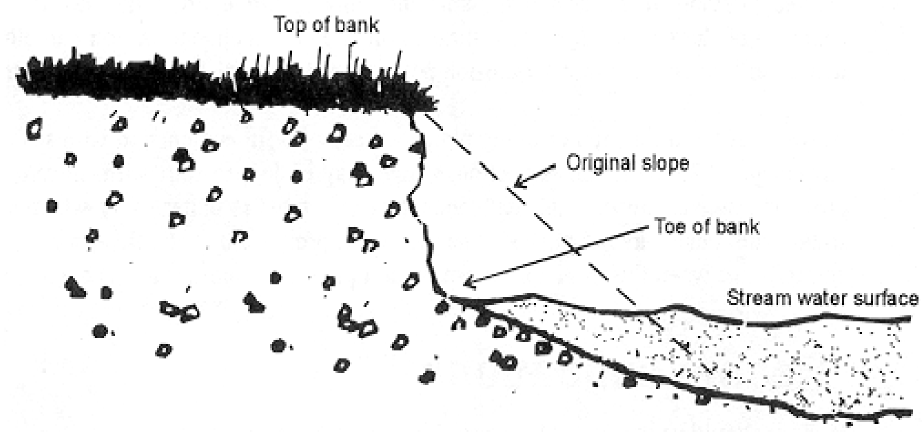
Wherever possible, it is best to protect banks with living plants that are adapted to the site. Natural plant communities are aesthetically pleasing, provide a habitat for fish and wildlife, afford a self-maintaining cover, and are less expensive and damaging to the environment.

Special attention should be given to the preservation of fish and wildlife habitat, and trees of significant value for wildlife food or shelter, or for aesthetic purposes. Wildlife habitat can be improved by using woody plants and grasses that provide food and/or cover for native wildlife species. The retention of a 30-foot riparian zone along stream channels that is established to trees, shrubs, or grasses may provide wildlife, landscaping and water quality benefits.

Where construction will adversely affect a significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include pools, riffles, flats, cascades, or other similar provisions.

Upstream development accelerates streambank erosion by increasing the velocity, frequency, and duration of flow. As a result, many natural streams that were stable become unstable following urbanization.

Most natural stream channels have bank-full capacity to pass the runoff from a 2-year recurrence interval storm. In a typical urbanizing watershed, however, stream channels may become subject to a 3 to 5 times as many bank-full flows if stormwater runoff is not properly managed. Stream channels that were once parabolic in shape and covered with vegetation may be transformed into wide rectangular channels with barren banks.



The following is a partial list of elements which may be involved in a plan for streambank protection.

- **Obstruction removal** - The removal of fallen trees, stumps, debris, minor ledge outcroppings and sand and gravel bars that may cause water turbulence and deflection, causing erosion of the bank.
- **Clearing** - The removal of trees and brush which adversely affect the growth of desirable bank vegetation.
- **Bank sloping** - The reduction of the slope of streambanks. Consideration should be given to flattening the side slope of the channel in some reaches to facilitate the establishment of vegetation or for the installation of structural bank protection.
- **Fencing** - Artificial obstructions to protect vegetation needed for streambank protection or to protect critical areas from damage from stock trails or vehicular traffic.
- **Vegetation** - Vegetative streambank stabilization is generally applicable where bankfull flow velocity does not exceed 6 feet/second and soils are erosion-resistant. Above 6 feet/second, structural measures are generally required.

- **Riprap** - Heavy angular stone placed on the streambank to provide armor protection against erosion.
- **Jetties** - Deflectors constructed of posts, piling, fencing rock, brush other materials which project into the stream to protect banks at curves and reaches subjected to impingement by high velocity currents.
- **Revetments** - Pervious or impervious structures built on or parallel to the stream to prevent scouring streamflow velocities adjacent to the streambank.
- **Bioengineering** - Bioengineering utilizes live plant parts in combination with structural methods to provide soil reinforcement and prevent surface erosion.

Structural measures, when employed correctly, immediately ensure satisfactory protection of stream banks. Structures are expensive to build, however, and to maintain. Without constant upkeep, they are exposed to progressive deterioration by natural agents. The materials used may prevent reestablishment of native plants and animals. Often structural measures destroy the appearance of the stream. Also, structural stabilization and channelization can alter the hydrodynamics of a stream and transfer erosion potential and associated problems downstream.

In contrast, the utilization of living plants instead of or in conjunction with structures has many advantages. The degree of protection, which may be low to start with, increases as the plants grow and spread. Repair and maintenance of structures is unnecessary where self-maintaining streambank plants are established. The protection provided by natural vegetation is more reliable and effective when the cover consists of natural plant communities adapted to their site.

Design Recommendations

Designs should be developed in accordance with the following principles:

- The grade must be controlled, either by natural or artificial means, before any permanent type of bank protection can be considered feasible; unless the protection can be safely and economically constructed to a depth well below the anticipated lowest depth of bottom scour.
- Streambank protection should be started at a stabilized or controlled point and ended at a stabilized or controlled point on the stream.
- Make protective measures compatible with other channel modifications planned or being carried out in other channel reaches.
- Ensure that the channel bottom is stable or stabilized by structural means before installing any permanent bank protection.
- Channel clearing, if needed to remove stumps, fallen trees, debris and bars which force the streamflow into the streambank, should be an initial element of the work.
- Changes in channel alignment should be made only after an evaluation of the effect on the land use, interdependent water disposal systems, hydraulic characteristics, and existing structures.

- Measures must be effective for the minimum design velocity of the peak discharge of the 10-year storm and be able to withstand greater floods without serious damage.
- Vegetative protection should be considered on the upper portions of eroding banks and especially on those areas which are subject to infrequent inundation.
- Stabilize all areas disturbed by construction as soon as complete.

Vegetative Methods

Channel reaches are often made stable by establishing vegetation where erosion potential is low and installing structural measures where the attack is more severe, such as the outside of channel bends and where the natural grade steepens. Vegetative methods must be effective for the design flow.

Bank reshaping and disturbance should be kept to a minimum except as necessary to install the practice. Where this is needed, banks should be shaped to result in a bank slope of 1:1 or flatter.

A temporary seeding should be used on all sites to provide protection while the permanent cover is becoming established.

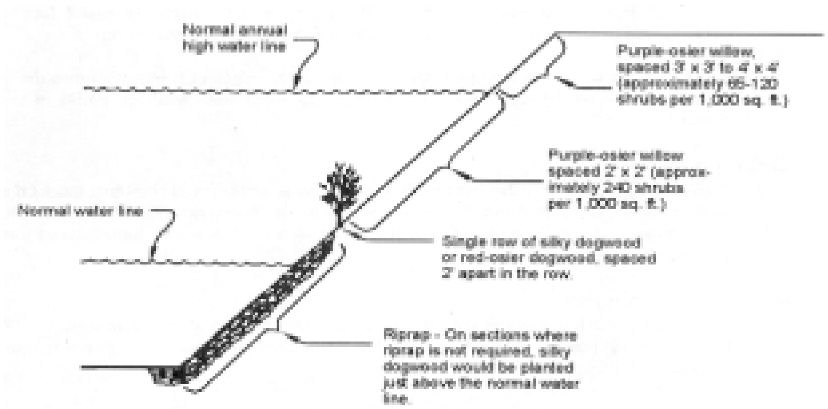
Streambanks to be protected using grasses may need to be shaped on a 2:1 or 3:1 slope to provide for adequate seedbed preparation. The use of sod, instead of seeding, should be evaluated where economically justified and technically feasible.

The type of vegetative cover to be used should be based on the soil type, stream velocities, adjacent land use and anticipated level of maintenance to be performed.

A maintenance program should be established to provide sufficient moisture, fertility, replacement of dead or damaged plants and protection from damage by insects, diseases, machinery and human activities.

Streambanks stabilized using grasses should be evaluated as to whether an occasional or periodic mowing and fertilization are to be performed to maintain a healthy protective ground cover.

Sites should be protected from damage by vehicular and human traffic for the length of time necessary to get vegetative cover well established, but no less than one full growing season.



Staking

This involves inserting and tamping live, rootable vegetative cuttings into the ground. If correctly prepared and placed, the live stake will root and grow.

Dormant Woody Plantings

This is planting live, dormant-stem cuttings of woody plant species ½ to 3 inches or more in diameter.

Grasses

Where a good seedbed can be prepared, and on smaller streams where flow velocities are less, it may be feasible to stabilize eroding streambanks by seeding grasses above or in combination with dormant woody plantings. See recommendations in **Permanent Seeding** and in the supplementary material in Part 4.

A temporary seeding or mulching should be completed on those sites where a permanent seeding will not be established within 30 days following installation of a project. See **Temporary Seeding**.

Structural Methods

Generally applicable where flow velocities exceed 6 feet/second or where vegetative streambank protection is inappropriate.

Since each reach of channel requiring protection is unique, measures for structural streambank protection should be installed according to a plan based on specific site conditions.

Riprap

Riprap is the most common structural method used, but other methods such as gabions, deflectors, reinforced concrete, log cribbing, and grid pavers should be considered, depending on site conditions.

When possible, slope banks to 2:1 or flatter, and place a gravel filter or filter fabric on the smoothed slopes before installing riprap. Place the toe of the riprap at least 1 foot below the stream channel bottom or below the anticipated depth of channel degradation.

It is important to extend the upstream and downstream edges of riprap well into the bank and bottom. Extend riprap sections the entire length between well-stabilized points of the stream channel.

Gabions

These rectangular, rock-filled wire baskets are pervious, semi-flexible building blocks that can be used to armor the bed and/or banks of channels or act as deflectors to divert flow away from eroding channel sections. Design and install gabions in accordance with manufacturer's standards and specifications.

Reinforced concrete

May be used to armor eroding sections of the streambank by constructing retaining walls or bulk heads. Provide positive drainage behind these structures. Reinforced concrete may also be used as a channel lining for stream stabilization.

Log Cribbing

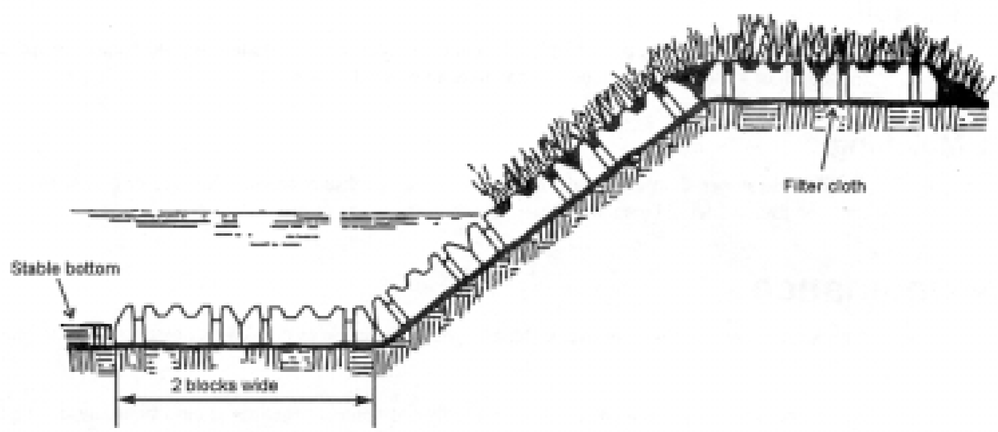
Retaining structure built of logs to protect streambanks from erosion. Vegetation can be planted between logs.

Grid pavers

Modular concrete units with interspersed void areas that can be used to armor the streambank while maintaining porosity and allowing the establishment of vegetation. These structures may be obtained in precast blocks or mats that come in a variety of shapes, or they may be formed and poured in place. Design and install in accordance with manufacturer's instructions.

Revetment

Structural support or armoring to protect an embankment from erosion. Riprap or gabions are commonly used. Gabions may be either stacked or placed as a mattress. Install revetment to a depth below the anticipated channel degradation and into the channel bed as necessary to provide stability.



Bioengineering Methods

Bioengineering combines structural and vegetative methods.

Streams in urban settings may carry an increase in runoff of such great magnitude that they cannot be maintained in a natural state. Soil bioengineering methods can provide for stabilization without complete visual degradation and higher effectiveness than purely mechanical techniques.

See Part 4 for descriptions of bioengineering methods and practices.

Construction Recommendations

Where possible: trees should be left standing; brush and stumps not removed; and construction operations carried on from one side, leaving vegetation on the opposite side.

Spoil resulting from excavation and shaping should be leveled or removed to permit free entry of water from adjacent land surface without excessive erosion or harmful ponding.

Trees and other fallen natural vegetation that do not deter stream flow should be left for fish habitat.

Vegetation should be established on all disturbed areas immediately after construction, weather permitting. If weather conditions are such as to cause a delay in the establishment of vegetation, the area should be mulched.

Topsoil

When soil conditions are particularly adverse for herbaceous vegetation, topsoil should be spread to a depth of 4 inches or more on critical areas to be seeded or sodded.

Mulching

Seeded side slopes should be mulched. Where streambanks are steeper than 2:1 or higher than 10 feet, the mulch should be anchored with paper twine fabric or equivalent material.

Maintenance

Check after every high-water event. Repairs should be made as quickly as possible after the problem occurs.

All temporary and permanent erosion and sediment control practices should be maintained and repaired as needed to assure continued performance of their intended function.

Streambanks are always vulnerable to new damage. Repairs are needed periodically. Banks should be checked after every high-water event is over. Gaps in the vegetative cover should be fixed at once with new plants, and mulched if necessary. Fresh cuttings from other plants on the bank can be used, or they can be taken from mother-stock plantings if they are available.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts ***Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning and Design Manual***, Raleigh, NC, September, 1988.

U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL, ***Urban Conservation Practice Standards***, 1994.

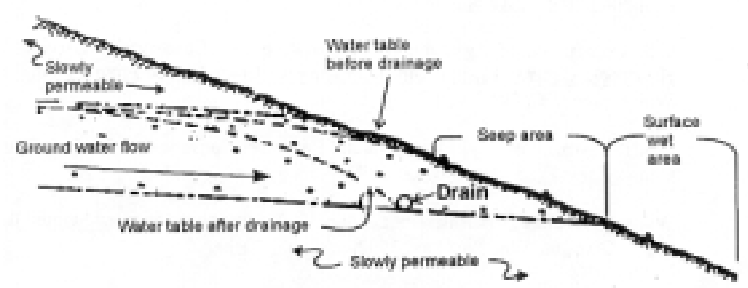
U.S. Department of Agriculture, Natural Resources Conservation Service, ***Engineering Field Handbook,*** *Chapter 18, Soil Bioengineering for Upland Slope Protection and Erosion Reduction* Washington, DC, October, 1992.

U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL, ***Urban Conservation Practice Standards***, 1994.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Subsurface Drain

A perforated conduit such as a pipe, tubing, or tile installed beneath the ground to intercept, collect, and convey excess ground water to a satisfactory outlet.



Purpose

- To provide a dewatering mechanism for draining excessively wet soils.
- To improve soil and water conditions for vegetative growth.
- To prevent sloughing of steep slopes due to ground water seepage.
- To improve stability of structures with shallow foundations by lowering the water table.

Where Practice Applies

Wherever excessive water must be removed from the soil.

The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

An adequate outlet for the drainage system must be available either by gravity or by pumping. The quantity and quality of discharge should not damage the receiving stream.

Advantages

- An effective way to lower the water table.
- Subsurface drains often provide the only practical method of stabilizing excessively wet, sloping soils.

Disadvantages/Problems

Problems may be encountered with tree roots.

Planning Considerations

Contact the local Conservation Commission regarding any work conducted in a wetland resource area. The Wetlands Protection Act requires that for work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Request for Determination of Applicability” or a “Notice of Intent” with the Conservation Commission.

Subsurface drains usually consists of perforated, flexible conduit installed in a trench at a designed depth and grade. The trench around the conduit is often backfilled with a sand-gravel filter or gravel envelope. Backfill over the drain should be an open, granular soil of high permeability.

Subsurface drainage systems are of two types; relief drains and interceptor drains. Relief drains are used either to lower the water table in order to improve the growth of vegetation, or to remove surface water. They are installed along a slope and drain in the direction of the slope. They can be installed in a gridiron pattern, a herringbone pattern, or a random pattern.

Interceptor drains are used to remove water as it seeps down a slope to prevent the soil from becoming saturated and subject to slippage. They are installed across a slope and drain to the side of the slope. They usually consist of a single pipe or series of single pipes instead of a patterned layout.

Design Recommendations

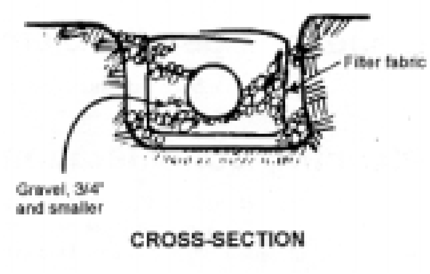
Subsurface drain should be sized for the required capacity. Design charts are available in Natural Resources Conservation Service references and from other sources. Manufacturers of special purpose drain configurations can provide instructions for design.

The minimum velocity required to prevent silting is 1.4 feet per second. The line should be installed on a grade to achieve at least this velocity.

The outlet of the subsurface drain should empty into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining.

Construction Recommendations

The trench should be constructed on continuous grade with no reverse grades or low spots.



Soft or yielding soils under the drain should be stabilized with gravel or other suitable material.

Deformed, warped, or otherwise unsuitable pipe should not be used.

A sand-gravel filter at least three inches thick should be placed all around the pipe. Manufactured filters designed for the purpose, such as filter fabric, may be used as alternatives.

The trench should be backfilled immediately after placement of the pipe. No sections of pipe should remain uncovered overnight or during a rainstorm. Backfill material should be placed in the trench in such a manner that the drain pipe is not displaced or damaged.

Maintenance

Subsurface drains should be checked periodically to ensure that they are freeflowing and not clogged with sediment.

The outlet should be kept clean and free of debris.

Surface inlets should be kept open and free of sediment and other debris.

Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees as a last resort. Drain placement should be planned to minimize this problem.

Where drains are crossed by heavy vehicles, the line should be checked to ensure that it is not crushed.

References

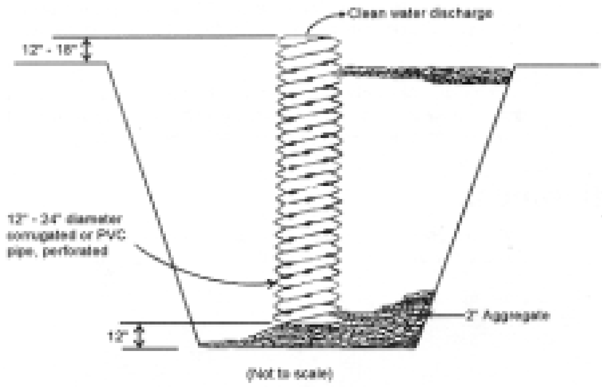
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, S***torm Water Management For Construction Activities*** EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Sump Pit

A temporary pit which is constructed to trap and filter water for pumping into a suitable discharge area. A perforated vertical standpipe is placed in the center of the pit to collect filtered water. The purpose of this practice is to remove excessive water in a manner that improves the quality of the water.



Where Practice Applies

Sump pits are constructed when water collects during the excavation phase of construction. This practice is particularly useful in urban areas during excavation for building foundations.

Planning Considerations

Discharge of water pumped from the standpipe should be to a suitable practice such as a sediment basin, sediment trap, or a stabilized area.

If water from the sump pit will be pumped directly to a storm drainage system, geotextile filter fabric should be wrapped around the standpipe to ensure clean water discharge. It is recommended that ¼ to ½ inch mesh hardware cloth wire be wrapped around and secured to the standpipe prior to attaching the filter fabric. This will increase the rate of water seepage into the standpipe.

Design Recommendations

A perforated vertical standpipe is placed in the center of the pit to collect filtered water. The standpipe will be a perforated 12 to 24-inch diameter corrugated metal or PVC plastic pipe. Water is then pumped from the pit to a suitable discharge area. The pit will be filled with coarse aggregate.

Maintenance

The sump pit will become clogged with sediment, oils, and organic matter over time. It is important to remove grass clippings and leaves from the surface of the aggregate in order to prolong its life.

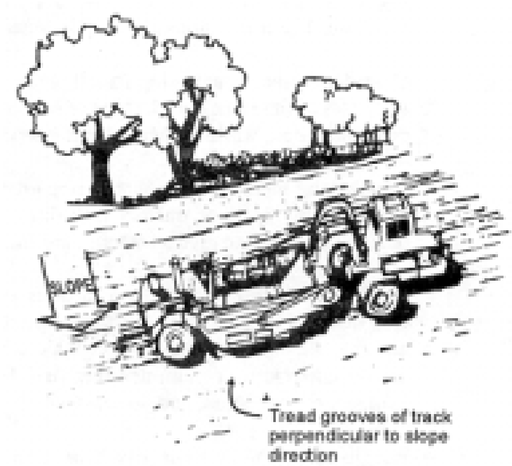
The pit should be checked after every major storm to evaluate its effectiveness. If the pit and filter fabric become plugged with sediment, the pit should be rehabilitated. In some cases complete removal and replacement of the entire dry well may be necessary.

References

U.S. Department of Agriculture, Natural Resources Conservation Service, Champaign, IL, Urban Conservation Practice Standards, 1994.

Surface Roughening

Roughening a bare soil surface with horizontal grooves running across the slope, stair stepping, or tracking with construction equipment; or by leaving slopes in a roughened condition by not fine grading them.



HEAVY EQUIPMENT CAN BE USED TO MECHANICALLY SCARIFY SLOPES

Purpose

To aid the establishment of vegetative cover from seed, to reduce runoff velocity and increase infiltration, and to reduce erosion and provide for sediment trapping.

Where Practice Applies

All construction slopes require surface roughening to facilitate stabilization with vegetation, particularly slopes steeper than 3:1. This practice should also be done prior to forecasted storm events and before leaving a job site for a weekend.

Advantages

Surface roughening provides some instant erosion protection on bare soil while vegetative cover is being established.

It is an inexpensive and simple erosion control measure.

Disadvantages/Problems

While this is a cheap and simple method of erosion control, it is of limited effectiveness in anything more than a moderate storm.

Surface roughening is a temporary measure. If roughening is washed away in a heavy storm, the surface will have to be re-roughened and new seed laid.

Planning Considerations

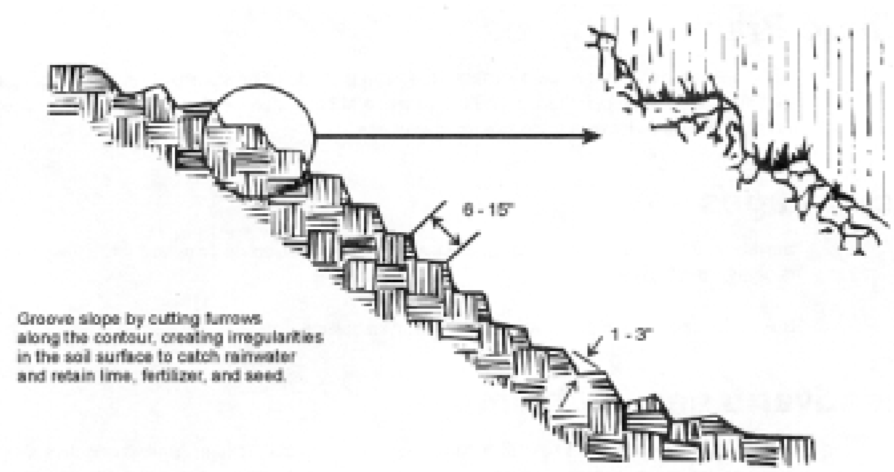
Roughening a sloping bare soil surface with horizontal depressions helps control erosion by aiding the establishment of vegetative cover with seed, reducing runoff velocity, and increasing infiltration. The depressions also trap sediment on the face of the slope.

Consider surface roughening for all slopes. The amount of roughening required depends on the steepness of the slope and the type of soil. Stable, sloping rocky faces may not require roughening or stabilization, while erodible slopes steeper than 3:1 require special surface roughening.

Roughening methods include stair-step grading, grooving, and tracking. Equipment such as bulldozers with rippers or tractors with disks may be used. The final face of slopes should not be bladed or scraped to give a smooth hard finish.

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 the potential for erosion. Rough slope 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. Niches in the surface provide microclimates which generally provide a cooler and more favorable moisture level than hard flat surfaces; this aids seed germination.



Construction Recommendations

Roughening methods include stair-step grading, grooving, and tracking. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.

Graded areas with slopes greater than 3:1 but less than 2:1 should be roughened before seeding. This can be accomplished in a variety of ways, including “track walking,” or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.

Graded areas steeper than 2:1 should be stair-stepped with benches. The stair-stepping will help vegetation become established and also trap soil eroded from the slopes above.

Disturbed areas which will not require mowing may be stair-step graded, grooved, or left rough after filling.

Stair-step grading is appropriate for soils containing large amounts of soft rock. Each “step” catches material that sloughes from above, and provides a level site where vegetation can become established. Stairs should be wide enough to work with standard earth moving equipment.

Areas which will be mowed (these areas should have slopes less steep than 3:1) may have small furrows left by disking, harrowing, raking, or seed-planting machinery operated on the contour.

It is important to avoid excessive compacting of the soil surface when scarifying. Tracking with bulldozer treads is preferable to not roughening at all, but is not as effective as other forms of roughening, as the soil surface is severely compacted and runoff is increased.

Maintenance

Areas which are graded in this manner should be seeded as quickly as possible.

Regular inspections should be made. If rills appear, they should be regraded and reseeded immediately.

References

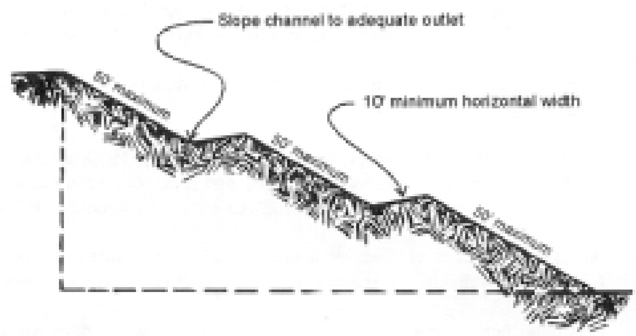
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual, Boston***, Massachusetts, June, 1993.

U.S. Environmental Protection Agency, ***Storm Water Management For Construction Activities***, EPA-832-R- 92-005, Washington, DC, September, 1992.

Washington State Department of Ecology, ***Stotmwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Terrace

A ridge and channel constructed across a slope and used to convey runoff water. Reduces erosion damage by intercepting surface runoff and conducting it to a stable outlet at a nonerosive velocity.



Where Practice Applies

Terraces are utilized on slopes having a water erosion problem. They should not be constructed on deep sands or on soils that are too stony, steep, or shallow to permit practical and economical installation and maintenance. Terraces should be used only where suitable outlets are or will be made available.

Advantages

Terraces lower the velocity of runoff, increase the distance of overland flow, and reduce slope length. They also hold moisture and minimize sediment.

Disadvantages/Problems

May significantly increase cut and fill costs and cause sloughing if excessive water infiltrates soils.

Design Recommendations

Spacing

The maximum recommended spacing is a maximum vertical distance of 20 feet between terraces or other practices such as a diversion, dike, or sediment fence at the top or bottom of a slope.

Channel Grade

Channel grades may be either uniform or variable with a maximum grade of 0.6 feet per 100 feet length. For short distances, terrace grades may be increased to improve alignment. The channel velocity should not exceed that which is nonerosive for the soil type with the planned treatment.

Outlet
All terraces should have adequate outlets. Such an outlet may be a grassed waterway, vegetated area, or subsurface drain outlet. In all cases the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Vegetative cover should be used in the outlet channel.

The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow.

Vertical spacing may be increased as much as 0.5 feet or 10 percent, whichever is greater, to provide better alignment or location, to avoid obstacles, to adjust for equipment size, or to reach a satisfactory outlet.

Capacity
The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.

Cross-Section
The terrace cross-section should be proportioned to fit the land slope. The ridge height should include a reasonable settlement factor and "freeboard" (vertical distance between top of ridge and water elevation in the channel at dewsign flow).

The minimum cross-sectional area of the terrace channel should be 8 square feet for land slopes of 5 percent or less, 7 square feet for slopes from 5 to 8 percent, and 6 square feet for slopes steeper than 8 percent. The terrace should be constructed wide enough to be maintained using a small bulldozer.

Maintenance

Maintenance should be performed as needed. Terraces should be inspected regularly; at least once a year, and after large storm events.

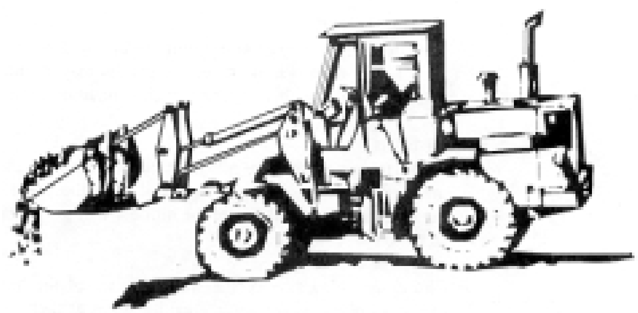
References

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Topsoiling

Preserving and using topsoil to provide a suitable growth medium and enhance final site stabilization with vegetation.



Where Practice Applies

- Where a sufficient supply of quality topsoil is available.
- Where slopes are 2:1 or flatter.
- Where the subsoil or areas of existing surface soil present the following problems:
    - The structure, pH, or nutrient balance of the available soil cannot be amended by reasonable means to provide an adequate growth medium for the desired vegetation.
    - The soil is too shallow to provide adequate rooting depth or will not supply necessary moisture and nutrients for growth of desired vegetation.
    - The soil contains substances toxic to the desired vegetation.
- Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown.

Advantages

Advantages of topsoil include higher organic matter and greater available water-holding capacity and nutrient content.

Topsoil stockpiling ensures that a good growth medium will be available for establishing plant cover on graded areas.

The stockpiles can be used as noise and view baffles during construction.

Disadvantages/Problems

Stripping, stockpiling, and reapplying topsoil, or importing topsoil may not always be cost-effective. It may also create an erosion problem if improperly secured.

Unless carefully located, storage banks of topsoil may also obstruct site operations and therefore require double handling.

Topsoiling can delay seeding or sodding operations, increasing exposure time of denuded areas.

Most topsoil contains some weed seeds.

Planning Considerations

Topsoiling may be required to establish vegetation on shallow soils, soils containing potentially toxic materials, very stony areas, and soils of critically low pH.

Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of organic matter. It is the major zone of root development and biological activities for plants, carrying much of the nutrients available to plants, and supplying a large share of the water used by plants. It should be stockpiled and used wherever practical for establishing permanent vegetation.

The need for topsoiling, should be evaluated. Take into account the amount and quantity of available topsoil and weigh this against the difficulty of preparing a good seedbed on the existing subsoil. Where a limited amount of topsoil is available, it should be reserved for use on the most critical areas. In many cases topsoil has already been eroded away or, as in wooded sites, it may be too trashy.

Make a field exploration of the site to determine if there is surface soil of sufficient quantity and quality to justify stripping. Topsoil should be spread at a depth of 2 to 4 inches. More topsoil will be needed if the subsoil is rocky.

Topsoil should be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, clay loam). Areas of natural ground water recharge should be avoided.

Allow sufficient time in scheduling for topsoil to be spread and bonded prior to seeding, sodding, or planting.

Do not apply topsoil if the subsoil has a contrasting texture. Sandy topsoil over clayey subsoil is a particularly poor combination; water can creep along the junction between the soil layers and causes the topsoil to slough.

Stripping

Stripping should be confined to the immediate construction area. A 4 to 6 inch stripping depth is common, but depth may vary depending on the particular soil. All surface runoff control structures should be in place prior to stripping.

Stockpiling

Locate the topsoil stockpile so that it does not interfere with work on the site.

Side slopes of the stockpile should not exceed 2:1.

Surround all topsoil stockpiles with an interceptor dike with gravel outlet and silt fence.

Either seed or cover stockpiles with clear plastic or other mulching materials within 7 days of the formation of the stockpile.

Placement

Topsoil should not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or when conditions exist that may otherwise be detrimental to proper grading or proposed sodding or seeding.

Do not place topsoil on slopes steeper than 2:1, as it will tend to slip off.

If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. The best method is to actually work the topsoil into the layer below for a depth of at least 6 inches.

Maintenance

Maintain protective cover on stockpiles until needed.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Tree and Shrub Planting

Stabilizing disturbed areas by establishing a vegetative cover of trees or shrubs.

Purpose

- To stabilize the soil with vegetation other than grasses or legumes.
- To provide food and shelter for wildlife.
- To provide windbreaks or screens.

Where Practice Applies

Trees and shrubs may be used:

- On steep or rocky slopes,
- Where mowing is not feasible,
- As ornamentals for landscaping purposes, or
- In shaded areas where grass establishment is difficult.

Advantages

Trees and shrubs can provide superior, low-maintenance, long-term erosion protection. They may be particularly useful where site aesthetics are important.

Besides their erosion and sediment control values, trees and shrubs also provide natural beauty and wildlife benefits.

Disadvantages/Problems

Except for quick-growing species; it may take a number of years for trees to reach full size.

Trees and shrubs may be expensive to purchase and establish. They may also be more subject to theft than materials used in other practices.

Planning Considerations

There are many different species of plants from which to choose, but care must be taken in their selection. It is essential to select planting material suited to both the intended use and specific site characteristics.

None of these plants, however, is capable of providing the rapid cover possible by using grass and legumes. Vegetative plans must include close-growing plants or an adequate mulch with all plantings.

When used for natural beauty and wildlife benefits, trees and shrubs are usually more effective when planted in clumps or blocks.

Species Selection

When erosion or sediment control is not of primary, immediate concern; areas may be stabilized using rugged, fast-growing trees and shrubs that once established have a good record of taking care of themselves. These plants may not be the best ornamentals, but establishment can usually be made with these low-maintenance trees and shrubs.

In some cases, it may be desirable to use trees and shrubs as screening plants to shield sites such as gravel pits from public view. These plants should be given the best possible attention at planting time, with good soil water, and mulching.

Shrub and tree species recommendations for various soil conditions, densities, and arrangements will be found in Part 4 of this document.

Planting

Trees and shrubs will do best in topsoil. If no topsoil is available, they can be established in subsoil with proper amendment. If trees and shrubs are to be planted in subsoil, particular attention should be paid to amending the soil with generous amounts of organic matter. Mulches should also be used.

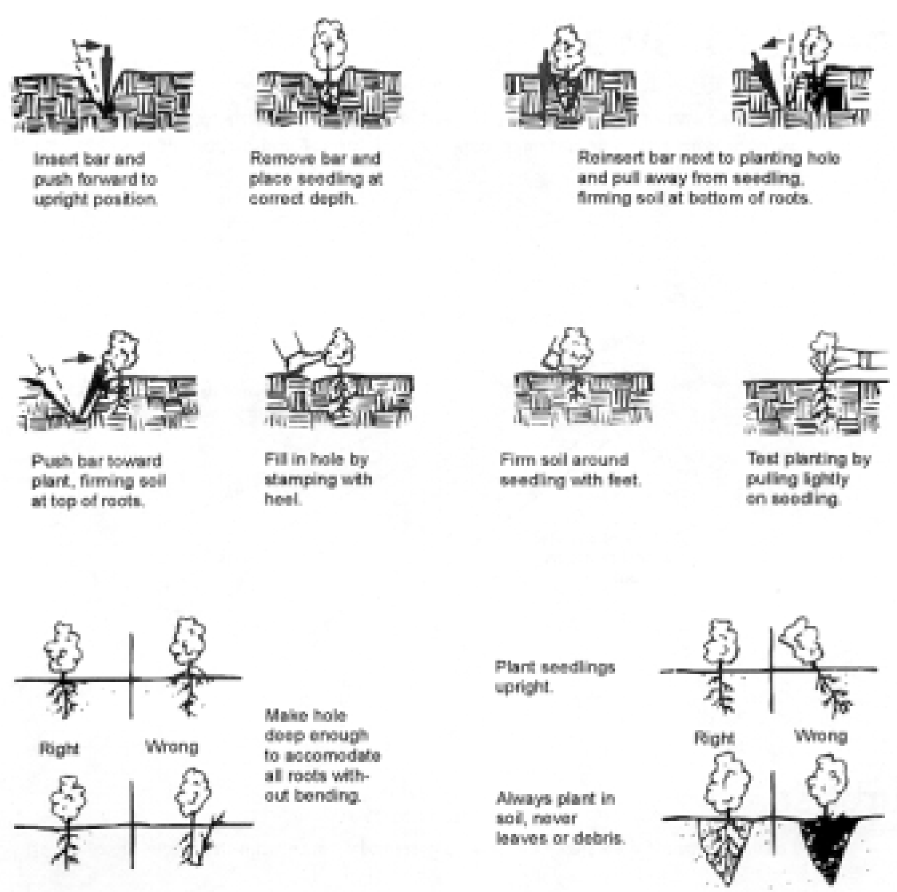
Good quality planting stock should be used. For mass plantings one or two-year old deciduous seedlings, and 3 or 4-year old coniferous transplants should be used. For smaller planting groups or individuals specimen plants, bare rooted, container grown or balled and burlaped stock may be preferred because of their larger size. Stock should be kept cool and moist from time of receipt until planted.

Competing vegetation, if significant, should be destroyed or suppressed prior to planting by scalping a small area where the plant is to be placed.

Stock should be planted in the spring by May 15. No fertilizer should be used at the time of planting unless it is a slow-release type formulated for trees and shrubs.

Plants should be planted at the approximate depth they were growing in the nursery; the roots should be uncrowded; the soil should be firmly packed against the roots after setting.

Shrubs should be mulched to a depth of 4 inches or more with woodchips, bark, peat moss or crushed stone. Mulch to the edge of the planting at, but not less than, one foot from the trunk.



Maintenance

Deciduous plants should be fertilized six months to one year after planting with ¼ pound of a 10-6-8 fertilizer per plant (or 25 lbs. per 1,000 sq. ft. for block plantings) or the equivalent. A slow release fertilizer is preferred. Evergreens should be fertilized half as much.

The planting should be inspected after the first and second growing seasons. Replanting and repairs, as needed to provide adequate cover, should be scheduled. Fertilizer should be applied to shrubs every 3 to 5 years after planting.

References

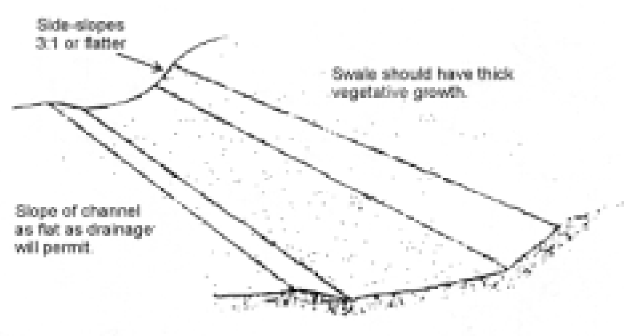
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Vegetated Swale

Vegetated swales are broad channels, either natural or constructed, with dense vegetation; whose purpose is to retard or impound concentrated runoff and dispose of it safely into the drainage system.

Purpose

To reduce runoff velocities, and reduce potential erosion from the discharge of runoff.



Vegetated swales may also remove some particulate pollutants from stormwater runoff and increase infiltration.

Where Practice Applies

This practice applies to all sites where a dense stand of vegetation can be established and where either a stable outlet exists or can be constructed as a suitable conveyance system to safely dispose of the runoff flowing from the swale.

The swale can be used by itself or in combination with erosion and sediment control practices:

- In residential areas of low to moderate density where the percentage of impervious cover is relatively small.
- In a drainage easement at the side or back of residential lots.
- Adjacent to parking areas.
- Along highway medians as an alternative to curb and gutter drainage systems.

Planning Considerations

The vegetated swale and the grassed waterway are very similar. The difference in the two practices is mainly in purpose. The vegetated swale is used for water quality improvement and peak runoff reduction; accomplished by limiting the velocity in the swale. The grassed waterway or outlet is used to convey runoff at a non-erosive velocity.

Vegetated swales are best suited on small drainage areas where the amount of impervious cover is relatively small. If dense vegetation cannot be established and maintained in the swale, then its effectiveness is severely reduced.

The seasonal high water table should be at least two feet below the bottom of the swale in order to provide for more effective infiltration and treatment of the runoff and to provide better growing conditions for the vegetation. Subsurface drainage may be needed to control high water table and improve the condition of the swale.

The swale should be constructed prior to any other channel or facility which will drain into it and flow should be diverted out of the swale until adequate vegetation is established.

Vegetated swales should generally not receive construction-stage runoff; if they do, presettling of sediments should be provided.

Swales should be protected from siltation by a sediment pond or basin when the erosion potential is high; otherwise, presettling is not generally needed for normal operation.

Soil moisture should be sufficient to provide water requirements during the dry season, but where the water table is not so high as to cause long periods of soil saturation. Irrigate if moisture is inadequate during summer drought. If saturation will be extended or the slope is minimal but grasses are still desired, consider subdrains.

Prevent bare areas by avoiding gravel, rocks, and hardpan near the surface.

Design Recommendations

The minimum capacity should be that required to convey the peak runoff expected from a 10-year frequency 24-hour duration storm.

The maximum design velocity for a vegetated swale should be one foot per second during passage of the 10-year frequency storm.

The minimum recommended length of a vegetated swale is 200 feet. If a shorter length must be used, increase swale cross-sectional area by an amount proportional to the reduction in length below 200 feet, in order to obtain the same water residence time.

The channel slope should normally be between 2 and 4 percent. A slope of less than 2 percent can be used if underdrains are placed beneath the channel to prevent ponding. A slope of greater than 4 percent can be used if check dams are placed in the channel to slow the flows accordingly.

Install log or rock check dams approximately every 50 feet, if longitudinal slope exceeds 4 percent. Adjust check dam spacing in order not to exceed 4 percent slope within each channel segment between dams.

The cross section for a vegetated swale may be parabolic, triangular, or trapezoidal.

If flow is introduced to the swale via curb cuts, place pavement slightly above the swale elevation. Curb cuts should be at least 12 inches wide to prevent clogging.

Subsurface drainage measures should be provided if sites have high water tables or seepage problems, except where water-tolerant vegetation such as reed canary grass can be used. There should be no base flow present in the swale.

Vegetative Recommendations

Swales should be vegetated with an appropriate grass mixture: The swale should be mulched if necessary for establishment of good quality vegetation. A temporary diversion should be used to divert runoff away from the swale until vegetation is established that is capable of preventing erosion.

Select vegetation according to what will best establish and survive in the site conditions. Select fine, close-growing, water-resistant grasses. If a period of soil saturation is expected, select emergent wetland plant species. Protect these plants during establishment by netting.

Select a grass height of 6 inches or less and a flow depth of less than 5 inches. Grasses over that height tend to flatten down when water is flowing over them, which prevents sedimentation.

Construction Recommendations

Avoid compaction during construction. If compaction occurs, till before planting to restore lost soil infiltration capacity.

Divert runoff during the period of vegetation establishment. Sodding is an alternative for rapid stabilization. Where it is not possible to divert runoff, cover graded and seeded areas with a suitable erosion control slope covering material.

Maintenance

Timely maintenance is important to keep the vegetation in the swale in good condition. Mowing should be done frequently enough to keep the vegetation in vigorous condition and to control encroachment of weeds and woody vegetation, however it should not be mowed too closely so as to reduce the filtering effect.

Fertilize on an “as needed” basis to keep the grass healthy. Over-fertilization can result in the swale becoming a source of pollution.

The swale should be inspected periodically and after every major storm to determine the condition of the swale. Rills and damaged areas should be promptly repaired and re-vegetated as necessary to prevent further deterioration.

Vegetated swales planted in grasses must be mowed regularly during the summer to promote growth and pollutant uptake. Plan on mowing as needed to maintain proper height. Remove cuttings promptly, and dispose in a way so that no pollutants can enter receiving waters.

Remove sediments during summer months when they build up to 6 inches at any spot or cover vegetation. If the equipment leaves bare spots, re-seed them immediately.

Inspect periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizer to receiving waters or ground water.

Clean curb cuts when soil and vegetation buildup interferes with flow introduction.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual,*** Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Water Bar

A ridge or ridge and channel constructed diagonally across a sloping road or utility right-of-way that is subject to erosion. Used to prevent erosion on long, sloping right-of-way routes by diverting runoff at selected intervals.

Where Practice Applies

- Where runoff protection is needed to prevent erosion on sloping access right-of-ways.
- On sloping areas generally less than 100 feet in width.

Disadvantages/Problems

Need maintenance periodically for vehicle wear.

Planning Considerations

Narrow rights-of-way on long slopes used by vehicles can be subject to severe erosion. Surface disturbance and tire compaction promote gully formation by increasing the concentration and velocity of runoff.

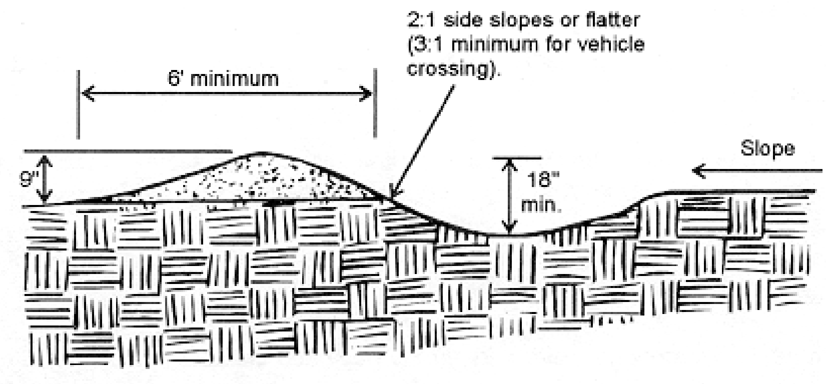
Water bars are constructed by forming a ridge or ridge and channel diagonally across the sloping right-of-way. Each outlet should be stable, and should be able to handle the cumulative effect of upslope diversion outlets. The height and side slopes of the ridge and channel are designed to divert water and to allow vehicles to cross.

Design Recommendations

Height - 18 inches minimum from channel bottom to top of settled ridge.
Side slopes - 2:1 or flatter (3:1 or flatter where vehicles cross).
Spacing - For right-of-way widths less than 100 feet; spacing as follows:

Slope (%)	Diversion Spacing (feet)
< 5	125
5 to 10	100
10 to 20	75
20 to 35	50
>35	25

Base width of ridge - 6 feet minimum.
Grade - Constant or slightly increasing, not to exceed 2%.
Outlet - Diversion must cross the full access width and extend to a stable outlet.



Installation

Construct the diversion system as soon as the access right-of-way has been cleared and graded. Locate first diversion at required distance from the slope crest depending on steepness of right-of-way slope. Set crossing angle to keep positive grade less than 2% (approximately 60-degree angle preferred).

Mark location and width of ridge and disk the entire length.

Fill and compact ridge above design height and compact with wheeled equipment to the design cross section.

Construct diversions on constant or slightly increasing grade not to exceed 2%. Avoid reverse grades.

Set direction of water bars to utilize the most stable outlet locations. If necessary, adjust length of waterbars or make small adjustments to spacing.

Do not allow runoff from upslope water bars to converge with downslope water bar outlets.

Construct sediment traps or outlet stabilization structures as needed.

Seed and mulch the ridge and channel immediately.

Common Trouble Points

Overtopping ridge where diversion crosses low areas - Build water bars to grade at all points.

Erosion between water bars - Spacing too wide for slope. Install additional water bars.

Ridge worn down - Channel filled where vehicles cross; surface not stable; or side slopes too steep: may need gravel.

Erosion at outlets - Install outlet stabilization structure or extend upslope water bar so runoff will not converge on lower outlets.

Erosion in channel - Grade too steep. Realign water bar.

Maintenance

Inspect water bars periodically for vehicle wear. Inspect for erosion and sediment deposition after heavy rains.

Remove debris and sediment from diversion channel and sediment traps, repair ridge to positive grade and cross section. Add gravel at crossing areas and stabilize outlets as needed.

Repair and stabilize water bars immediately if right-of-way is disturbed by installation of additional utilities.

In removing temporary water bars, grade ridge and channel to blend with natural ground. Compact channel fill and stabilize disturbed areas with vegetation. Water bars should not be removed until all disturbed areas draining to them have been stabilized, inspected, and approved.

If water bars are designed for permanent use, correct any erosion problems, stabilize outlets, and apply permanent seeding.

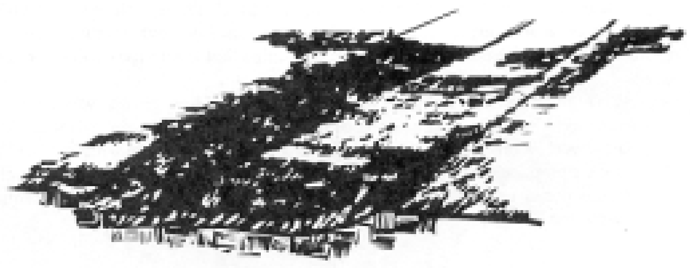
References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Waterway, Grassed

A natural or constructed waterway or outlet shaped or graded and established in suitable vegetation as needed for the safe disposal of runoff water. Used to convey and dispose of concentrated runoff to a stable outlet without damage from erosion, deposition, or flooding.



Where Practice Applies

This practice applies to construction sites where:

- Concentrated runoff will cause damage from erosion or flooding,
- A vegetated lining can provide sufficient stability for the channel cross section and grade,
- Slopes are generally less than 5 percent, and
- Space is available for a relatively large cross section.

Typical uses include roadside ditches, channels at property boundaries, and outlets for diversions.

Planning Considerations

Grass-lined channels resemble natural systems and are usually preferred where design velocities are suitable. Select appropriate vegetation and construct channels early in the construction schedule before grading and paving increase runoff rates.

Two major considerations for a grassed waterway are adequate capacity and sufficient erosion resistance.

The channel cross section should be wide and shallow with relatively flat side slopes so surface water can enter over the vegetated banks without causing erosion.

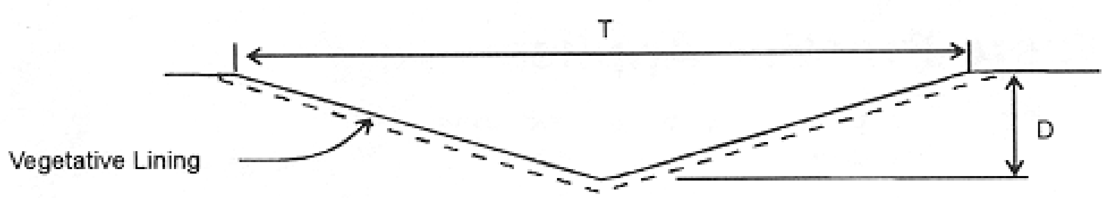
Vegetation should be established before runoff is allowed to flow in the waterway.

Supplemental measures may be needed with this practice. These may include but not be limited to such things as:

- Grade control structures,
- Level spreaders,
- Paved or rock-lined bottom, or
- Subsurface drain to eliminate wet spots and permit growing suitable vegetation.

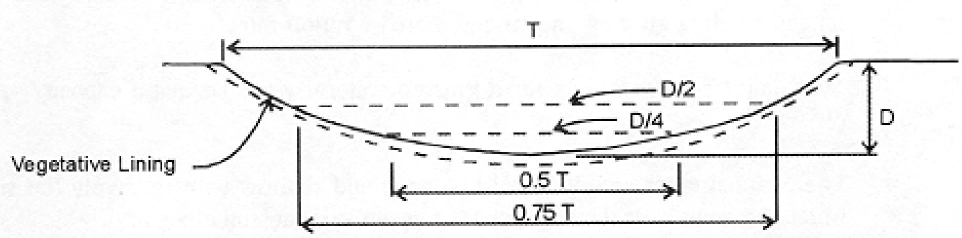
Primary considerations for a stormwater conveyance channel are the volume, velocity, and duration of flow expected in the channel. In addition, there are several other factors that should be taken into consideration when planning a channel. These include soil characteristics, safety, aesthetics, availability of land, compatibility with land use and surrounding environment, and maintenance requirements. The type of cross section that is selected depends on these factors.

Triangular sections are used where the volume of flow is relatively small, such as in roadside ditches. Vegetation can be used in these ditches where the velocities are low. On steep slopes, however, where higher velocities are encountered; it may be necessary to line the channel with rock riprap, concrete, asphalt or other erosion resistant lining. Triangular cross-sections may be more prone to erosion because during small flows, the flow is concentrated in the narrow v-section.



Triangular Cross-section

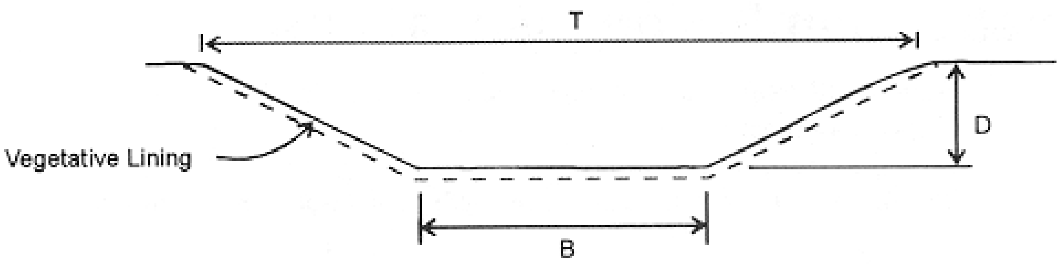
Parabolic sections are suited for higher flows, but require the use of more land because the channels are generally shallow and wide. These channels seem to blend better in natural settings when grass mixtures are used as a lining. When velocities exceed the capability of vegetation, rock riprap can be used as a lining. When there is a continuous base flow in the channel it may be possible to use a combination of rock riprap and vegetation as a lining. The base flow would be carried by the riprap section and the higher flows by the vegetated section as long as the vegetation is capable of withstanding the velocity.



Parabolic Cross-section

A trapezoidal channel is usually used where the flows are relatively large and at higher velocities. These channels are usually lined with materials other than vegetation. Trapezoidal channels usually take up less land than either triangular or parabolic channels.

Regardless of the channel shaped selected, the outlet should be checked to determine if it is stable. It may be necessary to have some type of energy dissipater to prevent scour to the receiving outlet if there is an overflow or if velocities in the contributing channel are higher than the outlet can withstand.



Trapezoidal Cross-section

Design Recommendations

Capacity - The minimum capacity should be that required to convey the peak runoff expected from a storm of 10-year frequency. Peak runoff values should be determined by accepted methods.

To provide for loss in channel capacity due to vegetal matter accumulation, sedimentation, and normal seedbed preparation, the channel depth and width may be increased proportionally to maintain the hydraulic properties of the waterway. In parabolic channels, this may be accomplished by adding 0.3 foot to the depth and 2 feet to the top width of the channel. This is not required on waterways located in natural watercourses.

Cross Section - The cross section may be parabolic, triangular, or trapezoidal.

Grade - Generally restricted to slopes 5% or less.

Sideslopes - Generally 3:1 or flatter to establish and maintain vegetation and facilitate mowing.

Where a paved or stone-lined bottom is used in combination with vegetated side slopes, it should be designed to handle the base flow, snowmelt, or runoff from a one-year frequency storm, whichever is greater. The flow depth of the paved section should be a minimum of 0.5 feet.

Width - The bottom width of waterways or outlets should not exceed 50 feet unless multiple or divided waterways or other means are provided to control meandering of low flows within this limit.

Drainage - Subsurface drainage measures should be provided in the design for sites having high water table or seepage problems, except where water-tolerant vegetation such as reed canarygrass can be used. Where there is base flow present or long duration flows are expected, a stone center or underground outlet should be used.

Outlet - The outlet must be stable. Channels carrying sediment must empty into sediment traps.

Stabilization - Waterways should be stabilized with vegetative measures or stone centers. If a vegetated lining is supplemented by stone center, or other erosion-resistant materials, the velocity may be increased by 2.0 ft/sec.

Construction Recommendations

Remove all trees, brush, stumps, and other objectionable material from the foundation area and dispose of properly.

Install traps or other measures to protect grassed waterways from sediment.

The channel section should be free of bank projections or other irregularities which prevent normal flow.

Excavate and shape channel to dimensions shown on plans. Overcut entire channel 0.2 ft to allow for bulking during seedbed preparation and growth of vegetation. If installing sod, overcut channel the full thickness of the sod.

Remove and properly dispose of excess soil so that surface water may enter the channel freely.

Earth removed and not needed in construction should be spread or disposed of so as not to interfere with the functioning of the waterway.

Fills placed in waterways should be thoroughly compacted in order to prevent unequal settlement that could cause damage in the completed waterway.

Protect all concentrated inflow points along channel by installing a temporary liner, riprap, sod, or other appropriate measures.

Stabilize outlets and install sediment traps as needed during channel installation.

Vegetate the channel immediately after grading. Smooth slopes facilitate maintenance.

Establishing Vegetation

Waterways should be protected by vegetative means as soon after construction as practical, and before diversions or other channels are outletted into them. Consideration should be given to jute matting, excelsior matting, or sodding of channel to provide erosion protection as soon after construction as possible.

Install sod instead of seeding in critical areas, particularly where slopes approach 5%.

Seeding, fertilizing, mulching, and sodding should be in accord with applicable vegetative standards for permanent cover. See Permanent Seeding.

One-half to one bushel of oats should be added to the basic mixture for quick cover and to help anchor the mulch.

Very moist waterways are often best vegetated by working rootstocks of reed canarygrass into the seedbed.

When soil conditions are unfavorable for vegetation (such as very coarse-textured subsoil material), topsoil should be spread to a depth of 4 inches or more on at least the center half of parabolic shaped channels or on the entire bottom of trapezoidal shaped channels.

Seeded channels should be mulched. For critical sections of large channels, and for steep channels, the mulch should be anchored by cutting it lightly into the soil surface, or by covering with paper twine fabric or equivalent material; or jute netting should be used.

Common Trouble Points

Erosion occurs in channel before vegetation is fully established
Repair, reseed, and install temporary liner.

Gullying or head cutting in channel
Grade too steep for grass lining (steep grade produces excessive velocity). Channel and liner should be redesigned.

Sideslope caving
May result from any of the following:

- channel dug in unstable soil (high water table),
- banks too steep for site conditions, or
- velocity too high, especially on outside of channel curves.

Overbank erosion, spot erosion, channel meander, or flooding
Avoid debris and sediment accumulation. Stabilize trouble spots and revegetate. Riprap or other appropriate measures may be required.

Ponding along channel
Approach not properly graded, surface inlets blocked.

Erosion at channel outlet
Install outlet stabilization structure.

Sediment deposited at channel outlet
Indicates erosion in channel or watershed. Find and repair any channel erosion. Stabilize watershed, or install temporary diversions and sediment traps to protect channel from sediment-laden runoff.

Maintenance

During the initial establishment period, flow should be diverted out of the channel if at all possible to allow for a good stand of grass. If this is not possible use matting. In any case during the establishment period, the channel should be checked after every rainfall to determine if the grass is still in good condition and in place.

After the vegetation has become established, the channel should be checked periodically and after every major storm to see if damage has occurred. Any damaged areas should be repaired and revegetated immediately.

Maintenance of the vegetation in the grassed waterway is extremely important in order to prevent rilling, erosion, and failure of the waterway.

Mowing should be done frequently enough to control encroachment of weeds and woody vegetation and to keep the grasses in a vigorous condition. The vegetation should not be mowed too closely so as to reduce the erosion resistance in the waterway.

Periodic applications of lime and fertilizer may be needed to maintain vigorous growth.

Remove all significant sediment and debris from channel to maintain the design cross section and grade and prevent spot erosion.

Existing waterways can often be best repaired by working sods of witchgrass (quackgrass) into the seedbed.

It is important to check the channel outlet and all road crossings for blockage, sediment, bank instability, and evidence of piping or scour holes.

References

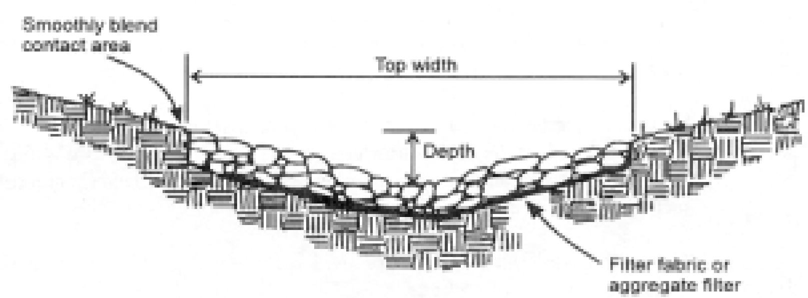
Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, S***tormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Waterway, Lined

A waterway with an erosion resistant lining of concrete, stone, or other permanent material. The lined section extends up the side slopes to design flow depth. The earth above the permanent lining should be vegetated or otherwise protected.



Purpose

To provide for safe disposal of runoff from other conservation structures or from natural concentrations of flow, without damage by erosion or flooding, where unlined or grassed waterways would be inadequate.

Where Practice Applies

This practice applies where channel flow velocities exceed those acceptable for a grass lined waterway and/or conditions are unsuitable for the establishment of grass lined waterways. Specific conditions include:

- Concentrated runoff is of such magnitude that a lining is needed to control erosion.
- Steep grades, wetness, prolonged or continuous base flow, seepage, or piping would cause erosion.
- The location is such that use by people, animals, or vehicles preclude use of vegetated waterways.
- High value property or adjacent facilities warrant the extra cost to contain design runoff in limited space.
- Soils are highly erosive or other soil or climate conditions preclude using vegetation.

Planning Considerations

Linings can consist of: rock riprap; non-reinforced, cast-in-place concrete, flagstone mortared in place; or similar permanent linings.

Riprap liners are considered flexible and are usually preferred to rigid liners.

Riprap is less costly, adjusts to unstable foundation conditions, is less expensive to repair, and reduces outlet flow velocity.

Riprap or paved channels can be constructed with grass lined slopes where site conditions warrant.

Volume, velocity, and duration of flow expected are primary considerations for a lined waterway. Other factors include soil characteristics, safety, aesthetics, availability of land, compatibility with land use and surrounding environment, and maintenance requirements. The type of cross section that is selected depends on these factors.

Typical cross sections that can be used include triangular or v-shaped sections, parabolic sections, and trapezoidal sections.

- Triangular sections are used where the volume of flow is relatively small, such as in roadside ditches.
- Parabolic sections are suited for higher flows, but require the use of more land because the channels are generally shallow and wide. When velocities exceed the capability of vegetation, rock riprap can be used as a lining. When there is a continuous base flow in the channel it may be possible to use a combination of rock riprap and vegetation as a lining. The base flow would be carried by the riprap section and the higher flows by the vegetated section; as long as the vegetation is capable of withstanding the velocity.
- A trapezoidal channel is usually used where the flows are relatively large and at higher velocities. Trapezoidal channels usually take up less land than either triangular or parabolic channels.

Regardless of the channel shaped selected, the outlet should be checked to determine if it is stable. It may be necessary to have some type of energy dissipater to prevent scour to the receiving outlet if there is an overflow or if velocities in the contributing channel are higher than the outlet can withstand.

The Wetlands Protection Act requires that for any stream crossing or other work conducted in a wetland resource area, or within 100 feet of a wetland resource area, the proponent file a “Determination of Applicability” or a “Notice of Intent” with the local Conservation Commission.

Design Recommendations

See also **Riprap**.

Capacity - The minimum capacity should be adequate to carry the peak rate of runoff from a 10-year frequency storm.

Cross Section - The cross section may be triangular, parabolic, or trapezoidal. Monolithic concrete may be rectangular.

Velocity

Rock Riprap Lined Waterways - Rock riprap linings can be designed to withstand high velocities by choosing a stable rock size. Riprap should have a transition material (bedding) placed between the rock and the soil. This transition material can be either a well graded sand-gravel mixture or a geotextile fabric.

Concrete-Lined Waterways - Velocity is usually not a limiting factor in the design of concrete-lined waterways. Keep in mind however that the flow velocity at the outlet must not exceed the allowable velocity for the receiving outlet.

Drainage - Drainage is not a factor when considering using a rock riprap waterway since subsurface water will drain through the transition material and the rock. Concrete lined channels may require drainage to reduce uplift pressure and collect seepage water.

Filters or bedding - Filters or bedding should be used to prevent piping. Filter fabric may be used as the filter. Drains should be used, as required, to reduce uplift pressure and collect water. Weep holes may be used with drains if needed.

Rock Riprap or Flagstone - Stone used for riprap or flagstone should be dense and hard enough to withstand exposure to air, water, freezing and thawing. Flagstone should be flat for ease of placement, and have the strength to resist exposure and breaking.

Construction Recommendations

Outlet must be stable. Stabilize channel inlet points and install needed outlet protection during channel installation.

Remove all trees, brush, stumps, and other objectionable material from channel and spoil areas and dispose of properly.

Construct cross section to the lines and grades shown in plans. Install filter fabric or gravel layer as specified in the plan.

Common Trouble Points

Foundation not excavated deep enough or wide enough
Riprap restricts channel flow, resulting in overflow and erosion.

Side slopes too steep
Causes instability, stone movement and bank failure.

Filter omitted or damaged during stone placement
Causes piping and bank instability.

Riprap poorly graded or stones not placed to form a dense, stable channel lining
Results in stone displacement and erosion of foundation.

Riprap not extended far enough downstream
Causes undercutting. Outlet must be stable.

Riprap not blended to ground surface
Results in gullying along edge of riprap.

Maintenance

Check riprap-lined waterways periodically and after every major storm for scouring below the riprap layer, and to see that the stones have not been dislodged by the flow. Plastic filter cloth, if used, should be completely covered and protected from sunlight.

If the rocks have been displaced or undermined, the damaged areas should be repaired immediately. Woody vegetation should not be allowed to become established in the rock riprap and if present should be removed. Debris should not be allowed to accumulate in the channel.

Give special attention to outlets and points where concentrated flow enters channel. Repair eroded areas promptly.

Concrete-lined waterways should be checked to ensure that there is no undermining of the channel. If scour is occurring at the outlet, appropriate energy dissipation measures should be taken.

If the waterway is below a high sediment-producing area, sediment should be trapped before it enters.

Check for sediment accumulation, piping, bank instability, and scour holes. Sediment and debris deposits should be removed before they reduce the capacity of the channel.

References

Connecticut Council on Soil and Water Conservation, ***Connecticut Guidelines for Soil Erosion and Sediment Control***, Hartford, CT, January, 1985.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management Manual***, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, ***Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire***, Rockingham County Conservation District, August 1992.

North Carolina Department of Environment, Health, and Natural Resources, ***Erosion and Sediment Control Field Manual***, Raleigh, NC, February 1991.

Rainfall, Runoff, and Land Use Change

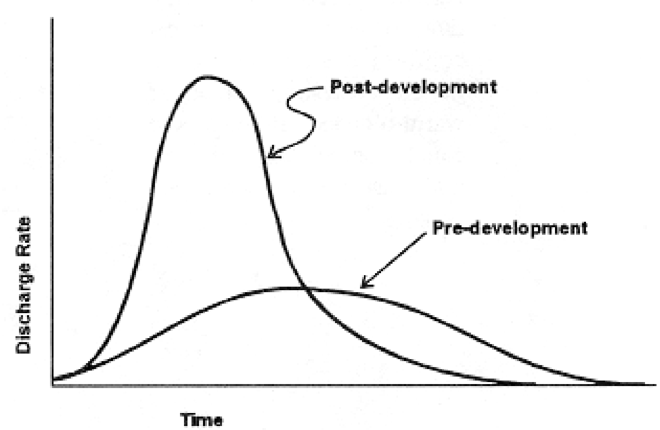
Effects of Development

There are two main effects that urbanization has on stormwater. First, an increase in the volume and rate of runoff as development takes place in a watershed. Second, an increased risk of degrading water quality; both surface water and ground water.

Hydrologic Changes

Undeveloped land that is in woods, grass, and/or agriculture, has an ability to absorb rainfall. Rainfall is infiltrated into the soil, used by vegetation, or runs off. Water reaches the earth's surface by rain and snow. Some water is retained on the upper surface of the soil and is either evaporated or transpired into the atmosphere by grass, plants and trees. Some water infiltrates into the soil and becomes groundwater which eventually reaches streams, lakes and oceans.

The remainder of the water falling to the earth becomes runoff and flows into the streams, lakes and oceans as surface flow. Evaporation takes place on these bodies of water and sends the moisture back into the atmosphere as vapor.



Pre- and Post-development Hydrographs

When development takes place, vegetation may be removed and replaced with impervious surfaces. These surfaces include roads, streets, parking lots, roof tops, driveways, walks, etc. which reduce the amount of rainfall that can infiltrate into the soil and therefore create more runoff into the surface water system.

In addition to the increase in impervious surfaces, urbanization creates a significant amount of ground surface modification. Natural drainage patterns are modified and runoff is transported via road ditches, storm sewers, drainage swales, and constructed channels. These modifications increase the velocity of the runoff; which in effect decreases the time that it takes for runoff to travel through the watershed. This decreased time creates higher peak discharges.

Increase In Pollution Potential

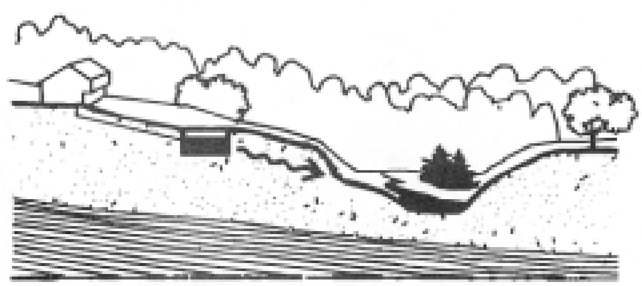
The largest urban non-point pollution source is sediment and the nutrients and trace metals attached to it. In addition, the runoff from urban areas may carry bacteria, toxic chemicals, hydrocarbons and organic substances.

Sediment is a major pollutant from urban areas. Runoff from construction sites during the urbanization process is the largest source of sediment. Sediment fills road ditches, streams, rivers, lakes and wetlands. A good erosion and sediment control plan can substantially decrease the amount of sediment being produced from urban areas and transported off site.

Nutrients from urban areas are a major concern to surface water quality because of their effects on water bodies. The two major nutrients are nitrogen and phosphorous. Nutrient enrichment can cause an increase in algal growth. Nitrogen consumes large amounts of oxygen in the nitrification process within the water. Both conditions can impair the use of our surface waters for water supply, recreation, and fish and wildlife habitat.

Main sources of nutrients in urban areas include improper use of fertilizers, and organic matter from lawn clippings and leaves. Auto emissions can also contribute phosphorous in areas of heavy traffic.

Trace metals can degrade water quality because of the effect they may have on aquatic life. The most common trace metals found in urban runoff are lead, zinc and copper, however other trace metals such as chromium, nickel and cadmium are frequently found.

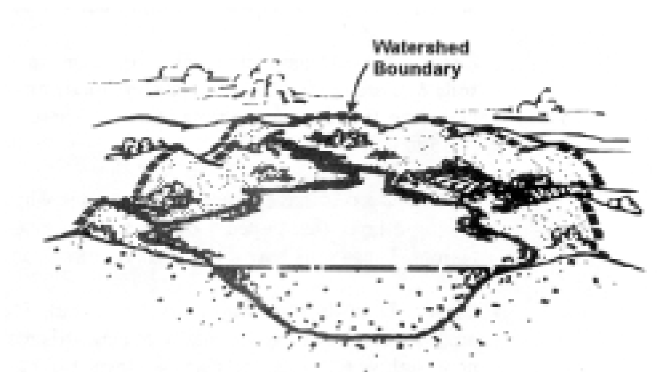


Bacteria levels can increase due to urbanization. Fecal coliform bacteria are found in the intestinal tract of warm-blooded animals and can be associated with animal wastes and failed septic systems.

Hydrocarbons from petroleum are commonly found in urban runoff. The hydrocarbons attach to fine sediment and are then transported and deposited throughout the surface water system. Common sources of hydrocarbons are from roads, streets, and parking lots. Other sources include gasoline stations, fuel storage facilities, and improper disposal of motor oil.

Factors affecting surface runoff

Surface runoff is the volume of excess water that runs off a drainage area, or watershed. Peak discharge is the peak rate of runoff from a drainage area for a given rainfall.



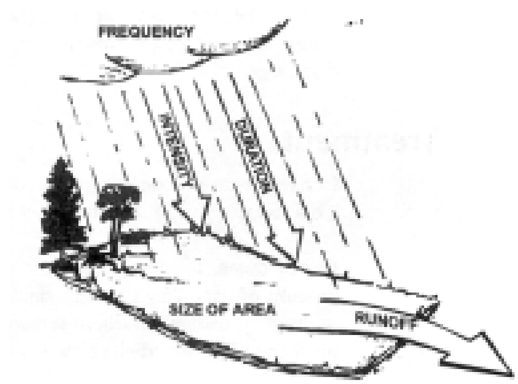
A watershed is a drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation. The term watershed is synonymous with drainage area; the contributing area, in acres, square miles, or other unit is usually expressed as drainage area.

General

Rainfall is the primary source of water that runs off the surface of small watersheds. The main factors affecting the volume of rainfall that runs off are the kind of soil, type of vegetation and amount of impervious area in the watershed. Factors that affect the rate at which water runs off are watershed topography and shape along with man-made features in a watershed.

Rainfall

The peak discharge from a small watershed is usually caused by intense rainfall. The intensity of rainfall affects the peak discharge more than it does the volume of runoff. The melting of accumulated snow may result in a greater volume of runoff, but usually at a lesser rate than runoff caused by rainfall. The melting of a winter's snow accumulation over a large area may cause major flooding along rivers. Intense rainfall that produces high peak discharges in small watersheds usually does not extend over a large area. Therefore, the same intense rainfall that causes flooding in a small tributary is not likely to cause major flooding in a main stream that drains 10 to 20 square miles.



Hydrologic soil groups

Soils may be classified into four hydrologic soil groups, defined as follows:

Group A soils have low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of sands and gravels that are deep, well drained to excessively drained, and have a high rate of water transmission (greater than 0.30 in/hr).

Group B soils have moderate infiltration rates when thoroughly wetted and consist chiefly of soils that are moderately deep to deep, moderately well drained to well drained, and have moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission (0.15 to 0.30 in/hr).

Group C soils have low infiltration rates when thoroughly wetted and consist chiefly of soils having a layer that impedes downward movement of water and soils of moderately fine to fine texture. These soils have a slow rate of water transmission (0.05 to 0.15 in/hr).

Group D soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission (0 to 0.05 in/hr).

Cover Type

“Cover type” describes conditions at the soil surface; e.g. vegetation, bare soil, impervious surfaces such as parking areas, roofs, streets, or roads. Cover type affects runoff in several ways. The foliage and its litter maintain the soil’s infiltration potential by preventing the impact of the raindrops from sealing the soil surface. Some of the raindrops are retained on the surface of the foliage, increasing their chance of being evaporated back into the atmosphere. Some of the intercepted moisture takes so long to drain from the plant down to the soil that it is Withheld from the initial period of runoff.

Ground cover also allows soil moisture from previous rains to transpire, leaving a greater void in the soil to be filled. Vegetation, including its ground litter, forms numerous barriers along the path of the water flowing over the surface of the land. This increased surface roughness causes water to flow more slowly, lengthening the time of concentration and reducing the peak discharge.

Treatment

Conservation practices reduce erosion and help maintain an “open structure” at the soil surface. This reduces runoff, but the effect diminishes rapidly with increases in storm magnitude.

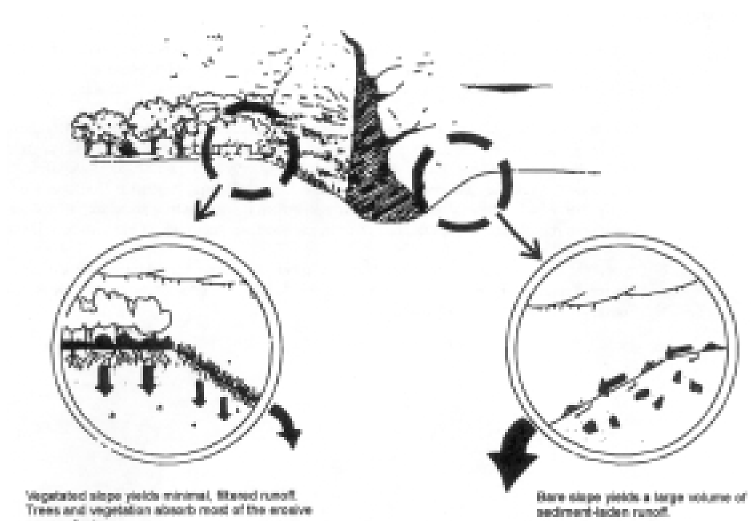
Check dams, terraces, detention ponds, and similar practices reduce erosion and decrease the amount of runoff by creating small reservoirs. Closed-end level terraces act as storage reservoirs without spillways. Gradient terraces, surface roughening, vegetation increase the distance water must travel or impede its flow - and thereby increase the time of concentration.

Hydrologic conditions

Hydrologic condition indicates the effects of cover type and treatment on infiltration and runoff rates. It is generally estimated from the density of plant and crop residue on the area. Good hydrologic condition indicates that the soil usually has low runoff potential for that specific hydrologic soil group, cover type and treatment. Some factors to consider in estimating the effect of cover on infiltration and runoff are: canopy or density of leaves, amount of year-round cover, percent of residue cover, and the degree of surface roughness.

In most cases, the hydrologic condition of the site affects the volume of runoff more than any other single factor. The hydrologic condition considers the effects of cover type and treatment on infiltration and runoff and is generally estimated from density of plant cover and residue on the ground surface. Good hydrologic condition indicates that the site usually has a lower runoff potential.

A grass cover is “good” if the vegetation covers 75 percent or more of the ground surface. Cover is “poor” if vegetation covers less than 50 percent of the ground surface. Grass cover is evaluated on the basal area of the plant, whereas trees and shrubs are evaluated on the basis of canopy cover.



Topography

The slopes in a watershed have a major effect on the peak discharge at downstream points. Slopes have little effect on how much of the rainfall will run off. As watershed slope increases, velocity increases, time of concentration decreases, and peak discharge increases. An average small watershed is fan-shaped. As the watershed becomes elongated or more rectangular, the flow length increases and the peak discharge decreases.

Potholes may trap a small amount of rain, thus reducing the amount of expected runoff. If potholes and marshland areas make up one-third or less of the total watershed and do not intercept the drainage from the remaining two-thirds, they will not contribute much to the peak discharge. These areas may be excluded from the drainage area for estimating peak discharge. If potholes constitute more than one-third of the total drainage or if they intercept the drainage, a “pond and swamp adjustment factor” can be applied.

Runoff

“Runoff” is the water leaving the watershed during and after a storm. It may be expressed as the average depth of water that would cover the entire watershed. The depth is usually expressed in inches. The volume of runoff is computed by converting depth over the drainage area to volume and is usually expressed in acre-feet.

Hydrologic Methods

Hydrologic methods are well-covered in literature such as Soil Conservation Service (SCS) Technical Release 55, Urban Hydrology for Small Watersheds, other technical documents of various state and federal agencies, commercial publishing houses, and numerous computer programs.

In order to assist designers preparing development plans and local Conservation Commissions reviewing such plans; checklists for reviewing reports prepared using SCS technical releases TR-20, Computer Program for Project Formulation - Hydrology, and TR-55, Urban Hydrology for Small Watersheds, have been included in this section. Natural Resources Conservation Service (formerly Soil Conservation Service) engineers often receive queries about technical details of hydrologic procedures, and a summary of common questions and answers has also been included.

Note: Technical Releases issued prior to November 1994 are referred to as Soil Conservation Service Technical Releases. After November 1994, they are referred to as Natural Resources Conservation Service Technical Releases.

Checklist for Reviewing Reports Using SCS TR-55 Analysis

☑ Watershed map at a scale of 1 inch = 500 feet or larger. Show watershed boundary, sub-area boundaries, and sub-area names or numbers. Show time of concentration, curve number, and drainage area for each sub-area on the map. Contour maps must include some additional area outside the property line boundaries.

☑ Large scale map showing different soils within each sub-area boundary. May also be used to delineate drainage areas. Show the flow route used for calculating time of concentration for each sub-area.

☑ Tabulation sheet or computer printout showing runoff curve number and time of concentration calculations for each sub-area. Drainage areas, hydrologic soils groups, and land use areas should be documented and supported from soils maps or other references.

☑ Tabulation sheet showing calculations and equations used for any storage estimates to design a detention basin.

☑ Narrative explanation and documentation for any sheet flow lengths used that exceed 50 feet.

☑ TR-55 printout showing graphical or tabular peak discharge calculations. include printouts for both pre-development and post-development conditions. The printout showing the design of a detention basin should be included. These printouts should document any claim of zero discharge increase for all required storms.

☑ The written report should state the initial conditions and storm frequencies to be analyzed. Include a summary table showing the pre-development, post-development, and designed system peak discharges for all design frequencies.

☑ Show a sketch of the structure outlet system with elevations and dimensions.

Checklist for Reviewing Reports Using SCS TR-20 Analysis

☑ TR-20 watershed map at a scale of 1 inch = 500 feet or larger. Show sub-area boundaries, cross section locations and numbers, structure locations and numbers, and sub-area names or numbers. Show time of concentration, curve number, and drainage area for each sub-area on the map. Contour maps must include some additional area outside the property line boundaries.

☑ Large scale map showing different soils within each sub-area boundary. May also be used to delineate drainage areas. Show time of concentration calculation path used for each sub-area.

☑ Tabulation sheet or computer printout showing runoff curve number and time of concentration calculations for each sub-area. Drainage areas, hydrologic soils groups, and land use areas should be documented and supported from soils maps or other references.

☑ Tabulation sheet showing calculations and equations used for structure stage, discharge, and storage volumes, and cross-section elevation, discharge, area calculations. Include sketches of structures and cross sections showing elevations and dimensions used in the calculations.

☑ Narrative explanation and documentation for any sheet flow lengths used that exceed 50 feet.

☑ TR-20 printout showing input listing and a minimum output of the summary tables. The minimum required output is listings and summary tables for the pre-development, post-development, and post-development-with-control for all required storms. These printouts should document any claim of zero discharge increase for all required storms.

☑ The written report should state the initial conditions and storm frequencies to be analyzed. Include a summary table showing the pre-development, post-development, and designed system peak discharges for all design frequencies.

Common Questions and Answers About Urban Hydrology for Small Watersheds, TR-55

General

Q. What is the minimum acceptable drainage area for the procedure?
A. The procedure does not have a drainage area limit. It is governed by a minimum time of concentration of 0.1 hours.

Q. What rainfall distribution should be used for Massachusetts?
A. All of Massachusetts is covered by the Type III rainfall distribution. This distribution represents the influence of thunderstorms and tropical storms (e.g. hurricanes) along the coast.

Q. What is the difference between the Type II and Type III rainfall distributions?
A. The Type III distribution is a little less intense than the Type II distribution. The Type III distribution reduces the peak discharges by 34 percent for short time of concentrations of 0.1 hours, by 17 percent for a Tc of 1.0 hours, by 8 percent for a Tc of 3 hours, and approximately the same for time of concentrations of 7 to 10 hours.

Time of Concentration

Q. How do you handle time of concentrations less than 0.1 hours?
A. The procedure has a minimum time of concentration of 0.1 hour. If the computed Tc is less than 0.1 hour, use the minimum value of 0.1 hour. The lower limit is consistent with the available rainfall intensity information from the National Weather Service. The rainfall distribution curve incorporates the high intensity rainfall storm having a 5-minute duration.

Q. What is the acceptable limit for the length of sheet flow?
A. The procedure designates a maximum limit of 300 feet for sheet flow. Considering the definition of sheet flow as flow on a plane surface, a more practical limit in the northeast is 50 to 100 feet.

A good example of sheet flow is flow from the crown of a football field to the edge of the field, where the flow becomes concentrated in a grass swale. In woods the sheet flow length is also short because flow can be diverted by stonewalls, fallen trees, and tree roots. Considering the contributing area represented by sheet flow in proportion to the total drainage area, the travel time for sheet flow should be a small part of the total time of concentration. If the sheet flow length is greater than 10 percent of the total hydraulic length for the watershed or subarea, re-evaluate the sheet flow and travel time calculations.

Q. For sheet flow, should a surface cover of "woods with dense underbrush" be used?
A. This surface cover should be avoided, because the "n" value for this cover type is extrapolated from research data and does not represent typical conditions in the Northeast.

Q. Does shallow concentrated flow need to be used in the time of concentration calculations?
A. The method for shallow concentrated flow is used to calculate the travel time for the transition between sheet flow and open channel flow. If cross section information is available for the shallow concentrated flow segments, they can be treated as open channel flow for calculating travel time.

Q. How can USGS quad sheets be used to calculate time of concentrations?
A. The first segment can be a 50-foot length for sheet flow at the top of the watershed. Shallow concentrated flow will represent segments across parallel contour lines and defined watercourses on the maps. Open channel flow will be used for streams indicated by blue lines on the maps. A field visit of the area should be made to check the flow path and obtain information on the hydraulic characteristics of the channel. This information should include measuring the top width and depth of the channel for bank-full conditions.

Q. Can the upland method (Figure 15.2 in NEH-4) be used to calculate time of concentrations?
A. This method was originally developed for estimating time of concentrations in small rural watersheds. Based on more recent research and analyses, the sheet flow equation in TR-55 has superseded the upland method.

Q. Can other methods be used to calculate time of concentration?
A. The recommended method for calculating time of concentration is the stream hydraulics method. Travel times are calculated based on flow characteristics for each segment in the flow path. Other methods can be used, but they should be checked to see if the results are realistic for the site conditions. The same method should be used when analyzing existing and developed situations.

Hydrographs

Q. Can the hydrograph developed by the Tabular Method be used for detention basin routing?
A. The composite hydrograph developed by the Tabular Method is only a partial hydrograph at the design point based upon rounded time of concentration and travel time values in the tables. The partial hydrograph can be extrapolated to get a total hydrograph for routing by other methods, but this is still an approximation of the entire

hydrograph. If hydrographs are needed within the drainage basin or a more precise hydrograph is needed, another hydrologic method should be used such as TR-20.

Q. Does the Tabular method consider reach routing?
A. The subarea hydrograph is translated downstream based on the travel time for the reach. The method does not consider storage routing in the reach. Floodplain storage in a reach will reduce the peak flow similar to reservoir routing, as well as lag the timing of the peak. If reach storage routing needs to be considered, use the TR-20 hydrology model.

Storage Effects

Q. Can you account for pond and swamp storage within the drainage basin?
A. The Graphical Method has an adjustment factor to account for ponds and swarms spread throughout the basin and not in the time of concentration flow path. In both the Graphical and Tabular Methods, the storage effects within the time of concentration flow path can partially be accounted for by increasing the travel time for the segment, based upon typical pond routings.
The TR-20 hydrology model should be used in order to analyze the actual effects of pond and swamp storage within the basin by routing each storage area.

Q. Can you get a hydrograph with the TR-55 storage routing method?
A. The method just determines the peak outflow or total storage volume required for a detention basin. It is based on average storage and routing effects for many structures and is on the conservative side. If an outflow hydrograph or a more refined storage analysis is needed, the inflow hydrograph needs to be routed by other procedures. The Tabular Method can be used to create an approximate inflow hydrograph. The TR-20 hydrology model can be used to create an inflow hydrograph, conduct storage routings of a detention basin, and calculate the outflow hydrograph.

References

Gustafson, C. J., and L. N. Boutiette, Jr., ***Controlling Surface Water Runoff***, Soil Conservation Service, Amherst, MA, 1993.

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U.S. Department of Agriculture, , Washington, DC, Engineering Field Handbook, Chapter 2, ***Estimating Runoff and Peak discharge***.

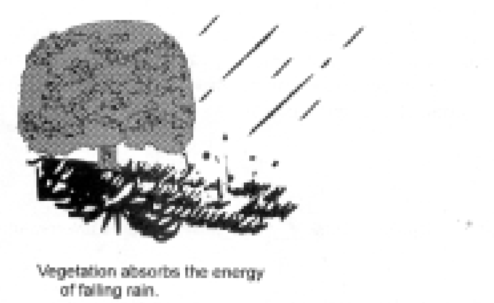
U.S. Department of Agriculture, Soil Conservation Service, Washington, DC, ***Urban Hydrology for Small Watersheds, Technical Release 55***, June, 1986.

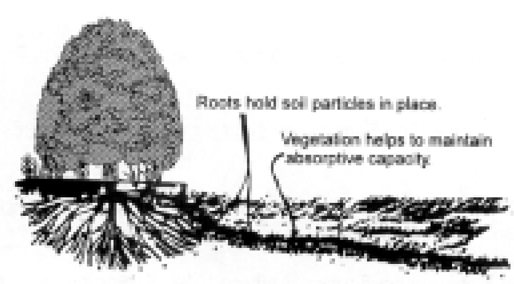
U.S. Department of Agriculture, Soil Conservation Service, Amherst, MA, ***Supplement to the TR-55 Hydrology Procedure***, 1992.

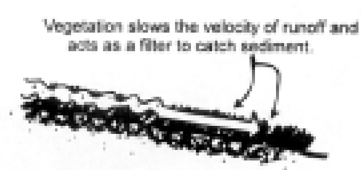
Plants, Vegetation, Soil Covers

Vegetation protects the soil surface from raindrop impact, a major force in dislodging soil particles and moving them downslope. It also shields the soil surface from the scouring effect of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity. Vegetative cover is relatively inexpensive to achieve and tends to be self-healing; it is often the only practical, long-term solution to stabilization and erosion control on most disturbed sites in Massachusetts.

The shielding effect of a plant canopy is augmented by roots and rhizomes that hold the soil, improve its physical condition, and increase the rate of infiltration, further decreasing runoff. Plants also reduce the moisture content of the soil through transpiration, thus increasing its capacity to absorb water.







Planning from the start for vegetative stabilization reduces cost, minimizes maintenance and repair, and makes erosion and sediment control measures more effective and less costly to maintain. Final landscaping is also less costly where soils have not been eroded, slopes are not too steep, and weeds are not allowed to proliferate.

Design projects so that only the area that is totally necessary is disturbed. The existing natural areas provide low-maintenance landscaping, shade, and screening, and soil stability. Large trees increase property value, but must be properly protected during construction.

Besides preventing erosion, healthy vegetative cover provides a stable land surface that absorbs rainfall, cuts down on heat reflectance and dust, restricts weed growth, and complements architecture. It creates a pleasant environment, and an attractive site. Property values can be increased dramatically by small investments in erosion control. Vegetative cover and landscaping represent only a small fraction of total construction costs and contribute greatly to the marketing potential of a development.

Site Considerations

Species selection, establishment methods, and maintenance procedures should be based on site characteristics including soils, slope, aspect, climate, and expected management.

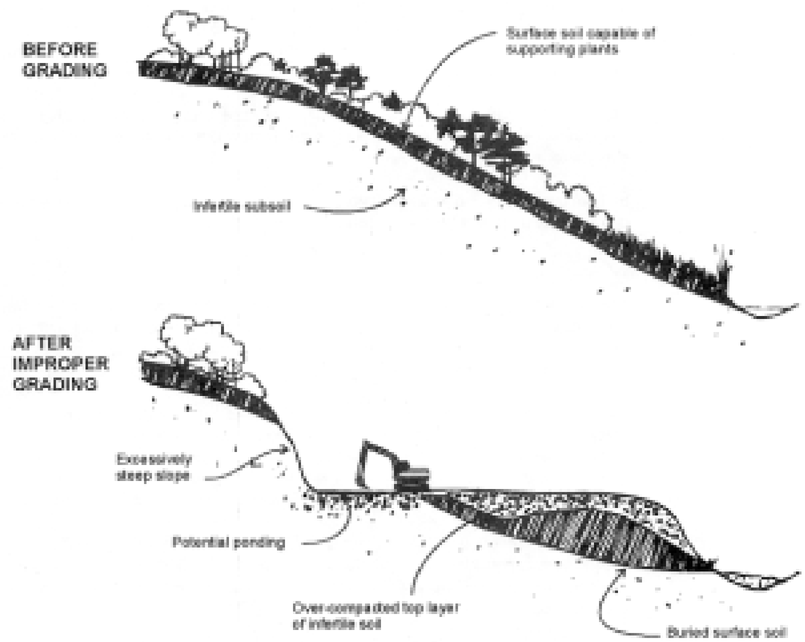
Soils

Many soil characteristics - including texture, organic matter, fertility, acidity, moisture retention, drainage, and slope - influence the selection of plants and the steps required for their establishment.

Nature of Disturbed Soils

Most disturbed sites end up, after grading, with a surface consisting of acid, infertile subsoil materials that lack nutrients necessary for supporting plant growth. Such soils may not be capable of supporting the dense growth necessary to prevent erosion.

Construction activities further decrease soil productivity by increasing compaction, making slopes steeper, and altering drainage patterns. Topsoiling, addition of soil amendments, and special seedbed preparation are generally required. Some native plant species are better suited to these conditions.



Soils Investigation

The vegetative plan should be based on thorough soil sampling and testing in the area of planned construction. Different soils should be sampled separately. Contact the local Conservation District office for suggestions on providers of these services. Test results should include lime and fertilizer recommendations. Fertilizing according to the soil test ensures the most efficient expenditure of money for fertilizer and a minimum of excess fertilizer to pollute streams or groundwater. Soil sampling should begin well in advance of planting because 1 to 6 weeks are required to obtain soil test results.

Information on the soil type is useful in selecting the plants to be used. Native plants growing on similar soils will be good candidates for revegetation.

Wet and dry areas should be checked at the time of maximum wetness and when the dry areas can be differentiated from the wet ones; making it possible to place plants in the microsites for which they are best adapted.

Soil Limitations

Certain soil factors are difficult to modify and can impose severe limitations on plant growth. These include such things as rooting depth, stoniness, texture, and properties related to texture such as organic matter content, and water- and nutrient-holding capacity.

Extremely coarse (gravelly) textures result in droughtiness and nutrient deficiencies. Fine textures, on the other hand, impede infiltration and decrease permeability, thereby increasing the volume of runoff. Light sandy soils may need special treatment with mulches or tackifiers to stabilize them sufficiently to allow plant establishment. Other soils may have a hardpan that limits water and root penetration.

Toxic levels of elements such as aluminum, iron, and manganese are limiting to plant growth. These become less soluble as the pH is raised, however, so that toxicity problems can usually be eliminated by liming.

Soil survey reports may refer to “poor,” “severe,” and “droughty,” soils. These are soils that require special treatment beyond routine tillage and fertilization.

Slope

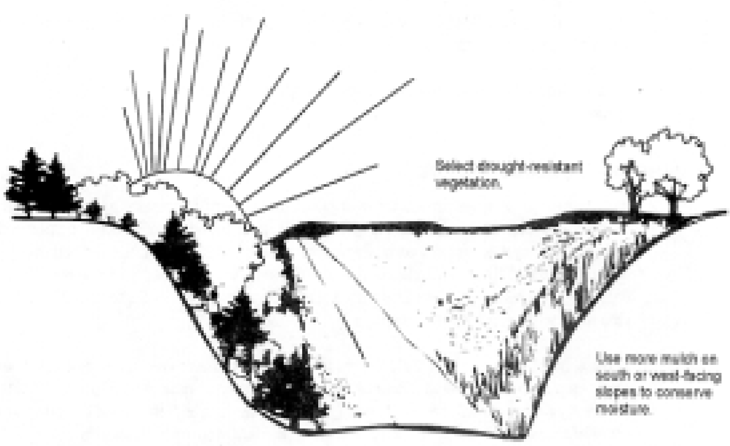
The steeper the slope, the more essential a vigorous vegetative cover is. Good establishment practices, including seedbed preparation, quality seed, lime, fertilizer, mulching and tacking are critical. The degree of slope may limit the equipment that can be used in seedbed preparation, planting, and maintenance; steep slopes also increase costs.

The severity of past erosion will indicate the degree of mechanical stabilization and slope preparation necessary for plant establishment. Shallow surface erosion will indicate the need for maximum surface plant cover. More deep-seated erosion will indicate the need for a high percentage of deep-rooted species. Relatively small rills and gullies will be smoothed as a matter of course during construction, whereas large gullies may need to be reworked with heavy equipment.

Slope angles steeper than 30-34 percent are difficult to revegetate. Steep slopes should be laid back whenever possible. Vegetation establishment is difficult at best on the tops of cuts. Rounding improves the chances of successful revegetation and minimizes chances of future undercutting.

Aspect

Aspect affects soil temperature and available moisture. South- and west-facing slopes tend to be hotter and drier, and often require special treatment. For example, mulch is essential to retain moisture, and drought-tolerant plant species should be added to the seed mixture. South- and west-facing slopes also may be subject to more frost heaving due to repeated cycles of freezing and thawing.



Temperatures are lower on north- and northeast-facing slopes than on south- and west-facing slopes. Colder temperatures lead to lower evapotranspiration values which result in more available water for plant growth. The effective growing season is reduced somewhat, however; soil temperatures are lower, affecting seed germination, and the possibility of frost damage is greater.

Climate

Climatic differences determine the appropriate plant selections based on such factors as cold-hardiness, tolerance to high temperatures and high humidity, and resistance to disease. Native plant lists give historic information on plants known to have survived in regions over centuries.

Microclimate

Valleys, draws, and low spots will have different microclimates from immediately adjacent higher areas. They will tend to have higher soil moisture because of higher water tables. They will be colder than adjacent higher ground. These conditions will affect plant performance in the same way that they do on slopes of different aspects.

Exposure to winds will vary from site to site in a general area. The winds may occur in either summer or winter or both. Wind increases evapotranspiration and reduces the effective water availability. Summer winds will make plant establishment more difficult, and winter winds may increase winter damage.

Soil pH

Soil pH may limit choices of plant species. Some plants require acid soils, some alkaline, and some are tolerant of a wide range of pH. High soil pH (7.5 and above) or low pH (4.5 or below) may restrict availability of plant nutrients or may make toxic ions available. Extremely low pH levels will increase availability of aluminum, and manganese and other metal ions that are toxic to plants. The pH in surface soils may be satisfactory for plant growth, but highway cuts may expose strata with abnormally high or low pH levels.

Management

When selecting plant species for stabilization, consider post-construction land use and the expected level of maintenance. In every case, future site management is an important factor in plant selection.

Where a neat appearance is desired, use plants that respond well to frequent mowing and other types of intensive maintenance.

At sites where low maintenance is desired, longevity is particularly important. Try to use native species.

Seasonal Considerations

Newly constructed slopes and other unvegetated areas should be seeded and mulched, or sodded, as soon as possible after grading. Where feasible, grading operations should be planned around optimal seeding dates for the particular region. The most effective times for planting perennials generally extend from April through May and from August through September. Outside these dates the probability of failure is higher. Late summer (August 15 - September 30) is the best period to establish grass/legume seedings.

If the time of year is not suitable for seeding permanent cover (perennial species), a temporary cover crop should be planted. Otherwise, the area must be stabilized with gravel or mulch. Temporary seeding of annual species (small grains, Sudangrass, or German millet) often succeeds at times of the year that are unsuitable for seeding permanent (perennial) species,

Dormant seeding can be made from the end of November through March. This type of seeding needs to be adequately protected with mulch, or better yet, erosion control fabric.

Seasonality must be considered when selecting species. Grasses and legumes are usually classified as "warm" or "cool" season in reference to their season of growth. Cool season plants produce most of their growth during the spring and fall and are relatively inactive or dormant during the hot summer months, therefore late summer into early fall is the most dependable time to plant them. Warm season plants greenup late in the spring, grow most actively during the summer, and go dormant at the first frost in fall. Spring and early summer are preferred planting times for warm-season plants.

Plant Species

Species selection should be considered early in the process of preparing the erosion and sedimentation control plan. For practical, economical stabilization and long-term protection of disturbed sites, species selection should be made with care. Many widely occurring plants are inappropriate for soil stabilization because they do not protect the soil effectively, or because they are not quickly and easily established. Plants that are preferred for some sites may be poor choices for others; some can become troublesome pests.

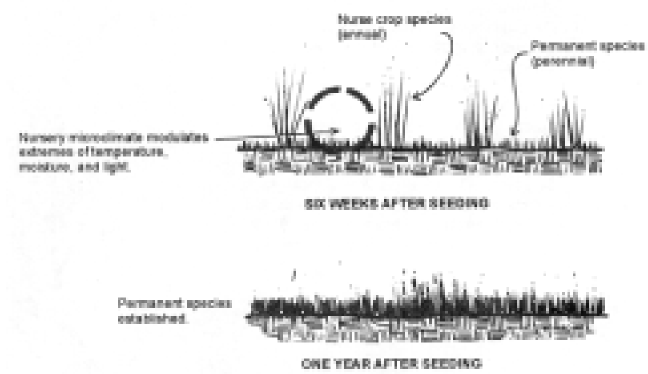
Initial stabilization of most disturbed sites requires grasses and legumes that grow together without gaps. This is true even where part or all of the site is planted to trees or shrubs. In landscape plantings, disturbed soil between trees and shrubs must also be protected either by mulching or by permanent grass-legume mixtures. Mulching alone is an alternative, but it requires continuing maintenance.

Mixtures vs. Single-Species Plantings

Single-species plantings are warranted in many cases, but they are more susceptible than mixtures to damage from disease, insects, and weather extremes. Also, mixtures tend to provide protective cover more quickly. The inclusion of more than one species should always be considered for soil stabilization and erosion control.

Addition of a quick-growing annual provides early protection and facilitates establishment of perennials. More complex mixtures might include a quick-growing annual, one or two legumes, and one or two perennial grasses.

Companion or "Nurse" Crops



The addition of a "nurse" crop (quick-growing annuals added to permanent mixtures) is a sound practice for soil stabilization, particularly on difficult sites - those with steep slopes; poor, stony, erosive soils; late seedings, etc. - or in any situation where the development of permanent cover is likely to be slow. The nurse crop germinates and grows rapidly, holding the soil until the slower growing perennial seedlings become established. Seeding rate of the nurse crop must be limited to avoid crowding, especially under optimum growing conditions.

Legumes: Nitrogen-Fixing Plants

Legumes should be used when practical because of their ability to improve sites by adding nitrogen. They should be inoculated at planting with appropriate bacteria. Commercial inoculants are available for many species. Native species for which no commercial inoculant is available should be inoculated by incorporating soil from native stands in the soils in which transplants are grown, or by topdressing with native soils.

Annuals

Annual plants grow rapidly and then die in one growing season. They are useful for quick, temporary cover or as nurse crops for slower-growing perennials.

Winter rye

Winter rye (grain) is usually superior to other winter annuals (wheat, oats, crimson clover, etc.) both for temporary seeding and as a nurse crop in permanent mixtures. It has more cold hardiness than other annuals and will germinate and grow at lower temperatures. By maturing early, it offers less competition during the late spring period, a critical time in the establishment of perennial species.

Rye grain germinates quickly and is tolerant of poor soils. Including rye grain in fall-seeded mixtures is almost always advantageous, but it is particularly helpful on difficult soils and erodible slopes or when seeding is late. Overly thick stands of rye grain will suppress the growth of perennial seedlings. Limit seeding rates to the suggested level. About 50 pounds per acre is the maximum for this purpose. Where lush growth is expected, that rate should either be cut in half, or rye grain should be eliminated from the mixture.

Annual ryegrass

Annual ryegrass provides dense cover rapidly, but may be more harmful than beneficial in areas that are to be permanently stabilized. Annual ryegrass is highly competitive, and if included in mixtures, it crowds out most other species before it matures in late spring or early summer, leaving little or no lasting cover. It can be effective as a temporary seeding, but if allowed to mature the seed volunteers and seriously interferes with subsequent efforts to establish permanent cover. Winter rye (grain) is preferable in most applications.

German millet

German millet is a fine-stemmed summer annual, useful for temporary seeding, as a nurse crop, and for tacking mulch. It is better adapted to sandy soils than are the Sudangrasses. Normal seeding dates are between the last frost in spring and the middle of August.

Sudangrass

Only the small-stemmed varieties of Sudangrass should be used. Like German millet, Sudangrass is useful for temporary seeding and as a nurse crop, but it is adapted to soils higher in clay content.

Perennials

Perennial plants remain viable over winter and initiate new growth each year. Stands of perennials persist indefinitely under proper management and environmental conditions. They are the principal components of permanent vegetative cover. Wherever possible, use native species for plantings

Native vs. Non-Native Species

In general, if a plant is indigenous to a given area of the country, it is a native. Some define “native” more narrowly, even to a plant indigenous to a given site.

Non-native plant species have been used to control erosion since the dust-bowl days of the 1930s. They are vigorous, establish their dense root systems in the soil, and stabilize bare earth.

These non-native plants, however, can be very competitive. Introduced, invasive plants can cause many more problems than they will solve. They crowd out native species and reduce plant diversity. They are capable of taking over landscapes, resulting in a monoculture. Natural ecosystems are degraded and the site may become vulnerable to disease and pest threats.

Even when non-natives are only a minor component of the seed mix, they tend to outperform and overrun natives for the first few years. Then, over the long term, 10 to 15 years, introduced species may weaken and die out. Native species generally have long-term superiority over non-native species.

Non-natives typically offer two features often lacking with native species; they are readily available and much cheaper than natives. Compared to earthmoving costs on most sites, however, the cost of seed is very small.

In addition to price and availability, project objectives can also affect the decision to plant native or introduced species. For example, an introduced species may be the only seed available that will establish soon enough to protect from a fast-approaching winter and its storms.

Native Species

Native plants evolved under local soil and climatic conditions and are best adapted to sites similar to those on which they grow. They are adapted to annual fluctuations in rainfall and temperatures. Natives often have minimal fungus and insect problems or exist in reasonable balance with such pests. At a proper site, they become established, reproduce, and perform satisfactorily without supplementary irrigation or maintenance. Native plants blend aesthetically with the surrounding vegetation.

Using native plants maintains the genetic integrity of plant populations in the area. Native plants have adapted to an environment; an important consideration in establishing environmentally-sound and low maintenance landscapes.

Native plants are especially adapted to poorer soils and may require no fertilizers or pesticides. Some of them, e.g. sweetfern, refuse to grow well, and sometimes not at all, if given fertilizer. Native plants are also adapted to the soils and require little or no watering.

Retaining native buffers produces great benefits for wildlife. Establishing islands of vegetation offers increased biotic diversity and helps produce wildlife benefits.

Native species maintain natural diversity providing an alternative to boring landscapes which routinely appear around shopping centers, industrial buildings and condominiums. Some people feel that disturbed land should reflect the natural plant systems in place before the site was disturbed.

Native species may be slow to establish, but this is not a significant drawback. Some sort of mulch is usually used anyway to control erosion on newly-seeded disturbed areas. Generally, it takes a year or so before native species can begin protecting the soil, but within two or three years they can provide as much cover as non-natives. Native species are becoming popular for highway embankments, utility corridors, and other development sites.

The availability of native planting stock, seeds or transplants, is sometimes limited because of lack of demand or limited knowledge about propagation methods and cultural requirements. There may be limited numbers of species adapted to artificially altered or disturbed sites. The use of introduced species may be necessary when the numbers of suitable plant species is limited. Increased demand for native plant materials, however, will encourage nursery suppliers to stock them.

Non-Native Species

Other terminology: "Introduced," "Exotic."

The number of introduced species with potential for revegetation of any particular site is usually greater than the number of native species. The commercial availability of introduced species is usually greater because they are the plants of our cultivated landscapes, and more information is usually available about their propagation and cultural requirements.

Introduced plants may sometimes be better adapted to an area than native plants. This may be so because of random chance in evolution or because evolutionary changes in the native plant spectrum have not occurred as rapidly as climatic changes. Introduced plants sometimes have fewer problems than natives because diseases and pests have been "left behind." Introduced species may be more pleasing, aesthetically, than many natives in urbanized areas because they blend with the surroundings.

There are now about 900 alien or introduced plant species in Massachusetts, about a third of the state's flora. In their native habitats, many of these plants were restrained by the pests and diseases that evolved with them over thousands of years. When brought into a new environment, however, they are not bound by natural restraints. The characteristics of disease resistance, fast growth, abundant reproduction, easy propagation, wildlife food production allow them to outcompete and overwhelm native plants.

Native Grasses

Big Bluestem* *Andropogon gerardii*

Big Bluestem is a long-lived perennial, warm-season native grass that has excellent drought resistance. It is being used in critical area seedings where cool season species cannot tolerate the high temperatures or coarse soils. It is selected for the Northeast for its standard durability. It grows from 5 to 7 feet tall and is very leafy.

Big Bluestem is an erosion control plant for sand and gravel pits, mine

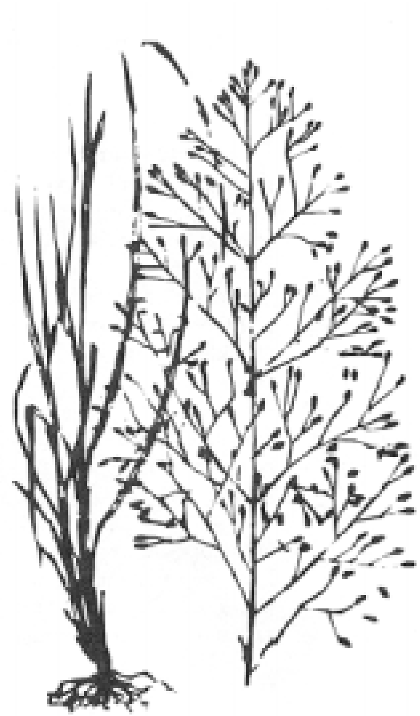
spoil, and road sides. It is also excellent cover for wildlife.
Seed Big Bluestem in the early spring, taking care to compact the soil after seeding. Seed at 15 to 20 pounds per acre. It is slow to germinate and establish the first year but will produce fair to good cover by the end of the second year.
Big Bluestem grows well on hot, droughty sites. It tolerates medium to low fertility, acid, sandy, loamy, and clayey soils, has poor shade tolerance and prefers well-drained sites.

Little Bluestem* *Schizachryrium scoparium*
Little Bluestem is a persistent, low maintenance, warm-season bunch type perennial grass. As a native grass, Little Bluestem is almost always incorporated into mixes used to produce longliving native stands. Used as a cover plant on slopes and road banks.
Grows well on either uplands or lowlands. It is drought tolerant and adapted to wide variety of soil types, but is not very shade tolerant. Its russet-red color in fall and winter make it desirable for landscaping.
Height: 1 - 3’
Seedling vigor is weak, and control of competition is necessary. For best results, soil pH should be between 5.5 to 6.5.

Deertongue *Dichanthelium clandestinum*
Deertongue is a native warm-season bunch grass that grows to a height of 1-1/2 to 3 feet. It has broad, short leaves and a strong, fibrous root system. It will tolerate sites with a pH as low as 3.8 and aluminum concentrations which limit growth of other species.
Deertongue is excellent for revegetating acid mine spoil and ground cover for erodible sandy areas, such as road banks, ditch banks, and gravel pits. The seeds are eaten by many species of birds.
Deertongue grows in low-fertility, acid, loamy, and sandy soils. It has excellent drought tolerance, poor shade tolerance, and tolerates moderately well drained soil.
Establish by seeding early in spring. Seed 12 to 15 pounds per acre. It can be seeded with 10 to 15 pounds of tall fescue or perennial ryegrass for quick cover. It will produce complete cover in 2 years.

Eastern Gamagrass* *Tripsacum dactyloides*
A native, warm-season, perennial, tall grass that grows in large clumps from 1 - 4 feet in diameter on stems 3 - 9 feet tall. Regrows vigorously after mowing. Height: 3 - 9’

Indiangrass* *Sorghastrum nutans*
Indiangrass is a native, perennial warm season bunch type grass that grows 3 to 5 feet in height and produces most heavily from July through September.
Indiangrass is excellent for wildlife habitat, critical area seeding and as roadside beautification and erosion control. Indiangrass is winter hardy. It grows best in deep, well-drained soil, but is tolerant of moderately wet soil.



Tumble Lovegrass* *Eragrostis Spectabilis*
Fine-leaved bunch grass; tan, purplish, dainty, feathery seed heads. Grows best in sandy soil. Height: 10 - 12"

Annual Ryegrass *Lolium multiflorum*
Annual Ryegrass is a short lived, annual grass useful for obtaining quick ground cover for lawns, slopes, and mine spoils. It usually germinates in 4 to 7 days, making it very effective for soil erosion. It is adapted to a wide range of soil conditions. Seed in mixtures at a rate of 20 to 30 pounds per acre.

Switchgrass* *Panicum virgatum*
Switchgrass is a medium height to tall perennial grass that grows native in nontidal marshes, stream banks, lake shores, moist woods, and fresh tidal marshes.
Grows under a wide range of soils: low-fertility, acid, sandy, clayey, and loamy soils. Winterhardy, and has excellent heat and drought tolerance, low shade tolerance. Does well on moderately well drained soils. Feathery, open heads; orange-yellow in winter.
Switchgrass is a valuable soil stabilization plant on strip mine spoil, sand dunes, dikes, and other critical areas. It is also suitable for low windbreak plantings in truck crop fields and provides food and excellent nesting and fall and winter cover for wildlife.
Switchgrass requires 1 to 2 years to become totally established. Little or no management is required after establishment.
Height: 4 - 5'
Varieties:
"Blackwell" - reclamation (performs better under low maintenance and wet soils), 4 to 5 feet tall.
"Shelter" - Plant Material Center released variety, wildlife cover, 4 to 6 feet tall. Besides being a good plant for revegetation of surface mine spoil, sand and gravel pits, and steep, sandy roadside cuts, Shelter is an excellent wildlife plant that provides year-round cover and food during the fall and winter. Its stiff stems resist lodging and will recover to an upright position after winter snowstorms.

Canada Wildrye *Elymus canadensis*
A cool season, native grass that prefers moist sites. This perennial bunch grass has very good seedling vigor and early spring growth, which make it easy to establish and cover ground rapidly. (See also Wetland Grasses.)

Riverbank Wild Rye *Elymus riparius*
This rye grows along nontidal shores, wet woods, meadows, prairies and also fresh tidal marshes. With the exception of having a somewhat nodding spike, this perennial grass has very similar characteristics to Virginia Wild Rye. (See also **Wetland Grasses**.)

Virginia Wildrye *Elymus virginicus*
A cool-season, native grass that tolerates both moist and dry sites, shade and full sun. Medium height perennial. While it can be planted alone, it makes an excellent component in a flood plain mix or a habitat mix. (See also **Wetland Grasses**.)

Broomsedge *Andropogon virginicus*
Broomsedge is a very hardy perennial which will tolerate both low pH and fertility. It is a clump type grass that will grow to a height of 1 to 3 feet. Mainly found in upland wet areas, an excellent ground cover, and provides feed for game and songbirds.
**Denotes warm-season grass.*

Other Grasses

Kentucky bluegrass
Kentucky bluegrass has higher lime and fertility requirements than some other perennial grasses. Bluegrass spreads by strong rhizomes and, where adapted, is an excellent soil stabilizer, readily filling in damaged spots. It has undergone intensive breeding activity in recent years, resulting in varieties with more heat tolerance and resistance to hot-weather diseases.

Creeping Red Fescue *Festuca rubra*
Creeping Red Fescue grows in medium fertility, slightly acid, clayey and loamy soils. It has fair drought tolerance, excellent shade tolerance and requires well drained soils. It will produce a complete cover of attractive, uniform sod in one year.
It is a cool season, fine textured, lawn grass that has narrow, bright green leaves. Similar to bluegrass.

It spreads by short underground stems to produce a tight, dense sod for stabilizing road banks and north facing slopes. Above-ground stems have a reddish tint and grow to a height of 18 inches. Red fescue may turn brown in hot, dry summer weather but will recover in the fall.

Red fescue is established by seeding on a firm seed bed in spring or early fall. It is usually used in a mix constituting 25 to 60 percent of the total and seeded at 3 to 5 pounds per thousand square feet. 'Pennlawn' is the most popular variety available.

Red Top *Agrostis alba*

Redtop is a tough, cool-season perennial grass tolerant of infertile, droughty, somewhat acid soils.

Red Top will provide quick cover for critical areas such as grassed waterways, road banks, diversions, and strip mine spoils. Other uses include erosion control, and temporary grass in turf seedings. It can be a useful component of mixtures on dry, stony slopes.

It is a fast-starting, sod-forming grass that is about 18 inches tall at maturity. It will produce effective ground cover the first year. Because it is fast starting and tolerates cold temperatures and poorly drained soils, red top is widely used as a component in mixtures planted on disturbed sites in Northeast.

Red Top grows in clayey, loamy, and sandy soils. It has poor shade tolerance.

Perennial Ryegrass *Lolium perenne*

Perennial Ryegrass is a fast growing, short term grass used for soil stabilization and improvement and lawns. Rapid growth rate is the primary conservation value, producing complete cover in a few months.

It grows in medium fertility, acid, clayey and loamy soils. It has fair drought tolerance, poor shade tolerance and will tolerate somewhat poorly drained soil. It grows to a height of 1 to 2 feet. Many long, narrow leaves extend from the base of the plant.

Oftentimes, seeding mixtures containing red fescue, redtop, Canada bluegrass, or perennial ryegrass are used; as they provide good short term erosion protection, but will allow indigenous plants to eventually naturalize the site.

When used in mixes, ryegrass should not exceed 20% of the mix. The turf varieties are longer lived and include 'Manhattan II,' 'Pennant' and 'Pennfine.'

Native Legumes

Roundhead lespedeza *Lespedeza capita*

Roundhead lespedeza is common on sand dunes, dry fields, sandy woods, and roadsides. It is important for soil stabilization. It flowers from June to September. The foliage is eaten by deer and turkeys. Seeds are consumed by upland birds and rodents.

Roundhead lespedeza seed is commercially available. The seed should be scarified to assure high rates of germination. Life span: perennial.

Panicled tickclover *Desmodium paniculatum*
Panicled tickclover is infrequent to locally common in dry woods, especially if the soil is rocky or sandy. It occasionally is found on roadsides. It flowers from July to September. It is consumed by domestic livestock and deer while it is immature. Rodents and birds utilize the seeds.
Seed is not commercially available. Panicled tickclover has no value for landscaping or erosion control. Life span: perennial.

Canada tickclover *Desmodium canadense*
Canada tickclover is infrequent to common in prairies and thickets and along rivers and roads. It is most common in sandy soil. It flowers from July to September. Foliage is eaten by deer and rabbits. Many kinds of rodents and birds eat the seeds.
Canada tickclover is poor for erosion control. It has no value for landscaping. Life span: perennial.

Yellow wildindigo *Baptisia tinctoria*
Yellow wildindigo is scattered to common in open woods and clearings. It flowers from late May through July. Life span: perennial.
Seed is seldom commercially available. Most seed is destroyed in the legume by weevils. Germination may be improved by scarification and stratification. It is an attractive landscape plant.
Caution must be taken, because it may be poisonous to humans.

Groundnut *Apios americana*
Groundnut is infrequent to locally common in moist soils of ravines, pond and stream banks, and thickets. Life span: perennial.
Seeds are eaten by upland game birds and song birds. Tubers are eaten by mice, rabbits, and squirrels.
Seed is not commercially available. The plant has no potential for landscaping, although it holds promise as a tangle vine for erosion control.

Beach pea *Lathyrus japonicus*
Native to coastal Massachusetts. Adapted to beach/dune sites. Life span: perennial.
Seeded in moist, inter-dune areas.

Bush clover *Lespidesa capitata*
Bush clover may be used in locations where Sericea Lespedeza would previously have been recommended.

Native Ground Covers

Wintergreen *Gaugtheria paceumbens*
6" (Height) x 3' (Spread)
Acid, average/dry soil. Partial shade. Evergreen, reddish in winter, pinkish-white flowers, red berries.

Bearberry *Artostaphylus uva-ursi*
9" x 3'
Sandy soil. Full sun to partial shade. Evergreen, bronze in fall, urn-shaped flowers, red berries, sturdy and reliable.

Cranberry *Vaccinium macrocarpon*
4" x 3'
Cool, moist soil. Full sun. Evergreen, dense, glossy, red edible fruit.

Bunchberry *Cornus Canadensis*
6"
Moist, acid soil. Partial/full shade. Excellent under pines, broad-leaved evergreens, lovely fruit, whorled leaves, beautiful.

Trailing arbutus *Epigaea repens*
5" x 2'
Acid, sandy soil with oak leave/pine needle mulch. Evergreen; dainty, fragrant flowers, does not tolerate disturbance. State flower of Massachusetts.

Virginia creeper *Parthenocissus quinequefolia*
35'
Vine/ground cover. Tolerant as to soil. Sun/shade. Excellent low-maintenance cover, does not need support, red in fall, blue berries.

Coastal Dune Vegetation

Revegetation of construction sites requires special attention to selection of plant species. In the foredune area there are only a few plants that tolerate the stresses of the beach environment. They must be able to survive salt spray, sand blasting, burial by sand, saltwater flooding, drought, heat, and low nutrient supply.

'Cape'American beachgrass

American beachgrass is a cool-season perennial dune grass; for dune building and as a stabilizer in the foredune zone. Easy to propagate, it establishes and grows rapidly, and is readily available from commercial nurseries.

It is an excellent sand trapper capable of growing upward with four feet of accumulating sand in one season. New plantings are usually effective at trapping wind-blown sand by the middle of the first growing season. Beachgrass is also a good plant for interior dune zones as well as other droughty, sandy sites inland.

American beachgrass is extremely valuable for initial stabilization and dune building in disturbed areas. It is severely affected by heat and drought and tends to deteriorate and die behind frontal dunes as the sand supply declines.

It is also susceptible to a fungal disease (Marasmius blight) and a soft scale insect (Eriococcus carolinae). Beachgrass plantings should, therefore, be reinforced with plantings of woody species such as beach plum or barberry. Interior dune areas are candidates for a wider variety of coastal woody shrubs.

Saltmeadow cordgrass

A warm-season perennial useful for transplanting on low areas subject to saltwater flooding. It is a heavy seed producer and is often the first plant on moist sand flats. It collects and accumulates blowing sand, creating an environment suitable for dune plants.

Saltmeadow cordgrass is easy to transplant on moist sites but does not survive on dry dunes. Plants should be dug from young, open stands. Survival of transplants from older, thick stands is poor. Nursery production from seed is relatively easy, and the pot-grown seedlings transplant well. Propagation by seed is possible, but the percentage of viable seed varies.

Beach plum

A shrub of the New England coastal areas, of special interest for its edible fruit. It grows well in sandy, dry, windswept sites, and produces a profusion of white flowers in early May. Beach Plum grows to about 6 feet in height and makes an excellent massed seaside planting or a hedge to prevent erosion because it can tolerate salt spray. Nursery grown plants are recommended, as transplanting from the wild is not often successful. Produces flowers and fruit in 3 to 4 years; matures in 7 to 8 years.

Beach Plum requires cross-pollination to insure fruit production so it is necessary to have more than one plant if plums are desired. Beach plum can be grown in areas other than coastal dunes. Grows in medium-fertility, acid, loamy, and sandy soils; excellent drought tolerance; fair shade tolerance; tolerates moderately well-drained soil.

Bayberry

Bayberry is a semi-evergreen shrub that grows to a height of 6 to 8 feet. Ideal for sunny, coastal sites. Grows in low-fertility, acid, clayey, loamy, and sandy soils; excellent drought tolerance, poor shade tolerance; tolerates moderately well-drained soil. Versatile for landscaping and revegetating, sand dunes and inland areas; berries provide food for birds. It can also help stabilize dry slopes prone to erosion.

Produces fruit in 3 to 4 years; matures in 7 to 8 years. Fruit appears only where both male and female shrubs are planted in the same area. Roots fix nitrogen, which helps bayberry grow in low-fertility soil. Establish by planting bare-root or container-grown seedlings 2 years old.

Bayberry does best in open sites. It can be rejuvenated by cutting it back hard, which stimulates underground lateral stem growth. Stems root at the nodes where new leaves form, and new plants can be established by pinning down a prostrate stem node tightly against the soil.

Rugosa Rose

Rugosa Rose produces large bushy masses of greenery topped by red and white blossoms from soil that is little more than loose sand. Spreading and sprawling, its six-foot branches covered with spines, the plant is a formidable barrier that deters trampling feet and anchors dunes.

It is useful for roadside and dunes, replacing plants which could not tolerate the abuse of pedestrian traffic.

Intertidal Vegetation

In saltwater areas, smooth cordgrass is transplanted in the intertidal zone from mean sea level to mean high water, and saltmeadow cordgrass from mean high water to the storm tide level. In brackish water areas (10 parts per thousand or less of soluble salts), giant cordgrass may be used in the intertidal zone. Greenhouse-grown seedlings of these plants can be obtained from commercial sources, but usually only on special order. Transplants may be dug from young, open natural stands of smooth and saltmeadow cordgrass.

Smooth cordgrass

Smooth cordgrass is the dominant plant in the regularly flooded intertidal zone of saltwater estuaries along the Atlantic and Gulf Coast of North America. It is adapted to anaerobic, saline soils that may be clayey, sandy, or organic. It will tolerate salinities of 35 parts per thousand (ppt) but grows best from 10 to 20 ppt.

Plant height varies from 1 to 7 ft depending on environmental conditions and nutrient supply. It produces a dense root and rhizome mat that helps prevent soil movement. Transplants can be obtained by digging from new, open stands of the grass or may be grown from seed in pots. Seed are collected in September and stored, covered with seawater, and refrigerated. The plants and seedlings grow rapidly when transplanted on favorable sites.

Saltmeadow cordgrass

A fine-leaved grass, 1 to 3 ft in height, that grows just above the mean high tide line in regularly flooded marshes, and throughout irregularly flooded marshes. It can be propagated in the same way as smooth cordgrass except that seed may be stored dry under refrigeration. A stand of saltmeadow cordgrass provides good protection from storm wave erosion.

Giant cordgrass

Grows in brackish, irregularly-flooded areas. Stems are thicker and taller than in the other cordgrasses, growing to a height of 9 to 10 feet. Seedlings are easy to produce in pots and these can be successfully transplanted, but survival of plants dug from existing stands is poor.

Salt grass *Distichlis spicata*

Salt grass is another appropriate plant for intertidal zones.

Native Shrubs

Bayberry *Myrica pensylvanica*
9' (Height) x 9' (Spread)
Sandy/clay soils. Full sun to half-shade. Excellent for massing, borders, foundation plantings.

Mountain Laurel *Kalmia latifolia*
11' x 11'
Acid, moist, well-drained soil. Sun/shade. Evergreen, magnificent in flower, exquisite in mass.

Common Buttonbush *Cephalanthus occidentalis*
9' x 16'
Moist soil. Sun. Loose in appearance; white, fragrant flowers; best for naturalizing in wet areas.

Pinxterbloom Azalea *Rhododendron nudiflorum*
9' x 9'
Dry, sandy, acid soil. Bright green foliage, yellow in fall, fragrant light-pink flowers, deciduous.

Roseshell Azalea *Rhododendron noxeum*
9' x 9'
Moist/dry soil. Deciduous, much-branched, bright pink flowers with clove-like scent.

American Elder *Sambucus canadensis*
9'x 6'
Moist/dry soil. White profuse flowers, edible fruit, good for naturalizing.

Hardhack Spirea *Spiraea tomentosa*
5' x 5'
Moist soil. Sun. Pink spike-like flowers, thicket of wand-like stems.

Canada Yew *Taxus canadensis*
5'x 7'
Moist, sandy soil. Needs winter shade. Evergreen, hardy; suitable for underplanting in cool, shaded situations.

Lowbush Blueberry *Vaccinium augustifolium*
2'x 2'
Dry, acid soil. Sun/partial shade. White flowers, sweet berry, lustrous blue-green foliage.

Highbush Blueberry *Vaccinium corymbosum*
9' x 10'
Dry, acid soil. Sun/partial shade. Excellent fall color, rounded, compact, edible fruit, white flower.

American Cranberrybush *Viburnum Viburnum milobum*
9' X 9'
Well-drained, moist soil. Sun/partial shade. Informal hedges; excellent flower, fruit, foliage.

Summersweet Clethra *Clethra alnifolia*
6' x 5'
Moist, acid soil. Sun/shade. White fragrant flowers, handsome foliage, pest-free.

Grey Dogwood *Cornus racerosa*
12' x 12'
Moist, well-drained soil. Sun/shade. (***See also Wetland Shrubs***.)

Beaked Filbert *Corylus cornuta*
6'x 6'
Well-drained, loamy soil. Sun/light shade. Interesting beaked fruits, refined, edible fruit.

Common Winterberry *Ilex verticillata*
8'x 8'
Moist, acid soil. Sun/partial shade. Shrub borders, massing waterside planting, male and female required for fruit, red fruit framed by snow. (***See also Wetland Shrubs***.)

Common Juniper *Juniperus communis*
7' x 10"
Dry soil. Sun. Useful for undergrowth and naturalized plantings, extremely hardy, evergreen.

Common Spicebush *Lindera benzdin*
9' x 9'
Moist, well-drained soil. Sun/half shade. Splendid plant in flower and fall color, ornamental fruit. (***See also Wetland Shrubs***.)

Bush Cinquefoil *Potentilla pruticosa*
3' x 3'
Moist, well-drained soil. Sun/partial shade. Low hedge, perennial border, yellow flowers, graceful appearance.

Blackhaw Viburnum *Viburnum prunifolium*
13'x 10'
Tolerant as to soil. Sun/shade. Massing, shrub border, stiffly branched, red in fall, white flowers.

Rugosa Rose (naturalized) *Rosa rugosa*
5'x 5'
Well-drained soil. Sun. Beautiful in foliage, flower, fruit, hedging, low maintenance, hardy, fragrant flowers.

Native Trees

Red maple *Acer rubrum*
50' (Height) x 50' (Spread)
Acid, moist soil. One of first trees to color in fall, dazzling fall color.

Sugar maple *Acer saccharum*
70' x 50'
Well-drained, slightly acid soil. Beautiful fall color, pleasing growth habit.

Shadblow *Amelanchier canadensis*
20' x 20'
Average/moist soil. White flowers, edible sweet fruit, yellow in fall.

Sweet birch *Betula lenta*
50'x 40'
Rich, moist, well-drained soil. Reddish-brown bark, best of birches for fall color.

Paper birch *Betula papyrifera*
60'x 30'
Well-drained, acid soil. Full sun. Handsome for bark and fall color, splendid in winter with evergreens.

Common choke cherry *Prunus virginiana*
25' x 22'
Well-drained soil. Sun to partial shade. Rounded crown, red/purple edible fruit, white fragrant flowers.

White oak *Quercus alba*
75' x 75'
Moist, well-drained acid soil. Sun. Majestic tree for large areas.

Northern red oak *Quercus borealis*
75'x 60'
Acid, well-drained soil. Shade tolerant. High wildlife value, ascending branches, globular.

Rosebay rhododendron *Rhododendron maximum*
20'x 10'
Moist, acid soil. Shade. Loose, open habit; large, evergreen leaves; rose flowers.

Pussy willow *Salix discolor*
25' x 6'
Moist soil. Sun. Multiple trunks, leggy, high wildlife value.

Canada hemlock *Tsula canadensis*
50' x 30'
Moist, well-drained, acid soil. Sun/shade. Evergreen hedges, graceful, does not tolerate wind or drought.

Nannyberry viburnum *Viburnum lentago*
20' x 15'
Moist/dry soil. Sun/shade. Durable naturalizing or shrub borders, white flowers, handsome fruit, good winter food for birds. (***See also Wetland Trees.***)

Shagbark hickory *Carya ovata*
70'x 35'
Adaptable to wide range of soils. Edible nuts, "shaggy" bark, picturesque. Use chips for barbecues.

Pagoda dogwood *Cornus alternifolia*
20'x 30'
Moist, acid, well-drained soil. Partially shaded. Horizontal, low-branched, excellent textural effects.

Flowering dogwood *Cornus florida*
40' x 40'
Acid, well-drained soil. Four-season character; flower, foliage, fruit, winter habit.

Witchhazel *Hamamelis virginiana*
25' x 20'
Moist soil. Sun/shade. Shrub border, fragrant flowers, yellow in fall. (***See also Wetland Trees***.)

Eastern red cedar *Juniperus virginiana*
45' x 14'
Moist soil. Sun. Windbreaks, hedges, reddish-brown bark, evergreen.

Eastern larch *Larix laricina*
60' x 25'
Moist, well-drained acid soil. Sun. Excellent in groves, horizontal, drooping branches, deciduous.

Eastern white pine *Pinus strobus*
70'x 30'
Tolerant as to soil. Sun/some shade. Handsome, beautiful hedge, graceful, plume-like branches.

Quaking aspen *Populus tremuloides*
40' x 25'
Tolerant as to soil. Narrow leaves flutter in breeze, yellow in fall.

Black cherry *Prunus serotina*
50'x 25'
Moist/dry soil. Sun. Oval-headed; lustrous, dark-green leaves, edible fruit.

Native Wetland Herbs and Grasses

Sweet flag *Acorus calamus*
Sweet Flag is a perennial herb usually 1 to 4 feet tall. It flowers from May to August and has a very pleasant aroma. It grows in shallow waters, nontidal marshes, wet meadows, and fresh tidal marshes.

Swamp Aster *Aster puniceus*
Swamp Aster is a popular wetland perennial herb. It differs from New England Aster in that it often has hairy, purplish stems. It blooms from July to October sporting a bluish, daisy-like flower. The Swamp Aster, also known as the Red Stalk or Purple Stemmed Aster, prefers very moist, swampy areas.

Nodding Bur Marigold *Bidens cernua*
Bur Marigold is an annual herb that reaches up to 3-1/2 feet tall. Its large, yellow, daisy-like flowers, which contain six to eight "petals," will nod as their maturity increases from July into October. It grows in freshwater marshes and along stream banks.

Beggar Ticks *Bidens frondosa*
Beggar-Ticks, also known to many as the Stick-Tight, is an annual herb reaching up to 4 feet. It produces small yellow to orange flowers from June to October. It is found in many wet areas including ditches, pastures, and wet meadows and fields.

Fringed Sedge *Carex crinita*
Fringed Sedge is a perennial grass like plant growing up to 4-1/2 feet high. It flowers from May through June and grows in fresh water marshes, wet meadows, forested wetlands, pond borders, and ditches.

Lurid Sedge *Carex lurida*
This sedge will reach up to 3-1/2 feet tall. It flowers from June into October and grows in freshwater marshes, wet meadows, forested wetlands, ditches, and pond borders.

Fox Sedge *Carex vulpinoidea*
Fox Sedge is very hardy, an ideal pioneer plant when establishing new wetlands. It is a perennial grass like plant reaching up to 3-1/2 feet tall. It flowers from June through August. It grows in fresh water marshes, wet meadows, and other wet places.

Grass-Leaved Goldenrod *Solidago graminifolia*
Grass Leaved Goldenrod is a perennial herb growing up to 4 feet tall. Small yellow flowers appear on the top of the stem from July through October. It grows in nontidal marshes and meadows, various open, moist or dry inland habitats and brackish tidal marshes.

Hop Sedge *Carex lupulina*
These sedges are perennial grasslike plants very common to wetlands. They add beauty as well as seed for ducks and other wildlife. They reach heights between 1- ½ to 3 feet tall and bloom from May to October. They grow well in open woodlands, seasonally flooded areas, standing water, and saturated soils.

Riverbank Wild Rye *Elymus riparius*
This rye grows along nontidal shores, wet woods, meadows, prairies and also fresh tidal marshes. With the exception of having a somewhat nodding spike, this perennial grass has very similar characteristics to Virginia Wild Rye.

Virginia Wild Rye *Elumus virginicus*
Virginia Wild Rye is an excellent pioneer species to use when establishing a new wetland. A cool season perennial, it is good for wildlife cover and food and grows up to 5 feet tall. It is also good for forage. It is found in flood plains, thickets, along road sides, and many other wet areas. It is shade and drought tolerant and can handle wet areas better than Riverbank Wild Rye.

Canada Wild Rye *Elymus canadensis*
Canada Wild Rye is a cool season perennial bunch grass. It is good for wildlife food and cover, growing up to 6 feet tall. It is also good for forage. It grows in dry or moist soils and is drought tolerant.

Joe-Pye Weed (Spotted Flat-Topped) *Eupatoriadelphus maculatus or Eupatorium maculatum*
A very common wetland plant in the northeastern United States. It grows in forested wetlands, saturated fields or meadows, and in shrub swamps. It can be identified by its purple or purplespotted stems and a flat-topped inflorescence with small pinkish or purplish flowers that bloom from July through September.

Boneset *Eupatorium perfoliatum*
Boneset is a perennial herb reaching up to 5 feet high. It flowers in late July through October. Nontidal and fresh tidal marshes, wet meadows, shrub swamps, low woods, shores and other moist areas.

Arrow Arum *Peltandra virginica*
Arrow Arum is a fleshy perennial herb that grows up to 2 feet tall. Inconspicuous flowers on a spike enclosed within a pointed leaf-like structure will appear from May through July. Arrow Arum grows in shallow waters of ponds, lakes, swamps, and marshes.

Pennsylvania Smartweed *Polygonum pennsylvanicum*
Smartweed is an annual herb reaching a height of 6-1/2 feet tall. It grows well in fresh water marshes and wet fields and meadows. Its pink or purple flowers are very small and are arranged in dense clusters.

Blue Flag *Iris versicolor*
A member of the Iris family, Blue Flag is an eye-catching wetland perennial herb that grows in many wet areas including nontidal and tidal marshes, wet meadows, and shores. A blue flower can be seen on the Blue Flag from May through July.

Rattle Snake Grass *Glyceria canadensis*
This perennial grass grows to a height up to 3-1/2 feet tall. It blooms from June through August in forested wetlands, wet meadows, and bogs.

Fowl Manna Grass *Glyceria striata*
A perennial grass that will reach 4 feet in height. It prefers freshwater marshes, open forested wetlands, and other saturated soils. It blooms from June on into September.

Soft Rush *Juncus effusus*
Soft Rush is a perennial grass-like plant that grows up to 3-1/2 feet tall. It flowers from July into September. It grows in nontidal marshes, wet meadows, shrub swamps, wet pastures, and fresh tidal marshes.

Sensitive Fern *Onoclea sensibilis*
Sensitive Fern grows up to 3-1/2 feet tall. It flowers from June into October. It grows in nontidal marshes, meadows, forested wetlands, and fresh tidal marshes, and moist woodlands.

Rice Cutgrass *Leersia oryzoides*
Rice Cutgrass is a medium height to tall perennial grass growing up to 5 feet high. It flowers from June into October. It grows in nontidal marshes, wet meadows, ditches, muddy shores, and fresh tidal marshes.

Wool Grass *Scirpus cyperinus*
Wool Grass is a medium height to tall perennial grass like plant that grows up to 6-1/2 feet high. It flowers from August through September. It grows in nontidal marshes, wet meadows, swamps, and fresh tidal marshes.

Soft-Stemmed Bulrush *Scirpus validus*
This perennial herb grows to a height of up to 10 feet. It flowers from June into September. It grows in inland shallow waters, shores, nontidal marshes, and brackish and fresh tidal marshes.

Canada Goldenrod *Solidago canadensis*
Canada Goldenrod is a medium to tall perennial herb, sporting small yellow flowers in August through October. It grows well along stream banks, and in upland wet areas.

Eastern Bur-Weed *Sparganium americanum*
Eastern Bur-Weed is a perennial growing up to 3-1/2 feet tall. It flowers from May through August. It grows in muddy shores, shallow waters and nontidal marshes.

Prairie Cordgrass *Spartina pectinata*
Prairie Cordgrass is a native perennial that grows from 2 to 7 feet tall. It flowers from July through September and grows in wet spots.

Narrow-Leaved Cattail *Typha angustifolia*
Narrow-Leaved Cattail provides food and shelter for wildlife and is used to control erosion. It has narrow leaves (1/2" wide) and reaches up to 6 feet tall.

Cattail *Typha latifolia*
The Cattail is a perennial herb growing to 10 feet high. It flowers from May through July. It grows in nontidal marshes, ponds, ditches, and fresh tidal marshes.

Blue Vervain *Verbena hastata*
Blue Vervain is a perennial herb that grows up to 5 feet tall. The flowers are bluish to violet and are borne on several dense spikes. Its blooms begin in June and continue through October. It does well in nontidal marshes, wet meadows, open shrub swamps, and moist fields.

Turtlehead *Chelone glabra*
Turtlehead is a perennial herb growing up to 3 feet tall. The flowers, which bloom from July to September, resemble turtle heads as the petals are two-lipped and tubular. It can be found growing along stream banks, forested wetlands, swamps and fresh water marshes.

Native Wetland Shrubs and Trees

Red Osier Dogwood *Cornus stolonifera*
Has red stems, green leaves, and white fruit. Its ability to spread by layering and its tolerance of wet soils makes it an excellent choice for stream bank erosion control. It is also a useful upland plant, providing food and cover for wildlife and color for shrub borders and landscaping. Grows in medium-fertility, slightly acid, clayey, loamy, and sandy soils. It has moderate shade tolerance and poor drought tolerance.
When planting along stream banks, plant at the waters edge, using rooted cuttings or fresh hardwood unrooted cuttings that are at least 9 to 12 inches long and leaving 2 inches of the stem above ground. Spreads by layering where stems contact the ground. It is moderately fast growing, reaching a height of 6 to 10 feet.

Button bush *Cephalanthus occidentalis*
Button Bush is a broad leaved, deciduous, tall shrub or small tree growing to 33 feet high. Its flowers are white and appear from May though June. It grows in nontidal and fresh tidal marshes and shrub swamps, forested wetlands, and borders of streams, lakes and ponds.

Grey Dogwood *Cornus racemosa*
Grey Dogwood is a shrub similar to Silky Dogwood, but possesses grey twigs and white berries. It grows in medium fertility, acid, clayey, loamy and sandy soils. Unlike Silky Dogwood it requires well-drained soil. It is best adapted along stream banks, in forested wetlands and shrub wetlands. It can be established by seed or unrooted cuttings.

Silky dogwood *Cornus amomum*
Silky Dogwood is a broad leaved deciduous shrub that grows to a height of 9 to 12 feet. White flowers and blue or white berries remain until late summer or early fall. It is used for stabilizing lower slopes of stream banks. It also provides food and cover for game birds, song birds, rabbits, raccoon, and other wildlife.

To establish on stream banks plant Silky Dogwood seedlings, rooted cuttings or unrooted cuttings 2 feet apart or broadcast seed. Silky Dogwood provides effective stream bank protection in 3 to 5 years and also produces fruit at this age. Silky Dogwood grows in forested wetlands, shrub wetlands, stream banks, and moist woods. It grows in medium fertility, acid, clayey, loamy, and sandy soils. It has fair drought tolerance, fair shade tolerance and tolerates poorly drained soil.

Witch Hazel *Hamamelis virginiana*
Witch Hazel is a broad-leaved deciduous shrub or low tree up to 30 feet tall. It flowers from September into November. It grows in seasonally flooded swamps and forested wetlands, and tidal swamps.

Common Winterberry *Ilex verticillata*
Winterberry is a broad leaved, deciduous shrub growing up to 16 feet tall. It flowers from May through July. It grows in seasonally flooded shrub swamps and forested wetlands. Showy red berries remain on the plant until spring.

Spicebush *Lindera benzoin*
Spicebush is a broad leaved, deciduous shrub growing up to 16 feet tall. It flowers from March through July. It grows in nontidal marshes, ponds, ditches and fresh tidal woodlands.

Swamp Rose *Rosa palustris*
Swamp Rose is a broad-leaved, deciduous thorny shrub growing up to 7 feet tall. It blooms pink five-petalled flowers from May through July. It grows in upland fields, thickets, and woods, and forested wetlands.

Black Willow *Salix nigra*
A broad-leaved deciduous shrub or tree that can reach a height of 70 feet tall or more. It grows well in nontidal forested wetlands, fresh tidal marshes, tidal swamps, and wet meadows. Identifying characteristics of the Black Willow is its brownish or blackish deeply grooved bark and its narrow leaves.

Common Elderberry *Sambucus canadensis*
Elderberry is a broad leaved deciduous shrub growing up to 12 feet tall. It flowers from June through July. It grows in nontidal and fresh tidal marshes and swamps, meadows, old fields, moist woods, and along road sides.

Arrowwood Viburnum *Viburnum dentatum*
Arrowwood is a broad leaved deciduous shrub growing up to 15 feet tall. It flowers from May through July. It grows in nontidal and fresh tidal marshes, shrub swamps, and forested wetlands. It also does well in moist woods, and various drier sites.

Nannyberry or Wild Raisin *Viburnum lentago*
Nannyberry is a broad leaved deciduous shrub or small tree growing up to 27 feet tall. It has long, pointed leaves with winged stalks. It flowers from April into May and produces berries in the fall that are eaten by wildlife. It grows in forested wetlands, open upland woods and thickets, fence rows and road sides.

Northern or Smooth Arrowwood *Viburnum recognitum*
Arrowwood is a broad leaved deciduous shrub growing up to 15 feet tall. It flowers from May through July. It grows in nontidal and fresh marshes, shrub swamps, forested wetlands, moist woods and various drier sites.

American Cranberrybush *Viburnum trilobum*
This shrub provides winter food for grouse, songbirds, and squirrels and is useful for hedges and borders. It grows in medium-fertility, acid, clayey, loamy and sandy soils. It has poor drought tolerance, fair shade tolerance and tolerates poorly drained soil.

Establishing Vegetation

Site Preparation

The soil on a disturbed site must be modified to provide an optimum environment for germination and growth. Addition of topsoil, soil amendments, and tillage are used to prepare a good seedbed. At planting the soil must be loose enough for water infiltration and root penetration, but firm enough to retain moisture for seedling growth. Tillage generally involves disking, harrowing, raking, or similar method. Lime and fertilizer should be incorporated during tillage.

Topsoiling

The surface layer of an undisturbed soil is often enriched in organic matter and has physical, chemical, and biological properties that make it a desirable planting and growth medium. Topsoil should be stripped off prior to construction and stockpiled for use in final revegetation of the site.

Topsoiling may not be required for the establishment of less demanding, lower maintenance plants, but it is essential on sites having critically shallow soils or soils with other severe limitations. It is also essential for establishing fine turf and ornamentals.

Soil Amendments

Liming

Liming is almost always required on disturbed sites to decrease the acidity (raise pH), reduce exchangeable aluminum, and supply calcium and magnesium. Even on the best soils, some fertilizer is required. Suitable rates and types of soil amendments should be determined through soil tests. Limestone and fertilizer should be applied uniformly during seedbed preparation and mixed well with the top 4 to 6 inches of soil.

Organic amendments

Organic amendments, in addition to lime and fertilizer, may improve soil tilth, structure, and water-holding capacity—all of which are highly beneficial to seedlings establishment and growth. Some amendments also provide nutrients. Examples of useful organic amendments include well-rotted animal manure and bedding, crop residue, peat, and compost.

Organic amendments are particularly useful where topsoil is absent, where soils are excessively drained, and where soils are high in clay. The application of several inches of topsoil usually eliminates the need for organic amendments.

Surface Roughening

A rough surface is especially important to seeding sloped areas. Contour depressions and loose surface soil help retain lime, fertilizer, and seed. A rough surface also reduces runoff velocity and increases infiltration.

Permanent Cover

A permanent type of vegetation should be established as soon as possible: to reduce damages from sediment and runoff to downstream areas; and to avoid severe erosion on the site itself.

Vegetation may be in the form of grass-type growth by seeding or sodding, or it may be trees or shrubs, or a combination of these. Establishing this cover may require the use of supplemental materials, such as mulch or jute netting.

Planting Methods

Seeding is the fastest and most economical method that can be used with most species. However, some grasses do not produce seed and must be established by planting runners or stems (sprigging) or plugs cut from sod (plugging). Seedbed preparation, liming, and fertilization are essentially the same regardless of the method chosen.

Seeding

Uniform seed distribution is essential. This is best obtained using a cyclone seeder (hand-held), drop spreader, conventional grain drill, cultipacker seeder, or hydraulic seeder. The grain drill and cultipacker seeders (also called grass seeder packer or Brillion drill) are pulled by a tractor and require a clean, even seedbed.

On steep slopes, hydroseeding may be the only effective seeding method. Surface roughening is particularly important when preparing slopes for hydroseeding. In contrast to other seeding methods, a rugged and even trashy seedbed gives the best results.

Hand-broadcasting should be considered only as a last resort, because uniform distribution is difficult to achieve. When hand-broadcasting of seed is necessary, minimize uneven distribution by applying half the seed in one direction and the other half at right angles to the first. Small seed should be mixed with sand for better distribution.

A “sod seeder” (no-till planter) is used to restore or repair weak cover. It can be used on moderately stony soils and uneven surfaces. It is designed to penetrate the sod, open narrow slits, and deposit seed with a minimum of surface disturbance. Fertilizer is applied in the same operation.

Inoculation of legumes

Legumes have bacteria, rhizobia, which invade the root hairs and form gall-like “nodules.” The host plant supplies carbohydrates to the bacteria, which supply the plant with nitrogen compounds fixed from the atmosphere. A healthy stand of legumes, therefore, does not require nitrogen fertilizer. Rhizobium species are host specific; a given species will inoculate some legumes but not others. Successful establishment of legumes, therefore, requires the presence of specific strains of nodule-forming, nitrogen-fixing bacteria on their roots. In areas where a legume has been growing, sufficient bacteria may be present in the soil to inoculate seeded plants, but in other areas the natural Rhizobium population may be too low.

In acid subsoil material, if the specific Rhizobium is not already present, it must be supplied by mixing it with the seed at planting. Cultures for this purpose are available through seed dealers.

Sprigging and Plugging

Sprigging refers to planting stem fragments consisting of runners (stolons) or lateral, belowground stems (rhizomes), which are sold by the bushel. This method can be used with most warm-season grasses and with some ground covers, such as periwinkle. Certain dune and marsh grasses are transplanted using vertical shoots with attached roots or rhizomes. Lawn-type plants are usually sprigged much more thickly.

Broadcasting is easier but requires more planting material. Broadcast sprigs must be pressed into the top ½ to 1 inch of soil by hand or with a smooth disk set straight, special planter, cultipacker, or roller.

Plugging differs from sprigging only in the use of plugs cut from established sod, in place of sprigs. It is usually used to introduce a superior grass into an old lawn. It requires more planting stock, but usually produces a complete cover more quickly than sprigging.

Sodding

In sodding, the soil surface is completely covered by laying cut sections of turf. A commercial source of high-quality turf is required and water must be available. Plantings must be wet down immediately after planting, and kept well watered for a week or two thereafter.

Sodding, though quite expensive, is warranted where immediate establishment is required, as in stabilizing drainage ways and steep slopes, or in the establishment of high-quality turf. If properly done, it is the most dependable method and the most flexible in seasonal requirements. Sodding is feasible almost any time the soil is not frozen.

Irrigation

Irrigation, though not generally required, can extend seeding dates into the summer and insure seedling establishment. Damage can be caused by both under and over-irrigating. If the amount of water applied penetrates only the first few inches of soil, plants may develop shallow root systems that are prone to desiccation. If supplementary water is used to get seedlings up, it must be continued until plants become firmly established.

Mulching

Mulch is essential to the revegetation of most disturbed sites, especially on difficult sites such as southern exposures, channels, and excessively dry soils. The steeper the slope and the poorer the soil, the more valuable it becomes. In addition, mulch fosters seed germination and seedling growth by reducing evaporation, preventing soil crusting, and insulating the soil against rapid temperature changes.

Mulch may also protect surfaces that cannot be seeded. Mulch prevents erosion in the same manner as vegetation, by protecting the surface from raindrop impact and by reducing the velocity of overland flow. There are a number of organic and a few chemical mulches that may be useful, as well as nets and tacking materials.

Maintenance

Satisfactory stabilization and erosion control requires a complete vegetative cover. Even small breaches in vegetative cover can expand rapidly and, if left unattended, can allow serious soil loss from an otherwise stable surface. A single heavy rain is often sufficient to greatly enlarge bare spots, and the longer repairs are delayed, the more costly they become. Prompt action will keep sediment loss and repair cost down.

New seedlings should be inspected frequently and maintenance performed as needed. If rills and gullies develop, they must be filled in, re-seeded, and mulched as soon as possible. Diversions may be needed until new plants take hold.

Maintenance requirements extend beyond the seeding phase. Damage to vegetation from disease, insects, traffic, etc., can occur at any time. Herbicides and regular mowing may be needed to control weeds; dusts and sprays may be needed to control insects. Herbicides should be used with care where desirable plants may be killed. Weak or damaged spots must be relimed, fertilized, mulched, and reseeded as promptly as possible. Refertilization may be needed to maintain productive stands.

Vegetation established on disturbed soils often requires additional fertilization. Frequency and amount of fertilization can best be determined through periodic soil testing. A fertilization program is required for the maintenance of fine turf and sod that is mowed frequently. Maintenance requirements should always be considered when selecting plant species for revegetation.

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Native Grasses and Legumes for Eastern Massachusetts

Essex, Middlesex, Suffolk, Norfolk, Plymouth, Bristol, Barnstable, Dukes and Nantucket Counties

Dry Sites

Ticklegrass	Agrostis hyemalis	(no Essex) (no seed source)(cool season)
Upland Bentgrass	Agrostis prennans	(no seed source)(cool season)
Beachgrass	Ammophila brevigulata	(cool season)
Big Bluestem	Andropogon gerardii	(warm season)
Broomsedge	Andropogon virginicus	(warm season)
Common Hairgrass	Deschampsia flexuosa	(no seed source) (warm)
Deertongue grass	Dichanthehum clandestinum	(warm season)
Canada Wild Rye	Elymus canadensis	(no Cape and Islands) (cool season)
Tumble Lovegrass	Eragrostis spectabilis	(warm season)
Red Fescue	Festuca rubra	(cool season)
Nimblewill	Muhlenbergia schreberi	(no seed source)
Switchgrass	Panicum virgatum	(warm season)
Little Bluestem	Schizachyrium scoparium	(warm season)
Dropseed	Sporabolus cryptandrus	(no Cape and Islands) (warm season)
Poverty Dropseed	Sporobolus vaginiflorus	(Annual) (warm season)
Indiangrass	Sorghastrum nutans	(warm season)
Purple Sandgrass	Triplasis purpurea	(Annual) (cool season)
Wild Indigo	Baptisia tinctoria	
Showy Tick-Trefoil	Desmodium canadense	
Beach Pea	Lathyrus japonicus var. glaber	
Round Head Bush Clover	Lespideza capitata	

Moist Sites

Creeping/Marsh Bentgrass	Agrostis stolonifera var. palustris	(cool season)
Fringed Bromegrass	Bromus ciliatus	(cool season)
Deertongue Grass	Dichanthelium clandestinum	(warm season)
Canada Wild Rye	Elymus canadensis	(cool season)
Virginia Wild Rye	Elymus virginicus	(cool season)
Purple Lovegrass	Eragrostis pectinacea	(warm season)
Switchgrass	Panicum virgatum	(warm season)
Fowl Meadow Grass	Poa palustris	(cool season)
Salt Meadow Cordgrass	Spartina patens	(tidal)
Giant Cordgrass	Spartina cynocuroides	(brackish)
Eastern Gammagrass	Tripsacum dactyloides	(warm season)
Ground Nut	Apios americana	
Showy Tick-Trefoil	Desmodium canadense	

Wet Sites

Creeping Bentgrass	Agrostis stolonifera var. palustris	(cool season)
Fringed Bromegrass	Bromus ciliatus	(cool season)
Blue Joint Reed Grass	Calamagrostis canadensis	(cool season)
Stout Wood Reed	Cinna arundinacea	(cool season)
Canada Manna Grass	Glyceria canadensis	(cool season)
Fowl Meadow Grass	Glyceria striata	(cool season)
Rice Cut Grass	Leersia oryzoides	(cool season)
Marsh Mully	Muhlenbergia glomerata	(no Islands)
Smooth Cordgrass	Spartina altiniflora	(tidal)
Freshwater Cordgrass	Spartina pectinata	

Native Grasses and Legumes for Central and Western Massachusetts

Worcester, Franklin, Hampshire, Hampden and Berkshire Counties

Dry Sites

Big Bluestem	Andropogon gerardii	(warm season)
Broomsedge	Andropogon virginicus	(warm season)(no Berkshire or Franklin)
Common Hair Grass	Deschampsia flexuosa	(warm season)(no seed source)
Deertongue Grass	Dicanthelium clandestinum	(warm season)
Nodding Wild Rye	Elymus canadensis	(cool season)
Tumble Lovegrass	Erogrostis spectabolis	(warm season)
Red Fescue	Festuca rubra	(cool season)
Nimblewill	Muhlenbergia schreberi	(no seed source)
Switchgrass	Panicum virgatum	(warm season)
Little Bluestem	Schizachyrium scoparium	(warm season)
Yellow Indiangrass	Sorghastrum nutans	(warm season)
Sand Dropseed	Sporobolus cryptandrus	(no seed source)
Poverty Dropseed	Sprobolus vaginiflorus	(Annual)
Wild Indigo	Baptisia tinctoria	
Showy Tick Trefoil	Desmodium canadense	
Narrow-leafed Tick Trefoil	Desmodium paniculatum	
Round Head Bush Clover	Lespideza capitata	

Moist Sites

Creeping/Marsh Bentgrass	Agrostis stolonifera var. palustris	(cool season)
Fringed Bromegrass	Bromus Ciliatus	(cool season)
Wood Reed grass	Cinna arundinacea	(cool season)
Riverbank Wild Rye	Elymus riparius	(cool season)
Virginia Wild Rye	Elymus virginicus	(cool season)
Green Muhly	Muhlenbergia glomerata	
Switchgrass	Panicum virgatum	(warm season)
Ground Nut	Apios americana	
Showy Tick Trefoil	Desmodium canadense	

Wet Sites

Creeping/Marsh Bent Grass	Agrostis stolonifera var. palustris	(cool season)
Blue Joint Reed Grass	Calamagrostis canadensis	(cool season)
Wood Reed Grass	Cinna arundinacea	(cool season)
Canada Mannagrass	Glyceria canadensis	(cool season)
Fowl Meadow Grass	Glyceria striata	(cool season)
Rice Cut Grass	Leersia oryzoides	(cool season)
Fowl Meadow Grass	Poa palustris	(cool season)
Fresh Water Cordgrass	Spartina pectinata	

Courtesy of Natural Resources Conservation Service, Amherst, MA.
Source: Massachusetts Natural Heritage and Endangered Species Program

Tree and Shrub Plantings

Trees For Dry Soils

Scientific Name	Common Name	Mature Height
Acer Negundo	Box Elder	60’
Betula populifolia	Gray Birch	30’
*Pinus resinosa**	Red Pine	80’
*Pinus strobus**	Eastern White Pine	90’
*Pinus sylvestris**	Scotch Pine	60’
Populus tremuloides	Quaking Aspen	50’

Shrubs For Dry Soils

Scientific Name	Common Name	Mature Height
Acer ginnala	Amur Maple	20’
Ceanothus americanus	New Jersey Tea	2’
Comptonia peregrina	Sweet Fern	3’
Corylus americana	American Hazelnut	6’
Gaylussacia baccata	Black Huckleberry	3’
*Juniperus communis**	Common Juniper	3-30’
*Juniperus virginiana**	Red-cedar	10-90’
Myrica pennsylvanica	Bayberry	5’
Rhus aromatica	Fragrant Sumac	3’
Rhus copallina	Shining Sumac	30’
Rhus glabra	Smooth Sumac	9-15’
Rhus typhina	Stagborn Sumac	30’
Rosa rugosa	Rugosa Rose	6’
Rosa virginiana	Virginia Rose	3’
Viburnum lentago	Nannyberry	15’

**evergreen*

Trees For Moderately Moist Soils

Scientific Name	Common Name	Mature Height
Fraxinus pennsylvanica	Green Ash	50’
Picea abies*	Norway Spruce	150’
Picea pungens*	Colorado Spruce	100’
Pinus strobus*	Eastern White Pine	100-150’
Populus nigra ‘Italica’	Lombardy Poplar	90’
Pseudotsuga menziesii*	Douglas-fir	100-300’
Salix nigra	Black Willow	40’
Sorbus americana	American Mountain Ash	25’
Thuja occidentalis*	American Arbor-vitae	60’
Tilia americana	Basswood	60-80’
Tsuga canadensis*	Canada Hemlock	90’

Shrubs For Moderately Moist Soils

Scientific Name	Common Name	Mature Height
Cornus amomum	Silky Dogwood	6-10’
Cornus racemosa	Gray-stemmed Dogwood	6’
Corylus americana	American Hazelnut	6’
Corylus cornuta	Beaked Hazelnut	12’
Forsythia Z intermedia	Border Forsythia	9’
Hamemelis virginiana	Common Witchhazel	15’
Ilex glabra	Inkberry	5’
Myrica pennsylvanica	Bayberry	5’
Rhododendron maximum	Rhododendron	20’

**evergreen*

Trees For Very Moist Soils

Scientific Name	Common Name	Mature Height
Acer negunda	Box Elder	60’
Acer rubrum	Red Maple	60’
Acer saccharinum	Silver Maple	70’
Fraxinus pennsylvanica	Green Ash	40’
Fraxinus nigra	Black Ash	45’
Larix laricina	American Larch	60’
Platanus occidentalis	Sycamore	100’
Populus deltoides	Eastern Cottonwood	70’
Salix nigra	Black Willow	40’
Salix bebbiana	Bebb Willow	25’
Thuja occidentalis	White Cedar	60’

Shrubs For Very Moist Soils

Scientific Name	Common Name	Mature Height
Alnus rugosa	Speckled Alder	20’
Alnus serulata	Smooth Alder	20’
Aronia arbutifolia	Red Chokeberry	20’
Clethra alnifolia	Sweetpepper Bush	10’
Cornus amomum	Silky Dogwood	8’
Cornus stolonifera	Red Osier Dogwood	8’
Ilex verticillata	Winterberry	10’
Lonicera canadensis	Canada Honeysuckle	15’
Lyonia ligustrium	Maleberry	8’
Rhododendrum canadensis	Rhodora***	12’
Rubus odoratus	Purple Flowering Raspberry	8’
Salix discolor	Pussy Willow	10’
Salix lucida	Shining Willow	8’
Sambucus canadensis	Elderberry	10’
Vaccinium corymbosum	Highbush Blueberry	10’
Viburnum cassinoides	Wild Raisin	12’
Viburnum acerifolium	Mapleleaf Viburnum	6’
Viburnum dentatium/recognitum	Arrowwood	8’
Viburnum trilobum	Highbush Cranberry	15’

Spacing Distance

For water erosion control:

Small to medium shrubs	1' x 1' to 2' x 2'
Medium to large shrubs	2' x 2' to 4' x 4'
Trees	4' x 4' to 8' x 8'

For wind erosion control:

Small to medium shrubs	2' x 2' to 4' x 4'
Medium to large shrubs	4' x 4' to 6' x 6'
Trees	6' x 6' to 10' x 10'

References

Technical assistance provided by Natural Resources Conservation Service staff at Amherst, MA, Massachusetts Native Plant Advisory Committee, and the Massachusetts Natural Heritage and Endangered Species Program.

"Introducing Natives," Erosion Control, The Journal For Erosion & Sediment Control Professionals, Vol. 2, No. 4, July/August 1995.

North Carolina Sediment Control Commission, ***Erosion and Sediment Control Planning Design Manual***, Raleigh, NC, September, 1988.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Soil Bioengineering

Soil bioengineering methods use vegetative materials in combination with more traditional landshaping, rock placement, and structural techniques. Bioengineering techniques can be used for immediate protection of slopes against surface erosion, cut and fill slope stabilization, earth embankment protection, and small gully repairs.

Stems and branches of living plants are used as soil reinforcing and stabilizing material. Techniques include live staking, fascines, brushlayers, branchpacking, and live gully repair. Roots develop and foliage sprouts when the vegetative cuttings are placed in the ground. The resulting vegetation becomes a major structural component of the bioengineering system.

Bioengineering combines biological elements with engineering design principles. The requirements for both must be considered when planning and designing measures. Engineering requirements may call for highly compacted soil for fill slopes, for example, while plants prefer relatively loose soil. Using a sheepsfoot roller for compaction is a solution that would integrate biological and engineering requirements because it compacts the soil, but also allows plant establishment in resulting depressions in the slope.

Vegetation can be used with rigid construction such as surface armoring, gravity retaining walls, and rock buttresses to create vegetated structures. Vegetation enhances the structures and helps reduce surface erosion, but usually does not provide any reinforcement benefits.

Vegetated cribwalls, gabions, and rock walls are bioengineering techniques that use porous structures with openings through which vegetative cuttings are inserted and established. The structural elements provide immediate resistance to sliding, erosion, and washout. As vegetation becomes established, roots develop, binding the slope together in a unified, coherent mass. Over time, the structural elements diminish in importance as the vegetation increases in strength and functionality.

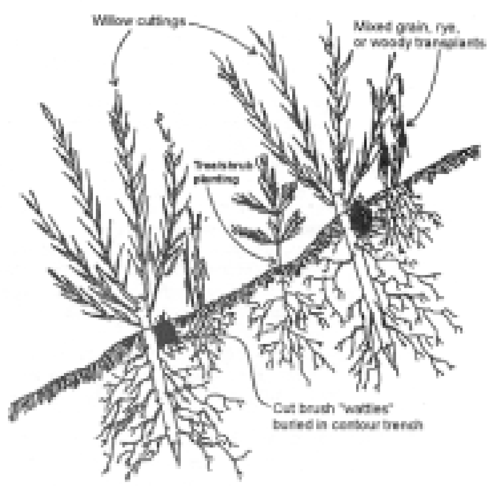
Contact the local Conservation Commission regarding any stream crossing or other work conducted in a wetland resource area. The Massachusetts Wetland Protection Act requires that the proponent file a "Request for Determination of Applicability" or "Notice of Intent."

Material in this section is adapted from Chapter 18, *Soil Bioengineering for Upland Slope Protection and Erosion Reduction*, of the Natural Resources Conservation Service *Engineering Field Handbook,* and from *Stormwater Management Manual for the Puget Sound Basin*, Washington State Department of Ecology.

Vegetative Components

Vegetation offers long-term protection against surface erosion on slopes. It provides some protection against shallow mass movement. Vegetation helps to prevent surface erosion by:

- Binding and restraining soil particles in place,
- Reducing sediment transport,
- Intercepting raindrops,
- Retarding velocity of runoff,
- Enhancing and maintaining infiltration capacity,
- Minimizing freeze-thaw cycles of soils susceptible to frost.



Woody vegetation has deeper roots and provides greater protection against shallow mass movement by:

- Mechanically reinforcing the soil with roots,
- Depleting soil-water through transpiration and interception,
- Buttressing and soil arching action from embedded stems.

Examples

Fascines:

Woody species, such as shrub willow or shrub dogwood, are used for "live fascines" -long bundles of branch cuttings bound together into sausage-like bundles. The bundles are placed with the stems oriented generally parallel to the slope contour.

Live fascines dissipate the energy of flowing water by trapping debris and providing a series of benches on which grasses, seedlings, and transplants establish more easily. Portions of the live fascines root and become part of the stabilizing cover. Live fascines provide an immediate increase in surface stability and can further improve soil stability to depths of two to three feet as roots develop.

Brushlayering:

Live branches or shoots of such woody species as shrub willow, dogwood, or privet are placed in successive layers with the stems generally oriented perpendicular to the slope contour. This orientation is the optimal direction for maximum reinforcing effect in a slope. Brushlayering can improve soil stability to depths of 4 to 5 feet.

Structural Components

Structural measures help stabilize a slope against shallow mass movement and protect the slope against rill and gully formation. Structures also help establish vegetation on steep slopes or in areas subject to severe erosion. They may make it feasible to establish plants on slopes steeper than would normally be possible. Structures stabilize slopes during critical seed germination and root growth. Without this stabilization, vegetative plantings would fail during their most vulnerable time.

Materials

Structures can be built from natural or manufactured materials. Natural materials, such as earth, rock, stone, and timber, usually cost less, are environmentally more compatible, and are better suited to vegetative treatment or slight modifications than are manufactured materials. Natural materials may also be available onsite at no cost.

Some structures are comprised of both natural and manufactured materials. Examples include concrete cribwalls, steel bin walls, gabion walls or revetments, welded wire or polymeric geogrid walls, and reinforced earth. In these cases steel and concrete mostly provide rigidity, strength, and reinforcement, whereas stone, rock, and soil provide mass. These types of structures have spaces that are often planted with herbaceous or woody vegetation.

Retaining Structures

A retaining structure of some type is usually required to protect and stabilize extremely steep slopes. Low retaining structures at the toe of a slope make it possible to grade the slope back to a more stable angle that can be successfully revegetated without loss of land at the crest. Structures are generally capable of resisting much higher lateral earth pressures and shear stresses than vegetation.

Grade Stabilization Structures

Grade stabilization structures are used to control and prevent gully erosion. A grade stabilization structure reduces the grade above it and dissipates the excess energy of flowing water within the structure itself. Debris and sediment tend to be deposited and trapped upstream of the structure. This, in turn, permits establishment of vegetation behind the structure, which further stabilizes the ground. Grade stabilization structures may range from a series of simple timber check darns to complex concrete overfall structures and earth embankments with pipe spillways.

Gully control is an example of the integration of structures and vegetation. Structural measures may be required in the short term to stabilize critical locations. The long-term goal is to establish and maintain a vegetative cover that prevents further erosion. Vegetation alone will rarely stabilize gully headcuts because of the concentrated water flow, overfalls, and pervasive forces that promote gully enlargement in an unstable channel system. Initially, the vegetation and the structure work together in an integrated fashion. The ultimate function of these structures, however, is to help establish vegetation which will provide longterm protection.

Factors to Consider

Bioengineering integrates the characteristics of vegetative components with those of structural components. The resulting systems and their components have benefits and limitations that need to be considered prior to selecting them for use.

Bioengineering is not appropriate for all sites and situations. In some cases, conventional vegetative treatment (e.g., grass seeding and hydro mulching) works satisfactorily at less cost. in other cases, the more appropriate and most effective solution is a structural retaining system alone or in combination with bioengineering.

Environmental Compatibility

Bioengineering systems generally require minimal access for equipment and workers and cause relatively minor site disturbance during installation. These are generally important considerations in environmentally sensitive areas, such as parks, woodlands, and scenic corridors where aesthetic quality, wildlife habitat, and similar values may be critical.

Cost Effectiveness

Combined slope protection systems are more cost effective than the use of either vegetative treatments or structural solutions alone in some instances. Where construction methods are labor intensive and labor costs are reasonable, the combined systems may be especially cost effective. If labor is scarce or costly, however, bioengineering systems may be less practical than structural measures.

Using native plant materials accounts for some of the cost effectiveness because plant costs are limited to labor for harvesting and handling and direct costs for transporting the plants to the site.

Planting Times

Bioengineering systems are most effective when they are installed during the dormant season, usually the late fall winter, and early spring. This often coincides with the time that other construction work is slow.

Constraints on planting times or the availability of the required quantities of suitable plant materials during allowable planting times may limit the usefulness of bioengineering methods.

Difficult Sites

Bioengineering may be an alternative for small, sensitive, or steep sites where the use of machinery is not feasible and hand labor is a necessity. Rapid vegetative establishment may be difficult, however, on extremely steep slopes.

Suitable soils are needed for plant growth. Rocky or gravelly slopes may lack sufficient fines or moisture to support plant growth. Restrictive layers in the soil, such as hardpans, may restrict root growth.

Vegetation would be of limited use on slopes that are exposed to high velocity water flow or constant inundation.

Harvesting Local Plant Material

Vegetation can often be obtained as dormant cuttings from local stands of willows and other suitable species. This stock is already well suited to the climate, soil conditions, and available moisture and is a good candidate for survival. Using local plant materials and gathering in the wild could result in short supplies or unacceptable depletion of site vegetation. Some localities have prohibitions against gathering native plants and materials must be purchased from commercial sources.

Biotechnical Strengths

Bioengineering systems are strong initially and grow stronger with time as vegetation becomes established. In some instances, the primary role of the structural component is to give the vegetation a better chance to become established. Bioengineering systems can usually withstand heavy rainfalls immediately after installation. Even if established vegetation dies, the plant roots and surface residue still furnish protection during reestablishment.

Design Considerations

Consider site topography, geology, soils, vegetation, and hydrology. Avoid extensive grading and earthwork in critical areas. Perform soil tests to determine if vigorous plant growth can be supported.

Topography and Exposure

Note the degree of slope in stable and unstable areas. Also note the presence or lack of moisture. The potential for success of bioengineering treatments can best be determined by observing existing stable slopes in the vicinity of the project site.

Note the type and density of existing vegetation in areas with and without moisture and on slopes facing different directions. Certain plants grow well on east-facing slopes, but will not survive on south-facing slopes.

Look for areas of vegetation that may be growing more vigorously than other site vegetation. This is generally a good indicator of excess moisture, such as seeps and a perched water table, or it may reflect a change in soils.

Geology and Soils

Note evidence of past sliding. If site evidence exists, determine whether the slide occurred along a deep or shallow failure surface. Leaning or deformed trees may indicate previous slope movement or downhill creep. In addition to site evidence, check aerial photos, which can reveal features that may not be apparent from a site visit.

Determine soil type and depth. Use the soil survey report, if available.

Hydrology

Determine the drainage area. Note whether water can be diverted away from the problem area.

Are there concentrated discharges?

Calculate peak flows through the project area.

If a seep area is noted, locate the source of the water. Determine whether the water can be intercepted and diverted away from the slope face.

Vegetation

Retain existing vegetation, limit the removal of vegetation. Vegetation provides excellent protection against surface erosion and shallow slope failures.

Bioengineering measures are designed to aid or enhance the reestablishment of vegetation.

Limit cleared area to the smallest practical size.

Limit duration of disturbance to the shortest practical time.

Remove and store existing woody vegetation that may be used later in the project.

Schedule land clearing during periods of low precipitation whenever possible.

Earthwork

Sites usually require some earthwork prior to the installation of bioengineering systems. A steep undercut or slumping bank, for example, requires grading to flatten the slope for stability. The degree of flattening depends on the soil type, hydrologic conditions, geology, and other site factors.

Scheduling and Timing

Planning and coordination are needed to achieve optimal timing and scheduling. The seasonal availability of plants or the best time of year to install them may not coincide with the construction season or with tight construction schedules. In some cases, rooted stock may be used as an alternative to unrooted dormant season cuttings.

Vegetative Damage to Inert Structures

Vegetative damage to inert structures may occur when inappropriate species or plant materials that exceed the size of openings in the face of structures are used. Vegetative damage does not generally occur from roots. Plant roots tend to avoid porous, open-faced retaining structures because of excessive sunlight, moisture deficiencies, and the lack of a growing medium.

Moisture Requirements and Effects

The backfill behind a stable retaining structure needs specific mechanical and hydraulic properties. Ideally, the fill is coarse-grained, free-draining, granular material. Excessive amounts of clay, silt, and organic matter are not desirable. Free drainage is essential to the mechanical integrity of an earth retaining structure and also important to vegetation, which cannot tolerate waterlogged soil conditions.

Establishing and maintaining vegetation, however, usually requires some fine-grained soils and organic matter in the soil to provide adequate moisture and nutrient retention. These requirements can often be satisfied without compromising the engineering performance of the structure. With cribwalls, for example, adequate amounts of fine-grained soils or other amendments can be incorporated into the backfill. Gabions can have the spaces between rocks filled with and soil to facilitate growth of vegetation. Woody vegetative cuttings can be placed between the baskets during filling and into the soil or backfill beyond the baskets. The needs of plants and the requirements of structures must be taken into account when designing a system.

Construction Materials and Techniques

General Considerations

Bioengineering measures have certain requirements and capabilities. Plant species must be suitable for the intended use and adapted to the site's climate and soil conditions. Species that root easily, such as willow, are required for such measures as live fascines, brushlayer, and live staking or where unrooted stems are used with structural measures. See the end of this section for a list of plant species suitable for use in bioengineering applications in Massachusetts.

Rooted plants and live dormant cuttings are living materials and must be handled properly to avoid excess stress, such as drying or exposure to heat. They must be installed in moist soil and adequately covered. The soil must be compacted to eliminate or minimize air pockets around the buried stems. If soils are not at or near moisture capacity, the installation should be delayed unless deep and regular irrigation can be provided during and following installation.

Bioengineering systems are best installed in the late fall at the onset of plant dormancy; either in the winter, as long as the ground is not frozen, or in early spring before growth begins. Installation after initial spring growth may be successful in some cases, but the risks of failure are high. Summer installation is not recommended. Rooted plants can be used, but they are sometimes less effective and more expensive.

All installations should be inspected regularly and provisions made for prompt repair if needed. Initial failure of a small portion of a system normally can be repaired easily and inexpensively. Neglect of small failures, however, can often result in the failure of large portions of a system.

Properly designed and installed vegetative portions of systems will become self-repairing to a large extent. Periodic pruning and replanting may be required to maintain healthy and vigorous vegetation. Structural elements, such as cribwalls, rock walls, and gabions, may require maintenance and/or replacement throughout their life. Where the main function of structural elements is to allow vegetation to become established and take over the role of slope stabilization, the eventual deterioration of the structures is not a cause for concern.

Bioengineering Materials

Plant tolerances to deposition, flooding, drought, and salt should be considered in selecting species for adverse site conditions.

Locating and Selecting Plant Materials

Commercial Sources

Commercially grown plant materials are suitable sources of vegetation for use in bioengineering systems; however, it is necessary to allow adequate lead time for their procurement and delivery.

Native Species

Correctly selected live dormant cuttings harvested from existing stands of living woody vegetation are the preferred bioengineering materials. The use of indigenous live materials requires careful selection, harvesting, handling, and transporting. They should result in plants that have deep and strong root systems, are relatively inexpensive, are usually effective, and can be installed quickly.

Live plant materials can be cut from existing native or naturalized stands found near the project site or within practical hauling distance. The source site must contain plant species that will propagate easily from cuttings. Cuttings are normally ½ to 2 inches in diameter and range in length from 2 to 6 feet.

Chain saws, bush axes, loppers, and prunners are recommended for cutting living plant material. Safety precautions must be followed when using these tools. Onsite plant material should be harvested with great care. In some places a large area can be cut, but other sites require selective cutting. Cuts should be made at a blunt angle, 8 to 10 inches from the ground, to assure that the source sites will regenerate rapidly and in a healthy manner.

The harvesting site should be left clean and tidy. Remnant materials that are too large for use in bioengineering projects should be chipped or left in piles for wildlife cover. A site may be needed again for future harvesting and should be left in a condition that will enhance its potential for regeneration.

Binding and Storage

Live cuttings should be bundled together securely at the collection site for easy loading and handling and for protection during transport. Side branches and brushy limbs should be kept intact.

Transporting

The bundles of live cuttings should be placed on the transport vehicles in an orderly fashion to prevent damage and facilitate handling. They should be covered with a tarpaulin during transportation to prevent drying and additional stress.

Handling

Live cuttings should arrive on the job site within eight hours of harvest and should be installed immediately. This is especially critical when the ambient temperature is 50 degrees F or above.

Live cuttings not installed on the day they arrive should be placed in controlled storage conditions and protected until they can be installed. When in storage, the cuttings must receive continuous shade, must be sheltered from the wind, and must be continuously protected from drying by being heeled into moist soils or stored in uncontaminated water. All live cuttings should be removed from storage and used within 2 days of harvest.

Installing Plant Materials

Timing

Installation of live cuttings should begin concurrently with earth moving operations if they are carried out during the dormant season. All construction operations should be phased together whenever possible. The best time for installation of bioengineering systems is during the dormant season.

Planting Medium

Bioengineering projects ideally use onsite stockpiled topsoil as the planting medium of choice. Gravel is not suitable for use as fill around live plant materials. A planting medium is needed that includes fine-grained soil and organic material, and is capable of supporting plant growth.

Muddy soils that are otherwise suitable should not be used until they have been dried to a workable moisture content. Heavy clays should be mixed with organic soils to increase porosity. Select soil backfill does not need to be organic topsoil but it must be able to support plant growth.

Soil samples should be taken of the onsite materials prior to planting live woody cuttings. Soil samples should also be taken of all fill materials that are brought to the site prior to use. Nutrient testing should include analyses for plant nutrients, metal contents, and pH. Laboratory reports should include recommended fertilizer and lime amendments for woody plant materials.

All fill soil around the vegetative cuttings should be compacted to densities approximating the surrounding natural soil densities. The soil around plants should be free of voids.

Establishment Period

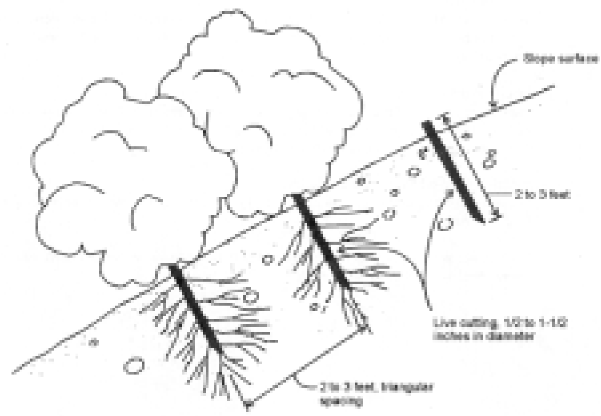
Bioengineering measures should be checked periodically after installation. Recommended schedule:

First two months:
Inspect biweekly. Check for insect infestations, soil moisture, and other conditions that could lead to poor survivability. Take action, such as the application of supplemental water, to correct any problems.

Next six months:
Inspect monthly. Systems 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.
Initial 2-year establishment period:
Perform reestablishment work as needed every six months. This will usually consist of replacing dead material.
Make additional inspections during periods of drought or heavy rains. Damaged sections should always be repaired immediately.

Live Staking



Live staking involves the insertion and tamping of live, rootable vegetative cuttings into the ground. If correctly prepared and placed, the live stake will root and grow. Stakes create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture.

Live staking increases the opportunity for natural invasion and establishment of other plants from the surrounding plant community.

Recommended Uses

Most willow species root rapidly and begin to dry out a slope soon after installation. Live staking is appropriate for repair of small earth slips and slumps that frequently are wet.

May be used for pegging down surface erosion control materials.

Can be used to stabilize intervening area between other bioengineering techniques, such as live fascines.

Well-adapted to relatively uncomplicated site conditions when construction time is limited and an inexpensive method is necessary.

Construction Recommendations

Select cuttings ½ to 1 ½ inches in diameter and 2 to 3 feet long.

The cuttings must have side branches cleanly removed and the bark intact.

The ends should be cut at an angle for easy insertion into the soil. The top should be cut square.

Cuttings should be installed the same day that they are prepared.

Installation

Tamp the live stake into the ground at right angles to the slope. The installation may be started at any point on the slope face.

The live stakes should be installed 2 to 3 feet apart using triangular spacing. The density of the installation will range from 2 to 4 stakes per square yard.

The buds should be oriented up.

About four-fifths of the length of the live stake should be installed into the ground. Pack soil firmly around stakes after installation.

Be careful not to split the stakes during installation. Stakes that do split should be replaced.

An iron bar can be used to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammer head filled with shot or sand).

Dormant Woody Plantings

This involves the use of live, dormant-stem cuttings of woody plant species from ½ to 3 inches or more in diameter. The plantings create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture.

Recommended Uses

Dormant plantings are appropriate for repair of small earth slips and slumps that frequently are wet.

Can be used to stabilize intervening area between other bioengineering techniques, such as live fascines.

A technique for relatively uncomplicated site conditions when construction time is limited and an inexpensive method is necessary.

Materials and Preparation

Cuttings, stakes and posts to be used as live dormant woody materials should be obtained from moisture-loving species that will either root naturally or respond to treatment with rooting hormones. Always select healthy materials native or adaptable to the planting site.

The proper preparation and handling of selected materials is very important. Make clean cuts and avoid split ends.

Always plant materials with the butt end down. The butt end should be tapered to mark it for proper orientation as well as facilitate driving it into the soil if done so manually. The top end should be flat, especially on stakes and posts, to facilitate manual driving.

Trim lateral branches to leave the bark ridge and branch collar intact.

The diameter and length of the plant materials varies with the type:

Dormant "cutting" - The diameter of cuttings should be a minimum of one-half inch and a maximum of less than one (1) inch. Cuttings should be at least 12 inches but less than 18 inches in length.

Dormant "stake" - Stakes should be one to three inches in diameter at the top and 18 inches to six feet in length.

Dormant "post" - Posts should be greater than three inches in diameter at the top end. Length will vary with the depth to saturated soil and the difference in feet between the channel bottom and low bank elevation. However, posts should be a minimum length equal to the difference in feet between the lowest point of channel scour and the low bank elevations or 7 feet, whichever is less.

All "stakes" and "posts" should extend a minimum of two feet below the maximum depth of the streambed scour.

There should be at least two lateral buds and/or terminal bud scars above the ground on "cuttings." A terminal bud scar should be within 1 to 4 inches of the top. Cuttings put out the largest number and strongest shoots just below a terminal bud scar (annual growth scar).

Planting materials must not be allowed to dry out. They should be kept moist and covered during transport to the planting site and during planting operations. Material should be kept submerged in water up to the time of planting. It is best to plant materials the same day they are cut and prepared. One exception is Eastern Cottonwood, which has exhibited increased survival rates if soaked in water for 1 to 2 days prior to planting.

Select native or naturalized species that root readily with or without the use of rooting hormones. Rooting hormones, if used, should be applied according to manufacturers' recommendations.

Wood species with short, dense, flexible top growth and large, deep, fibrous root systems are recommended. Other desirable characteristics include rapid initial growth, ability to reproduce by seed or vegetatively, and resistance to insects and diseases.

Layout

Dormant "stakes" and "posts" should be placed in staggered rows at two-foot by two-foot, two-foot by four-foot, or four-foot by four-foot spacings. Dormant "cuttings" may be scattered between rows of "stakes" and "posts."

On eroding streambanks over 15 feet high, use a minimum of 4 rows of dormant "stakes" or "posts."

Installation

All materials should be cut and installed while in a dormant stage. The following periods are recommended for practice installation: November 1 until ground becomes frozen, or February 1 to April 1 provided ground is not frozen or buds have not broken dormancy.

Be sure that the planting material is right side up (butt end in the ground).

Set the materials as deep as possible with at least the bottom 12 inches into a saturated soil layer. Deep planting insures an adequate moisture supply for root development, minimizes water loss due to transpiration and prevents root breakage caused by movement between the planting material and the soil during high velocity water flows.

Avoid excessive damage to the bark of the planting material, especially stripping.

Be sure there is good contact between the soil and planting material. “Dormant cuttings” will have the soil tamped around them. Dormant materials may be installed using an iron bar for “cuttings” and a post hole digger, powered auger or a metal ram on a backhoe or similar equipment for “stakes” and “posts.”

In soft, nonrestricted soils, “stakes” or “posts” may be manually driven into place using a wooden maul. If a sledge is used, care must taken to avoid splitting the planting material. Extreme care is needed in driving the stakes or posts, and should be limited to soils such as sandy soils, where use of the other methods is not feasible.

Post lengths should be extended 4 to 6 inches to allow for a new flat cut to eliminate any damaged materials after manual driving. At least 40 percent, and preferably 50 percent or more, of the planting material should be below ground level after planting.

Where damage by beaver may occur, treating materials with a repellant, such as ropel, or enclosing them with chicken wire is recommended.

All “stakes” and “posts” located in the stream channel should have a minimum of 12 inches extending above the normal water level.

Recommended Species

Species selection should consider the position of the plant in the bank profile.

Zone 1

Below normal waterline to upper limit of saturation area kept moist by capillary water movement. This zone includes the greatest potential for periodic inundations and the least moisture stress.

Zone 2

Area from upper limit of Zone 1 to 2-3 feet from the top of the bank. This area may be subject to rapid drying and greater moisture stress.

Zone 3

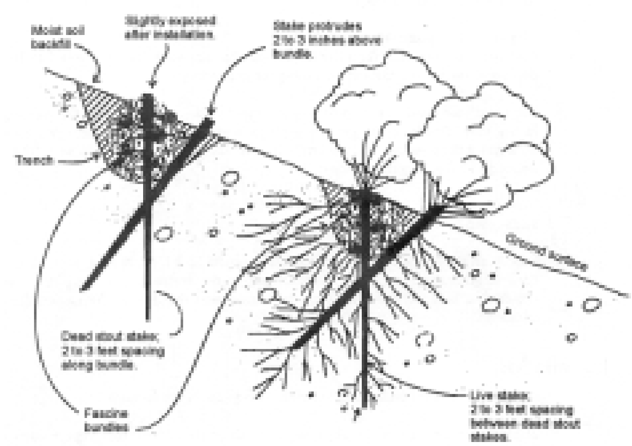
Area 2-3 feet below the top of the bank to a minimum of 30 feet into the floodplain.

Plant Zone	Common Name/Scientific Name	Growth Form
1	Black Willow* Salix nigra	Tree
1	Bankers Willow* Salix cottettii	Shrub
1	Purple-osier willow* Salix purpurea	Shrub
1	Sandbar Willow* Safix interior	Tree
1	Carolina Willow* Safix caroliniana	Tree
1	Peach-leaved Willow* Salix amycdaloides	Tree
1	Buttonbush* Cephalanthis occidetalis	Shrub
1,2,3	Red-osier Dogwood* Comus stolonifera	Shrub
2,3	Silky Dogwood Comus amomum	Shrub
2,3	Flowering Dogwood Comus florida	Tree
2,3	Green Ash Fraxinus pennsylvanica	Tree
2,3	Sycamore* Platanus occidentalis	Tree
1,2,3	Bald Cypress Taxodium distichum	Tree
1,2	River Birch Betula nigra	Tree
1,2,3	Eastern Cottonwood* Populus deltoides	Tree
1,2,3	Swamp Cottonwood* Populus heterophylla	Tree

**These species are suitable for use as dormant woody cuttings, stakes or posts. All species of willow and cottonwood do not require hormone treatment for rooting.*

Fascines

Fascines are long bundles of live branch cuttings bound together into sausage-like structures. When cut from appropriate species and properly installed with live and dead stout stakes, fascines will root and immediately begin to stabilize slopes.



Advantages

An effective stabilization technique for slopes.

Immediately reduces surface erosion or rilling.

Enhances vegetative establishment by creating a microclimate conducive to plant growth.

Capable of trapping and holding soil on the face of the slope, thus reducing a long slope, into a series of shorter slopes.

Recommended Uses

To protect slopes from shallow slides (1 to 2 foot depth).

On steep, rocky slopes, where digging is difficult.

Construction guidelines

Fascines should be placed in shallow contour trenches on dry slopes and at an angle on wet slopes to reduce erosion and shallow face sliding. This causes little site disturbance when installed by a trained crew.

Live materials

Cuttings must be from species, such as young willows or shrub dogwoods, that root easily and have long, straight branches.

Live material sizes and preparation

Cuttings tied together to form live fascine bundles may vary in length from 5 to 30 feet or longer, 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 uniform-sized bundle. Live stakes should be 2 ½ feet long in cut slopes and 3 feet long in fill slopes.

Inert materials

String used for bundling should be untreated twine.

Dead stout stakes used to secure the fascines should be 2 ½-foot long, untreated, 2 by 4 lumber. Each length can be cut again diagonally across the 4-inch face to make two stakes from each length. Use new, sound, unused lumber. Any stakes that shatter during installation should be discarded.

Installation

Prepare the fascine bundles and live stakes immediately before installation.

Beginning at the base of the slope, dig a trench on the contour just large enough to contain the live fascine. The trench will vary in width from 12 to 18 inches, depending on the angle of the slope to be treated. The depth will be 6 to 8 inches, depending on the individual bundle's final size. Place the live fascine into the trench.

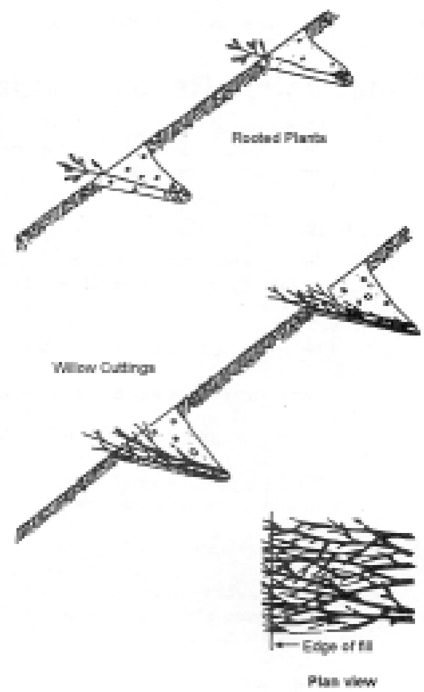
Drive the dead stout stakes directly through the live fascine every 2 to 3 feet along its length. Extra stakes should be used at connections or bundle overlaps. Leave the top of the stakes flush with the installed bundle.

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.

Repeat the preceding steps to the top of the slope; at intervals on the contour or at an angle up the face of the bank. When possible, place one or two rows over the top of the slope.

Long straw or similar mulching material should be placed between rows on 2.5:1 or flatter slopes, while slopes steeper than 2.5:1 should have jute mesh or similar material placed in addition to the mulch.

Brushlayer



Brushlayering consists of placing live branch cuttings in small benches excavated into the slope. The benches can range from 2 to 3 feet wide. These systems are recommended on slopes up to 2:1 in steepness and not to exceed 15 feet in vertical height.

Brushlayers are similar to fascine systems because both involve the cutting and placement of live branch cuttings on slopes. The two techniques differ principally in the orientation of the branches and the depth to which they are placed in the slope. In brushlayering, the cuttings are oriented more or less perpendicular to the slope contour. The perpendicular orientation is more effective for earth reinforcement and mass stability of the slope.

Brushlayer branches serve as reinforcing units. The portions of the brush that protrude from the slope face assist in retarding runoff and reducing surface erosion.

Purpose

Brushlayers perform several immediate functions in erosion control earth reinforcement, and mass stability of slopes:

- Breaking up the slope length into a series of shorter slopes separated by rows of brushlayer.
- Reinforcing the soil with the unrooted branch stems.
- Reinforcing the soil as roots develop, adding significant resistance to sliding or shear displacement.
- Providing slope stability and allowing vegetative cover to become established.
- Trapping debris on the slope.
- Aiding infiltration on dry sites.
- Drying excessively wet sites.
- Adjusting the site's microclimate, thus aiding seed germination and natural regeneration.
- Improving slope stability by acting as horizontal seepage drains.

Construction Recommendations

Live material sizes

Branch cuttings should be ½ to 2 inches in diameter and long enough to reach the back of the bench. Side branches should remain intact for installation.

Installation

Starting at the toe of the slope, benches should be excavated horizontally, on the contour, or angled slightly down the slope, if needed to aid drainage. The bench should be constructed 2 to 3 feet wide.

The surface of the bench should be sloped so that the outside edge is higher than the inside.

Live branch cuttings should be placed on the bench in a crisscross or overlapping configuration.

Branch growing tips should be aligned toward the outside of the bench.

Backfill is placed on top of the branches and compacted to eliminate air spaces. The brush tips should extend slightly beyond the fill to filter sediment.

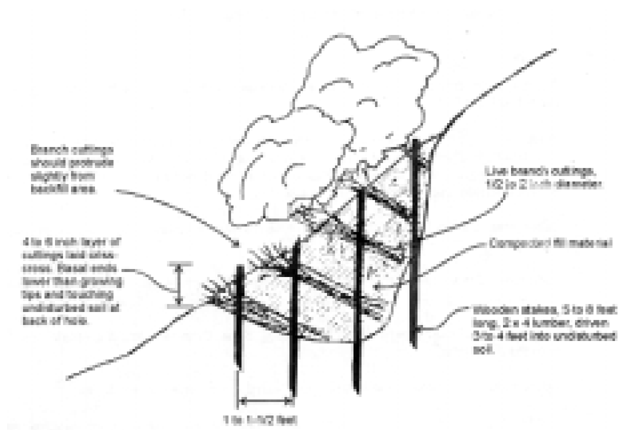
Each lower bench is backfilled with the soil obtained from excavating the bench above.

Long straw or similar mulching material with seeding should be placed between rows on 3:1 or flatter slopes, while slopes steeper than 3:1 should have jute mesh or similar material placed in addition to the mulch.

The brushlayer rows should vary from 3 to 5 feet apart, depending upon the slope angle and stability.

Branchpacking

Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes. Branchpacking provides immediate soil reinforcement.



Where Practice Applies

- Effective in earth reinforcement and mass stability of small earthen fill sites.
- Produces a filter barrier, reducing erosion and scouring conditions.
- Repairs holes in earthen embankments other than dams where water retention is a function.

Construction Recommendations

Live material

Live branch cuttings may range from ½ inch to 2 inches in diameter. They should be long enough to touch the undisturbed soil at the back of the trench and extend slightly from the rebuilt slope face.

Inert material

Wooden stakes should be 5 to 8 feet long and made from 3- to 4-inch diameter poles or 2 by 4 lumber, depending upon the depth of the particular slump or hole.

Installation

Starting at the lowest point, drive the wooden stakes vertically 3 to 4 feet into the ground. Set them 1 to 1 ½ feet apart.

A layer of living branches 4 to 6 inches thick is placed in the bottom of the hole, between the vertical stakes, and perpendicular to the slope face. They should be placed in a crisscross configuration with the growing tips generally oriented toward the slope face. Some of the basal ends of the branches should touch the back of the hole or slope.

Subsequent layers of branches are installed with the basal ends lower than the growing tips of the branches.

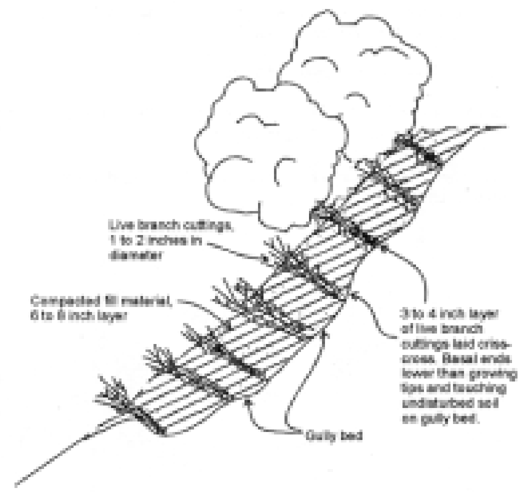
Each layer of branches must be followed by a layer of compacted soil to ensure soil contact with the branch cuttings.

The final installation should match the existing slope. Branches should protrude only slightly from the filled face.

The soil should be moist or moistened to insure that live branches do not dry out.

The live branch cuttings serve as “tensile inclusions” for reinforcement once installed. As plant tops begin to grow, the branchpacking system becomes increasingly effective in retarding runoff and reducing surface erosion. Trapped sediment refills the localized slumps or holes, while roots spread throughout the backfill and surrounding earth to form a unified mass. Branchpacking is not effective in slump areas greater than 4 feet deep or 5 feet wide.

Live gully repair



A live gully repair utilizes alternating layers of live branch cuttings and compacted soil to repair small rills and gullies. Similar to branchpacking.

Limited to rills or gullies which are a maximum of 2 feet wide, 1 foot deep, and 15 feet long.

Advantages

The installed branches offer immediate reinforcement to the compacted soil and reduce the velocity of concentrated flow of water.

Provides a filter barrier that reduces rill and gully erosion.

Construction Recommendations

Live material sizes

Live branch cuttings may range from ½ inch to 2 inches in diameter. They should be long enough to touch the undisturbed soil at the back of the rill or gully and extend slightly from the rebuilt slope face.

Inert materials

Fill soil is compacted in alternate layers with live branch cuttings.

Installation

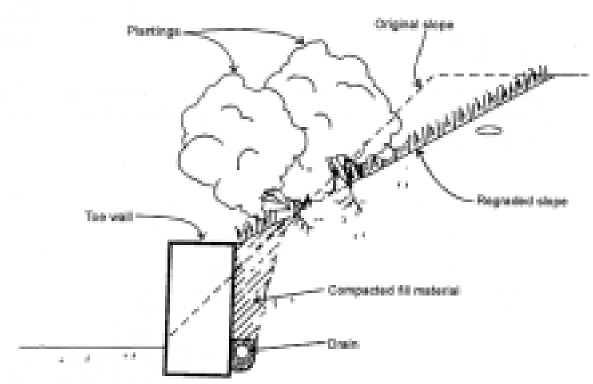
Starting at the lowest point of the slope, place a 3- to 4-inch layer of branches at lowest end of the rill or gully and perpendicular to the slope.

Cover with a 6 to 8 inch layer of fill soil.

Install the live branches in a crisscross fashion. Orient the growing tips toward the slope face with basal ends lower than the growing tips.

Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings.

Vegetated Structures



Vegetated structures consist of either low walls or revetments (concrete or rock and mortar) at the foot of a slope with plantings on the interposed benches.

A structure at the foot of a slope protects the slope against undermining or scouring and provides a slight buttressing effect. In the case of low walls, it allows regrading of the slope face to a more stable angle without excessive retreat at the crest.

Vegetation planted on the crest of the wall and the face of the slope protects against, erosion and shallow sloughing. In the case of tiered structures, the roots of woody plants grow into the soil and backfill within the structure, binding them together. The foliage in front covers the structure and enhances its appearance.

Low Wall/Slope Face Plantings

A low retaining structure at the foot of a slope makes it possible to flatten the slope and establish vegetation. Vegetation on the face of the slope protects against both surface erosion and shallow face sliding.

Several types of retaining structures can be used as low walls. The simplest type is a "gravity wall" that resists lateral earth pressures by its weight or mass. The following types of retaining structures can be classified as gravity walls:

- Masonry and concrete walls
- Crib and bin walls
- Cantilever and counterfort walls
- Reinforced earth and geogrid walls

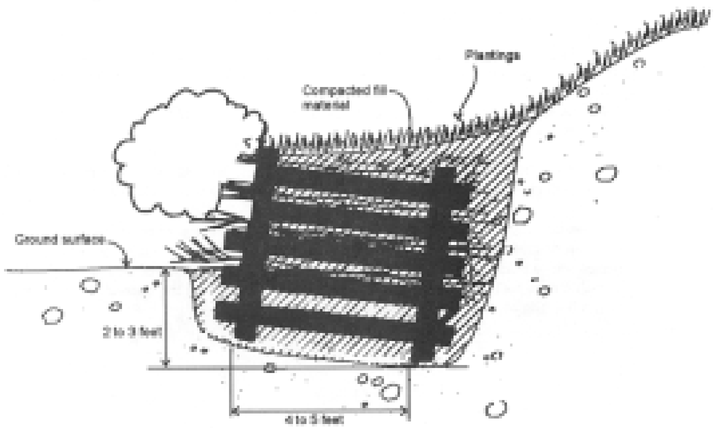
Each of these can be modified in a variety of ways to fit nearly any condition or requirement. The retaining structure should be designed by a qualified engineer.

Tiered Wall or Bench Plantings

These are alternatives to a low wall with face planting. They allows vegetation to be planted on slopes that would otherwise be too steep. Shrubs and trees planted on the benches screen the structure behind and lend a more natural appearance while their roots permeate and protect the benches.

Almost any type of retaining structure can be used in a tiered wall system. A tiered wall system provides numerous opportunities for use of vegetation on steep slopes and embankments.

Vegetated Cribwall



A cribwall is a structure formed by joining a number of cells together and filling them with soil, gravel, or rock to furnish strength and weight. A vegetated cribwall is filled with suitable backfill material and layers of live branch cuttings. The cuttings root inside the crib structure and extend into the slope. Once the live cuttings root and become established, the subsequent vegetation gradually takes over the structural functions of the wood members.

The cribwall provides immediate protection from erosion; while established vegetation provides longterm stability.

Where Practice Applies

This technique is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness.

Not designed for or intended to resist large, lateral earth stresses. Recommended only to a maximum of 6 feet in overall height, including the excavation required for a stable foundation.

Useful where space is limited and a more vertical structure is required.

Should be tilted back or battered if the system is built on a smooth, evenly sloped surface.

May also be constructed in a stair-step fashion, with each successive course of timbers set back 6 to 9 inches toward the slope face from the previously installed course.

Construction Recommendations

Live material sizes

Live branch cuttings should be ½ to 2 inches in diameter and long enough to reach the back of the wooden crib structure.

Installation

Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached.

Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.

Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 feet apart and parallel to the slope contour.

Place the next 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.

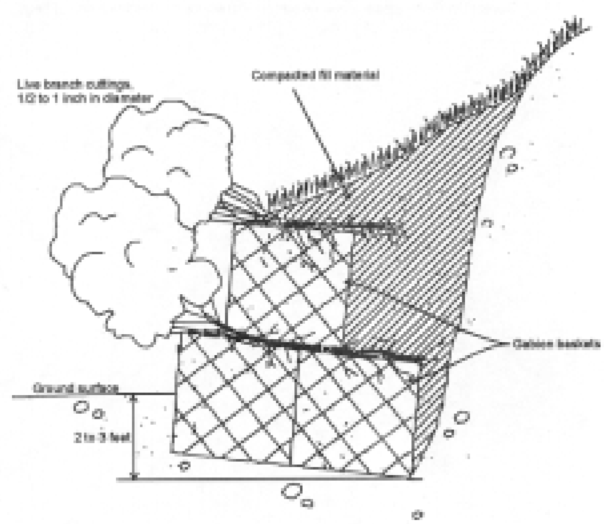
Each course of the live cribwall is placed in the same manner and nailed to the preceding course with nails or reinforcement bars.

When the cribwall structure reaches the existing ground elevation, place live branch cuttings on the backfill perpendicular to the slope; then cover the cuttings with backfill and compact.

Live branch cuttings should be placed at each course to the top of the cribwall structure with growing tips oriented toward the slope face. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the live branch cuttings. Some of the basal ends of the live branch cuttings should reach to undisturbed soil at the back of the cribwall with growing tips protruding slightly beyond the front of the cribwall.

Vegetated Gabions

Empty gabions are placed in position, wired to adjoining gabions, filled with stones and then folded shut and wired at the ends and sides. Live branches are placed on each consecutive layer between the rockfilled baskets. These will take root inside the gabion baskets and in the soil behind the structures. In time the roots consolidate the structure and bind it to the slope.



Construction Recommendations

Live material sizes

Branches should range from ½ to 1 inch in diameter and must be long enough to reach beyond the back of the rock basket structure into the backfill.

Installation

Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached.

Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure. This will provide additional stability to the structure and ensure that the living branches root well.

Place the fabricated wire baskets in the bottom of the excavation and fill with rock.

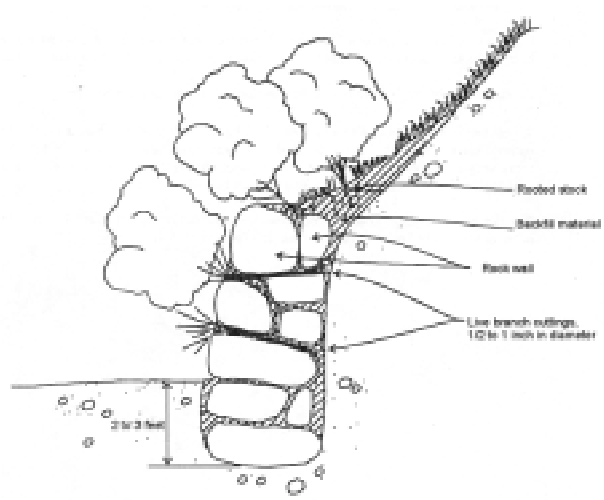
Place backfill between and behind the wire baskets.

Place live branch cuttings on the wire baskets perpendicular to the slope with the growing tips oriented away from the slope and extending slightly beyond the gabions. The live cuttings must extend beyond the backs of the wire baskets into the fill material. Place soil over the cuttings and compact it.

Repeat the construction sequence until the structure reaches the required height.

Vegetated Rock Wall

Vegetated rock walls differ from conventional retaining structures in that they are placed against relatively undisturbed earth and are not intended to resist significant lateral earth pressures. A vegetated rock wall is a combination of rock and live branch cuttings used to stabilize and protect the toe of steep slopes.



This system is appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness.

Construction Recommendations

Live material sizes

Live cuttings should have a diameter of ½ to 1-inch and be long enough to reach beyond the rock structure into the fill or undisturbed soil behind.

Inert materials

Inert materials consist of rocks and fill material for the wall construction. Rock should normally range from 8 to 24 inches in diameter. Larger boulders should be used for the base.

Installation

Starting at the lowest point of the slope, remove loose soil until a stable base is reached. This usually occurs 2 to 3 feet below ground elevation. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability to the structure.

Excavate the minimum amount from the existing slope to provide a suitable recess for the wall.

Provide a well-drained base in locations subject to deep frost penetration.

Place rocks with at least a three-point bearing on the foundation material or underlying rock course. They should also be placed so that their center of gravity is as low as possible, with their long axis slanting inward toward the slope if possible.

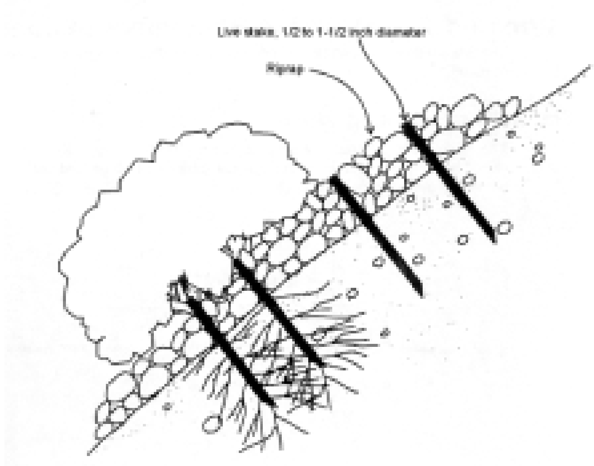
When a rock wall is constructed adjacent to an impervious surface, place a drainage system at the back of the foundation and outside toe of the wall to provide an appropriate drainage outlet.

Overall height of the rock wall, including the footing, should not exceed 5 feet.

A wall can be constructed with a sloping bench behind it to provide a base on which live branch cuttings can be placed during construction. Live branch cuttings should also be tamped or placed into the openings of the rock wall during or after construction. The butt ends of the branches should extend into the backfill or undisturbed soil behind the wall.

The live branch cuttings should be oriented perpendicular to the slope contour with growing tips protruding slightly from the finished rock wall face.

Joint Planting



Joint planting or vegetated riprap involves tamping live cuttings of rootable plant material into soil between the joints or open spaces in rocks that have previously been placed on a slope. Alternatively, the cuttings can be tamped into place at the same time that rock is being placed on the slope face.

Roots improve drainage by removing soil moisture. Over time, they create a living root mat in the soil base upon which the rock has been placed. The root systems of this mat help to bind or reinforce the soil and to prevent washout of fines between and below the rock units.

Construction Recommendations

Live material sizes

The cuttings must have side branches removed and bark intact. They should range in diameter from ½ inch to 1 ½ inches and be sufficiently long to extend into soil below the rock surface.

Installation

Tamp live branch cuttings into the openings of the rock during or after construction. The butt ends of the branches should extend into the backfill or undisturbed soil behind the riprap.

Orient the live branch cuttings perpendicular to the slope with growing tips protruding slightly from the finished face of the rock.

Slope Stabilization

Bioengineering techniques for slope stabilization involve using a combination of vegetative and mechanical measures on steep slopes, cut and fill banks, and unstable soil conditions that cannot be stabilized using ordinary vegetative techniques.

Advantages

Vegetation reduces sheet erosion on slopes and impedes sediment at the toe of the slope.

Where soils are unstable and liable to slip due to wet conditions, utilization of soil moisture by vegetation can reduce the problem.

Shrubs and trees shelter slopes against the impact of rainstorms, and the humus formed by decaying leaves further helps to impede runoff.

Mechanical measures help to stabilize soil long enough to allow vegetation to become established.

Disadvantages/Problems

The planting of non-seeded material such as live willow brush is a specialized operation and cannot be highly mechanized or installed by unskilled labor.

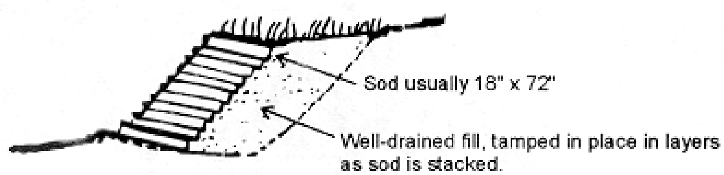
The methods described are effective but require familiarity with soils, hydrology, and other physical data to design measures that will solve the problem.

Design and Construction Recommendations

The following bioengineering methods can be used after slopes have been protected by diversion of runoff.

Sod walls or retaining banks

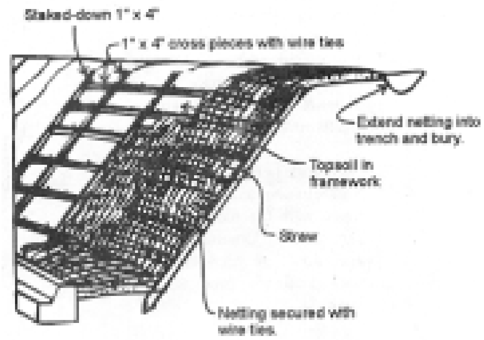
These may be used to stabilize terraces. Sod is piled by tilting it slightly toward the slope and should be backfilled with soil and compacted as they are built up. Sod walls can be as steep as 1: 8 but should not be higher than 5 feet.



SOD WALLS OR RETAINING BANKS

Timber frame stabilization

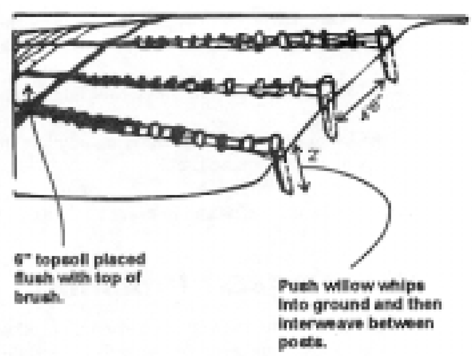
This can be effective on gradients up to 1:1. The following steps are involved in construction:



- Lay soil retarding frames of 2 x 4 in. vertical members and 1 x 4 in. horizontal members on slopes. Frames on slopes over 15 feet in length need to be anchored to slope to prevent buckling.
- Attach 14 gauge galvanized wires for anchoring wire mesh.
- Fill frames with moist topsoil and compact the soil.
- Spread straw 6 inches deep over slope.
- Cover straw with 14 gauge 4-inch mesh galvanized reinforced wire.
- Secure wire mesh at least 6 feet back of top slope.
- Plant ground cover plants through straw into topsoil.

Woven willow whips

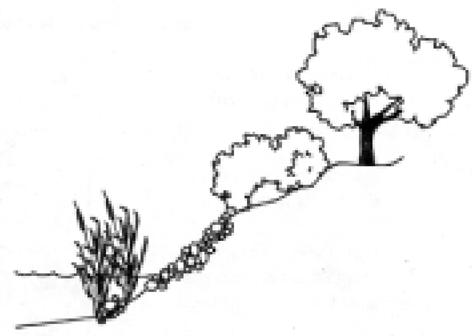
May be used to form live barriers for immediate erosion control. Construction:



- Three-foot poles are spaced at 5 foot distances and driven into the slope to a depth of 2 feet.
- Two-foot willow sticks are inserted between poles at one foot distances.
- Live willow branches 5 feet long are sunk to a depth of 1 inch and interwoven with poles and stocks.
- Spaces between the woven “fences” are filled with topsoil. Fences are generally arranged parallel to the slope or in a grid pattern diagonal to the direction of the slope.

Streambank Stabilization

Often channel reaches can be made stable by establishing vegetation where erosion potential is low and installing structural measures, or a combination of vegetative and structural measures on more vulnerable areas; such as the outside of channel bends and where the natural grade steepens.



Any work in or adjacent to a stream should be coordinated with the local Conservation Commission, and done in accordance with wetlands protection laws.

Advantages

Bioengineering techniques are generally less costly than structural practices and more compatible with natural stream characteristics.

Roots and rhizomes stabilize streambanks.

Certain reeds and bulrushes have the capability of improving water quality by absorbing certain pollutants such as heavy metals, detergents, etc.

Plants regenerate themselves and adapt to changing natural situations, thus offering a distinct economic advantage over mechanical stabilization.

Mechanical materials provide for interim and immediate stabilization until vegetation takes over.

Once established, vegetation can outlast mechanical structures and requires little maintenance while regenerating itself.

Aesthetic benefits and improved wildlife and fisheries habitat.

Disadvantages/Problems

Native plants may not be carried by regular nurseries and may need to be collected by hand, or obtained from specialty nurseries. Nurseries which carry these plants may require a long lead time for large orders.

Flow retarding aspects of vegetated waterways need to be taken into account.

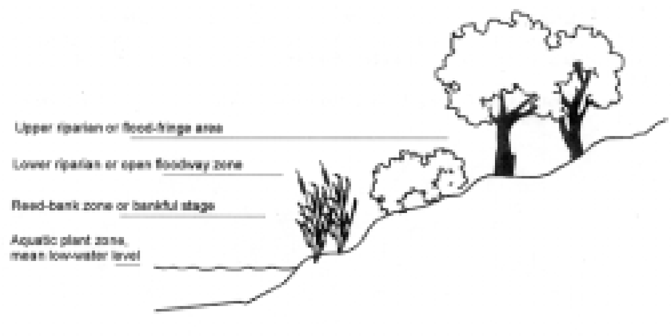
Planning Considerations

Streambanks can be divided into:

- Aquatic plant zones, at the mean low-water level;
- Reed bank zones, covered at bankfull stage;
- Lower riparian zones or open floodway zones naturally covered with willows and shrubbery plants;
- Upper riparian areas or flood fringe areas that would naturally be covered with canopy-forming trees.

Aquatic plant zones

Aquatic plants are often considered weeds and a nuisance, though they do slow down streamflow and protect the streambed.



STREAMBANK VEGETATIVE ZONES

Primary emphasis of streambank stabilization lies in the bankfull zone.

Reed bank zone

The reed bank zone forms a permeable obstacle, slowing down current waves by friction. Plant shoots, with a root clump, can be planted in pits at ½ to 1 foot depth below water, or in a reed roll.

Lower riparian zone

Lower riparian zones often have a natural growth of willow, alder, cottonwood, small maples, and various berries. These vegetative types can be reintroduced on denuded floodplains to stabilize the soil with their roots. In periods of high water, their upper branches reduce the speed of the current and thereby the erosive force of water. The most commonly used vegetative stabilizer is willow; because of its capability to develop secondary roots on cut trunks and to throw up suckers. Willows are planted either as individual cuttings bound together in various forms or wired together in fascines.

Slip banks of the lower riparian zone and tidal banks can be stabilized with grass. First the bank needs to be graded to a maximum slope of 3:1. Topsoil should be conserved for reuse; lime and fertilizer should be applied. Coarse grass and beach grass should be planted at the water's edge to trap drift sand; and bermuda grass, suitable for periodic inundation, should occupy the face of the slope, followed by tall fescue on higher ground.

In the lower riparian zone (open floodway) bank stabilization efforts should be concentrated on critical areas only. The stabilizing effect of riprap can be supplemented with willows which will bind soil through their roots and screen the bank. Banks can be paved with stone (set in sand). Willow cuttings in joints need to be long enough to extend to natural soil and should have 2 to 4 buds above surface. Willow branches in riprap should be installed simultaneously.

Branches should extend 1 foot into the soil below stone and 1 ½ feet above ground, pointing downstream.

Bioengineering Techniques for Streambank Stabilization

Reed Roll

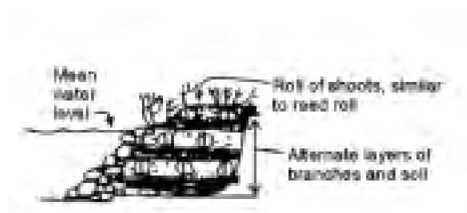
A trench 1- ½ feet wide and deep is dug behind a row of stakes; wire netting is then stretched from both sides between upright planks; coarse gravel is dumped on this and covered with reed clumps until the two edges of the netting can just be held together with wire. The upper edge of the roll should not be more than two inches above water level. The planks are then removed and gaps in the ditch are backfilled.

Reed Berm

Reed berms, consisting of a combination of reeds and riprap, break wave action and erosion of banks by currents. Banks should not exceed a 2:1 slope. Riprap is placed to form a berm that extends beyond the surface at mean low-water level, separating the reed bed from the body of water.

Fascines

Packed fascine-work can be employed on cut banks. It consists of one foot layers of branches covered with young, freshly cut shoots secured by stakes. The spaces between the shoots are filled with dirt and another layer is added on top.



Brush-mesh

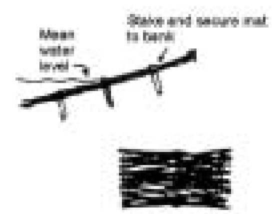
A variation is the brush-mesh technique, which is designed to stabilize breached cut banks and to encourage the deposition of sediment. It involves the following steps:

- Placement of poles at 10 foot distance.
- Placement of large branches and brush facing the stream.
- Setting cuttings of live willow branches between the brush vertically, and
- Securing vertical willows with cuttings set diagonally facing the streamflow.

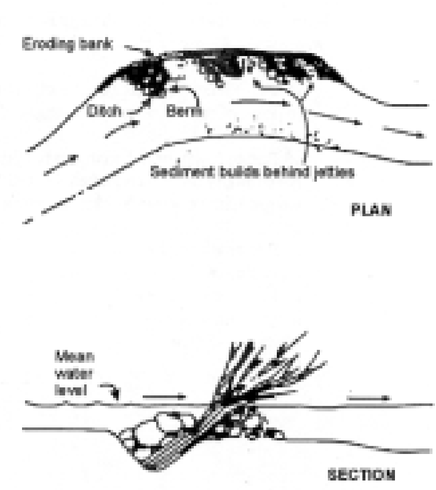
Streams in urban settings may carry an increase in runoff of such great magnitude that they cannot be maintained in a natural state. Soil bioengineering methods can provide for stabilization more aesthetically and with higher effectiveness than purely mechanical techniques. This applies primarily to: the reed bank zone and the lower riparian zone. The following techniques apply to the reed bank zone:

Willow Mattress

Willow mattresses are made from 4 to 6 foot willow switches set into six inch trenches and held down by stakes that are braided or wired together. The entire mattress is lightly covered with soil.



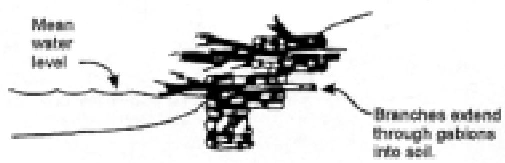
Willow Jetty



Willow jetties can be constructed at the water level to stabilize a cutbank by deflecting the current and by encouraging deposition of sediment.

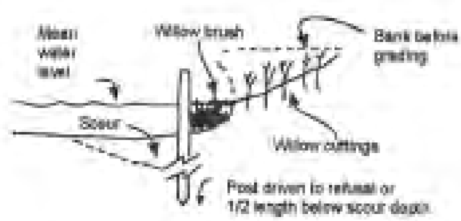
- Dig ditches diagonally to direction of flow, and place fill to form berm downstream from ditch.
- Set 2-foot willow branches (4-foot may be needed) at 45 degree angle and 3-inch spacing facing downstream.
- Weigh down branches with riprap extending beyond water level.

Willow Gabions



Willow gabions can be used when a hard-edged effect is desired to deflect the eroding flow of water. Live willow branches, pointing downstream, are inserted through the wire mesh when the gabion is packed with stone and an addition of finer materials. Branches need to be long enough to extend through the gabion into the soil of the bank. They also should be placed at an angle back into the slope.

Piling revetment



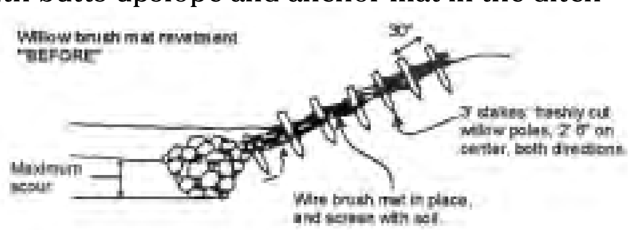
Piling revetment with wire facings is suited for the stabilization of cutbanks with deep water. It involves the following steps:

- Drive heavy timbers (8-12 inch diameter) on 6 to 8-foot centers along bank to be protected to point of refusal or one half length of pile below maximum scour.
- Fasten heavy wire fencing to the post and if the streambed is subject to scour, extend it horizontally on the streambed for a distance equal to the anticipated depth of scour and weight with concrete blocks. As scour occurs, this section will drop into place.
- Pile brush on the bank side of the fence, and plant willow saplings on bank to encourage sediment deposits.

Willow Branch Mat Revetment

Willow branch mat revetment takes the following steps to install:

- Grade slope to approximately 2:1 and excavate a 3 foot ditch at the toe of slope.
- Lay live willow brush with butts upslope and anchor mat in the ditch below normal waterline by packing with large stones.
- Drive 3-foot willow stakes 2 ½ feet on center to hold down brush; connect stakes with No. 9 galvanized wire and cover brush slightly with dirt to encourage sprouting.



Maintenance

Under normal conditions, maintenance needs should be minor after the system is established. Maintenance generally consists of light pruning and removal of undesirable vegetation. Heavy pruning may be required to reduce competition for light or stimulate new growth in the project plantings.

A newly installed bioengineering project, however, will need periodic inspections until it is established. New vegetation is vulnerable to trampling, drought, grazing, nutrient deficiencies, toxins, and pests, and may require special attention at times.

In many situations, installed bioengineering systems become source sites for future harvesting operations. Selective removal of vegetation may be required to eliminate undesirable invading species. They should be cut out every 3 to 7 years.

More intensive maintenance may be needed to repair problem areas created by high intensity storms or other unusual conditions. Site washouts should be repaired immediately. Generally, reestablishment should take place for a one-year period following construction completion and consist of the following practices:

- Replacement of branches in dead unrooted sections
- Soil refilling, branchpacking, and compacting in rills and gullies
- Insect and disease control
- Weed control

Gullies, rills, or damaged sections should be repaired using of healthy, live branch cuttings; preferably installed during the dormant season. Use the branchpacking system for large breaks, and the live gully repair system for breaks up to 2 feet wide and 2 feet deep. If the dormant season has passed, consider using rooted stock.

Final Check

A final check should be made two years after the installation is completed. Healthy growing conditions (overall leaf development and rooted stems) should exist as follows:

Live stakes	70%-100% growing
Live fascines	20% - 50% growing
Live cribwall	30% - 60% growing
Brushlayers	40% - 70% growing
Branchpacking	40% - 70% growing
Live gully repair	30% - 50% growing
Vegetated rock wall	50% - 80% growing
Vegetated gabion	40% - 60% growing
Joint planting	50% - 70% growing

Growth should be continuous with no open spaces greater than 2 feet in linear systems. Spaces two feet or less will fill in without hampering the integrity of the installed living system.

References

Goldsmith, W. and Bestmann, L., An Overview of Bioengineering for Shore Protection, Proceedings of Conference XXIII, International Erosion Control Association, Reno, Nevada, February 1992.

Gray, Donald H. and Leiser, A. T., ***Biotechnical Slope Protection and Erosion Control***, Leiser Van Reinhold Inc., 1982.

U.S. Department of Agriculture, ***Natural Resources Conservation Service Engineering Field Handbook***, Chapter 18, Soil Bioengineering for Upland Slope Protection and Erosion Reduction.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Herbaceous Plants for Streambank Soil Bioengineering Applications in Massachusetts

Native Plants Suited for Planting in Saturated Soils and/or Coir Geotextile1/:

Scientific Name	Common Name	Notes
Asclepias incarnata	Swamp milkweed	Peat plugs/pots.
Acorns calamus or antericanus	Sweet Flag	Plants in peat plugs/ pots or dormant rootcuttings.
Calamagrostis canadensis	Blue Joint Reed Grass	Peat plugs/pots. Can be seeded if no standing or flowing water.
Carex spp.	Sedges	Some native species are: comosa, crinita,intumescens, lurida, stricta and vulpanoidea.Peat plugs/pots or bare-rooted OK.
Cinna arundinacea	Wood Reed Grass	Peat plugs/pots. Can be seeded if nostanding or flowing water.
Distichlis spicata	Sea Shore Saltgrass	Peat plugs/pots. Coastal areasonly.
Eupatorium perfoliatum and E. purpureum	Boneset and Joe-Pye Weed	Peat plugs/pots.

Scientific Name	Common Name	Notes
Glyceria canadensisand G. striata	Manna Grasses	Peat plugs/pots or bare-rooted plants.Can be seeded if no standing or flowing water.
Iris versicolor	Blue Flag Iris	Dormant plants.
Juncus canadensis and J. effusus	Rushes	Peat plugs/pots or bare rooted plants.
Leersia oryzoides	Rice Cut Grass	Peat plugs/puts. Can be seeded if no standing or flowing water.
Pontederia cordata	Pickerel Weed	Peat pots or bare rooted plants.
Sagittaria latifolia	Arrowhead	Plant as tuber or in peat plug/put.
Scirpus spp.	Bulrushes	Some native species are: S.acutus, S.atrovirens, S. cyperinus, S. pungens, S. validus. Peat plugs or bare root plants.
Sparganium spp.	Bur Reed	S. americanum and S. eutycarpum are native species.
Spartina alterniflora	Salt Marsh Grasses	Peat plugs/pots. Plantings within proper tidal zone is critical.
Spartina pectinata	Fresh Water Cordgrass	Peat pots/pots.
Typa latifolia and T angustifolia	Cattails	Peat pots or bare root plants.
Verbena hastata	Blue Vervain	Peat plugs/pots.

Herbaceous Plants for Streambank Soil Bioengineering Applications in Massachusetts (Continued)

Grasses Suited for Planting on Streambanks in Combination with Bioengineered Applications2/3/:

Name	Status	Application	Notes
Agrostis alba Red Top	Introduced	All bank zones	Cool Season.
Agrostis stolonifera, var. palustris Creeping/Marsh Bentgrass	Native statewide	Low to mid bank zone	Cool Season.
Ammophila breviligulata American Beachgrass	Native to coastal counties	Sandy, gravelly droughty bank	Cape cultivar is native to MA Use culms to establish
Andropogon gerardii Blue Bigstem	Native statewide	Droughty upper bank	Warm season
Andropogon virginicus Broomsedge	Native statewide except Berkshire and Franklin	Mid to upper bank zone	Warm season
Dichanthelium clandestinum Deertongue Grass	Native statewide	Mid to upper bank zone	Warm season.
Elymus canadensis Nodding Wild Rye	Native statewide	Mid to upper bank zone	Cool season.
Festuca rubra Red Fescue	Native away from coastal areas. Introduced to coast.	Mid to upper bank zone	Cool season. Shade tolerant
Lolium perenne Perennial Ryegrass	Introduced	Mid to upper bank zone	Cool season. Fast growing-short term.
Panicum virgatum Switchgrass	Native statewide	Mid to upper bank zone	Warm season.
Sorghastrum nutans Indiangrass	Native statewide	Mid to upper bank zone	Warm season
Schizachyrium scoparium Little Bluestem	Native Statewide	Upper bank zone	Warm season

Notes:

Bank Zones:

Lower is at or near the normal waterline to the upper limit of saturation due to capillary action.

Mid is the surface area above the upper limit of the lower zone to about 3 feet from the top of bank.

Upper is the surface area about 3 feet from the top of bank and extending into the riparian zone.

Seeding Periods:
Warm season grasses are seeded in spring up to June 1, or as a dormant seeding November - March.
Cool season grasses are seeded in spring up to June 1, or in late summer/early fall August 15 - October.

1/ Table prepared by R. DeVergilio, Natural Resources Conservation Service, Amherst, MA., with technical input from M. Marcus, New England Wetland Plants, Inc., Amherst MA. Technical review by C. Miller, Plant Materials Specialist, NRCS, Somerset, NJ.
2/ Table prepared by R. DeVergilio, Natural Resources Conservation Service, Amherst, MA., with technical input from C. Miller, Plant Materials Specialist, NRCS, Somerset NJ.
3/ Grasses are usually seeded upon the bank or over a particular bioengineering application, however most species listed are also commercially available as rooted plants.
4/ Beachgrass is established by vegetative means only (planting of dormant culms).

Native plant review by The Massachusetts Native Plant Advisory Committee,1/29/96

Woody Plants for Streambank Soil Bioengineering Applications in Massachusetts

Name	Native	Size, Form	Plant Material Type 1/	Rooting Ability	Notes
Alnus rugosa/serrulata Speckled/Smooth Alder	State wide	Large Shrubs	Rooted Plants only	Poor	Good for low to mid bank zone
Aronia arbutifolia Red Chokecherry	Statewide	Shrub	Rooted Plants only	Poor	Good for low to mid bank zone
Baccharis halimifolia Eastern False Willow	Coast only	Med. Shrub	Facines Cuttings Rooted Plants	Good	Good for low to mid bank zone. Resistant to salt spray
Cephalanthus occidentalis Button Bush	Statewide	Med. Shrub	Layering Cuttings Rooted Plants	Good	Good for low bank zone. Prefers at least periodic inundation.
Clethera alnifolia Sweet Pepper Bush	Statewide	Med. Shrub	Rooted plants only	Poor	Good for mid-upper bank zone. Good for salt tolerance.
Cornus amomum Silky Dogwood	Statewide	Small Shrub	All	V. Good	Good for all bank zones. Tolerates shade.
Cornus racemosa Gray Dogwood	Statewide	Med. Shrub	All	Good	Good for mid-upper bank zone. Tolerates shade and drought.
Cornus sericea Red Osier Dogwood	Western MA only 2/	Med. Shrub	All	V. Good	Good for all bank zones.
Ilex opaca American Holly	SE MA	Sm.Tree	Rooted Plant only	Poor	Good for upper bank zone. Shad and drought tolerant.
Ilex verticillata Winterberry Holly	Statewide	Med. Shrub	Rooted plant only	Poor	Mid to lower banks. Prefers seasonal flooding.
Lindera benzoin Spicebush	Statewide	Shrub	Rooted Plant only	Poor	All bank zones. Good shade tolerance.
Populus balsamifera Balsam Poplar	W. MA only 2/	Tree (see note)	All	V. Good	3/ Use cautiously on streambanks. Good for riparian zone.
Populus deltoides Eastern Cottonwood	W. MA only 2/	Tree (see note)	All	V. Good	3/ Use cautiously on streambank. Good for riparian zone.
Rhododendron viscosum	Statewide	Med. Shrub	Rooted Plant only	Poor	Good for mid- to lower bank zones

Woody Plants for Streambank Soil Bloengineering Applications in Massachusetts (Continued)

Name	Size, Native	Form	Plant Material Type 1	Rooting Ability	Notes
Rosa palustris Swamp Rose	Statewide	Sm. Shrub	Facines Rooted Plants	Good	Low-mid bank zone
Salix amygdaloides Peachleaf Willow	No-Introduced	Lg. Shrub	All	V.Good	Good for all bank zones
Salix discolor Pussy Willow	Statewide	Med. Shrub	All	V.Good	Good for all bank zones
Salix eriocephala Erect Willow	Statewide	Lg. Shrub	All, But no Brush Mattress	V.Good	Good for all bank zones.
Salix exigua Sandbar Willow	CT River Valley	Lg. Shrub	All	Good	Mid to lower bank zones
Salix nigra Black Willow	Statewide	Tree (see note)	All	V.Good	3/ Use cautiously on streambank. Good for riparian zone.
Salix Humilis Prarie Willow	Statewide	Med. Shrub	All	Good	Good for bank zones
Salix pupurea Purpleosier Willow	No- (see note)	Lg. Shrub	All	V.Good	“Streamco” Cultivar released by NRCS. All bank zones
Salix x cottetii Dwarf Willow	No - (see note)	Sm. Shrub	All	V.Good	“Bankers” cultivar released by NRCS. Low to mid-bank zones
Sambucus canadensis American Elderberry	Statewide	Sm. Shrub	Facines Cuttings	Good	Good for mid-bank zone. Use with other good rooting species only.
Spirea tomentosa Steeple Bush	Statewide	Sm. Shrub	Layering	Poor-Fair	Midto upper bank.Use with other good rooting species only.
Virburnum dentatum Southern Arrowood	South and East	Med. Shrub	Rooted Cuttings and plants	Fair	Good for mid-bank zone
Virburnum recognitum Northern Arrowood	North and West	Med. Shrub	Rooted plants	Poor	Good for all bank zones. Rooted cuttings good.
Virburnum trilobum 4/ American Cranberry Bush	Yes, but not Cape and islands	Med. Shrub	Rooted Plants	Poor	Good for all bank zones. Good shade tolerance.
Virburnum lentago Nannyberry	Yes, but not Cape and islands	Lg. Shrub	Facines, Stakes	Fair	Good for mid-bank. Tolerates shade. Use with other good rooting species only.

Notes:
Table prepared by R. DeVergilio, Natural Resources Conservation Service, Amherst MA. Adapted from NRCS data base 'Plants For BioEngineering, Uses, H. W. Everett, 11/95'. Native plant review by the Massachusetts Native Plant Advisory Committee.
Special Note...... 'Streamco' and 'Bankers' are not native to Massachusetts. It is recommended they only be used in combination with native species.
1/ Plant Material Types: 'All' includes Dormant Fascines, Stakes, Brush Mattresses, Layering, and Cuttings as well as Rooted Cuttings and Plants.
2/ Western Mass. includes Berkshire, Franklin, Hampshire, and Hampden Counties.
3/ Tree species, such as cottonwood, poplar and black willow, are recommended for riparian area plantings and are not recommended for establishment upon the streambank itself due to potential for windthrow at maturity, and subsequent damage to the streambank.
4/ *Viburnum opulus* is similar to *V.trilobum* and is often confused with it. *V. opulus* is introduced to Massachusetts.
Streambank Zones:
Lower is at or near the normal waterline to the upper limit of saturation due to capillary action.
Mid is the surface area above the upper limit of the lower zone to about 3 feet from the top of bank.
Upper is the surface area about 3 feet from the top of bank and extending into the riparian zone.

Erosion and Sediment Control Best Management Practices for Individual Homesites and Small Parcels

Construction on small developments can cause large amounts of sediment to be transported to receiving waters. The following are some of the damaging activities and conditions that may occur during development:

Exposed and unprotected soil is often left throughout the development. When runoff occurs, sediment is transported into the nearest stormwater facility or stream, eventually clogging it.

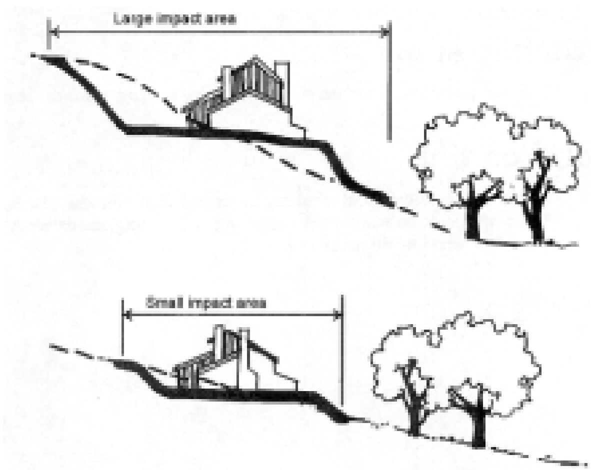
Vehicles and heavy equipment track soil from the development onto the street. Gullies formed by tire tracks become channels for runoff flow.

Vegetation bordering streams or lakes is often removed during construction. This increases the water temperature by removing shade. An increase in water temperature can contribute to algae blooms and may change the species composition of the lake or stream. Because the vegetation has been removed, there is no barrier to prevent sediment from entering the stream. This can clog spawning grounds and fish gills.

These problems may occur during work performed by subcontractors who are on-site for a very short time. Cooperation and communication between developers, builders, and subcontractors are essential to minimize erosion and damage to the environment.

Clearing and Grading

Plan and implement proper clearing and grading of the site. It is important to clear only the areas needed, thus keeping exposed areas to a minimum. Phase the clearing so that only those areas that are actively being worked are uncovered. Clearing limits should be flagged prior to the start of clearing work.



Excavated Basement Soil

Locate excavated basement soil a reasonable distance behind the curb, such as in the backyard or side yard area. This will increase the distance eroded soil must travel to reach the storm sewer system. Soil piles should be covered until the soil is either used or removed. Piles should be situated so that sediment does not run into the street or adjoining yards.

Backfilling

Backfill basement walls as soon as possible and rough grade the lot. This will eliminate large soil mounds which are highly erodible and prepares the lot for temporary cover which will further reduce erosion potential.

Removal of Excess Soil

Remove excess soil from the site as soon as possible after backfilling. This will eliminate any sediment loss from surplus fill.

Management Of Soil Banks

If a lot has a soil bank higher than the curb, a trench or berm should be installed moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion while providing a storage and settling area for stormwater.

Construction Road Access

Apply gravel or crushed rock to the driveway area and restrict truck traffic to this one route. Driveway paving can be installed directly over the gravel. This measure will eliminate soil from adhering to tires and stops soil from washing into the street. This measure requires periodic inspection and maintenance including washing, top-dressing with additional stone, reworking and compaction.

Soil Stabilization

Stabilize denuded areas of the site by mulching, seeding, planting, or sodding.

Street Cleaning

Provide for periodic street cleaning to remove any sediment that may have been tracked out. Sediment should be removed by shovelling or sweeping and carefully removed to a suitable disposal area where it will not be re-eroded.

References

Lobdell, Raymond, ***A Guide to Developing and Re-Developing Shoreland Property in New Hampshire***, North Country Resource Conservation and Development Area, Inc., Meredith, NH, 1994.

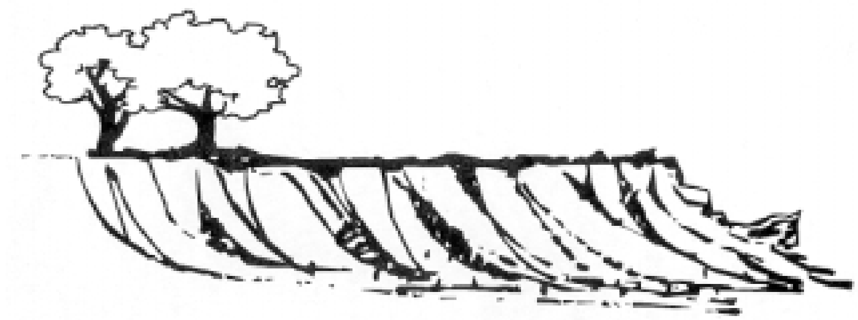
Minnesota Pollution Control Agency, Division of Water Quality, ***Protecting Water Qualily in Urban Areas, Best Management Practices for Minnesota***, MN, October, 1989.

Washington State Department of Ecology, ***Stormwater Management Manual for the Puget Sound Basin***, Olympia, WA, February, 1992.

Erosion and Sediment Control Best Management Practices for Sand and Gravel Pits

Erosion from sand and gravel pits can contribute a large amount of sediment to adjacent water courses. Sand and gravel also provides a very porous medium for transporting soluble pollutants to the underlying groundwater. Many sand and gravel operations are located within or near the recharge area of public and private wells. A major threat to groundwater exists when excavation activities take place in these areas. Exposure of the saturated zone in recharge areas can leave groundwater resources vulnerable to contamination because it decreases filtering. An added problem is that abandoned excavation pits have been used for the unregulated disposal of solid and liquid wastes and salt-laden snow.

The information in this section was adapted from *Resource Extraction, Guidelines for Sand and Gravel Pits*, in Chapter Four of the *Massachusetts Nonpoint Source Management Manual, Appendix D, Vegetating New Hampshire Sand and Gravel Pits*, in *Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire*, and *Revegetating Sand and Gravel Pits in the Northeast States* by Dickerson, Kelsey, Godfrey, Gaffney, and Miller.



Soil erosion, aesthetics, and adverse impacts on water quality are concerns associated with the operation, maintenance, and closure of sand and gravel pits. A good vegetative cover of grasses and legumes can alleviate these concerns. Vegetative cover will retard surface runoff and prevent erosion, reducing the sedimentation of nearby streams, waterways, and waterbodies. Vegetative cover will enhance the aesthetics of sand and gravel pits while providing nesting and escape cover for wildlife.

Controlling the removal of soil in recharge areas is a commonly used technique to minimize groundwater impacts. Many municipalities statewide have adopted earth removal bylaws which limit excavation within varied distances to the water table (ranging from 4 feet to 10 feet). When regulating excavation activities, the seasonal and annual fluctuations in the water table should be considered. To insure maximum groundwater protection, local controls should be designed to incorporate more conservative groundwater table estimates.

Massachusetts law (310 CMR 22.21 (2) (b) 6) prohibits the removal of soil, loam, sand, gravel or other mineral substance within 4 feet of the historical high groundwater table elevation. The regulations do allow for removal of soil provided the same soil is replaced at a final grade greater than 4 feet above the historical high water mark within 45 days. This is intended to facilitate necessary, short term excavation/soil movement activities while insuring that sand and gravel deposits associated with favorable groundwater areas are not replaced with materials of poorer quality. Building foundations and utility work are also given exemptions under this provision.

Sand and gravel pits are difficult sites to permanently vegetate. The difficulty is due to droughty conditions, low soil organic matter, low soil fertility, and lack of topsoil. Stockpiling topsoil can greatly reduce the difficulty of establishing vegetation. Most town by-laws prohibit selling topsoil. A 4-inch cap of topsoil will usually be sufficient for establishing selected vegetation that is otherwise compatible with the site condition.

Recommendations for sand and gravel pit operation.

Information Needed For Developing A Stabilization Plan

Topography for the "original ground surface" based on no greater than five-foot contour intervals (2 foot contour levels should be provided whenever possible).

Log of soil borings taken to the depth of the proposed excavation. The number of borings taken will vary with the size and geological make-up of the site.

Topographical map showing planned final grades, drainage facilities, etc. after excavation.

Operation Standards

No excavation should be closer than 200 feet to an existing public way unless specifically permitted by authorized official. No excavation should approach neighboring lot lines closer than 50 feet. (No excavation closer than 50 feet.) Natural vegetation should be left and maintained on the undisturbed land for screening and noise reduction purposes.

All loaded vehicles should be suitably covered to prevent dust and contents from spilling and blowing from the load.

The active gravel removal operation area should not exceed a total area of three acres at any one time.

All access roads leading to public ways should be treated with stone, or other suitable material to reduce dust and mud for a distance of 200 feet back from said public way; unless there is a stabilized construction entrance/tire wash at points of vehicular ingress/egress. Any spillage on public ways should be cleaned up by the operator.

Access roads should be constructed at an angle to the public way or constructed with a curve so as to help screen the operation from public view.

Most communities limit gravel removal close to the seasonal high water table; usually a range of 2 to 10 feet above seasonal high water table. This elevation should be established from test pits or soil borings and the level related to a permanent monument on the property. This information should show on the topographic plan.

During operations, when an excavation is located closer than 200 feet from a residential area or public way and where the excavation will have a depth of more than 15 feet with a slope in excess of 1: 1, a fence at least four feet high should be erected to limit access to this area.

No area should be excavated so as to cause accumulation of free standing water. Permanent drainage should be provided as needed in accordance with good construction practices. Drainage should not lead directly into streams or ponds.

All topsoil and subsoil should be stripped from the operation area and stockpiled for use in restoring the area after the removal operation has ceased.

No excavation should be allowed closer than 100 feet from a natural stream.

Restoration Standards

Slopes should be left no steeper than 3:1; to provide stability and facilitate seeding efforts.

Avoid long slopes to help prevent erosion and to allow access for seeding, mulching, and maintenance. Control slope length by installing one terrace (10 feet wide and sloped into the cut slope) for every 40 vertical feet.

All debris, stumps, boulders, etc., should be removed from the site and disposed of in an approved location, or in the case of inorganic material, buried and covered with a minimum of two feet of soil.

Following excavation and as soon as possible thereafter, ground levels and grades should be established as shown on the completed topographical plan.

Construct diversions at tops of slopes to divert runoff water away from the slope banks to a stable outlet.

Construct rock lined chutes or equivalent to conduct concentrated flow of water to stable outlets.

Remove large stones, boulders, and other debris that will hinder the seeding process and the establishment of vegetation.

Spread a minimum depth of 4 inches of topsoil over the site, if available. Supplement as necessary with subsoil retained from. pit operations.

Retained subsoil and topsoil should be respread over the disturbed area to a minimum depth of four inches. Seed with a grass or legume mixture designed for the specific site. (Recommendations follow.)

Trees or shrubs should be planted to provide screening, natural beauty, and erosion control during the establishment period.

Upon completion of the operation, the land should be left so that natural storm drainage leaves the property within the original watercourses that existed prior to construction. The rate and volume of surface water runoff should not be increased as a result of the excavation operations.

Obtain soil samples by collecting 6 to 8 small samples (one or two handfuls each) of soil material from the upper 4 inches of the area to be seeded. Mix the small samples to obtain one composite sample.

Use part of the sample for a soil test to determine lime and fertilizer needs. Run the balance of the sample(s) through a sieve analysis to determine the percent by weight passing a No. 200 sieve. Those passing are called “fines.”

If no soil tests are made, soil can be treated with three tons of lime per acre and 1,000 pounds of 10-10-10 fertilizer per acre. Basing lime and fertilizer recommendations on actual soil tests is preferable, however, and will result in much better long-term vegetative performance.

Planting Procedures

Species and Variety Selection

Select a grass/legume mix (see chart following) based on the percent weight passing a No. 200 sieve as outlined above. The standard conservation mixes available from local seed suppliers are not recommended on droughty sites. These mixes usually provide a green cover very quickly, but the plant species begin to die in two to four years on sterile and droughty sites.

Where percent by weight passing a No. 200 sieve is less than 15, select options from Mix 1.

Mix 2 is recommended if suppression of woody growth is desired and there is more than 15 percent by weight passing a No. 200 sieve.

Where percent by weight passing a No. 200 sieve is between 15 and 20, use Mix 1 or 2. Where percent by weight passing a No. 200 sieve is above 20, use Mix 1, 2, or 3.

Lime and Fertilizer Determination

Mix 1 - If soil test data is not available, lime at the rate of 1 ton/acre (50 lbs/1,000 sq ft). Fertilize with 500 lbs/acre (11 lbs/1,000 sq ft) of 10-20-20 or equivalent. Incorporate lime, fertilizer, and seed using rakes if seeding is done by hand. It is highly recommended to use a bulldozer to “track” the site after seeding. Tracking will incorporate the lime, fertilizer, and seed to promote seed germination.

Mix 2 - In lieu of a soil test, lime at the rate of 2 tons/acre (90 lbs/1,000 sq ft). Fertilize with 500 lbs/acre (11 lbs/1,000 sq ft) of 1020-20 or equivalent. The seed needs to be incorporated into the soil to ensure success and to shorten establishment time. This is most critical for the large seeded legumes in Mix 2. On the flatter slopes, use a bulldozer to “track in” the seed.

Mix 1. Warm season grasses.

Species	Varieties, listed in preferential order (select one)	Options for various Situations (1) Lbs Per Acre (PLS)		
		(2)	(3)	(4)
Switchgrass	Trailblazer, Pathfinder	6	2	6
Big Bluestem	Niagara, Kaw	4	2	4
Little Bluestem	Aldous, Camper, Blaze	2		
Deertongue Grass			— 5-10 —	
Indian Grass			— 5-10 —	

Notes:
(1) Warm season grass seed is sold and planted on the basis of pure live seeds (PLS). An adjustment is made to the bulk pounds of seed to compensate for inert material and dead seed.
(2) This combination most closely represents the naturally occurring vegetation where warm season grasses are native in the northeast.
(3) This combination has the fastest establishment and cover.
(4) This combination is the simplest and may be easier to obtain. Options 2 or 1, however, will produce better results.

Mix 2. Legumes and cool season grass.

Species	Varieties, listed in preferential order (select one)	Lbs Per Acre
Flatpea (1)	Lathco	10
Perennial pea (1)	Lancer	10
Perennial Ryegrass		10
Tall fescue	Ky-31, Rebel, Ken-Hi	10
Red Top		1

Notes:
(1) These legumes must be inoculated at time of seeding. If seeding by hand, use a sticking agent, such as cola or milk to stick inoculant to seed. If seeding with hydroseeder, use 4 times the recommended rate of inoculant.

Mulch Determination for Hydro and Hand Seeding

Mulching for Mix 1

Use weed-free mulch. Clean straw is recommended. Mulch at the maximum rate of 500-700 lbs/acre. Higher mulching rates and mulch with weed seed content will inhibit seeding success significantly. If the erosion hazard is low and the seed is incorporated, mulching is not necessary for seeding success. Do not apply mulch prior to tracking with a bulldozer.

Mulching for Mix 2

Mulch with weed-free hay or straw and mulch at the rate of 2-3 tons/acre. The higher mulching rate is recommended where seed incorporation is difficult.

Seeding Methods

Alternative 1 - Large areas and/or steep slopes

Apply lime, seed, and fertilizer with a hydroseeder and, depending on the consistency of the soil material, steepness of slope, and seed mixture used:

Press the seed into the soil by tracking with a bulldozer, or

Cover the seed by walking back and forth over steep loose sandy slopes, or

Apply mulch and a tackifier to hold the mulch in place.

Alternative 2 - Flat to gently sloping areas

(2:1 slopes maximum) Apply lime, seed, and fertilizer using farm type spreaders, and track the site with a bulldozer or apply mulch according to the circumstances.

Alternative 3 - Small areas

Apply lime, seed, and fertilizer by hand and rake.

Seeding Dates

Best seeding period is between snow melts in the spring and ends May 15. Early seeding is very important, especially for Mix 1. Actual seeding date depends on weather conditions, but substantial failure can be expected if seeding is done late.

Late summer and early fall seedings are not recommended. If late season seedings are necessary, they should be done after October 20 to prevent fall germination and subsequent winterkill.

Response of Seeding

The plant species in Mixes 1 and 2 germinate and grow slowly. Complete cover may not occur for 2-4 years. A well established stand, however, will last for years.

Follow-up seeding may be needed to establish vegetation on the more difficult parts of some sites. The need to do follow-up seeding can be determined the year after the initial planting.

Maintenance

Substantial stand vigor can be achieved if the site is topdressed with fertilizer one year after planting. If topdressing Mix 1, fertilize between June 15 and July 15. The timing of this topdressing, is important. Mixes 2 should be topdressed in the early spring.

Topdress Mixes 1 with a balanced fertilizer, applying 50 lbs of nitrogen/acre. For example, apply 250 lbs of 20-20-20/acre.

Topdress Mix 2 with 500 lbs of 0-20-20/acre in April, May, or June.

If mowing is desired to suppress woody growth, mow Mix 1 about mid-July leaving a stubble height of 6-8 inches. It is not necessary to mow Mix 2. A good cover of flatpea will prevent invasion of woody species.

References

Dickerson, John A., Kelsey, T. L., Godfrey, R. G., Gaffney, F. B., Miller, C., Revegetating Sand and Gravel Pits in the Northeast States, ____.

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, Massachusetts Nonpoint Source Management Manual, Boston, Massachusetts, June, 1993.

Minnick, E. L., and H. T. Marshall, Stormwater Management and Erosion Control for Urban and Developing Areas in New Hampshire, Rockingham County Conservation District, August 1992.

A Sample Erosion and Sedimentation Control Plan

This sample plan is for instructive purposes only. The specific number of maps, practices, drawings, specifications, and calculations required depends on the size and complexity of the development. The designer should select the most practical and efficient practices to control erosion and prevent sediment from leaving the site. The plan should be organized and presented in a clear, concise manner. Sufficient design and background information should be included to facilitate review. Construction details should be precise and clear for use by an experienced general contractor.

Due to size and space limitations, the following sections of the erosion and sedimentation control plan have not been included with this sample: vicinity map, site topography map, site development plan, erosion and sedimentation control plan drawing, detail drawings and specifications for the selected practices, vegetation plan, and supporting calculations.

Sample

EROSION AND SEDIMENTATION CONTROL PLAN ABC INDUSTRIES, INC.
ANYTOWN, MASSACHUSETTS
JULY 1995

Table of Contents

Narrative

Project Description

The purpose of the project is to construct two large commercial buildings with associated paved roads and parking area. Another building will be added in the future. Approximately 6 acres will be disturbed during this construction period. The site consists of a total of 11.1 acres and is located in ANYTOWN, Massachusetts.

Site Description

The site has rolling topography with slopes generally 4 to 6 percent. Slopes steeper to 10 to 20 percent in the northwest portion of the property where a small healed-over gully serves as the principal drainageway for the site. The site is now covered with woody vegetation, predominantly white pines, 15 to 20 feet high. There is no evidence of significant erosion under present site conditions. The old drainage gully indicates severe erosion potential and receives flow from 5 acres of woods off-site. There is one large oak tree, located in the western central portion of the property, and a buffer area, fronting Terri Road, that will be protected during construction.

Adjacent Property

Land use in the vicinity is commercial/industrial. The land immediately to the west and south has been developed for industrial use. Areas to the north and east are undeveloped and heavily wooded, primarily in white pine. Hocutt Creek, the off-site outlet for runoff discharge, is presently a well stabilized, gently-flowing perennial stream. Sediment control measures will be taken to prevent damage to Hocutt Creek. Approximately 5 acres of wooded area to the east contribute runoff into the construction area.

Soils

The soil in the project area is mapped as Paxton (see Natural Resources Conservation Service, soil survey for your town) fine sandy loam in B and C slope classes. Paxton soils are considered moderately well to somewhat poorly drained with permeability rates greater than 6 inches/hour at the surface but less than 0.1 inches/hour in the subsoil. The subsurface is pale brown sandy loam, 6 inches thick. The subsoil consists of a pale brown and brownish yellow sandy clay loam ranging to light gray clay, 36 inches thick. Below 36 inches is a layer of fine sandy loam to 77 inches. The soil erodibility (K factor; see soil survey for an explanation) ranges from 0.20 at the surface to 0.37 in the subsoil.

Due to the slow permeability of the subsoil that will be exposed during grading, a surface wetness problem with high runoff is anticipated following significant rainfall events. No groundwater problem is expected. The tight clay in the subsoil will make vegetation difficult to establish. Some topsoil exists on-site and will be stockpiled for landscaping.

Planned Erosion and Sedimentation Control Practices

Sediment Basin

A sediment basin will be constructed in the northwest corner of the property. All water from disturbed areas, about 6 acres, will be directed to the basin before leaving the site. (NOTE: The undisturbed areas to the east and north could have been diverted, but this was not proposed because it would have required clearing to the property line to build the diversion and the required outlet structure.)

Construction Entrance

A temporary gravel construction entrance will be installed near the north-west corner of the property. During wet weather it may be necessary to wash vehicle tires at this location. The entrance will be graded so that runoff water will be directed to an inlet protection structure and away from the steep fill area to the north.

Block and Gravel Inlet Protection

A temporary block and gravel inlet protection device will be installed at the drop inlet located on the south side of the construction entrance. Runoff from the device will be directed into the sediment basin. (NOTE: The presence of this device reduces the sediment load on the sediment basin and provides sediment protection for the pipe. In addition, sediment removal at this point is more convenient than from the basin.)

Temporary Diversions

Temporary diversions will be constructed above the 3:1 cut slopes south of Buildings A and B to prevent surface runoff from eroding these banks. (NOTE: Sediment-free water may be diverted away from the project sediment basin.) A temporary diversion will be constructed near the middle of the disturbed area to break up this long, potentially erosive slope should the grading operation be temporarily discontinued. A temporary diversion will be constructed along the top edge of the fill slope at the end of each day during the filling operation to protect the fill slope. This temporary diversion will outlet to the existing undisturbed channel near the north edge of the construction site and/or to the temporary inlet protection device at the construction entrance as the fill elevation increases.

Level Spreader

A level spreader will serve as the outlet for the diversion east of Building A and south of Building B. The area below the spreader is relatively smooth and heavily vegetated with a slope of approximately 4 percent.

Tree Preservation and Protection

A minimum 2 foot high protective fence will be erected around the large oak tree at the dripline to prevent damage during construction. Sediment fence materials may be used for this purpose.

Land Grading

Heavy grading will be required on approximately 6 acres. The flatter slope after grading will reduce the overall erosion potential of the site. The buildings will be located on the higher cut areas, and the access road and open landscaped areas will be located on fill areas.

All cut slopes will be 3:1 or flatter to avoid instability due to wetness, provide fill material, give an open area around the buildings, and allow vegetated slopes to be mowed. Cut slopes will be fine graded immediately after rough grading; the surface will be disked and vegetated according to the Vegetation Plan.

Fill slopes will be 2:1 with fill depths as much as 12 to 15 feet. Fill will be placed in layers not to exceed 9 inches in depth and compacted.

The fill slope in the north portion of the property is the most vulnerable area to erosion on the site. Temporary diversions will be maintained at the top of this fill slope at all times, and the filling operation will be graded to prevent overflow to the north. Filling will be done as a continuous operation until final grade is reached.

The paved road located on the fill will be sloped to the south and will function as a permanent diversion. The area adjacent to the roads and parking area will be graded to conduct runoff to the road culverts. Runoff water from the buildings will be guttered to the vegetated channels. The finished slope face to the north will not be back-bladed. The top 2 to 6 inches will be left in a loose and roughened condition. Plantings will be protected with mulch, as specified in the Vegetation Plan.

A minimum 15 foot undisturbed buffer will be maintained around the perimeter of the disturbed area. (NOTE: This will reduce water and wind erosion, help contain sediment, reduce dust, and reduce final landscaping costs.)

Temporary Sediment Trap

A small sediment trap will be constructed at the intersection of the existing road ditch and channel number 3 to protect the road ditch. Approximately 2 acres of disturbed area will drain into this trap.

Sediment Fence

A sediment fence will be constructed around the topsoil stockpile and along the channel berm adjacent to the deep cut area, as necessary to prevent sediment from entering the channels.

Sod Drop Inlet Protection

Permanent sod drop inlet protection will replace the temporary block and gravel structure when the contributing drainage area has been permanently seeded and mulched.

Grassed Waterway

Grassed waterways with temporary straw-net liners will be constructed around Buildings A and B to collect and convey site water to the project's sediment basin.

Should the disturbed areas adjoining the channels not be stabilized at the time the channels are vegetated, a sediment fence will be installed adjacent to the channel to prevent channel siltation.

Riprap-Lined Waterways

A riprap channel will be constructed in the old gully along the north side of the property starting in the northwest corner after all other construction is complete. This channel will replace the old gully as the principal outlet from the site.

Construction Road Stabilization

As soon as final grade is reached on the entrance road, the subgrade will be sloped to drain to the south and stabilized with a 6 inch course of ¾ inch stone. The parking area and its entrance road will also be stabilized with ¾ inch stone to prevent erosion and dust during the construction of the buildings and prior to paving.

Outlet Stabilization

A riprap apron will be located at the outlet of the three culverts to prevent scour.

Surface Roughening

The 3:1 cut slopes will be lightly roughened by disking just prior to vegetating, and the surface 4 to 6 inches of the 2:1 fill slopes will be left in a loose condition and grooved on the contour.

Surface stabilization

Surface stabilization will be accomplished with vegetation and mulch as specified in the Vegetation Plan. One large oak tree southwest of Building A and a buffer area between the parking lot and Terri Road will be preserved. Roadway and parking lot base courses will be installed as soon as finished grade is reached.

Dust control

Dust control is not expected to be a problem due to the small area of exposure, the undisturbed perimeter of trees around the site, and the relatively short time of exposure (not to exceed 9 months). Should excessive dust be generated, it will be controlled by sprinkling.

Construction Schedule

1. Obtain plan approval and other applicable permits.
2. Flag the work limits and mark the oak tree and buffer area for protection.
3. Hold a pre-construction conference at least one week prior to starting construction.
4. Install the sediment basin as the first construction activity.
5. Install the storm drain with the block and gravel inlet protection at the construction entrance/exit.
6. Install the temporary gravel construction entrance/exit.
7. Construct the temporary diversions above the proposed building sites. Install the level spreader and sediment trap and vegetate disturbed areas.
8. Complete site clearing except for the old gully in the northwest portion of the site. This area will be cleared during the last construction phase for the installation of the riprap channel.
9. Clear the waste disposal area in the northeast corner of the property, only as needed.
10. Rough grade site, stockpile topsoil, construct channels, install culverts and outlet protection, and install sediment fence as needed. Maintain diversions along the top of the fill slope daily.
11. Finish the slopes around the buildings as soon as rough grading is complete. Leave the surface slightly roughened and vegetate and mulch as soon as possible.
12. Complete the final grading for roads and parking and stabilize with gravel.
13. Complete the final grading for the buildings.
14. Complete the final grading of grounds, topsoil critical areas, and permanently vegetate, landscape, and mulch.
15. Install the riprap outlet channel and extend riprap to pipe outlet under entrance road.
16. After the site is stabilized, remove all temporary measures and install permanent vegetation on the disturbed areas.
17. Estimated time before final stabilization is 9 months.

Maintenance Plan

1. All erosion and sediment control practices will be checked for stability and operation following every runoff-producing rainfall but in no case less than once every week. Any needed repairs will be made immediately to maintain all practices as designed.
2. The sediment basin will be cleaned out when the level of sediment reaches 2 feet below the top of the riser. Gravel will be cleaned or replaced when the sediment pool no longer drains properly.
3. Sediment will be removed from the sediment trap and block and gravel inlet protection device when storage capacity has been approximately 50 percent filled. Gravel will be cleaned or replaced when the sediment pool no longer drains properly.
4. Sediment will be removed from behind the sediment fence when it becomes about ½ foot deep at the fence. The sediment fence will be repaired as necessary to maintain a barrier.
5. All seeded areas will be fertilized, reseeded as necessary, and mulched according to specifications in the Vegetation Plan to maintain a vigorous, dense vegetative cover.

Note: The appropriate official from Anytown, Massachusetts should conduct regular (weekly or bi-weekly) inspections of the site and control measures to ensure proper functioning. Orders should be issued if any conservation practice is observed to be malfunctioning or incorrectly built.

References

Massachusetts Department of Environmental Protection, Office of Watershed Management, Nonpoint Source Program, ***Massachusetts Nonpoint Source Management***, Boston, Massachusetts, June, 1993.

Glossary

Access road: A temporary or permanent road over which timber is transported from a loading site to a public road. Also known as a haul road.

Acre-foot: An engineering term used to denote a volume 1 acre in area and 1 foot in depth.

Adsorption: The adhesion of one substance to the surface of another.

Aggrade: The alteration of a channel caused by the deposition of sediment.

Aggregate: The stone or rock gravel needed for an infiltration practice, such as an infiltration trench or dry well.

Alignment: The horizontal route or direction of an access road.

Alluvial: Pertaining to material that is transported and deposited by running water.

Allochthonous: Derived from outside a system, such as leaves of terrestrial plants that fall into a stream.

Angle of repose: The maximum slope or angle at which a material, such as soil or loose rock, remains stable. Angle between the horizontal and the maximum slope that a soil assumes through natural processes.

Anti-seep Collar: A device constructed around a pipe or other conduit placed through a dam, dike, or levee for the purpose of reducing seepage losses and piping failures.

Anti-vortex Device: A facility placed at the entrance to a pipe conduit structure such as a drop inlet spillway or hood inlet spillway to prevent air from entering the structure when the pipe is flowing full.

Apron: A floor or lining to protect a surface from erosion, for example, the pavement below chutes, spillways, or at the toes of dams. Erosion protection placed below the streambed in an area of high flow velocity, such as downstream from a culvert.

Aquifer: A geologic formation or structure that transmits water in sufficient quantity to supply the needs for a water development; usually saturated sands, gravel, fractures, and cavernous and vesicular rock (Soil Conservation Society of America, 1982).

Autochthonous: Derived from within a system, such as organic matter in a stream resulting from photosynthesis by aquatic plants.

Backfill: The operation of filling an excavation after it has once been made.

Backwater: The water retarded upstream of a dam or backed up into a tributary by a flood in the main stream.

Bankfull event (also bankfull discharge): A flow condition in which streamflow completely fills the steam channel up to the top of the bank. In undisturbed watersheds, the discharge condition occurs on average every 1.5 to 2 years and controls the shape and form of natural channels. (Schueler, 1987)

Barrel: The concrete or corrugated metal pipe of a principal spillway that passes runoff from the riser through the embankment, and finally discharges to the ponds outfall.

Base Flow: The stream discharge from groundwater runoff.

Bedding: (1) The process of laying a drain or other conduit in its trench and tamping earth around the conduit to form its bed. The manner of bedding may be specified to conform to the earth load and conduit strength. (2) A site preparation technique whereby a small ridge of surface soil is formed to provide an elevated planting or seed bed. It is used primarily in wet areas to improve drainage and aeration for seeding.

Bedload: The sediment that moves by sliding, rolling, or bounding on or very near the streambed; sediment moved mainly by tractive or gravitational forces or both but at velocities less than the surrounding flow.

Bedrock: The more or less solid rock in place either on or beneath the surface of the earth. It may be soft or hard and have a smooth or irregular surface.

Berm: (1) A horizontal strip or shelf built into an embankment or cut, to break the continuity of a long slope, usually for the purpose of reducing erosion, improving stability, or to increase the thickness or width of an embankment. (2) A low earth fill constructed in the path of flowing water to divert its direction, or constructed to act as a counterweight beside the road fill to reduce the risk of foundation failure (buttress).

Best Management Practice (BMP): A structural, nonstructural, or managerial technique recognized to be the most effective and practical means to prevent and reduce nonpoint source pollutants. Should be compatible with the productive use of the resource to which applied and should be cost effective.

Blind Drain: A type of drain consisting of an excavated trench refilled with previous materials, such as coarse sand, gravel or crushed stones, through whose voids water percolates and flows toward an outlet. Often referred to as a French drain because of its initial development and widespread use in France.

Bordering Vegetated Wetlands: Freshwater wetlands which border on creeks, rivers, streams, ponds, and lakes. The types of freshwater wetlands are wet meadows, marshes, swamps, and bogs. They are areas where the topography is low and flat, and where the soils are annually saturated.

Borrow Area: A source of earth fill materials used in the construction of embankments or other earth fill structures.

Borrow pit: An excavation site outside the limits of construction that provides necessary material, such as fill material for embankments.
Bottomlands: A term often used to define lowlands adjacent to streams (flood plains in rural areas).

Broad-based dip: A surface drainage structure specifically designed to drain water from an access road while vehicles maintain normal travel speeds.

Brush barrier: A sediment control structure created of slash materials piled at the toe slope of a road or at the outlets of culverts, turnouts, dips, and water bars.

Buffer area: A designated area around a stream or waterbody of sufficient width to minimize entrance of sediment and pollutants into the waterbody.

Cantilever Outlet: A discharge pipe extending beyond its support.

Catch Basin: An underground basin combined with a storm sewer inlet to trap solids.

Channel Erosion: The widening, deepening, and headward cutting of small channels and waterways, due to erosion caused by flowing water.

Channel: An open cut in the earth's surface, either natural or artificial, that conveys water.

Check dam: A small dam constructed in a gully to decrease the flow velocity, minimize channel scour, and promote deposition of sediment.

Chemigation: The addition of one or more chemicals to the irrigation water.

Chemigated water: Water to which fertilizers or pesticides have been added.

Chopping: A mechanical treatment whereby vegetation is concentrated near the ground and incorporated into the soil to facilitate burning or seedling establishment.

Chute: A device constructed to convey water on steep grades, lined with erosion resistant materials.

Composting: A controlled process of degrading organic matter by microorganisms.

Conduit: A closed facility used for the conveyance of water.

Constructed wetlands: Those wetlands that are intentionally created on sites that are not wetlands for the primary purpose of wastewater or urban runoff treatment and are managed as such.

Contour: An imaginary line on the surface of the earth connecting points of the same elevation. A line drawn on a map connecting points of the same elevation.

Conveyance system: The drainage facilities, both natural and human-made, which collect, contain, and provide for the flow of surface water and urban runoff from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities (Washington Department of Ecology, 1992).

Cover crop: A close-growing crop grown primarily for the purpose of protecting and improving soil between periods of regular crop production or between trees and vines in orchards and vineyards (Soil Conservation Society of America, 1982).

Cradle: A device, usually concrete, used to support a pipe conduit.

Crop residue: The portion of a plant or crop left in the field after harvest.

Crop rotation: The growing of different crops in recurring succession on the same land.

Crown: A convex road surface that allows runoff to drain to either side of the road prism.

Cubic foot per second: Rate of fluid flow at which 1 cubic foot of fluid passes a measuring point in 1 second. Abbreviated: cfs. Synonym: Second-foot; CUSEC.

Culvert: A metal, wooden, plastic, or concrete conduit through which surface water can flow under or across roads.

Culvert, Box: Generally a rectangular or square concrete structure for carrying large amounts of water under a roadway.

Cut-and-Fill: Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments of fill areas.

Cutoff Trench: A long, narrow excavation constructed along the centerline of a dam, dike, levee, or embankment and filled with relatively impervious material intended to reduce seepage of water through porous strata.

Dam: A barrier to confine or raise water for storage or diversion, to create a hydraulic head, to prevent gully erosion, or for retention of soil, rock, or other debris.

Defoliant: A herbicide that removes leaves from trees and growing plants.

Denitrification: The anaerobic biological reduction of nitrate nitrogen to nitrogen gas.

Deposition: The accumulation of material dropped because of a slackening movement of the material-water or wind (Soil Conservation Society of America, 1982).

Desiccant: A chemical agent used to remove moisture from a material or object (Soil Conservation, of America, 1982).

Design Storm: A rainfall event of specific frequency and duration (e.g., a storm with a 2-year frequency and 24-hour duration) that is used to calculate runoff volume and peak discharge rate.

Detention: The temporary storage of storm runoff; used to control the peak discharge rates, and which provides settling of pollutants.

Detention Storage: The storage of storm runoff water for controlled release during or immediately following the design storm.

Detention Time: The amount of time that runoff water actually is stored. Theoretical detention time for a runoff event is the average time runoff of water resides in the basin over a period of release.

Dike: A temporary berm or ridge of compacted soil that channels water to a desired location. An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee.

Disking (harrowing): A mechanical method of scarifying the soil to reduce competing vegetation and to prepare a site to be seeded or planted.

Diversion: A channel with a supporting ridge on the lower side constructed across or at the bottom of a slope for the purpose of intercepting surface runoff.

Drain: Usually a pipe, ditch, or channel for collecting and conveying water.

Drainage: A general term applied to the removal of surface or subsurface water from a given area either by gravity or by pumping.

Drainage area: The contributing area to a single drainage basin, expressed in acres, square miles, or other unit of area.

Drainage structure: Any device or land form constructed to intercept and/or aid surface water drainage.

Dry Well: An excavated pit backfilled with aggregate or a constructed chamber placed in an excavation and backfilled with aggregate around the chamber. Provides temporary runoff storage and allows stored runoff to infiltrate into the soil.

Duff: The accumulation of needles, leaves, and decaying matter on the forest floor.

Effluent: Solid, liquid, or gaseous wastes that enter the environment as a by-product of man-oriented processes (Soil Conservation Society of America, 1982).

Emergency or Earth Spillway: A depression in the embankment of a pond or basin that is used to pass peak discharges greater than the maximum design storm controlled by the pipe spillway of the pond.

Empirical: Originating in or relying or based on factual information, observation, or direct sense experience.

Ephemeral stream: A channel that carries water only during and immediately following rainstorms.

Equivalent Opening Size (EOS): Pertains to geotextile fabric filter. It is the Equivalent Opening Size of the fabric as it relates to the US Standard Sieve Designation used in Soil Mechanics Laboratories.

Erosion: Wearing away of land by running water, waves, wind, ice, abrasion, and transportation.

Fallow: Allowing cropland to lie idle, either tilled or untilled, during the whole or greater portion of the growing season (Soil Conservation Society of America, 1982).

Field capacity: The soil-water content after the force of gravity has drained or removed all the water it can, usually 1 to 3 days after rainfall.

Fill slope: The surface formed where earth is deposited to build a road or trail.

Filter Fabric: Textile of relatively small mesh or pore size that is used to (1) allow water to pass through while keeping sediment out (permeable), or (2) prevent both runoff and sediment from passing through (impermeable).

Filter fence: A temporary barrier used to intercept sediment-laden runoff from small areas.

Flood: Water from a river, stream, watercourse, ocean, lake, or other body of standing water that temporarily overflows or inundates adjacent lands and which may affect other lands and activities through stage elevation, backwater and/or increased ground water level.

Flood Control: The elimination or reduction of flood losses by the construction of flood storage reservoirs, channel improvements, dikes and levees, by-pass channels, or other engineering works.

Flood Frequency: See “Recurrence Interval.”

Flood Plain: For a given flood event, that area of land adjoining a continuous watercourse which has been covered temporarily by flood water.

Flood Storage: Storage of water during floods to reduce downstream peak flows.

Flood Storage Area: Flood storage area is that portion of the impoundment area that may serve as a temporary storage area for flood waters.

Flume: An open conduit on a prepared grade, trestle, or bridge for the purpose of carrying water across creeks, gullies, ravines, or other obstructions; also used in reference to calibrated devices used to measure the flow of water in open conduits (Soil Conservation Society of America, 1982).

Forb: A broad-leaf herbaceous plant that is not a grass, sedge, or rush.

Ford: Submerged stream crossing where tread is reinforced to bear intended traffic.

Freeboard: The vertical distance from the top of an embankment to the highest water elevation expected for the largest design storm stored. The space is required as a safety margin in a pond or basin.

Geotextile: A product used as a soil reinforcement agent and as a filter medium. It is made of synthetic fibers manufactured in a woven or loose nonwoven manner to form a blanket-like product.

Grade: (1) The inclination or slope of a channel, conduit, etc., or natural ground surface, usually expressed in terms of the percentage of number of units of vertical rise (or fall) per unit of horizontal distance. (2) To finish the soil surface, a roadbed, top of embankment, bottom of excavation, etc.

Grade Stabilization Structure: A permanent structure used to drop water from a higher elevation to a lower elevation without causing erosion.

Grassed Waterway or Outlet: A natural or constructed channel shaped or graded and established with suitable vegetation as needed for the safe disposal of runoff water.

Headwater: (1) The upper reaches of a stream near its source; (2) the region where ground waters emerge to form a surface stream; or (3) the water upstream from a structure.

Heavy metals: Metallic elements with high atomic weights, e.g., mercury, chromium, cadmium, arsenic, and lead. They can damage living things at low concentrations and tend to accumulate in the food chain.

Herbaceous: A vascular plant that does not develop woody tissue (Soil Conservation Society of America, 1982).

Herbicide: A chemical substance designed to kill or inhibit the growth of plants, especially weeds (Soil Conservation Society of America, 1982).

High water mark: See Ordinary high water mark.

Highly erodible soils: Any soil with an erodibility class (K factor) greater than or equal to .43 in any layer.

Holding pond: A reservoir, pit, or pond, usually made of earth, used to retain polluted runoff water for disposal on land (Soil Conservation Society of America, 1982).

Hybrid: A plant resulting from a cross between parents of different species, subspecies, or cultivar (Soil Conservation Society of America, 1982).

Hydraulic gradient: A profile of the piezometric level of the water, representing the sum of the depth of flow and the pressure. In open channel flow it is the water surface.

Hydric soil: A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part.

Hydrograph: A graph showing variation in the water depth or discharge in a strewn or channel versus time.

Hydrology: The science that deals with the processes governing the depletion and replenishment of the water resources of the land areas of the earth.

Hydrophyte: A plant that grows in water or in wet or saturated soils (Soil Conservation Society of America, 1982).

Impervious: A term applied to a material through which water cannot pass, or through which water passes with great difficulty.

Impervious Area: Impermeable surfaces, such as pavement or rooftops, which prevent the infiltration of water into the soil.

Inert: A substance that does not react with other substances under ordinary conditions.

Infiltration: The penetration of water through the ground surface into subsurface soil.

Infiltration Trench: An excavated trench, usually 2 to 10 feet deep that is backfilled with a coarse graded stone aggregate. It provides temporary storage of runoff and permits infiltration into the surrounding soil.

Insecticide: A pesticide compound specifically used to kill or control the growth of insects.

Interflow: The portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface in, for example, a wetland, spring, or seep.

Intermittent stream: A watercourse that flows in a well-defined channel only in direct response to a precipitation event. It is dry for a large part of the year.

Invert: The floor, bottom, or lowest portion of the internal cross section of a conduit.

Lateral: Secondary or side channel, ditch, or conduit (Soil Conservation Society of America, 1982).

Leachate: Liquids that have percolated through a soil and that contain substances in solution or suspension (Soil Conservation Society of America, 1982).

Leaching: The removal from the soil in solution of the more soluble materials by percolating waters (Soil Conservation Society of America, 1982).

Legume: A member of a large family that includes many valuable food and forage species, such as peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches, and kudzu (Soil Conservation Society of America, 1982).

Levee: See Dike.

Level Spreader: An outlet constructed at zero percent grade across the slope that allows concentrated runoff to be discharged as sheet flow at a non-erosive velocity onto natural or man-made areas that have existing vegetation capable of preventing erosion.

Micronutrient: A chemical element necessary in only extremely small amounts (less than 1 part per million) for the growth of plants (Soil Conservation Society of America, 1982).

Mineral soil: Organic-free soil that contains rock less than 2 inches in maximum dimension.
Mulch: A natural or artificial layer of plant residue or other materials covering the land surface that conserves moisture, holds soil in place, aids in establishing plant cover, and minimizes temperature fluctuations.

Mulching: Providing any loose covering, such as grass, straw, bark, or wood fibers, for exposed soils to help control erosion and protect exposed soil.

Nonpoint source: Any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act. Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, seepage, or hydrologic modification.

Nutrients: Elements, or compounds, essential as raw materials for organism growth and development, such as carbon, nitrogen, phosphorus, etc. (Soil Conservation Society of America, 1982).

Ordinary high water mark: An elevation that marks the boundary of a lake, marsh, or streambed. It is the highest level at which the water has remained long enough to leave its mark on the landscape. Typically, it is the point where the natural vegetation changes from predominantly aquatic to predominantly terrestrial. The line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area.

Organic debris: Particles of vegetation or other biological material that can degrade water quality by decreasing dissolved oxygen and by releasing organic solutes during leaching.

Organophosphate: Pesticide chemical that contains phosphorus, used to control insects. Organophosphates are shortlived, but some can be toxic when first applied.

Outlet Protection: A rock lined apron or other acceptable energy dissipating material placed at the outlet of a pipe or paved channel and a stable downstream receiving channel.
Outslope: To shape the road surface to cause drainage to flow toward the outside shoulder.

Paved flume: A permanent lined channel constructed on a relatively steep slope. Its purpose is to conduct concentrated runoff down the slope without causing an erosion problem either on the slope or at the outlet.

Peak discharge: The maximum instantaneous rate of now during a storm, usually in reference to a specific design storm event.

Peak rate of runoff: The maximum rate of runoff during a given runoff event.

Pervious: A term applied to a material through which water passes relatively freely.

Percolation: The downward movement of water through the soil (Soil Conservation Society of America, 1982).

Perennial plant: A plant that has a life span of 3 or more years (Soil Conservation Society of America, 1982).

Perennial stream: A watercourse that flows throughout a majority of the year in a well-defined channel.

Permanent storage: The portion of a pond or infiltration BMP which is below the elevation of the lowest outlet of the structure.

Permanent wilting point: The soil water content at which healthy plants can no longer extract water from the soil at a rate fast enough to recover from wilting. The permanent wilting point is considered the lower limit of plant-available water.

Permeability: The quality of a soil horizon that enables water or air to move through it; may be limited by the presence of one nearly impermeable horizon even though the others are permeable (Soil Conservation Society of America, 1982).

Pesticide: Any chemical agent used for control of plant or animal pests. Pesticides include insecticides, herbicides, fungicides, nematocides, and rodenticides.

Pioneer roads: Temporary access ways used to facilitate construction equipment access when building permanent roads.

Plant-available water: The amount of water held in the soil that is available to plants; the difference between field capacity and the permanent wilting point.

Point source: Any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.

Pollutant: Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water (Section 502(6) of The Clean Water Act as amended by the Water Quality Act of 1987, Pub. L. 100-4).

Postdevelopment peak runoff: Maximum instantaneous rate of flow during a storm, after development is complete.

Precipitation: Any moisture that falls from the atmosphere, including snow, sleet, rain, and hail.

Principal or Pipe Spillway: A pipe structure normally consisting of a vertical conduit (riser) and a horizontal outlet conduit (barrel). It is used to control the water level and the discharge from a pond or basin.

Rainfall data: The average depth, in inches, of rainfall occurring over a watershed or subwatershed for a given frequency and duration storm event.

Reach: Any length of river or channel. Usually used to refer to sections which are uniform with respect to discharge, depth, area or slope, or sections between gaging stations.

Recurrence interval: The average interval of time within which a given event will be equalled or exceeded once. For an annual series the probability in any one year is the inverse of the recurrence interval. Thus a flood having a recurrence interval of 100 years (100-year frequency storm) has a 1 percent probability of being equalled or exceeded in any one year.

Release rate: The rate of discharge in volume per unit time from a detention facility.

Residue: See crop residue.

Retarding basin: A basin storage designed and operated to reduce the flood flows of a stream through temporary storage.

Retention: The holding of runoff in a basin without release except by means of evaporation, infiltration, or emergency bypass.

Retention storage: The storage of storm runoff water for release after the end of the design storm at a time and in amounts that can be conveniently handled by, the drainage system.

Return flow: That portion of the water diverted from a stream that finds its way back to the stream channel either as surface or underground flow (Soil Conservation Society of America, 1982).

Right-of-way: The cleared area along the road alignment that contains the roadbed, ditches, road slopes, and back slopes.

Riprap: A combination of graded stone, cobbles, and boulders used to protect streambanks, bridge abutments, or other erodible sites from runoff or wave action.

Riser: A vertical pipe connected to a barrel, extending from the bottom of a pond that is used to control the discharge rate for a specific design storm.

Root zone: The part of the soil that is, or can be, penetrated by plant roots (Soil Conservation Society of America, 1982).

Runoff: That part of precipitation or snow melt that runs off the land into streams or other surface water.

Runoff Curve Number: A factor in the NRCS/SCS Hydrologic Soil Cover Complex runoff determination method. Relates mass rainfall to mass runoff. It is based on soil characteristics, cover type and land treatment.

Salinity: The concentration of dissolved solids or salt in water (Soil Conservation Society of America, 1982).

Scour: Soil erosion when it occurs underwater, as in the case of a streambed.

Seed bed: The soil prepared by natural or artificial means to promote the germination of seeds and the growth of seedlings.

Sediment: The product of erosion processes, the solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice.

Sediment Basin: A basin constructed to collect and store sediment or other waterborne debris.

Sedimentation: The process or act of depositing sediment (Soil Conservation Society of America, 1982).

Seepage: Water escaping through or emerging from the ground along an extensive line or surface as contrasted with a spring, where the water emerges from a localized spot (Soil Conservation Society of America, 1982).

Settleable solids: Solids in a liquid that can be removed by stilling a liquid. Settling times of one hour or more are generally used.

Sheetflow: Water, usually storm runoff, flowing in a thin layer over the ground surface.

Silt fence: A temporary barrier used to intercept sediment-laden runoff from small areas.

Sinkhole: A depression in the earth's surface caused by dissolving of underlying limestone, salt, or gypsum; drainage is through underground channels; may be enlarged by collapse of a cavern roof (Soil Conservation Society of America, 1982).

Slope: Amount of deviation of a surface from the horizontal, measured as a numerical ratio, as a percent, or in degrees. Expressed as a ratio, the first number is the horizontal distance (run) and the second number is the vertical distance (rise), as 2:1. A 2:1 slope is a 50 per cent slope. Expressed in degrees, the slope is the angle from the horizontal plane, with a 90 degree slope being vertical (maximum) and a 45 degree slope being a 1:1 slope.

Sludge: The material resulting from chemical treatment of water, coagulation, or sedimentation (Soil Conservation Society of America, 1982).

Soil profile: A vertical section of the soil from the surface through all its horizons, including C horizons (Soil Conservation Society of America, 1982).

Soil survey: A general term for the systematic examination of soils in the field and in laboratories; their description and classification; the mapping of kinds of soil; the interpretation of soils according to their adaptability for various crops, grasses, and trees; their behavior under use or treatment for plant production or for other purposes; and their productivity under different management systems (Soil Conservation, Society of America, 1982).

Storm Sewer: A closed conduit for conducting storm water that has been collected by inlets or by other means.

Storm Runoff: The water from precipitation running off from the surface of a drainage area during and immediately following a period of rain.

Straw or Hay Bale Barrier: A temporary obstruction of straw or hay installed across or at the toe of a slope. It intercepts and detains small amounts of sediment from unprotected areas of limited extent and reduce runoff velocity down the slope.

Subsurface Drain: A conduit such as tile, pipe or plastic tubing, installed beneath the ground surface that collects and/or conveys excess water emanating from the soil.

Surface detention: The storm runoff detained on the surface of the ground at or near where the rainfall occurred, and which will either run off slowly or infiltrate into the soil.

Surface infiltration: That rainfall which percolates into the ground surface and which therefore does not contribute directly to the storm runoff flow.

Surface water: All water whose surface is exposed to the atmosphere.

Suspended sediment: The very fine soil particles that remain in suspension in water for a considerable period of time.

Swale: A natural depression or wide shallow ditch used to temporarily store, route, or filter runoff.

Temporary sediment trap: A small temporary ponding area that is formed by excavation or constructing an earthen embankment across a drainageway to reduce flow velocities thus allowing soil particles to fall out of suspension before discharging into the downstream waters.

Temporary Grade Stabilization Structure: A temporary barrier of rock, timber or straw or hay bales constructed across a swale or drainage ditch to reduce flow velocity.

Tillage: The operation of implements through the soil to prepare seedbeds and rootbeds, control weeds and brush, aerate the soil, and cause faster breakdown of organic matter and minerals to release plant foods (Soil Conservation Society of America, 1982).

Tilth: The physical condition of the soil as related to its ease of tillage, its fitness as a seedbed, and its impedance to seedling emergence and root penetration (Soil Conservation Society of America, 1982).

Time of Concentration: The time required for surface runoff from the most hydraulically remote part of a drainage basin to reach the basin outlet or the point under consideration.

Time of Flow: The time required for water to flow in a storm drain from the point where it enters to any given point or location beyond the inlet.

Topography: The relative positions and elevations of the natural or man-made features of an area that describe the configuration of its surface (Soil Conservation Society of America, 1982).

Trash rack: A barrier constructed to catch debris and exclude it from entering a downstream conduit.

Trench: An excavation made for installing pipes, masonry walls, and other purposes. A trench is distinguished from a ditch in that the opening is temporary and is eventually backfilled.

Turbidity: A cloudy condition in water due to suspended silt or organic matter.

Turnout: A drainage ditch that drains water away from roads and road ditches.

Vegetated buffer: Strips of vegetation separating a waterbody from a land use with potential to act as a nonpoint pollution source; vegetated buffers (or simply buffers) are variable in width and can range in function from a vegetated filter strip to a wetland or riparian area.

Vegetated filter strip: An area of vegetation for runoff to flow through when it leaves a disturbed site before it enters into a designed drainage system.

Vegetated swale: A natural or constructed broad channel with dense vegetation designed to treat runoff and dispose of it safely into the natural drainage system. Swales are designed to remove pollutants from stormwater runoff, increase infiltration and reduce the erosion potential at the discharge point.

Water bar: A diversion ditch and/or hump installed across a trail or road to divert runoff from the surface before the flow gains enough volume and velocity to cause soil movement and erosion, and deposit the runoff into a dispersion area.

Watercourse: A definite channel with bed and banks within which concentrated water flows continuously, frequently or infrequently.

Water table: The upper surface of the ground water or that level below which the soil is saturated with water; locus of points in soil water at which the hydraulic pressure is equal to atmospheric pressure (Soil Conservation Society of America, 1982).

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Weir: Device for measuring or regulating the flow of water.

Wetlands: Areas that are inundated or saturated by surface or ground water at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions; wetlands generally include swamps, marshes, bogs, and similar areas.

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Appendix D

Standard Method to Convert Water Quality Volume to a Discharge Rate

(for Sizing Flow Based Proprietary Manufactured Stormwater Treatment Practices)

Introduction

Computations following the standardized method shall be submitted with a Wetlands Notice of Intent (NOI) when a proprietary manufactured stormwater treatment device sized using a flow rate is proposed in connection with work proposed in a wetland resource area or associated buffer zone. The computational method primarily affects the sizing of the proprietary manufactured stormwater treatment separators, and not other types of stormwater treatment practices that are volume based (such as extended detention basins) or proprietary stormwater treatment filters sized using the Water Quality Volume (WQV).

Stormwater Standard No. 4 and Stormwater Standard No. 7 requires structural stormwater management practices to be sized to capture the required 1-inch WQV in accordance with the Massachusetts Stormwater Handbook[1]. Stormwater Standard No. 4 requires that the full WQV be captured and treated to remove 90% of the Total Suspended Solid (TSS) load. Stormwater Standard No. 7 for Redevelopment projects requires that the full WQV be captured and treated to remove 80% of the Total Suspended Solid (TSS) load.

Since manufactured proprietary stormwater separators are sized using discharge rates and not volume, the standardized method described below shall be used to convert the required WQV to a discharge rate (Q). No other methods are allowed to convert the WQV to the Q rate. This will ensure that flow rate based manufactured proprietary stormwater treatment practices are sized consistently from manufacturer to manufacturer. This section contains the following: caveats for method use, method description, examples of how to use the method, and documentation describing how the method was derived.

The following caveats apply to use of the method:

- All proprietary manufactured stormwater treatment separators must be sized to treat at least the first 1-inch of runoff times the impervious drainage area without resuspension or bypass of previously suspended solids. All proprietary manufactured stormwater treatment separators must be placed or configured to be offline, or contain an internal bypass to prevent resuspension of previously trapped solids
- Proprietary manufactured stormwater treatment separators may only be used to meet TSS pretreatment provisions contained in Stormwater Standards 3 - 6, unless written findings are issued by MassDEP indicating that the practice can be used as terminal treatment practice (see **Section 5.3** of the Massachusetts Stormwater Handbook for more information).
- The computations described below must be provided in the Stormwater Report accompanying Wetlands Notice of Intent or application for 401 Water Quality Certification. The evaluation of proprietary manufactured stormwater treatment separators for individual projects is conducted on a case-by-case basis through the NOI or WQC application review conducted by the issuing authority (i.e., Conservation Commission, MassDEP) as described in **Section 5.3** of the Massachusetts Stormwater Handbook.
- MassDEP reserves ability to revise this method in the future as may be needed to reflect documented increases to precipitation intensity, updates to design intensity storms, NRCS revisions to the WinTR55/TR20 methods, or changes to the National Pollution Discharge Elimination System (NPDES) permits issued by EPA for Massachusetts.

[1] Refer to 310 CMR 10.05(6)(k) (Wetlands Protection) and 314 CMR 9.06(6)(a) (Water Quality Certification) for the Stormwater Management Standards.

Method

- **Step 1.** Use Curve Number (CN) 98 to represent the runoff potential for impervious surfaces (see Method Derivation section below for explanation regarding how CN 98 was obtained).

  Only use impervious surfaces for these computations. Runoff from pervious surfaces should not be included in the WQV computations for peak WQF. The WQV required by Stormwater Standard No. 4 and Stormwater Standard No. 7is based only on impervious surfaces.

- **Step 2.** Compute the time of concentration (tc) using the methods described in TR-55 1986, Chapter 3.

- **Step 3.** Determine unit peak discharge using **Figure C-1** or **Table C-1**. **Table C-1** is in tabular form so is preferred. Using the tc determined in Step 2, read the unit peak discharge (qu) from **Figure C-1** or from **Table C-1**. qu is expressed in the following units: cfs/mi²/watershed inches (csm/in).

- **Step 4.** Compute the water quality flow (WQF) using the following equation:

$$Q_1 = (qu)(A)(WQV)$$

Where:

Q_1 = peak flow rate associated with first 1-inch of runoff

qu = the unit peak discharge, in csm/in.

A = impervious surface drainage area (in square miles)

WQV = water quality volume in watershed inches (1.0-inches)

See Example 1, applying use of the method to convert first 1-inch WQV to minimum Q_1 rate.

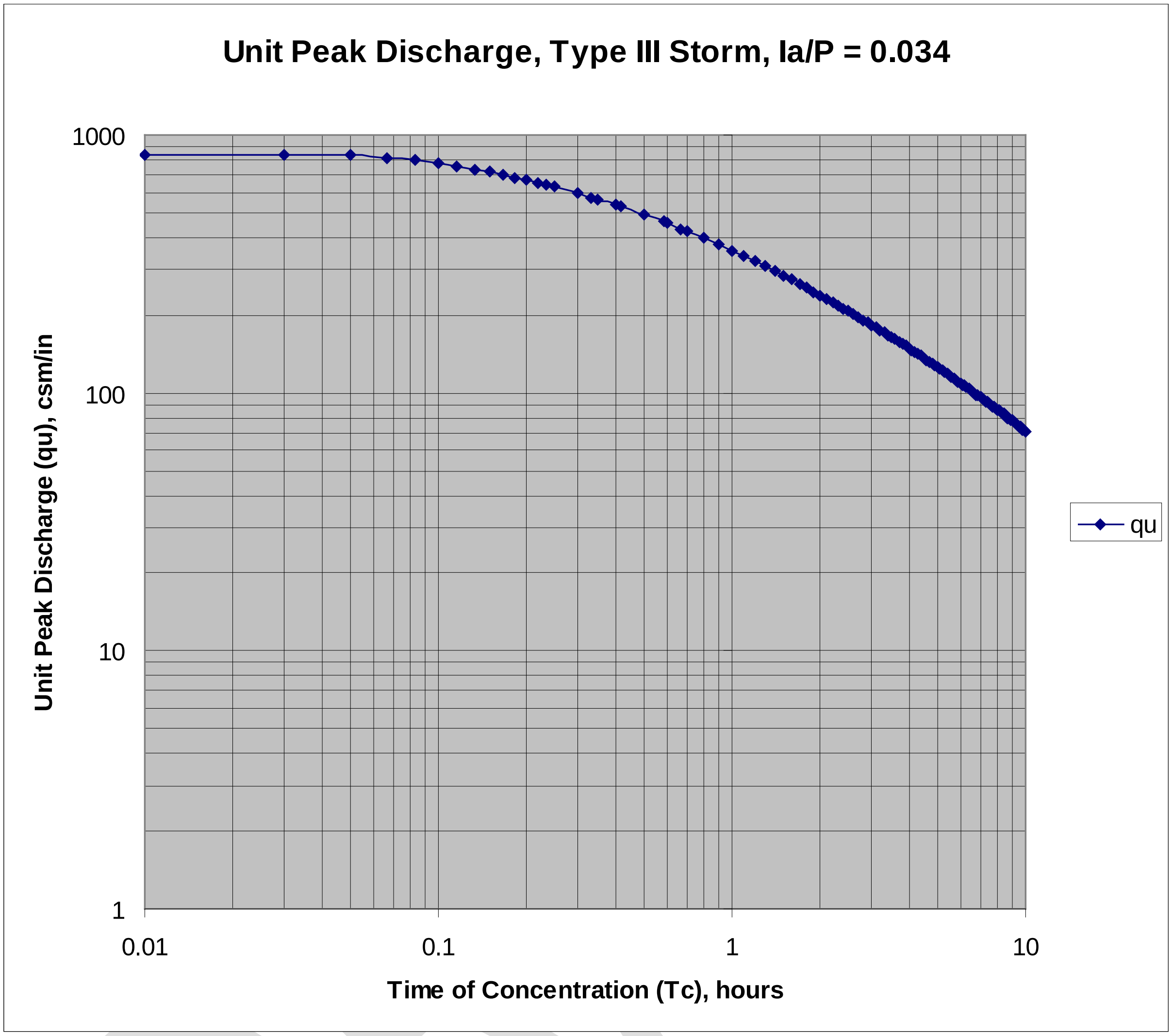

Figure C-1. For First 1-inch Runoff, Ia/P Curve = 0.034, Relationship Between Unit Peak Discharge and Time of Concentration for NRCS Type III Storm Distribution

Table C-1. For First 1-inch Runoff, Table of qu values for Ia/P Curve = 0.034, listed by tc, for Type III Storm Distribution

Tc (Hours)	qu (csm/in)
0.01	835
0.03	835
0.05	831
0.067	814
0.083	795
0.1	774
0.116	755
0.133	736
0.15	717
0.167	700
0.183	685
0.2	669
0.217	654
0.233	641
0.25	628
0.3	593
0.333	572
0.35	563
0.4	536
0.416	528
0.5	491
0.583	460
0.6	454
0.667	433
0.7	424
0.8	398
0.9	376
1	356
1.1	339
1.2	323
1.3	309
1.4	296
1.5	285
1.6	274
1.7	264
1.8	255
1.9	247
2	239
2.1	232
2.2	225
2.3	219
2.4	213
2.5	207
2.6	202
2.7	197
2.8	192
2.9	187
3	183
3.1	179
3.2	175
3.3	171
3.4	168
3.5	164
3.6	161
3.7	158
3.8	155
3.9	152
4	149
4.1	146
4.2	144
4.3	141
4.4	139
4.5	137
4.6	134
4.7	132
4.8	130
4.9	128
5	126
5.1	124
5.2	122
5.3	120
5.4	119
5.5	117
5.6	115
5.7	114
5.8	112
5.9	111
6	109
6.1	108
6.2	106
6.3	105
6.4	104
6.5	102
6.6	101
6.7	100
6.8	99
6.9	98
7	96
7.1	95
7.2	94
7.3	93
7.4	92
7.5	91
7.6	90
7.7	89
7.8	88
7.9	87
8	86
8.1	85
8.2	84
8.3	84
8.4	83
8.5	82
8.6	81
8.7	80
8.8	79
8.9	79
9	78
9.1	77
9.2	76
9.3	76
9.4	75
9.5	74
9.6	74
9.7	73
9.8	72
9.9	72
10	71

Example Calculation for the first 1-inch Runoff WQV

Problem Statement. One-acre site composed entirely of impervious surfaces, with time of concentration equal to 6 minutes. The proposed impervious surfaces are to be drained to a stream located in Zone II of a public drinking water supply. A proprietary separator is proposed to pretreat runoff to be directed to an Infiltration Basin. *Determine the peak flow rate (Q_1) to be used for sizing associated with the required 1-inch WQV.*

- **Step 1.** Use CN = 98 to represent the 1-acre impervious surface.
- **Step 2**. Determine tc

  tc = 6 minutes (given).

  Convert minutes to hours

  tc = (6 minutes) /(60 minutes/hr) = 0.1 hours
- **Step 3**. Determine qu using **Table C-1**.

  Using the tc column, read down to find tc = 0.1 hours. Read to the right of tc = 0.1 hours to find the qu value which is 774 csm/inch.

  Alternatively, you may use **Figure C-1** (Ia/P curve = 0.034). Find tc = 0.1 hours, read up to the Ia/P curve, then follow intersecting line to the left to interpolate the qu value. You'll note that using **Table C-1** is quicker in so far as no interpolation is required. In cases where the tc is not listed in **Table C-1**, you may need to use **Figure C-1**. In such instances, **Table C-1** may still assist you in bracketing the qu values to interpolate.
- **Step 4**. Determine Q_1

  Q_1 = (qu)(A)(WQV)

  Q_1 = (774 csm/in)(1-acre)(0.0015625 mi^2/acre)(1-inch)

  $Q_1 \approx$ 1.2 CFS

  The proprietary separator must be sized based on a minimum peak flow rate of 1.2 cfs to capture the required 1-inch WQV.

If the conversion factor to convert acres to square miles is not included, the result will not be correct. As different units are used in the computations, double check your units to ensure the result is correct.

Method Derivation

The Stormwater Advisory Committee convened to assist MassDEP with the 2008 stormwater revisions to the Wetlands and 401 Water Quality Certification regulations. The Advisory Committee tabled a method proposed at that time and asked its Proprietary BMP subcommittee to study the issue further. Subsequently, the Proprietary BMP subcommittee met from 2008 to 2011, examining multiple methods. Among the methods reviewed included the Rational Method used by New Jersey DEP, Ahlfeld et al 2004, Winkler et al 2001, Claytor and Scheuler 1996, Imbrium PCSWMM, and Bryant. The Ahlfeld and Winkler methods were funded by MassDEP through 319 funds and developed using Massachusetts precipitation data. The Claytor method is based on SCS TR-55 graphical methods. The PCSWMM method is a proprietary version of the EPA SWMM method, based on Mannings equation. The Bryant method was based on precipitation data compiled in the Ahlfeld and Winkler methods.

To assist in selecting a method, Rees and Schoen 2009 conducted third party review of the different approaches. Rees and Schoen found that the various methods produced different peak rate flows. Differences were also found between peak flow rates in coastal and inland areas. With some methods, the precipitation intensity associated with the ½-inch water quality volume produced a greater flow rate than the 1-inch water quality volume. The study concluded that the Claytor and Schueler 1996 method was the most complete in attempting to transform the Water Quality Volume to a flow rate.

Subsequent to the study, flow rate results from the Claytor and Schueler method were adapted for use in Massachusetts using both the first ½ - inch and 1-inch Water Quality Volumes. Flow rates were found to bypass a portion of the Water Quality Volume for the both the first ½ -inch and 1-inch of runoff depending on drainage area and treatment device size. As bypassed runoff is not treated, the Proprietary BMP Subcommittee agreed on meeting held in March 2011 that practices sized using the flow conversion method must be restricted to pretreatment only and directed to stormwater treatment practices. The Proprietary BMP Subcommittee subsequently recommended the Claytor and Schueler 1996 method be used, as adapted for use in Massachusetts, to the Stormwater Advisory Committee in May 2011.

The Claytor and Schueler 1996 approach in part utilizes the U.S. Natural Resource and Conservation Service Technical Release 55 (TR-55) Graphical Peak Discharge Method (NRCS / SCS 1986), adapted for small storm hydrology (Pitt 1999). It was adapted for use in Massachusetts by determining the precipitation values that generate the first ½ -inch and 1-inch of runoff, using the NRCS / SCS 1986 equations as described below.

***Note:** The Massachusetts Stormwater Handbook was updated in 2021. Massachusetts Stormwater Standard No. 4 and Stormwater Standard No. 7 now requires a required WQV equal to 1.0 for manufactured proprietary stormwater separators. This method has therefore been updated to only include a derivation for the 1.0 inch WQV.*

1. The Massachusetts Stormwater Standard No. 4 and Stormwater Standard No. 7 sets the required WQV equal to 1.0- inch.

2. The Claytor and Scheuler 1996 method requires a Curve Number (CN) be determined to represent the ability of a surface to effectively convey runoff. CN 98 was derived for impervious surfaces using small storm hydrology using the following equation (NRCS / SCS 1986). The precipitation depth associated with the first 1.0-inch of runoff is 1.2 watershed inches based on **Figure C-2** (NRCS 1986 Table 2-1) and **Figure C-3** (NRCS 1986 Figure 2-1).

$$CN = \frac{1000}{10 + 5P_t + 10Q_{WQV} - 10(Q_{WQV}{}^2 + 1.25Q_{WQV}P_t)^{0.5}}$$

Where:

CN = Runoff Curve Number = 98 for runoff from impervious surfaces

P_t = Precipitation depth

Q_{WQV} = Runoff depth related to Water Quality Volume = 1.0 watershed inches

This equation produces the result Pt = 1.2 inches, when CN = 98 and WQV = 1.0 inches

3. Potential maximum retention (S) in inches was derived using the following equation (NRCS 1986):

$$S = (1000/CN) - 10$$

This equation produces the result S = 0.204 when the CN = 98

4. The initial abstraction (Ia) was derived using the following equation (NRCS 1986):

$$Ia = 0.2S$$

This equation produces the result Ia = 0.041, when S = 0.204

*Also See **Figure C-6** (NRCS 1986, Table 4-1), where Ia = 0.041, for CN = 98*

5. The Ia/P Ratio was derived using the following equation (NRCS 1986):

$$Ia/P \text{ Ratio} = Ia/ P_t$$

Where:

Ia = 0.041 (for CN = 98)

P_t = 1.2 watershed inches

$$Ia/P \text{ Ratio} = 0.041/ 1.2 = 0.034$$

6. For the first 1-inch runoff, Ia/P curve for 0.034 ratio (**Figure C-1**) and corresponding table (**Table C-1**) were generated using coefficients C_0, C_1 and C_2 derived from regression of coefficients published in Appendix F in NRCS / SCS TR-55 1986.

Figures Used for Method Derivation

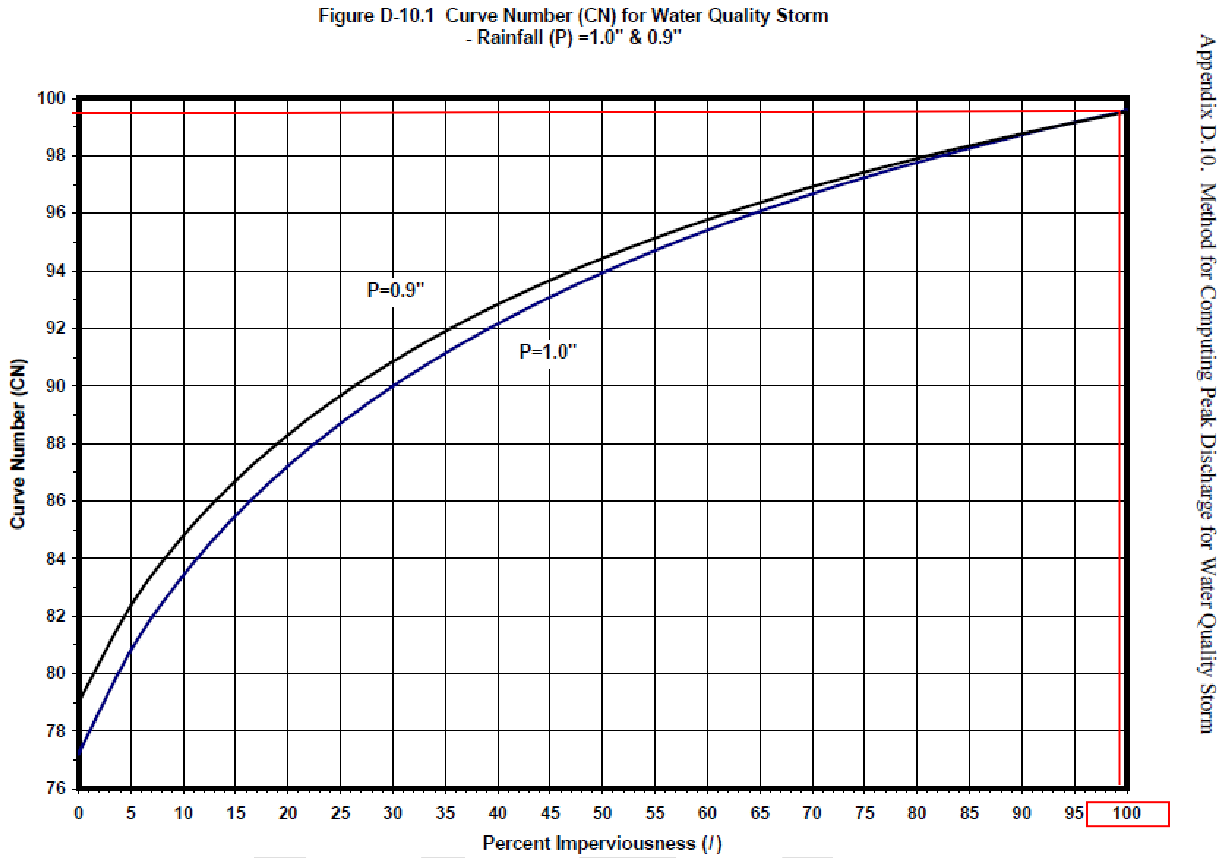

Figure C-2. Graph Depicting CN to Percent Impervious Relationship by Precipitation Depth (MD 2000, Figure D-10.1). Note at 100% imperviousness, precipitation depths coincide, making corresponding Runoff CN greater than 98.

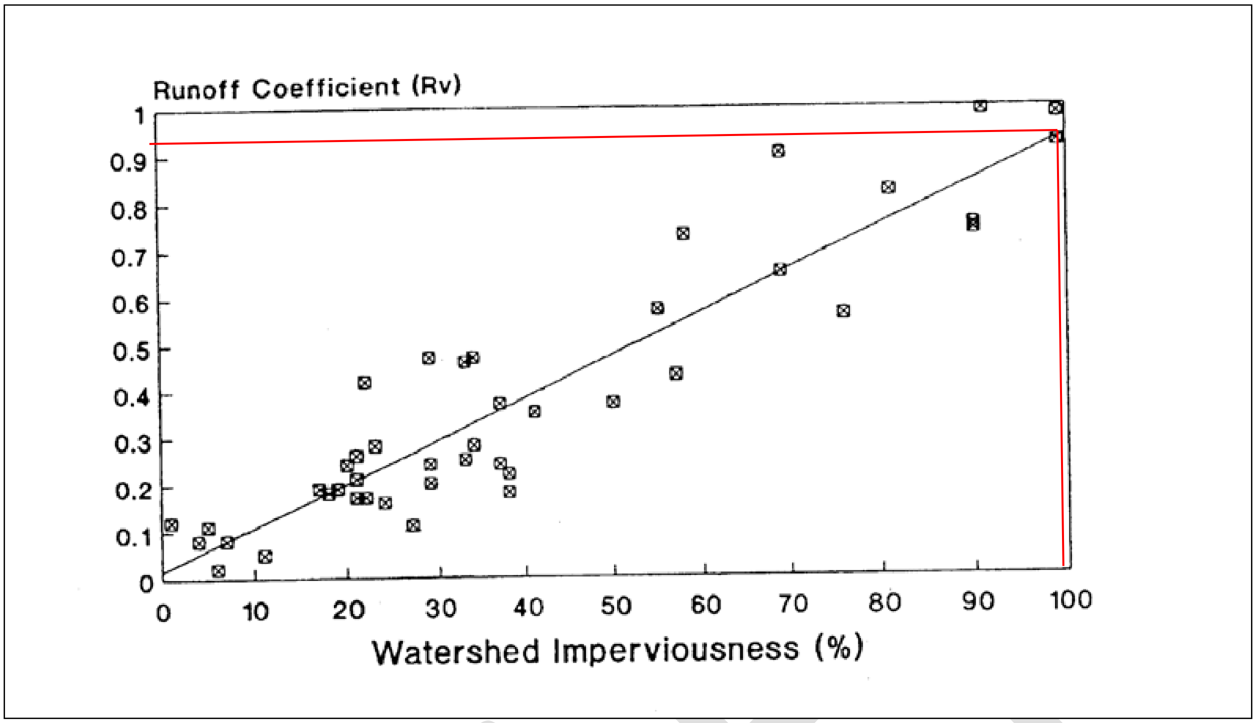

Figure C-3. Relationship Between Impervious Cover & Runoff Coefficient (Vermont 2002, from Schueler, 1987). Note at 100% imperviousness, Rv is between 0.9 and 1, meaning that most of the precipitation effectively becomes runoff.

Table 2-1 Runoff depth for selected CN's and rainfall amounts [1/]

Rainfall	Runoff depth for curve number of—												
	40	45	50	55	60	65	70	75	80	85	90	95	98
	inches												
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	.00	.00	.00	.00	.00	.00	.03	.07	.15	.27	.46	.74	.99
1.4	.00	.00	.00	.00	.00	.02	.06	.13	.24	.39	.61	.92	1.18
1.6	.00	.00	.00	.00	.01	.05	.11	.20	.34	.52	.76	1.11	1.38
1.8	.00	.00	.00	.00	.03	.09	.17	.29	.44	.65	.93	1.29	1.58
2.0	.00	.00	.00	.02	.06	.14	.24	.38	.56	.80	1.09	1.48	1.77
2.5	.00	.00	.02	.08	.17	.30	.46	.65	.89	1.18	1.53	1.96	2.27
3.0	.00	.02	.09	.19	.33	.51	.71	.96	1.25	1.59	1.98	2.45	2.77
3.5	.02	.08	.20	.35	.53	.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	.06	.18	.33	.53	.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	.14	.30	.50	.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	.24	.44	.69	.98	1.30	1.65	2.04	2.45	2.89	3.37	3.88	4.42	4.76
6.0	.50	.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

Figure C-4. Table Depicting Relationship Between Precipitation (P) and Direct Runoff (Q) by Curve Number (NRCS 1986, Table 2-1). 1.2 inches of precipitation effectively becomes 0.99-inch of runoff.

Figure 2-1 Solution of runoff equation.

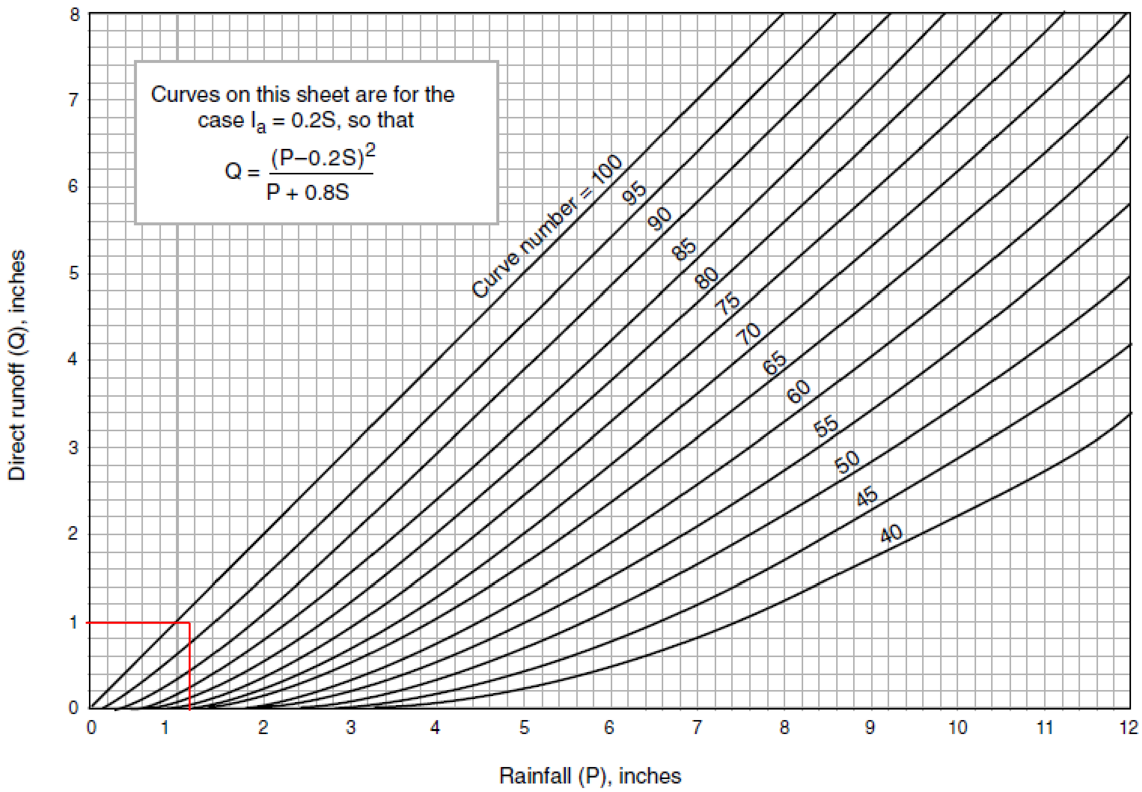

Figure C-5. Graph Depicting Relationship Between Precipitation (P) and Direct Runoff (Q) by Curve Number (NRCS 1986, Figure 2-1). This indicates that for a CN 98 (representing impervious surfaces), 1.2 inches of precipitation effectively equals 1-inch of direct runoff.

Table 4-1 I_a values for runoff curve numbers

Curve number	I_a (in)	Curve number	I_a (in)
40	3.000	70	0.857
41	2.878	71	0.817
42	2.762	72	0.778
43	2.651	73	0.740
44	2.545	74	0.703
45	2.444	75	0.667
46	2.348	76	0.632
47	2.255	77	0.597
48	2.167	78	0.564
49	2.082	79	0.532
50	2.000	80	0.500
51	1.922	81	0.469
52	1.846	82	0.439
53	1.774	83	0.410
54	1.704	84	0.381
55	1.636	85	0.353
56	1.571	86	0.326
57	1.509	87	0.299
58	1.448	88	0.273
59	1.390	89	0.247
60	1.333	90	0.222
61	1.279	91	0.198
62	1.226	92	0.174
63	1.175	93	0.151
64	1.125	94	0.128
65	1.077	95	0.105
66	1.030	96	0.083
67	0.985	97	0.062
68	0.941	$\boxed{98}$	$\boxed{0.041}$
69	0.899		

Figure C-6. Table Listing Ia by CN (NRCS 1986, Table 4-1). This indicates Initial Abstraction (Ia) for CN 98 = 0.041

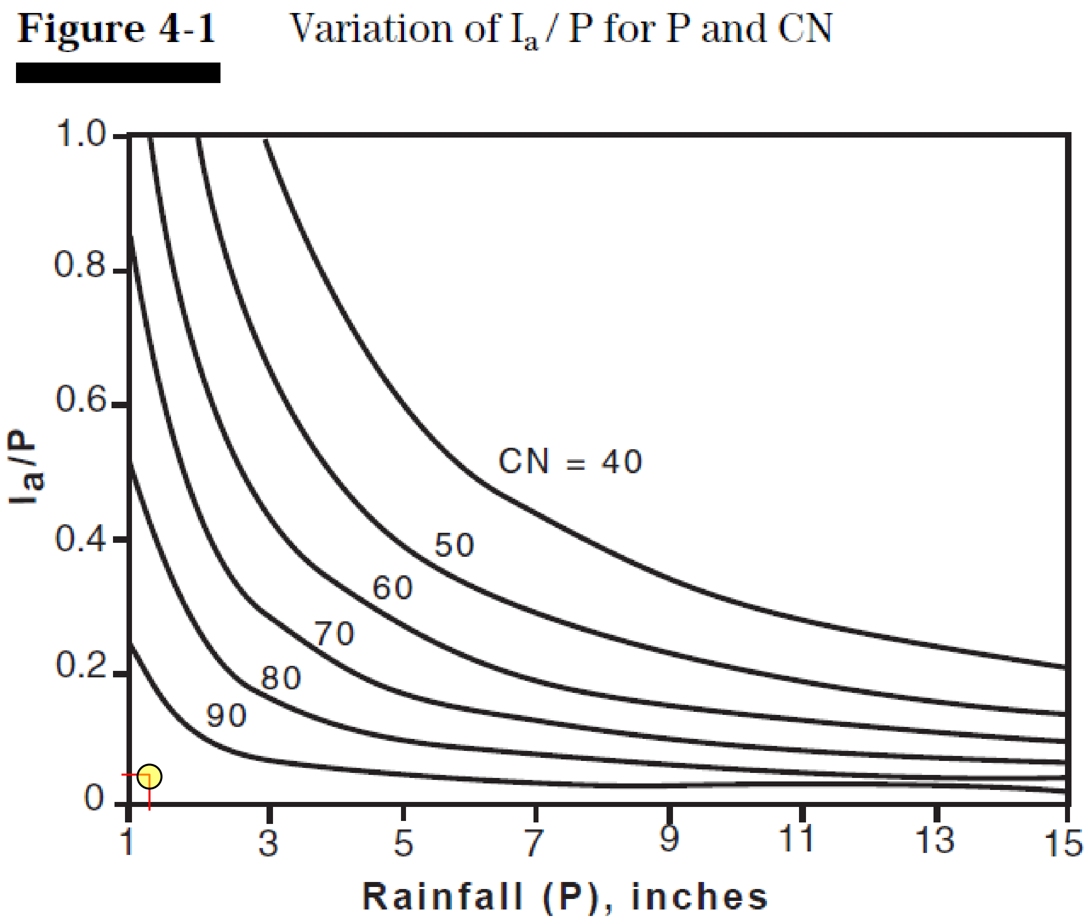

Figure C-7. Graph Depicting Ia/P to Precipitation Relationship by CN (NRCS 1986, Figure 4-1). Ia/P ratio of 0.034 corresponding to 1.2 inches of precipitation added. Ia/P ratio determined for CN 98, using Ia = 0.041, P = 1.2

Exhibit 4-III Unit peal discharge (q_u) for NRCS (SCS) type III rainfall distribution

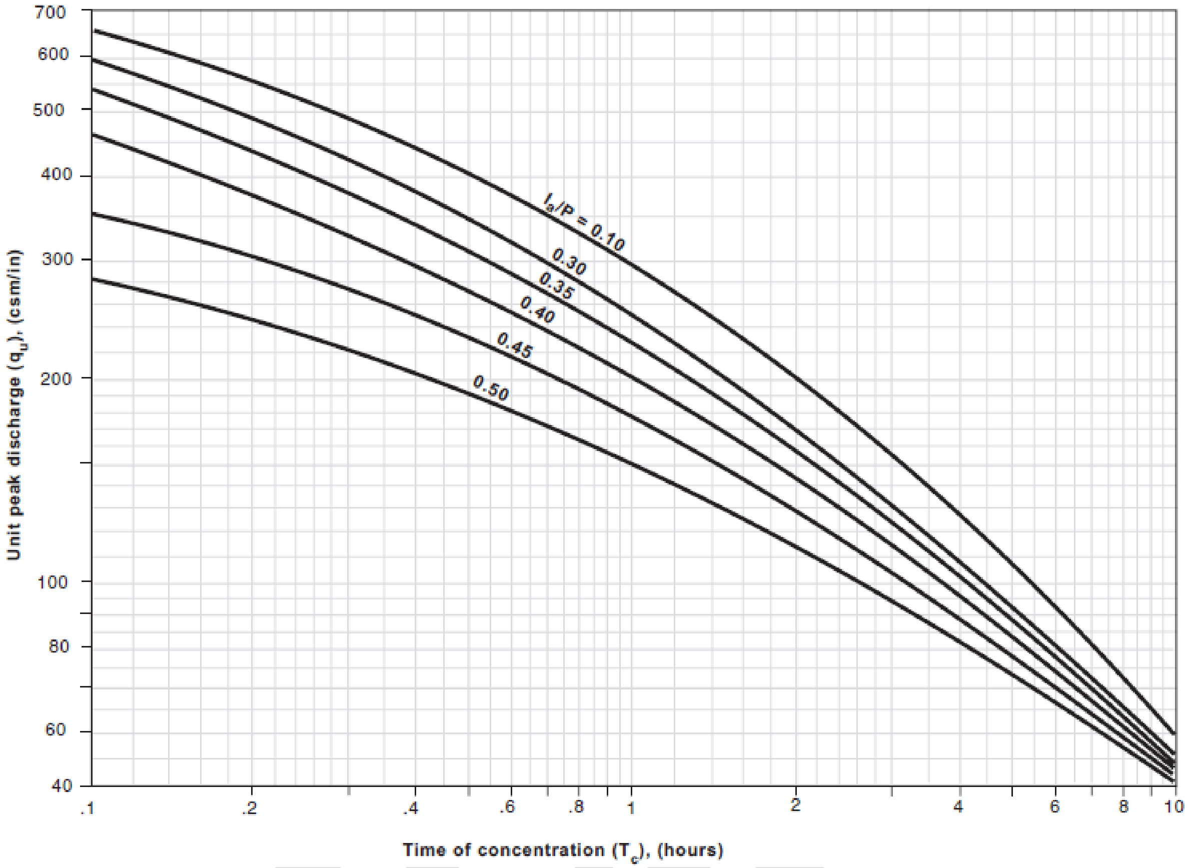

Figure C-8. Relationship Between Time of Concentration and Unit Peak Discharge for Ia/P Ratios from 0.10 to 0.50 for NRCS Type III Storm Distribution (NRCS 1986, Exhibit 4-III). NRCS / SCS 1986 specifies Type III storm distribution (tropical influenced storms) for Massachusetts. See Figure 1 and 2 for Ia/P Ratio = 0.034

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Appendix E

Redevelopment Checklist

Introduction

This Redevelopment Checklist must be completed and submitted with the WPA NOI or WQC Application for any project that includes Redevelopment as defined by **Section 2.3.7** of the Stormwater Handbook. Redevelopment portions of a project are subject to certain Stormwater Standards only to the Maximum Extent Practicable as summarized by **Table 2-5** of the Stormwater Handbook. If the Redevelopment Checklist demonstrates that full compliance cannot be achieved for applicable Stormwater Standards, a written alternatives analysis must be completed as detailed by **Section 6.1.4** of the Stormwater Handbook. The purpose of the written alternatives analysis is to demonstrate that the highest practicable level of stormwater management is being implemented if full compliance with the Stormwater Standards cannot be achieved.

Notes:

- The portion of a property that is currently undeveloped is not a Redevelopment and thus does not fall under Standard 7. To the extent that a project includes development of previously undeveloped areas, the project must comply **fully** with all the Stormwater Management Standards. See **Section 2.3.7** of the Stormwater Handbook for an example of a project with a mixture of Redevelopment and new development. For projects that have a mixture of Redevelopment and new development, full compliance with the Stormwater Standards is required for any component that constitutes new development.
- Retrofits are not a component of Redevelopment. Retrofits are site specific changes designed solely to improve water quality, reduce peak runoff rates, increase recharge, or reduce or eliminate combined sewer overflows (CSOs). This checklist is not required to be completed for Retrofits. Refer to **Section 2.3.7** and **Section 5.1** of the Stormwater Handbook for more information on Retrofit projects and how they must comply with the Stormwater Standards.
- The Redevelopment Checklist is intended to provide a summary of potentially applicable requirements. Refer to the Stormwater Handbook for more detailed requirements (e.g., sizing calculations, pretreatment requirements, setback requirements, site specific conditions such as discharge from metal roofs, etc.).[1]

This checklist must only be completed for the portion of the project that meets the definition of Redevelopment.

Existing Conditions

- ☐ **On-site:** For all Redevelopment projects, document existing conditions, including drainage areas, extent of resource areas, a description of the extent of impervious surfaces, soil types, existing land uses with higher potential pollutant loads, and current onsite stormwater management practices.
- ☐ **Watershed**: Determine if the project is located in a watershed or subwatershed, where flooding, low streamflow or poor water quality is an issue, including whether any of the resource areas have been identified as impaired on MassDEP's Integrated List of Waters and whether a TMDL is in effect for the pollutants identified in Standard 11.[2,3]

[1] Although MassDEP has endeavored to make sure that requirements in the regulations and other sections of the Massachusetts Stormwater Handbook are consistent, if there is a discrepancy between the information listed in this section and elsewhere in this document, the most restrictive must be applied.

[2] Integrated list of waters: https://www.mass.gov/lists/integrated-lists-of-waters-related-reports#2016-integrated-list-of-waters.

[3] Massachusetts TMDLs: https://www.mass.gov/total-maximum-daily-loads-tmdls.

The Project

Is the project a Redevelopment project as defined by 310 CMR 10.04 and 314 CMR 9.02?

- ☐ Improvement of existing roadways, including widening less than a single lane, adding shoulders, correcting substandard intersections, and improving existing drainage systems;
- ☐ development, rehabilitation, expansion and phased projects on previously developed sites, provided the Redevelopment results in no net increase in impervious area; and
- ☐ remedial projects specifically designed to provide improved stormwater management, such as projects to separate storm drains and sanitary sewers and stormwater retrofit projects.

The Stormwater Management Standards

The Redevelopment checklist reviews compliance with each of the Stormwater Management Standards.

Standard 1: No Untreated discharges or Erosion to Wetlands

See **Section 2.3.1** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance with Standard 1 is required for new outfalls.

Questions	Y	N	N/A
Has the Applicant documented that all new discharges associated with the project are adequately treated? The term "New Stormwater Discharges" is defined in 310 CMR 10.04 and 314 CMR 9.02.[4] *(See Standards 2 through 6 To demonstrate that discharges are adequately treated.)*	☐	☐	☐
Has the Applicant proposed appropriate SCMs to ensure that no new discharges will cause erosion in wetlands or waters of the Commonwealth? See **Section 2.3.1** and **Section 6.2.1** of the Stormwater Handbook for guidance.	☐	☐	☐
Will the proposed discharge comply with all applicable requirements of the Massachusetts Clean Waters Act and the regulations promulgated thereunder at 314 CMR 3.00, 314 CMR 4.00 and 314 CMR 5.00?	☐	☐	☐

Existing outfalls as defined in **Section 2.3.1** of the Stormwater Handbook shall be brought into compliance with Standard 1 to the Maximum Extent Practicable.

Questions	Y	N	N/A
Are there any existing discharges associated with the Redevelopment project for which new treatment could be provided?	☐	-	☐
If applicable, has the Applicant specified SCMs to ensure that the discharges are adequately treated and indicate the reasons for adopting or rejecting those	☐	☐	☐

[4] New Stormwater Discharge means new or increased runoff directed to a resource area from new Impervious Surface or through a New Stormwater Conveyance. Increased runoff means additional stormwater volume or higher discharge rate than currently exists. Stormwater discharges can be from public or privately owned Impervious Surfaces or conveyances.

Questions	Y	N	N/A
measures? *(See Standards 2 through 6 To demonstrate that discharges are adequately treated.)*			
If applicable, has the Applicant proposed SCMs to prevent erosion from existing stormwater discharges in accordance with **Section 2.3.1** of the Stormwater Handbook?	☐	☐	☐
If the answer to any of the above questions is No, has the Applicant completed a written alternatives analysis as detailed by **Section 6.1.4** of the Stormwater Handbook?	☐	☐	☐

Standard 2: Peak Rate Attenuation

See **Section 2.3.2** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Compliance to the Maximum Extent Practicable is required for Standard 2. In addition, existing conditions must be improved.

Questions	Y	N	N/A
Does the Redevelopment compare post-development to existing conditions?	☐	☐	☐
Have measures been implemented to attenuate peak discharge rates during the 2-, 10-, and 100-year 24-hour storm events to less than the peak rates under current estimated conditions? Refer to **Table 2-7** of the Stormwater Handbook for a list of SCMs that are suitable to attenuate peak flows. (*As indicated by **Section 2.3.7** of the Stormwater Handbook, all Redevelopment Projects <u>must improve existing conditions</u>. The peak runoff rate from the site must therefore be reduced*).	☐	☐	☐
Is the project located adjacent to a water body or watercourse subject to adverse impacts from flooding during the 100-year 24-hour storm event? If so, are portions of the site available to increase flood storage adjacent to existing Bordering Land Subject to Flooding (BLSF)?	☐	☐	☐
If the answer to any of the above questions is No, has the Applicant completed a written alternatives analysis as detailed by **Section 6.1.4** of the Stormwater Handbook?	☐	☐	☐

Standard 3: Stormwater Recharge

See **Section 2.3.3** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Compliance with Standard 3 is required to the Maximum Extent Practicable.

Questions	Y	N	N/A
Does the post-development design provide recharge to fully or partially offset loss of recharge caused by pre-development impervious surface? (*As indicated by **Section 2.3.7** of the Stormwater Handbook, all Redevelopment Projects must <u>improve existing conditions</u>. Recharge must therefore be increased*).	☐	☐	☐

Questions	Y	N	N/A
Are proposed Stormwater Control Measures properly designed and sized retain and infiltrate the requirement for recharge volume equivalent to, or greater than, **1.0 inch** multiplied by the total post-construction impervious surface on the site? See **Table 2-1** and **Table 2-7** of the Stormwater Handbook for a list of SCMs that provide recharge. See **Section 6.2.3** of the Stormwater Handbook for sizing and design guidance.	☐	☐	☐
If Yes, does the site design use Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques to meet the required recharge volume? Other SCMs shall only be used to meet those portions of the recharge standard that cannot be fully met by ESSD and LID. See **Section 4.2.3** for a list of MassDEP recognized ESSD / LID techniques. Each MassDEP recognized ESSD / LID technique has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**). Most MassDEP recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).	☐	☐	☐
If the answer to any of the above questions is “No”, has the Applicant completed a written alternatives analysis as detailed by **Section 6.1.4** of the Stormwater Handbook? **Note:** Offsite mitigation may also be allowed for Standard 3 when the written alternatives analysis determines that MEP cannot be achieved on site (see **Section 6.3.7** of the Stormwater Handbook). Recharge for HSG D soils is required only to the Maximum Extent Practicable.	☐	☐	☐

Standard 4: Pollutant Removal

See **Section 2.3.4** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance with the long-term pollution plan requirement of Standard 4 is required. The 90% TSS and 60% TP requirement does not apply to Redevelopment projects. See Standard 7 for pollutant removal requirements associated with Redevelopment projects.

Questions	Y	N	N/A
Has the Applicant developed a long-term pollution plan (LTPPP) that fully meets the requirements of Standard 4 as outlined in **Section 4.3.2** of the Stormwater Handbook?	☐	☐	☐
Does the LTPPP include proper procedures for:			
• Good housekeeping	☐	☐	☐
• Storing materials and waste products inside or under cover	☐	☐	☐
• Vehicle washing	☐	☐	☐
• Routine inspections and maintenance of stormwater SCMs	☐	☐	☐
• Spill prevention and response	☐	☐	☐
• Maintenance of lawns, gardens, and other landscaped areas	☐	☐	☐

• Storage and use of fertilizers, herbicides, and pesticides	☐	☐	☐
• Pet waste management	☐	☐	☐
• Operation and management of septic systems	☐	☐	☐
• Proper management of deicing chemicals and snow disposal[5]	☐	☐	☐
• Measures to minimize snow disposal in the Buffer Zone	☐	☐	☐
• Measures to restrict the use of winter sand application to paved surfaces;	☐	☐	☐
• Measures to prohibit the use of oil application to unpaved roads and automotive parking areas	☐	☐	☐
• Measures to restrict the use of fertilizers	☐	☐	☐
• Measures to reduce polycyclic aromatic hydrocarbon (PAH) sources	☐	☐	☐
• Measures to reduce generation of runoff and nutrients, including a nutrient management plan	☐	☐	☐
• Other site specific items detailed in **Section 4.4.2** of the Stormwater Handbook (e.g., stockpile management).	☐	☐	☐

Standard 5: Land Uses with Higher Potential Pollutant Loads

See **Section 2.3.5** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance is required with the long-term pollution plan (LTPPP) requirement of Standard 5.

Questions	Y	N	N/A
Has the Applicant developed a long-term pollution plan (LTPPP) that fully meets the requirements of Standard 5 as outlined in **Section 4.3.2** of the Stormwater Handbook? (See Standard 4 for general LTPPP information.)	☐	☐	☐
Does the LTPPP include measures that eliminate or minimize any discharges that come into contact with the particular land uses that have the potential to generate high concentrations of pollutants? See **Section 2.3.5** and **Table 2-3** of the Stormwater Handbook.	☐	☐	☐
Has the Applicant considered implementation of any of the following operational changes to reduce the quantity of pollutants on site?			
• Process changes	☐	☐	☐
• Raw material changes	☐	☐	☐
• Product changes	☐	☐	☐
• Recycling	☐	☐	☐

[5] Snow Disposal Guidance: https://www.mass.gov/guides/snow-disposal-guidance; Deicing Storage Guidance: https://www.mass.gov/guides/guidelines-on-road-salt-storage

Questions	Y	N	N/A
• Leaf Liter Pick-up	☐	☐	☐
Does the LTPPP include provisions to protect the land uses with LUHPPL from exposure to rain, snow, snow melt, and stormwater runoff?			
• Enclosing and/or covering pollutant sources (e.g., placing pollutant sources within a building or other enclosure, placing a roof over storage and working areas, placing tarps under pollutant source)	☐	☐	☐
• Installing a containment system with an emergency shutoff to contain spills	☐	☐	☐
• Physically segregating the pollutant source to prevent run-on of uncontaminated stormwater	☐	☐	☐
• Other? ___________	☐	☐	☐

Compliance to the Maximum Extent Practicable for the treatment and pretreatment requirements of Standard 5 is required. Existing conditions must also be improved.

Questions	Y	N	N/A
If applicable, has the Applicant ensured compliance with the treatment and pretreatment requirements of Standard 5 to the Maximum Extent Practicable by directing the stormwater runoff from land uses with LUHPPLs to appropriate SCMs as summarized by **Table 2-3** of the Stormwater Handbook?	☐	☐	☐
Is the land use likely to generate stormwater with high concentrations of oil and grease? If so, has an oil grit separator, sand filter, organic filter, filtering bioretention area or equivalent been proposed for pretreatment (see **Table 2-3**)?	☐	☐	☐
Are treatment systems designed to capture a Water Quality Volume of at least **1 inch**? (see **Section 6.2.4** for sizing and design guidance for pollutant removals)	☐	☐	☐
If the Redevelopment converts a site from a non-LUHPPL use to a LUHPPL use, has the Applicant documented how the SCMs shall be modified or replaced to come into compliance with Standard 5?	☐	☐	☐
If the Redevelopment proposal is a Brownfield project, has the Applicant demonstrated how the stormwater management measures have been designed to prevent mobilization or remobilization of soil and groundwater contamination? See “Brownfield Redevelopment" in **Section 5.2.3** of the Stormwater Handbook.	☐	☐	☐
If the answer to any of the above questions is “No”, has the Applicant completed a written alternatives analysis as detailed by **Section 6.1.4** of the Stormwater Handbook to demonstrate that the highest practicable level of stormwater management is being implemented?	☐	☐	☐
Does the discharge comply with all applicable requirements of the Massachusetts Clean Waters Act, 314 CMR 3.00, 314 CMR 4.00 and 314 CMR 5.00?	☐	☐	☐

Standard 6: Critical Areas

See **Section 2.3.6** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance is required with the long-term pollution plan (LTPPP) requirement of Standard 6.

Questions	Y	N	N/A
Has the Applicant developed a long-term pollution plan (LTPPP) that fully meets the requirements of Standard 6 as outlined in **Section 4.3.2**. See Standard 4 for general LTPPP information.)	☐	☐	☐
Does the LTPPP include considerations for specific Critical Area types?			
Shellfish Growing Areas and Bathing Beaches. Measures to reduce pathogen loading such as enhanced trash segregation and covering.	☐	☐	☐
Outstanding Resource Waters, including Vernal Pools. Establish no vegetation mowing and pruning at least 100-feet from the Resource Area, including no application of fertilizers or pesticides.	☐	☐	☐
Stormwater Discharges within Zone I's, Zone II's, and IWPAs. Measures to prevent contaminants from being placed on impervious surfaces that will mobilize.	☐	☐	☐
Cold-Water Fisheries. Measures to reduce temperature of runoff (e.g., additional tree planting to provide shade over paved surfaces).	☐	☐	☐
Does the LTPPP address misc. considerations for all Critical Areas?			
Proper management of snow and deicing chemicals?	☐	☐	☐
Procedures for the proper storage of road salt?	☐	☐	☐
Procedures for the minimization of salt use for deicing of impervious surfaces for all Critical Area Types?	☐	☐	☐
Strategies and designs that allow for shutdown and containment where appropriate to isolate the system in the event of an emergency spill or other unexpected event (e.g., gate valves or plugs)?	☐	☐	☐

If applicable, compliance to the Maximum Extent Practicable with the pretreatment and treatment requirements of Standard 6.

Questions	Y	N	N/A
Does the Redevelopment project utilize the pretreatment, treatment and infiltration SCMs approved for discharges near or to critical areas as outlined in **Tables 2-4a** through **2-4d** of the Stormwater Handbook for discharges near or to shellfish growing areas and bathing beaches, near or to outstanding resource	☐	☐	☐

Questions	Y	N	N/A
waters, within Zone Is, Zone IIs, and Interim Wellhead Protection Areas, and cold-water fisheries?			
Are treatment systems designed to capture a Water Quality Volume of at least 1 inch? (See **Section 6.2.4** for sizing and design guidance for pollutant removals.)	☐	☐	☐
If the answer to any of the above questions is "No", has the Applicant completed a written alternatives analysis as detailed by **Section 6.1.4** of the Stormwater Handbook to demonstrate that the highest practicable level of stormwater management is being implemented?	☐	☐	☐
Does the discharge comply with the Massachusetts Clean Waters Act, 314 CMR 3.00, 314 CMR 4.00, and 314 CMR 5.00?	☐	☐	☐

Standard 7: Redevelopment

See **Section 2.3.7** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance for the pollutant removal requirements of Standard 7 is required. Refer to other Stormwater Standards for other requirements.

Questions	Y	N	N/A
Are pollutant removal requirements met?			
Does the proposed Stormwater Management System remove 80% of Total Suspended Solids (TSS) and 50% of Total Phosphorus (TP) from the total average annual post-construction load generated from impervious surface area on the site? See **Table 2-2** of the Stormwater Handbook for a list of pollutant removal credits. See **Section 6.2.4** of the Stormwater Handbook for design and sizing guidance, including pretreatment requirements.	☐	☐	☐
If Yes, does the site design use Environmentally Sensitive Site Design (ESSD) or Low Impact Development (LID) techniques to meet the required pollutant removals? In accordance with Standard 4, other SCMs shall only be used to meet those portions of the TSS/TP removal requirements that cannot be fully met by ESSD and LID. See **Section 4.2.3** for a list of MassDEP recognized ESSD / LID techniques. Each MassDEP recognized ESSD / LID technique has an accompanying Fact Sheet or Specification that describes the practice in more detail (see **Appendix A**). Most MassDEP recognized ESSD / LID techniques also have an associated ESSD Credit to help Applicants meet the ESSD and LID implementation requirement (see **Appendix A**).	☐	☐	☐
If the answer to any of the above questions is "No", has the Applicant completed a written alternatives analysis as detailed by **Section 6.1.4** of the Stormwater Handbook?	☐	☐	☐

Questions	Y	N	N/A
Note: The written alternatives analysis must identify Offsite Mitigation alternatives in accordance with **Section 6.3.7** of the Stormwater Handbook when the 80% TSS and 50% TP removal requirement cannot be met on-site.			
Are other requirements met?			
Are existing conditions improved? Improve existing conditions means to reduce peak runoff rate and increase stormwater recharge.	☐	☐	☐

Standard 8: Construction Period Control

See **Section 2.3.8** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance is required for Standard 8.

Questions	Y	N	N/A
Has the Applicant submitted a construction period erosion, sedimentation, and pollution prevention plan (CPPP) that meets the requirements of Standard 8 as outlined in **Section 4.3.3** of the Stormwater Handbook?	☐	☐	☐

Standard 9: Operation and Maintenance Plan

See **Section 2.3.9** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance is required for Standard 9.

Questions	Y	N	N/A
Has the Applicant submitted a long-term Operation and Maintenance plan that meets the requirements of Standard 9 as outlined in **Section 2.3.9** of the Stormwater Handbook?	☐	☐	☐

Standard 10: Illicit Discharges to Drainage System

See **Section 2.3.10** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Full compliance is required for Standard 10.

Questions	Y	N	N/A
Are there any known or suspected illicit discharges to the stormwater management system at the Redevelopment project site?	☐	☐	☐
Has an illicit connection detection program been implemented using visual screening, dye or smoke testing?	☐	☐	☐
Have an Illicit Discharge Compliance Statement and associated site map been submitted with the NOI and /or WQC application verifying that there are no illicit discharges to the stormwater management system at the site?	☐	☐	☐

Questions	Y	N	N/A
Have all illicit discharges been removed or are planned to be removed as part of the project, and has the Applicant implemented all measures to prevent new illicit discharges?	☐	☐	☐

Standard 11: Total Maximum Daily Loads

See **Section 2.3.11** of the Massachusetts Stormwater Handbook for a definition and explanation of this Stormwater Standard. Compliance is required for Standard 11 as described below.

Questions	Y	N	N/A
Will the project discharge to a wetland resource area for which a TMDL (or Alternative TMDL) has been developed by MassDEP and approved by EPA? See **Section 2.3.11** of the Stormwater Handbook for guidance on how to identify TMDLs. (Indicate **N/A** if the answer is No.)	☐	-	☐
If so, have the Applicant identified which applicable pollutants apply to the TMDL? TMDL pollutants include: Phosphorus, Nitrogen, Pathogens, and Metals. See **Section 2.3.11** of the Stormwater Handbook for guidance on how to identify applicable TMDL pollutants.	☐	☐	☐
If so, has the Applicant selected SCMs that are suitable for treating applicable TMDL pollutant(s)? See **Table 4-6** of the Stormwater Handbook.	☐	☐	☐
If so, has the Applicant sized suitable SCMs to fully comply with the 80% TSS and 50% TP pollutant removal requirement? (See Standard 7 questions above)	☐	☐	☐
If so, has the Applicant sized suitable SCMs to comply with Standard 3 recharge requirements? (see Standard 3 questions above)	☐	☐	☐
If the answer to any of the above questions is “No”, has the Applicant completed a written alternatives analysis as detailed by **Section 6.1.4** of the Stormwater Handbook? **Note:** The written alternatives analysis must identify Offsite Mitigation alternatives in accordance with **Section 6.3.7** of the Stormwater Handbook when the 80% TSS and 50% TP removal requirement cannot be met on-site. Offsite mitigation may also be allowed for Standard 3 when the written alternatives analysis determined MEP cannot be achieved on site. (see **Section 6.3.7** of the Stormwater Handbook).	☐	☐	☐