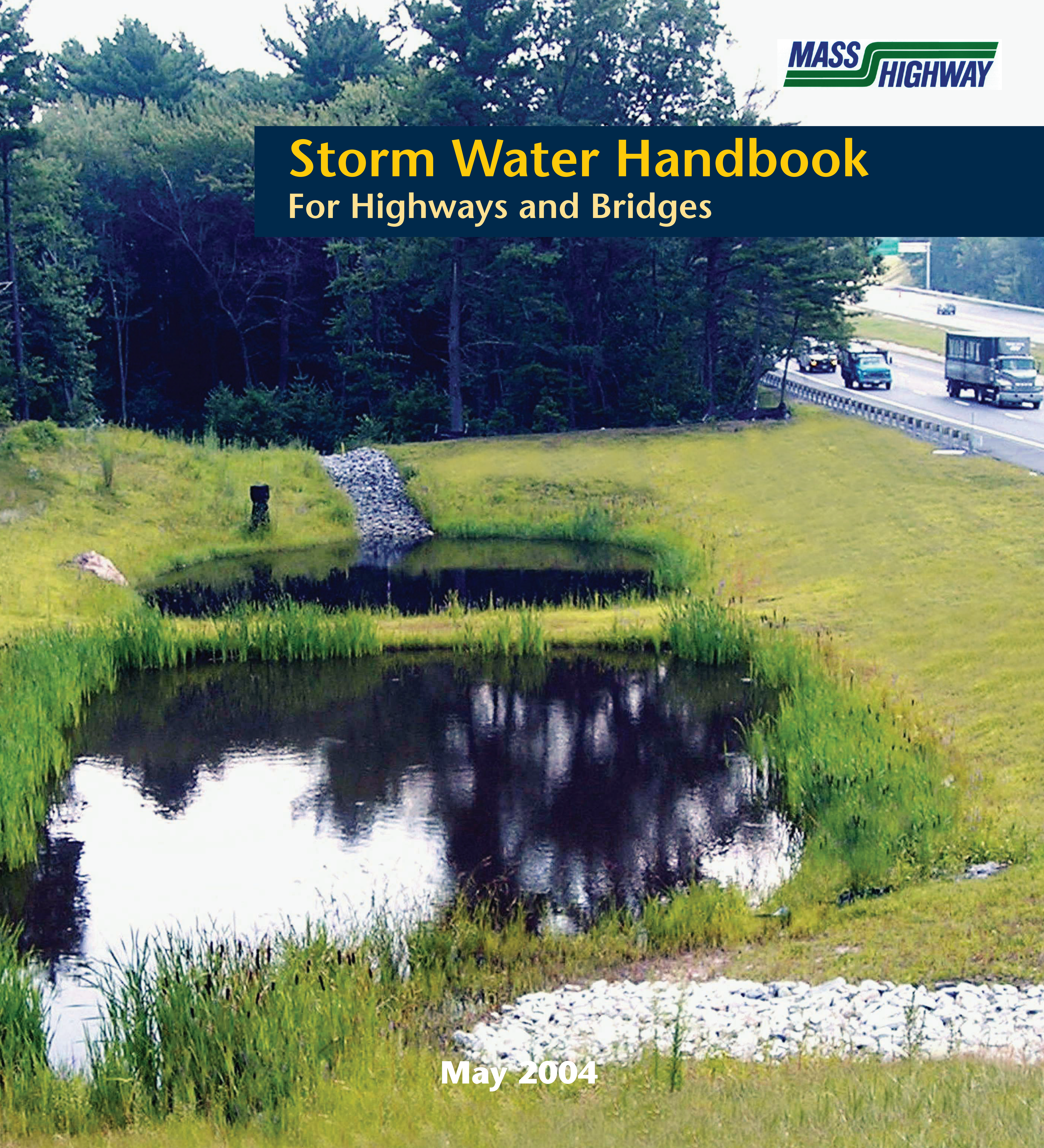
MASS HIGHWAY

Storm Water Handbook

For Highways and Bridges



May 2004

The
MASS HIGHWAY
Storm Water Handbook

For Highways and Bridges

May 2004

The Commonwealth of Massachusetts
Mitt Romney, Governor

The Executive Office of Transportation and Construction
Daniel A. Grabauskas, Secretary of Transportation

Massachusetts Highway Department
John Cogliano, Commissioner

MASS HIGHWAY

Mitt Romney
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Daniel A. Grabauskas
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Commissioner

The MassHighway Stormwater Handbook

The Massachusetts Department of Environmental Protection and the MassHighway are pleased to present the MassHighway Stormwater Handbook. The Handbook represents the culmination of a cooperative effort undertaken by the Commonwealth's environmental and transportation agencies to manage stormwater from MassHighway roadways and facilities.

We look forward to the collaborative efforts of the state our respective state agencies in promoting effective stormwater management while advancing the Commonwealth's transportation and environmental protection strategies.

Robert W. Golledge, Jr., Commissioner
Department of Environmental Protection

John Cogliano, Commissioner
MassHighway

May 7, 2004

This information is available in alternate format. Call Debra Doherty, ADA Coordinator at 617-292-5565. TDD Service - 1-800-298-2207.

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Members of the SBRC included the following MassHighway personnel:

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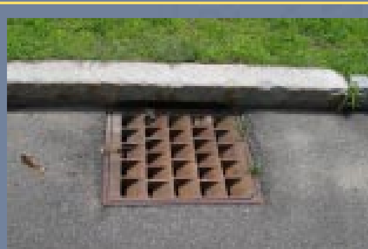
Nancy Palmstrom and David Nyman, P.E., of ENSR International, also have provided technical advice and have played a key role in compiling this document.

Note Regarding the MassHighway Drainage Design Manual

MassHighway considers this **Storm Water Handbook** a companion volume to the **MassHighway Drainage Design Manual**. Planning and design professionals should use both references when developing roadway project designs. This **Storm Water Handbook** provides the controlling guidance relative to compliance with the DEP Stormwater Management Policy.

MassHighway may periodically update this Storm Water Handbook. Please check the MassHighway web-site (http://www.state.ma.us/mhd/environ/publications.htm) for the most current version.

Executive Summary



MassHighway Storm Water Handbook
Executive Summary

This Storm Water Handbook has been prepared for roadway designers, public works personnel, and other persons involved in the design, permitting, review, and implementation of highway and bridge improvement projects in the Commonwealth of Massachusetts. The objective of this Handbook is to provide guidance on how to comply with the 1996 Stormwater Management Policy of the Massachusetts Department of Environmental Protection (DEP), when developing cost-effective storm water management strategies for highway projects.

This Handbook focuses on the unique constraints of existing roadways. It provides guidance for storm water management practices readily and reasonably applicable to highway improvement projects. Many of the principles discussed also apply to new road construction.

Section 1 of the Handbook sets forth its purpose in more detail. It also provides a brief background on the DEP Stormwater Management Policy.

Section 2 describes how to determine whether the Stormwater Management Policy applies to a particular project. For projects where the Policy applies, the Handbook discusses how the Standards specified in that Policy may apply to a particular project.

Section 3 discusses in detail a number of special considerations regarding existing highway and bridge projects that must be taken into account when applying the standards. That Section also offers project development and design strategies that may facilitate compliance with the policy and standards. Section 3 includes a discussion of non-structural and source control measures for controlling storm water pollutant loads from highway runoff.

Section 4 presents a process for screening and selecting Best Management Practices (BMPs) for application to roadway improvement projects. The Section focuses on the ability of candidate BMPs to meet the objectives of the DEP Stormwater Management Policy, within the physical, operational, economic, and regulatory constraints of any particular project. This Section also addresses construction-related BMPs (sediment and erosion control practices), and operation and maintenance considerations.

Section 5 provides information on an array of specific Best Management Practices (BMPs) for controlling storm water discharges. The DEP has published a Stormwater Management Policy Handbook and related Technical Handbook, which refer to many of these BMPs. Section 5 of the MassHighway Storm Water Handbook includes additional BMPs appropriate for use along roadways. This Section provides a set of fact sheets, offering a brief summary of each BMP (including appropriate design references), basic design criteria for each BMP, and a schematic drawing showing a typical example of each BMP.

Section 6 lists design and regulatory references. Planners, designers, and reviewers of roadway projects will need to use this reference material in conjunction with the Handbook.

This Storm Water Handbook should serve as a useful tool, when used in conjunction with MassHighway Design Manuals and other applicable references, for the design of effective storm water management systems to serve roadway projects throughout Massachusetts.

Table of Contents

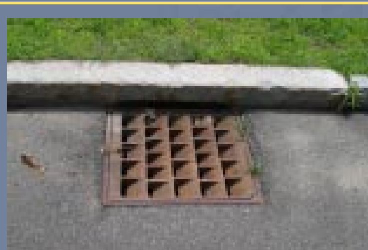


TABLE OF CONTENTS

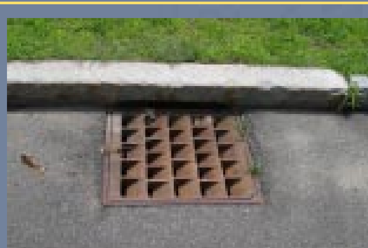
LIST OF TABLES

LIST OF FIGURES

List of Abbreviations Used in this Document

BMP	Best Management Practice
CMR	Code of Massachusetts Regulations
DEP	Massachusetts Department of Environmental Protection
DPW	Department of Public Works
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GEIR	Generic Environmental Impact Report
MEPA	Massachusetts Environmental Policy Act
MGL	Massachusetts General Laws
MTA	Massachusetts Turnpike Authority
NOI	Notice of Intent (under the Massachusetts Wetlands Protection Act)
NPDES	National Pollutant Discharge Elimination System (under the Federal Clean Waters Act)
NRCS	Natural Resources Conservation Service
O&M	Operation and Maintenance
ORW	Outstanding Resource Water
RDA	Request for Determination of Applicability (under the Massachusetts Wetlands Protection Act)
ROW	Right of Way
TMDL	Total Maximum Daily Load
TRM	Turf Reinforcement Materials
TSS	Total Suspended Solids
WPA	Massachusetts Wetlands Protection Act
WQV	Water Quality Volume

Introduction



1.0 INTRODUCTION

1.1 Purpose

This Storm Water Handbook has been prepared for roadway designers, public works personnel, and other persons involved in the design, permitting, review, and implementation of highway and bridge improvement projects in the Commonwealth of Massachusetts. The objective of this Handbook is to provide guidance on how to comply with the 1996 Stormwater Management Policy of the Massachusetts Department of Environmental Protection (DEP), when developing cost-effective storm water management strategies for highway projects. The Handbook offers strategies at each project stage, including planning, design, construction, and operation and maintenance.

As discussed in detail in the following sections, a variety of physical constraints associated with existing highways often limit the options for storm water management improvements. Therefore, this Handbook deals in depth with the unique constraints of existing highways, and the storm water management practices that can be readily and reasonably applied to highway improvement projects. However, many of the principles discussed in the following pages also apply to new construction. The information provided herein will assist permitting authorities in evaluating roadway projects with a more complete understanding of limiting factors (i.e., technological, physical, operational, and financial) to storm water management for highway and bridge improvement projects.

1.2 Background

The Massachusetts Department of Environmental Protection issued the Stormwater Management Policy and Performance Standards on November 18, 1996. DEP issued final guidance related to the Policy and Performance Standards in April 1997 (DEP 1997a; DEP 1997b). The Stormwater Management Policy and Performance Standards are currently implemented as policy through the Wetlands Protection Act and its Regulations (310 CMR 10.00) at the local level. The Policy and Standards may also be applied through various state regulations governing surface and ground water quality (314 CMR 9.00, 314 CMR 3.00, 314 CMR 4.00, 314 CMR 5.00, 314 CMR 6.00).

At the time of publication of this Handbook, the Stormwater Policy and its performance standards are implemented through these regulatory mechanisms. In the future, the Policy and standards may be incorporated into regulation. Riverfront Area provisions incorporated into the Wetlands Protection Regulations reference the management of storm water according to standards established by DEP, as well as certain highway activities that are grandfathered or exempt. Refer to the more detailed discussion of the applicability of the Wetlands Protection Act in Section 2 of this handbook.

The Policy and Standards require the design professional to consider measures to enhance storm water management including the control of discharge rates, recharge to the groundwater, quality of discharge, erosion and sediment controls, and drainage system operation and maintenance activities. Compliance of various types of roadway projects with the Stormwater Policy is discussed in detail in Section 2.0.

1.3 Relationship to NPDES Storm Water Program

In 1990, the U.S. Environmental Protection Agency (EPA) promulgated rules establishing Phase I of the National Pollutant Discharge Elimination System (NPDES) storm water program. The Phase I rules address discharges from large municipal separate storm sewer systems and certain industrial activities, including construction activities disturbing 5 acres or more of land.

A Construction General Permit was developed to cover discharges from the construction activities. Coverage under this permit requires filing of a Notice of Intent (NOI) with the permitting authority (for projects in Massachusetts, the EPA Region 1 office) and preparation of a Storm Water Pollution Prevention Plan (SWPPP). This General Permit is applicable to highway projects involving disturbance of 5 acres or more.

In 1999, the EPA issued the Phase II Rule of the NPDES storm water program. The Phase II Rule addresses discharges from small municipal separate storm sewer systems (MS4s). The Phase II Rule also reduces the threshold for soil disturbance at construction sites from 5 acres down to one acre. The Phase II Rule went into effect on May 1, 2003.

Roadway construction projects that exceed the soil disturbance threshold require filing a Notice of Intent with the EPA under the Construction General Permit, and preparation of an appropriate SWPPP. Erosion and sediment controls described in the SWPPP will typically also address the requirements of Standard #8 of the Stormwater Management Policy, where it is applicable (Section 4.5 of this Handbook offers further discussion of erosion and sediment controls).

A roadway construction project that requires such a filing under the NPDES Construction General Permit may also involve a discharge to an Outstanding Resource Water (ORW), as designated in the Massachusetts Surface Water Quality Standards (314 CMR 4.00). In that case, the following forms should also be filed with the Massachusetts DEP, prior to filing with the EPA for coverage under the Construction General Permit:

- Form BRP WM 08B - NPDES Stormwater General Permit Notice of Intent for Discharges to Outstanding Resource Waters (ORWs) from Construction Sites or Industrial Sites
- Form BRP WM 09 - Approval of NPDES Stormwater Pollution Prevention Plans for Construction or Industrial General Permits (Discharging to Outstanding Resource Waters (ORWs) only)

In addition to affecting MassHighway construction activities, the NPDES Phase II Rule will apply to MassHighway as an “operator of MS4s” (as defined under the Phase II Rule). Phase II requires implementation of six minimum control measures, including the following elements:

1. Public Education and Outreach
2. Public Participation/Involvement
3. Illicit Discharge Detection and Elimination
4. Construction Site Runoff Control
5. Post-Construction Runoff Control
6. Pollution Prevention/Good Housekeeping

While this Handbook has been developed primarily to address the requirements of the MA DEP Stormwater Management Policy, MassHighway may have to provide additional measures to meet more restrictive storm water requirements for NPDES Phase II compliance, including DEP's TMDL Program. In particular, this Handbook is relevant to elements 4, 5, and 6 of the NPDES program as listed above.

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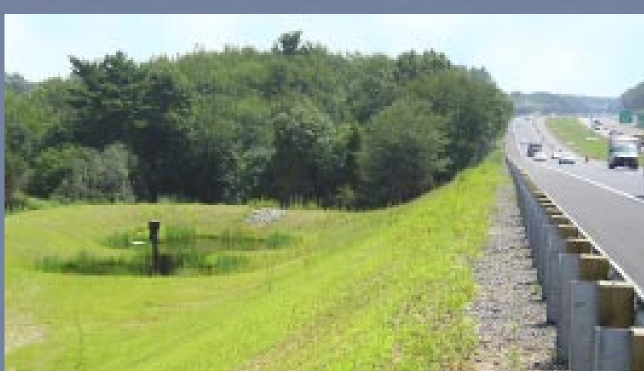
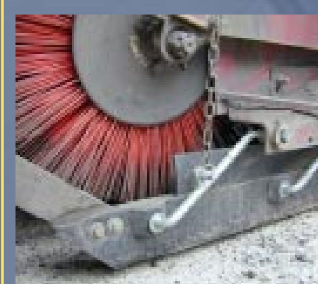
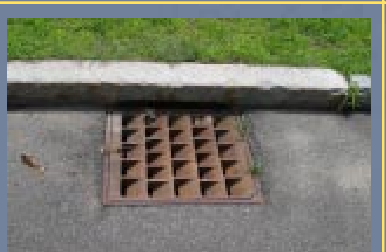
Application of the Storm Water Management Policy to Highway and Bridge Improvement Projects

Application of the Storm Water Management Policy to Highway and Bridge Improvement Projects







2.0 APPLICATION OF THE STORMWATER MANAGEMENT POLICY TO HIGHWAY AND BRIDGE IMPROVEMENT PROJECTS

This Section of the Handbook discusses how DEP Stormwater Management ***Policy*** and its ***Standards*** apply to road and highway projects. The ***Policy*** is generally applicable to projects falling under the jurisdiction of the Wetlands Protection Act, and under certain other regulatory programs administered by DEP. If the Policy applies to a project, certain ***Standards*** then apply, depending on the nature of the project.

> Section 2.1 describes how to determine whether the DEP Stormwater Management Policy applies to a particular project.
>
> Section 2.2 discusses which of the ***Standards*** are likely to apply to a project, if the Policy has been determined to apply.

The DEP Stormwater Management Policy and the specific Stormwater Management Standards are set forth in DEP's storm water management guidance manual, Volume One: Stormwater Management Policy Handbook (March, 1997). The designer should refer directly to that volume when developing the storm water design for a roadway project. The designer should also consult the DEP's web-site (www.state.ma.us/dep) for updates on the Policy and for the current Stormwater Management Form used for Notices of Intent filed under the Wetlands Protection Act Regulations.

2.1 Applicability of Stormwater Management Policy

The requirement to comply with the DEP Stormwater Management Policy varies depending on the type and location of the roadway project as well as the permits required. Generally, any project that requires a Notice of Intent (NOI) under the Wetlands Protection Act will be subject to the DEP Stormwater Management Policy. However, even if the project is not within Wetlands Protection Act jurisdiction, it may be subject to the Policy, as discussed below. Figure 2-1 presents a decision matrix for determining whether a project falls under the Policy. Additional guidance is discussed below.

2.1.1 <u>Wetlands Protection Act Projects</u>

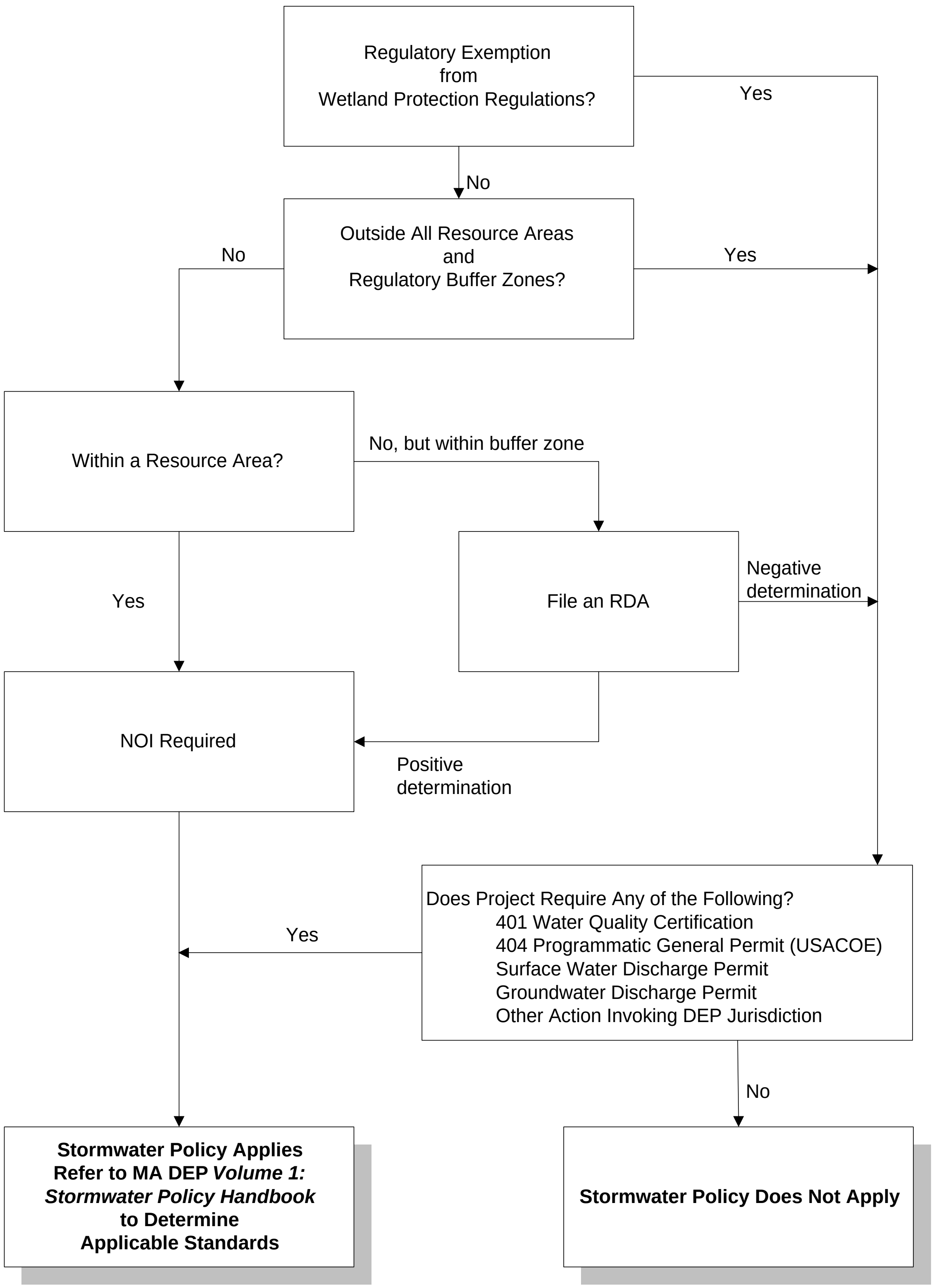
The DEP Stormwater Management Policy is currently being implemented through the Wetlands Protection Act (WPA) and its Regulations (310 CMR 10.00), as well as various other existing regulatory programs.

The Wetlands Protection Act (MGL 131, Section 40) and its Regulations (310 CMR 10.00), as amended by the Rivers Protection Act, cover activities which include:

- Proposed work within Resource Areas (including Riverfront Area). Such work includes the "discharge" of fill and/or the installation of storm water Best Management Practices (BMPs) or discharges;

- Any proposed work within the 100-foot Buffer Zone if the work will alter any Resource Area;

FIGURE 2-1
FLOW CHART TO DETERMINE APPLICABILITY OF STORMWATER POLICY TO HIGHWAY PROJECT



- New point source storm water discharges, either closed or open channel, within a Resource Area (including Riverfront Area).

Work or discharges outside the 100-foot Buffer Zone or resource area (including Riverfront Area) do not ordinarily fall within jurisdiction of the Act. As noted in *Stormwater Management Volume 1* (DEP, 1997a):

> *"Jurisdiction under the Wetlands Protection Act does not extend beyond the resource areas, including the riverfront area, and the 100-foot buffer zone unless and until an activity outside this area actually causes an alteration of a resource area. If an alteration from activities outside geographic jurisdiction occurs, the activity may be regulated (after-the-fact jurisdiction)."*

The Transportation Bond Bills have historically exempted most bridge projects from review under the WPA, Massachusetts Environmental Policy Act (MEPA), and Chapter 91 (the Public Waterfront Act). A bridge project has been exempt when funded by a Transportation Bond Bill and when it has met the following criteria:

> *"for the repair, reconstruction, replacement or demolition of existing state highway bridges and other bridges, including the immediate roadway approaches necessary to connect said bridges to the existing adjacent highway system, in which the design is substantially the equivalent of, and in similar alignment to, the structure to be reconstructed or replaced…"*

Designers should refer to the applicable Transportation Bond Bill to confirm that a given project meets the criteria specified in the Bill. The Bond Bill exemption notwithstanding, the water quality certification requirements of Section 401 (Federal Clean Water Act) still apply, including compliance with the DEP Stormwater Management Policy.

Certain minor activities may not require a filing under the Wetlands Protection Act. The designer should refer directly to the Wetlands Protection Act Regulations, to determine if a specific project activity falls in this category. The designer should also refer to *Stormwater Management Volume 1* (DEP, 1997a), for guidance on activities that would not normally trigger application of the Stormwater Management Policy.

According to *Stormwater Management Volume 1*, filing of a Request for Determination of Applicability should not normally trigger the application of the Stormwater Management Policy. Some roadwork and bridgework, such as cold planing, resurfacing, and other routine roadwork, are often conducted under a Negative Determination because the work will not alter a resource area.

According to the Regulations (310 CMR 10.58 (6)(a)) certain activities or areas pertaining to highways are grandfathered or exempted from requirements for the riverfront area. These include excavations, structures, roads, clearings, driveways, landscaping, utility lines, rail lines, airports owned by political subdivisions, marine cargo terminals owned by political subdivisions, bridges over two miles long, septic systems, or parking lots within the riverfront area in existence on August 7, 1996. Maintenance of such structures in their existing conditions is allowed without the filing of a Notice of Intent for work within the riverfront area, but not when such work is within other resource areas or their buffer zones. Maintenance of roads (limited to repairs, resurfacing, and repaving, but not enlargement) is included in this list of activities.

2.1.2

Other Permit and Activity Triggers

Stormwater Management Volume 1 (DEP, 1997a) identifies activities and permits, in addition to activities under the Wetlands Protection Act, that are likely to require compliance with the Stormwater Management Policy and Standards. The designer should refer directly to Volume 1 for the listing of other programs that may trigger application of the Stormwater Management Policy.

2.2 Applicability of Stormwater Management Standards

If the Stormwater Management Policy applies to a project, then the project must meet certain performance standards. The DEP Stormwater Management Policy identifies nine performance standards. These standards are listed in Table 2-1, and explained in *Stormwater Management Volume 1* (DEP, 1997a).

In addition to routine maintenance activities, MassHighway undertakes three general types of roadway projects, including emergency repairs, redevelopment (meeting the definition of “redevelopment” projects under the Policy), and new construction. Table 2-2 summarizes how the performance standards apply to routine maintenance and each of the three project types. Each type of project is further discussed below.

2.2.1 Emergency Repair Projects

Public roadway projects of an emergency nature generally cannot be delayed for the design and review of storm water management measures. Such projects are not required to comply with the Stormwater Management Policy and Standards for regulatory/procedural simplification. However, erosion and sediment controls (Standard 8) must be employed during repair activities.

DEP’s guidance (DEP 1997a) defines emergency road projects to include pothole and frost heave repair, repair of washouts, and other unanticipated activities. These projects are not exempt from other applicable regulatory requirements. For example, an application for emergency certification will need to be filed with the local conservation commission for an emergency road repair within a jurisdictional area, even though the repair is exempt from compliance with the Stormwater Management Policy.

2.2.2 Redevelopment Projects

Many roadway projects involve the construction of improvements that do not result in significant pavement widening or substantial alterations of the storm drainage system. Standard #7 of the Policy (Redevelopment) most likely applies to these projects. The definition of redevelopment under Standard #7 includes:

> *“Maintenance and improvement of existing roadways, including widening less than a single lane, adding shoulders, and correcting substandard intersections and drainage, and repaving…“*

Redevelopment projects must meet the Stormwater Management Standards to the maximum extent practicable. Where it is not practicable to meet all the standards, the storm water management system must be designed to improve existing conditions.

Table 2-1. DEP Stormwater Management Policy and Standards[1]
As Published November 1996

The DEP will presume that projects meeting the Stormwater Management Standards satisfy regulatory requirements. When one or more of the Standards cannot be met, an applicant may demonstrate that an equivalent level of environmental protection will be provided.

1. No new stormwater conveyances (e.g., outfalls) may discharge untreated stormwater directly to or cause erosion in wetlands or waters of the Commonwealth.

2. Stormwater management systems must be designed so that post-development peak discharge rates do not exceed pre-development peak discharge rates. [2]

3. Loss of annual recharge to groundwater should be minimized through the use of infiltration measures to the maximum extent practicable. The annual recharge from the post-development site should approximate the annual recharge from the pre-development or existing site conditions, based on soil types.

4. For new development, stormwater management systems must be designed to remove 80% of the average annual load (post-development conditions) of Total Suspended Solids (TSS). It is presumed that this standard is met when:
   a. Suitable nonstructural practices for source control and pollution prevention are implemented;
   b. Stormwater management best management practices (BMPs) are sized to capture the prescribed runoff volume; and
   c. Stormwater management BMPs are maintained as designed.

5. Stormwater discharges from areas with higher potential pollutant loads require the use of specific stormwater management BMPs (see chart in *Volume One: Stormwater Policy Handbook*, March 1997). The use of infiltration practices without pretreatment is prohibited.

6. Stormwater discharges to critical areas must utilize certain stormwater management BMPs approved for critical areas (see list in *Volume One: Stormwater Policy Handbook*). Critical areas are Outstanding Resource Waters (ORWs), shellfish beds, swimming beaches, cold water fisheries and recharge areas for public water supplies.

7. Redevelopment of previously developed sites must meet the Stormwater Management Standards to the maximum extent practicable. However, if it is not practicable to meet all the Standards, new (retrofitted or expanded) stormwater management systems must be designed to improve existing conditions.

8. Erosion and sediment controls must be implemented to prevent impacts during construction or land disturbance activities.

9. All stormwater management systems must have an operation and maintenance plan to ensure that systems function as designed.

1 For detailed information regarding the Standards, refer to Stormwater Management Volume 1: Stormwater Policy Handbook (DEP, 1997a).

2 As explained in the Policy, discharges to waters subject to tidal action do not need to maintain pre-development peak discharge rates, provided that the discharge is not to Bordering Land Subject to Flooding.

Table 2-2. Applicability of Stormwater Management Standards to Routine Maintenance and General Types of Roadway Projects

Maintenance/General Project Type	Applicability of Stormwater Management Standards	Remarks
Routine Maintenance (e.g., tree trimming; line painting; bridge painting; guard rail replacement; ditch cleaning; crack sealing; surface treatment (micro-thin overlay); slope repair; sign and/or signal replacement; pavement resurfacing, reclamation, and/or shoulder widening without drainage improvements)	Stormwater Management Standards do not apply.	1. These projects typically are conducted under a Negative Determination of Applicability. 2. Provide erosion and sediment controls.
Emergency Repair (e.g., repair of potholes, frost heaves, washouts)	Stormwater Management Standards do not apply.	1. Other regulatory requirements may still apply; refer to applicable regulations. 2. Provide erosion and sediment controls during repair activities.
Redevelopment (e.g., correcting substandard intersections; road profile improvements; drainage improvements; culvert replacement; footprint bridge replacement; pavement resurfacing, reclamation, and/or shoulder widening with drainage improvements)	Project must comply with Standard 7 of the Policy, which requires the project to meet all of the Stormwater Management Standards *to the maximum extent practicable*. If not practicable to meet all the standards, the storm water management system must be designed *to improve existing conditions*.	1. Confirm that the project qualifies as "redevelopment" as defined by the Policy. 2. See Section 2.2.2 regarding definition of *"to the extent practicable"*. 3. Designers should document reasonable efforts to meet the Standards, including documentation that alternative BMPs have been analyzed, where appropriate. Refer to BMP screening process presented in Section 4.
New Construction (e.g., new road; major realignment; new rest area; new maintenance depot; additional travel lanes; new bridges)	Project must meet all of the Stormwater Management Standards, for DEP to presume that the project satisfies regulatory requirements.	1. The Policy states that when one or more of the Standards cannot be met, an applicant may demonstrate *an equivalent level of environmental protection* will be provided. 2. Note that if a "new construction" project does not fully meet the Standards, the project proponent has a greater burden of proof to demonstrate that the project satisfies regulatory requirements.

DEP Policy guidance (DEP 1997a) acknowledges that repair work to small portions of the roadway or bridge (e.g., catch basin or manhole repair, headwall repair, and scupper repair), provides little opportunity for extensive improvements to the entire roadway drainage system. In such cases, Standard #7 may be met simply by improving existing conditions. The Stormwater Policy is not intended to create a disincentive to minor repairs that may produce water quality benefits, or minimize future water quality impacts (DEP 1997a).

A majority of highway and bridge projects will be subject to Standard #7 (Redevelopment). Similar to site redevelopment projects (also governed by Standard #7), constraints associated with public infrastructure projects may include: limited right-of-way, poor soils, large impervious areas, and existing drainage structures and systems.

In some cases, due to site specific conditions and constraints, redevelopment projects may not always be able to meet all of the performance standards. The goal is to meet as many of the standards as possible *to the maximum extent practicable*[1]. The design professional must demonstrate to the permitting authority what is achievable where the standards cannot be met on a redevelopment project.

The analysis of site constraints and opportunities, and examination of practicable alternatives to project design and siting, are reasonable efforts. As with site redevelopment projects, economic factors must also be weighed. The scope and efforts to be undertaken to meet the standards should be commensurate with the scale of the project, the potential impacts, and the sensitivity of the receiving resource. The design professional should consider the type of receiving water when applying the performance standards, and weighing associated constraints and issues. Areas with critical resources may warrant a higher level of effort when designing, constructing, and maintaining BMPs, and therefore have a more rigorous test of *practicability*.

2.2.3 New Construction or Improvements Exceeding "Redevelopment" Criteria

On projects that involve new roads on undeveloped right-of-way or new alignments, the entire project will likely be subject to applicable provisions of all of the Stormwater Management Standards. While these projects have unique constraints associated with the nature of roadway projects, there is greater opportunity for site planning and compliance with the Performance Standards for new highways than for existing highways.

Other projects may involve components of new construction within or adjacent to existing alignments, and may or may not involve additional right-of-way acquisition. On these projects, portions of the projects (e.g., existing paved areas) may qualify under Standard #7, with other portions being considered "new development," and subject to full compliance with the other standards. For instance, a widening of one lane or more will be considered "new development" under the DEP Stormwater Management Policy. The new pavement (equivalent to the net increase in impervious area) must be serviced by a drainage system meeting all applicable standards. The remaining pavement (paved area equivalent to existing conditions) should meet the standards to the extent practicable, and at a minimum provide for some improvement over existing conditions.

1 "To the extent practicable" means the applicant has made all reasonable efforts to meet the standards, including evaluation of alternative BMP designs and their locations (DEP, 1997a).

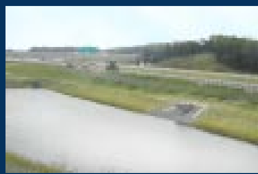
In some cases, due to site specific conditions and constraints, activities defined as "new development" may not always be able to meet all of the performance standards. In these cases, the DEP Stormwater Management Policy states:

> "*When one or more of the Standards cannot be met, an applicant may demonstrate that an equivalent level of environmental protection will be provided.*"

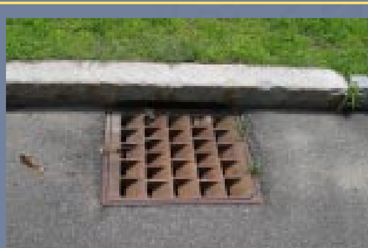
"Equivalent level of environmental protection" will vary project by project. This could involve measures that would provide water quality benefits, other than structural BMPs. Examples of measures that may provide an "equivalent level of environmental protection" include:

- Additional wetland restoration beyond that required;
- Wetlands enhancement;
- Land preservation;
- Wildlife habitat improvements;
- Additional compensatory flood storage (such as instances where there is difficulty in meeting the peak rate attenuation standard).

For such projects, early communication among the project proponent and affected stakeholders should be initiated to select a mutually acceptable design approach that provides an equivalent level of environmental protection in balance with the scope and nature of the project.



Constraints and Opportunities for Storm Water Management for Existing Highway and Bridge Projects



Constraints and Opportunities for Storm Water Management for Existing Highway and Bridge Projects

3.0 CONSTRAINTS AND OPPORTUNITIES FOR STORM WATER MANAGEMENT FOR EXISTING HIGHWAY AND BRIDGE PROJECTS

Section 2.0 has addressed how the Stormwater Management Policy and the Stormwater Management Standards generally apply to roadway projects, including emergency repairs, "redevelopment", and "new construction". As noted in Sections 1.0 and 2.0, most highway improvement projects involve existing roadways, and will likely fall under the "redevelopment" category or involve components of both "redevelopment" and "new construction". In either case, the improvement of existing roadways involves unique constraints associated with the fixed alignment and linear configuration of the roadway facility. Unlike a typical "site development" project, the opportunity to use site planning to configure the various elements of a roadway improvement design is very limited in the "existing roadway" setting.

Because roadways are linear, and often involve multiple drainage watersheds and outlets, the approach to storm water management design for these facilities differs qualitatively from other forms of development. Section 3.1 offers a project design strategy, referred to as the "macro" approach to storm water management design, particularly tailored to the roadway setting.

Section 3.2 discusses special considerations regarding existing highway and bridge projects that must be taken into account when applying the Stormwater Management Standards. The discussion identifies unique constraints on the practicability of implementing storm water management measures on roadway improvement projects. Section 3.3 offers project development and design strategies that may facilitate compliance with the Policy and Standards. Section 3.4 discusses non-structural and source control measures that may reduce pollutant loads from highway and bridge runoff. While the focus of the discussion is on existing roadways, many of the principles discussed apply to "new construction", as well.

3.1 Storm Water Management for Highways: The "Macro" Approach

Roadway projects are by nature very linear in configuration. A typical roadway improvement project can involve multiple culvert crossings and drainage system outlets. Frequently, multiple watersheds may be associated with a given section of roadway. Given this characteristic of roadways, this Handbook offers a design approach for providing storm water management by evaluating the project in a holistic manner, rather than outlet by outlet. This process is referred to as the "macro" approach.

In this process the designer develops an overall storm water management strategy, and selects and designs BMPs to implement that strategy, by evaluating storm water management measures within the overall project context. For projects involving significant drainage system alterations, this approach looks at the entire drainage system under study (or a sub-drainage area with multiple outlets), rather than individual outlets. This "macro" approach can be particularly helpful in addressing peak rate control objectives (Standard 2), but can be applied to the objectives of recharge (Standard 3) and water quality control (Standard 4), as well.

This "macro" approach generally proceeds as follows:

1. Identify downstream areas of potential impact:
    - resource areas, including "critical areas" as identified in the DEP Stormwater Management Policy;

- critical hydraulic structures located downstream (e.g., bridges and culverts on major tributaries, or flood control structures such as existing dams); and
- areas of potential flooding (e.g., areas identified in FEMA mapping and flood studies as subject to inundation during the 100-year flood).

2. Explore combining drainage outlets to reduce the number of outlets, considering:
   - maintenance of base flows to wetland resource areas that currently receive runoff;
   - peak rate control, recharge, and water quality treatment effectiveness; and
   - cost effectiveness.

   In combining drainage outlets, exercise care to avoid changing drainage patterns that affect existing wetland resource areas.

3. Design the overall highway drainage **system** (instead of individual outlets) to:
   - provide control of peak rates (if needed) at critical control points (such as capacity sensitive resource areas or structures);
   - prevent increased levels of flooding downstream or upstream of the project;
   - meet other storm water management objectives to the maximum extent practicable, including recharge and water quality treatment objectives.

Under this approach, the designer/engineer treats the highway segment under study in relationship to its overall drainage area, with overall impacts analyzed and addressed. Selected drainage outlets may be provided with peak rate control, recharge, and water quality control facilities, but not necessarily all outlets.

This approach allows storm water design to focus management efforts where they can be most effective. It allows for prioritizing storm water management efforts where the receiving waters are most sensitive to highway runoff impacts.

It also offers flexibility to the design, enhancing the practicability of meeting management objectives. For example, it may be possible to provide a greater level of treatment for one portion of the roadway drainage to offset a lower level of treatment of the discharge from another roadway segment. This approach is warranted where constraints (e.g., grades, proximity of wetlands, slope, bedrock, existing development) may preclude achieving desired treatment levels at each individual discharge. As with other measures, using this strategy should be based on analysis of the costs relative to achievable benefits.

Section 4.0 of this Handbook offers additional guidance in the application of this “macro” approach to the selection of Best Management Practices (BMPs) for meeting storm water objectives.

3.2 Special Considerations for Highway and Bridge Projects

Table 3-1 identifies the nine Performance Standards listed in the DEP Stormwater Management Policy. The table highlights the constraints, complexities, and opportunities associated with managing highway runoff to comply with these Performance Standards. Roadway planners and designers must develop storm water management strategies that address the special constraints that apply in the highway setting.

Special considerations relative to each of the nine Standards are discussed in further detail below:

3.2.1 New Direct Discharges of Untreated Storm Water (Standard #1)

Many roadway improvement (redevelopment) projects involve the correction of local drainage or flooding problems by the modification of existing outlets or the provision of new ones. Because of this, there may be locations where new direct discharges of storm water are unavoidable. Examples of such situations may include (but are not limited to) the following:

- Bridge decks with scuppers discharging directly to watercourse under bridge;
- Repositioned storm drain outlets serving existing catch basins, where the catch basins cannot be practicably replaced by deep sump catch basins (e.g., because of the presence of utilities or bedrock);
- Projects where the position of a wetland (or other resource) adjacent to a roadway and its storm water discharge precludes provision of full treatment;
- Projects requiring the installation of new drainage piping to replace existing open drainage systems. For instance, an existing road segment served by an open drainage system may require provision of a closed drainage system to correct an existing localized drainage/flooding problem, upgrade the shoulder to a new standard, or add a sidewalk to address pedestrian safety issues.

In cases such as these, full compliance with the remaining 8 performance standards to meet the definition of treated storm water under Standard #1 may not be practicable. Section 4.0 describes the process of evaluating and documenting BMP practicability. In some cases, there may be opportunities to provide at least some degree of treatment, or compensatory treatment at other discharges to the same receiving watercourse, to achieve improvement over existing conditions.

Designers should consider provision or enhancement of erosion control protection at these outlets, to prevent erosion in wetlands or waters of the Commonwealth to the maximum extent practicable.

3.2.2 Peak Rate Control (Standard #2)

Highway corridors present a unique challenge to the design professional when addressing pre- and post-development peak discharge rates. Typically there are multiple watershed sub-basins along the corridor, and the storm water design must meet multiple objectives. Likewise, space limitations will also pose a challenge for providing peak rate controls for some redevelopment projects. Options that may assist the design professional in addressing these limitations include:

- Detention storage may not be necessary at every drain outlet. The designer may want to consider a few well-placed basins designed to control peak rates of discharge at key control points;
- Existing low areas may serve as small detention basins by judicious installation of structural modifications such as flow control weirs or pervious check dams. The use of these depressions must be consistent with wetland regulations (some depressions are jurisdictional wetlands under the Wetlands Protection Act, and cannot be used for storm water treatment);
- Detention storage can be combined with other measures for a multi-purpose BMP. For instance, a wet pond or created wetland can be designed with freeboard for quantity control. In general, detention basins should be located in areas where it is cost-effective to provide both quantity and quality control within the same structure; and

Table 3-1. Performance Standards, Special Issues, and Possible Solutions for Highway Projects

Performance Standard	Special Issues	Possible Solutions to Issues
1. Avoid Direct Discharge of Untreated Storm Water	• Depending on the width of ROW available and distance from resource areas it may not be possible to avoid direct discharge within the resource area.	• In some cases it may be possible to position outlets so as to discharge runoff at an angle, thereby increasing the flow path distance to the resource. • Discharges treated by catch basins with sumps or other BMPs can be used to prevent direct discharge of untreated storm water to resource areas. • During early planning phases, planners may need to consider acquisition of additional ROW.
2. No Increase in Peak Discharge Rates	• Multiple outlets and drainage areas compounded by limits within ROW may make peak rate control difficult at individual outlets	• Combine outlets for treatment • Use a "macro" rather than "micro" management approach to address quantity control issues.
3. Minimize Loss of Annual Recharge	• Infiltration of runoff may adversely impact pavement strength and integrity. • Subsurface recharge systems are problematic for installation and maintenance.	• Infiltrate runoff only where consistent with the design, installation, and maintenance of required highway substructure. • Use surface methods of recharge where practicable. Generally, only use subsurface recharge systems under special circumstances (see Section 4.3.2).
4. 80% Removal of Annual Total Suspended Solids Load	• Space limitations within the ROW may limit the level of treatment that can be provided. • Storm water treatment systems must be sited and designed to avoid adverse impacts of water on the roadway substructure and for ease of inspection and maintenance.	• Storm water practices with the lower maintenance requirements and higher longevity are preferred. • Underground treatment systems are generally discouraged for highway use due to intensive maintenance and disposal requirements and relative difficulty of inspection.
5. Discharges from "areas with higher potential pollutant loads"	• Roadway surfaces do not normally constitute "areas with higher potential pollutant loads". • For other land uses contributing to a roadway drainage system, refer to Volume One: Stormwater Policy Handbook for list of affected land uses. • Special consideration must be given to source control and pretreatment of runoff.	• Storm water issues associated with MassHighway maintenance depots should be addressed with MassHighway Environmental Division.

Table 3-1. Performance Standards, Special Issues, and Possible Solutions for Highway Projects

Performance Standard	Special Issues	Possible Solutions to Issues
6. Protection of Critical Resources	• Because the relative percent impervious area for highways is quite high, it may be difficult to achieve the 1-inch runoff sizing rule.	• Treatment will be provided to the maximum extent practicable. • Refer to Section 3.2.6 for design measures to be considered for roadway projects that involve discharges to surface drinking water reservoirs. • In critical resource areas, a higher “standard of practicability” is warranted when the designer considers candidate BMPs and the acquisition of additional ROW.
7. Redevelopment Projects	• Highway projects may not consistently meet all the performance standards.	• To the extent practicable, public infrastructure projects should meet the performance standards, or improve existing conditions. • Refer to Section 3.4 for source control and non-structural approaches that contribute to water quality improvements. These measures can be used to “improve existing conditions” under this standard.
8. Erosion and Sediment Controls	• The need to maintain traffic during construction may affect the selection and application of methods.	• Refer to MassHighway Design Manual, as well as Chapter 4 of this document, for appropriate erosion and sediment control selection and design criteria.
9. BMP Operation and Maintenance	• Inspection (e.g., monthly) and maintenance frequencies outlined for certain structures in Volume 2 of the DEP Manual may be impracticable for public highway departments to implement.	• Suggested activities for operating and maintaining storm water management facilities in the highway setting are provided in Sections 3.2.9 and 4.6.

ROW = right-of-way

- With proper design, detention facilities located at intermediate locations in the watershed can often be sized to compensate for the flows reaching the conveyance system downstream of the detention point.

3.2.3 Recharge (Standard #3)

The Stormwater Management Policy requires the use of infiltration practices to the maximum extent practicable. However, the application of infiltration practices must be performed with special care in the highway setting. In densely developed urban areas, recharge practices will be extremely limited in application, if not altogether impractical. However, roadway planners and engineers need to exercise creativity when addressing the recharge standard, and to be particularly mindful of the higher level of water quality protection required when near critical areas.

Pavement strength and integrity are highly dependent on the condition of the roadway sub-base and sub-grade material. One of the major principles of pavement design is to drain the sub-structure of the road. Therefore, as a general rule, designers must avoid practices that introduce water into the sub-structure underlying the roadway. The zone of material requiring sub-drainage can be up to several feet in depth, depending on the type of roadway, type and number of vehicles using the road, type of native soil materials, and depth to groundwater. Except under some unique circumstances, infiltration practices should not be applied within the limits of the pavement and shoulder, or in close enough proximity to affect the sub-drainage of the roadway.

A disadvantage of infiltration systems is the difficulty in handling emergency spills. The design and siting of recharge systems, if otherwise shown feasible for the highway setting, should consider opportunities for preventing a potential spill from discharging into the ground.

To comply with the DEP Stormwater Management Policy, designers must consider measures to meet Standard #3 (mimic existing recharge to the extent practicable). The NPDES General Permit for MS4s in Massachusetts also establishes requirements for recharge of groundwater consistent with the Stormwater Management Policy. This requirement is addressed in the *NPDES Storm Water Management Plan for MassHighway Owned and Operated Highways* (MassHighway SWMP).

In considering recharge measures, the following examples illustrate where recharge practices should not be applied, and areas that may be potential locations for such practices.

Examples of locations where recharge practices <u>should not</u> be installed include:

- Within Zone 1 groundwater protection zones for drinking water supply;
- On existing roadways, wherever there is insufficient space to install a gravity-fed recharge BMP so that it does not place water within the roadway sub-base and sub-grade material;
- Within “hot spot” land uses (maintenance depots) that are located in the contributing watershed of a critical area;
- In areas with NRCS Hydrologic Group D soils; and
- In locations where at least a two foot separation from the bottom of the infiltrative surface of the recharge system to the seasonal high water table cannot be provided.

Examples of locations where recharge practices should be provided to the maximum extent practicable:

- In areas identified as "high" or "medium" stressed basins by the Massachusetts water Resources Commission report, *Stressed Basins in Massachusetts* (December 2001). [Refer to MassHighway SWMP, Table 4-2: MWRA Stressed Basins Classifications.]
- Highway medians (with consideration of the integrity of the pavement sub-base and sub-grade);
- Interior landscaped areas of highway access ramps (outside of zone influencing pavement sub-base and sub-grade);
- Areas where old pavement is being abandoned due to realignment or reconfiguration of roadway (outside of zone influencing pavement sub-base and sub-grade);
- Available rights-of-way, where drainage can be reasonably directed and where space permits installation, or where property interests can be reasonably acquired to expand rights-of-way to accommodate recharge; and
- Areas where the underlying soils are so well drained that the roadway sub-grade will not be compromised by introduction of the additional water (e.g., Cape Cod).

When infiltration practices are being considered, the designer must also consider provision of pretreatment, as well as issues of system maintenance, potential for system clogging, and provisions for system overflow when runoff exceeds infiltration capacity.

Designers should refer to the Recharge Technical Bulletin (currently under development by the DEP) for further guidance on the development of designs for systems to recharge storm water.

3.2.4 Removal of Total Suspended Solids (Standard #4)

In the roadway setting, designers must consider several issues relative to the provision of water quality treatment BMPs. These include the following:

- Space constraints within available right-of-way can limit the choice of BMPs, and consequently can also limit the extent of practicable treatment;
- The roadway surface and substructure must be designed for required vehicle loading, pavement integrity, and maintainability. Treatment BMPs must be located where they will not adversely impact the performance of the roadway. This requirement can limit the choice of BMPs, particularly if they must be sited within the paved area;
- Access for inspection and maintenance can be affected by available space, as well as by safety considerations. Designers should give preference to storm water management measures that are easy to inspect and maintain not only for reasons of cost, but also for reasons of safety (e.g., an underground structure requiring frequent inspections and cleaning can be hazardous if located close to the travel lanes of a high-volume roadway).

Given these considerations, the design of storm water management measures for existing roadways will likely focus on BMPs that are readily adaptable to roadway geometry and pavement structure requirements. For example, deep sump catch basins, vegetated filter strips, outlet sediment traps, and drainage channels (conventional channels and water quality swales) are particularly suited for use in the roadway setting. Section 4.0 describes a process for screening BMPs for feasibility of application on a project-specific basis, with the goal of achieving the TSS removal standard to the maximum extent practicable.

For a project to be presumed to meet Standard #4, it must have properly sized BMPs that are maintained as designed, and it must also provide suitable nonstructural practices for source control and pollution prevention. MassHighway provides non-structural and source control measures at a statewide and/or programmatic level. Section 3.4 describes these measures. Because MassHighway provides these measures as part of its overall program, it should be presumed on each MassHighway project that "suitable nonstructural practices for source control and pollution prevention" are in place, and contribute to the project's compliance with Standard #4.

3.2.5 Areas With Higher Potential Pollutant Loads (Standard #5)

Roadway surfaces do not constitute "areas with higher potential pollutant loads" under the DEP Stormwater Management Policy. Providing storm water management for runoff from road pavements should not normally trigger application of Standard #5.

Designers will need to evaluate land uses (other than roads) that may be part of a MassHighway (or municipal roadway) project, to determine whether such uses fall within the definition of "areas with higher potential pollutant loads".

Designers of projects associated with MassHighway maintenance facilities should work closely with the MassHighway Environmental Division to determine the applicability of Standard #5, and to address storm water management issues for these facilities.

3.2.6 Critical Areas (Standard #6)

Design elements relative to spill management control near critical areas are of particular concern in the roadway setting. In the Stormwater Policy, Volume 1, under a subsection entitled "Explanation of Standards", the DEP guidance states the following as part of the explanation of Standard #6:

> *"Stormwater management systems near public water supplies and other critical resources should incorporate designs which allow for shut-down and containment in the event of an emergency spill or other unexpected contamination event."*

This section describes how MassHighway approaches spill management issues on highway improvement projects within "Critical Areas" (as defined by the Stormwater Policy) – and in other areas as well.

Highway improvement projects by their very nature offer positive benefits relative to spill prevention. These benefits are not typical of other types of development projects. Most highway improvement projects are designed to increase safety, and provide for efficient movement of traffic. Thus, many highway improvement projects contribute significantly to the prevention of spills. The following are examples of highway improvements that would provide direct benefits in the prevention of spills:

- Improving curve alignments to enhance drivability and sight distances;
- Increasing useable shoulder width to provide for a vehicle recovery area;
- Correcting existing drainage problems and thus preventing hydroplaning and winter icing conditions;
- Improving intersection horizontal and vertical alignments for improved traffic flow and safety;
- Adding "rumble strips" where appropriate to combat driver fatigue;
- Any other roadway maintenance or improvement project that results in the reduced risk of accidents.

These benefits of highway improvement projects, coupled with the ability of trained response teams to act expeditiously in an emergency, adequately address the concern for spill control implicit in the provisions of Standard 6 of the Stormwater Policy.

Furthermore, the Massachusetts Highway Department and other agencies have executed a Memorandum of Agreement (*Unified Response Manual for Roadway Traffic Incidents*, July, 1998, as periodically amended) that provides for a well-defined program for responding to emergency spill events. Under this program, responder responsibilities are well established. Therefore, in the highway setting, the design objective is to make it possible for the emergency response teams to effectively perform their functions. Based on this objective, the following measures are recommended near critical areas to enable the response teams to provide for appropriate response measures:

1. During project development and design, identify the local party or chain-of-command responsible for HazMat response. Coordinate with this party, and with the party responsible for the "critical area" resource, to develop project design consistent with local spill response procedures and equipment. For example, at a water supply reservoir, these parties would most likely include the local fire department and the water system owner;
2. Minimize to the extent practical the number of discharge points that convey runoff toward the critical resource areas;
3. To the extent practical, provide for the access of emergency personnel, to facilitate their use of containment equipment;
4. To the extent practical, use standard catch basin inlets and other standard practices in the design, so that emergency response personnel are readily familiar with these features when they encounter them in the field, and can use standard response practices and equipment. Coordinate with the local HazMat responsible party and applicable resource manager (e.g., owner of a water supply reservoir), to ensure that either
   a. the design of the storm water system is consistent with the responder's spill containment procedures and equipment, or;
   b. the responder can reasonably implement necessary modifications of procedures and equipment to accommodate the proposed storm water facility design;
5. For projects where drainage systems will be altered near critical areas, provide one copy of final plans or detailed descriptive information (e.g. schematics and other data included in project construction documents) to the local HazMat responsible party. The plans or descriptive data should indicate the locations, sizes, and types of catch basins, storm drains, culverts, drainage outlets, and other drainage facilities. This information can assist the emergency response personnel in locating drainage facilities in their development of response plans and training programs;
6. Consider the provision of markings or other delineators to show the location of storm drain outlets. The intent of these indicators is to assist the spill response teams in identifying storm drain system features in the field.

In the highway setting, the design of structures with integral shut-off mechanisms is not recommended, because of the following:

- Trained responders must be responsible for the management of spills. The unmanaged detention of certain spills (e.g., volatile materials) can result in serious public safety hazards. Shut-off devices can be problematic, because they may be operated by personnel who are not trained in spill response, potentially resulting in extremely unsafe conditions. Also, the devices are subject to vandalism, weather-related corrosion, and mechanical malfunction resulting from prolonged exposure and non-use, so that they may not be reliable in a spill event;

- “First Responders” are anticipated to be trained in the management of a broad array of types of spills, which would include the use of specialized equipment and materials brought to the spill site for controlling and cleaning up spills. However, these First Responders may not have specific knowledge of the location, functional condition, and operating procedures for shut-off mechanisms that are located at a particular site, and may therefore not be able to use them in a timely and effective manner (note that state and local highway department personnel are not generally first responders to spill events);
- Shut-down devices can only be effective if the spill occurs within the component of the drainage system to which they are attached. The effectiveness of any one containment device is limited, because many events resulting in spills (e.g., truck rollovers) occur off the pavement, and outside of the contributing area of the drainage system. It is not possible to design and construct road improvements such that every spill will be captured by the drainage system.

For these reasons, the designer should use strategies listed in items 1-6 above (and not shut-down devices), coupled with the overall safety benefits inherent in highway improvement projects, to address spill management in the highway setting.

3.2.7 Redevelopment (Standard #7)

As noted throughout this Handbook, most roadway improvement projects are anticipated to fall under Standard #7 of the DEP Stormwater Management Policy. These projects are thus required to meet the other eight standards to the maximum extent practicable. Where it is not practicable to meet all the Standards, the project storm water design must improve existing conditions.

Section 4.0 of this Handbook has been specifically developed to assist designers in evaluating and documenting BMP practicability, accounting for site constraints and other feasibility factors, cost-effectiveness, and resource protection.

Section 3.4 also offers potential approaches for “improving existing conditions” under Standard #7, through non-structural and source control measures.

3.2.8 Erosion and Sediment Control (Standard #8)

Standard #8 of the DEP Stormwater Management Policy requires the implementation of erosion and sediment controls during construction. The implementation of such controls is considered a standard practice for roadway projects. For MassHighway projects, the designer should refer to current MassHighway design manuals as the primary reference for designing and implementing erosion and sediment controls. Additional guidance documents are cited in Section 4.5 of this handbook.

Federal requirements also deal with the application of erosion and sediment controls. Under Phase I of the U.S. EPA storm water NPDES program, land disturbance exceeding five acres or more requires the filing of a Notice of Intent (NOI) under the Construction General Permit, and preparation of a Storm Water Pollution Prevention Plan. Under Phase II of the NPDES storm water program, applications for permit coverage will be required for construction activities disturbing one to five acres of land (anticipated date for commencing such filings will be March 10, 2003).

The EPA regulations require all "operators" to file for permit coverage. An "operator" is defined as the party who either has control over the construction plans and specifications and has the ability to make modifications, or has control over construction activity as it is carried out at the site. Therefore, the owner of the roadway, as well as the Contractor, must jointly file the required NOIs for coverage under the Construction General Permit. On MassHighway projects, the Contract Documents should contain provisions to require the contractor to file the NOI and to prepare the necessary project-specific Storm Water Pollution Prevention Plan, consistent with MassHighway's NOI for the project.

3.2.9 Operation and Maintenance (Standard #9)

Recognizing that the public funding process may limit resources available for maintenance, DEP (1997a) states that BMPs for roadways should be easy to maintain and have infrequent maintenance requirements.

Operation and maintenance (O&M) activities are undertaken at a statewide, programmatic level under the State's highway operation and maintenance program. Given the number of individual projects undertaken, and the fact that O&M is generally implemented at a statewide level, project-specific maintenance and operation plans follow MassHighway's statewide policies. Maintenance considerations for BMP selection include the following:

- Provide for ease of maintenance;
- Use open-type BMPs (e.g., swales, wet ponds, detention basins) for ease of inspection and maintenance access; and
- Where possible, avoid unique (or project specific) O&M requirements, or BMPs requiring special equipment or procedures for maintenance.
- Develop operation and maintenance plans with due consideration for maintenance crews, to ensure that they understand and can readily implement maintenance requirements.

3.2.10 Water Quality Monitoring

The DEP states that water quality monitoring of BMPs should generally not be required (DEP 1997a). This statement in part reflects DEP's recognition that it is difficult and costly to develop and implement meaningful monitoring programs at the project level. Chapter 2 of the *Stormwater Management Volume 1: Stormwater Policy Handbook*, states the following:

> *"Sampling or monitoring requirements should not be necessary. Commissions and DEP may decide to impose sampling or monitoring requirements, however, when developers propose alternative stormwater management techniques not included in [the DEP Stormwater Management Handbooks] or in unusual circumstances where deemed necessary to protect sensitive resources or public health. DEP and MCZM intend to evaluate the Standards and BMPs recommended in these documents as they are implemented in Massachusetts rather than imposing oversight requirements on dischargers."*

3.2.11 Bridges

The effective drainage from bridge decks is important for reasons of safety and structural integrity. Runoff must be removed from the bridge deck efficiently to prevent hydroplaning and icing conditions (note that ice forms on bridge decks before other roadway surfaces). Also, runoff must be removed efficiently to help prevent excessive corrosion of the bridge deck and structural reinforcing steel by deicing salts.

For deck replacement or rehabilitation of existing bridges, or for new bridges in developed areas, there may be little opportunity to provide treatment of bridge runoff, particularly when the bridge crosses a water resource. Peak rate control should not be an issue, because there is little difference in time of concentration of water falling on the water surface (considered impervious for the purpose of hydrologic calculations) and the bridge deck.

In some cases, the surface drainage from short-span bridge decks can be conveyed by gutter flow to beyond the end of the bridge. In these cases, storm water management measures may be feasible. However, this feasibility will depend in part on the space available at the abutment for installation of treatment measures. In many instances, existing bridge abutments are within or in close proximity to protected resource areas, limiting the space available for storm water treatment in the immediate vicinity of the bridge.

Because of these geometric, structural, and safety considerations, storm water management objectives for bridges may generally need to be met through measures along other segments of the roadway.

3.3 Project Development and Design Strategies

Chapter 2 of DEP's *Stormwater Management Volume 2: Technical Handbook* (DEP 1997b) sets forth some guidelines and principles for planning of site development. Many of those principles apply to the development of undeveloped sites, and will similarly apply to the siting of new highway construction. Available planning strategies for redevelopment sites, including most roadway projects, are more limited. This Section focuses on some specific principles applicable to planning for storm water improvements of existing bridges and highways.

While this Handbook focuses on roadway improvement projects, many of the principles discussed apply to new road construction as well. Furthermore, designers should note that new roadway projects will need to fully meet the standards set forth in the DEP Stormwater Management Policy. For new construction, roadway planners will need to account for storm water management not only in the development of design concepts, but also in the securing of rights-of-way and easements.

The DEP Stormwater Management Policy mandates implementation of storm water management for development projects in general. Roadway improvement projects will be subject to this mandate as well. Therefore, in developing long range plans (system planning) for road and highway improvements, storm water management components will need to be anticipated. Project planning and budgeting will need to include allowance for storm water BMP construction, as well as operation and maintenance.

This also means that as individual projects advance to project development and preliminary design, storm water approaches will need to be considered early in the project development process. The following are guidelines for incorporating storm water management considerations into the planning of highway improvements.

1. Avoid/Minimize Impacts to Resource Areas;
2. Reduce and Minimize Impervious Surfaces If Safe and Feasible;
3. Reproduce Pre-Development Hydrologic Conditions; and
4. Fit the Development to the Terrain

Each are discussed in detail below. The design professional must balance the concepts presented below with other roadway design requirements, applied on a case-by-case basis in light of specific site constraints.

3.3.1 Avoid/Minimize Impacts to Resource Areas

Where existing roadways requiring rehabilitation or reconstruction are located adjacent to a resource area, encroachment should be minimized, where practicable. For example, if the lane or shoulder must be widened, consider the use of a steeper side slope (suitably stabilized with vegetation or other permanent erosion control measure), to minimize encroachment into a wetland or other identified resource area. The designer/engineer should balance this type of strategy with the need to meet safety design guidelines for slopes. In addition, the gradient of the slope must be geotechnically stable. Also, there may be sites where flatter slopes are preferred, to allow provision of vegetated filter strips to treat highway runoff, and to enhance edge habitat along the protected resource.

At water and wetland resource crossings, the designer should search for opportunities to intercept highway drainage before it reaches the resource area, and convey that drainage to storm water management facilities. In some instances (e.g., roadways immediately adjacent to or crossing resource areas), it may not be possible to provide treatment at the end of a drainage system. In such cases, it may be appropriate to provide treatment/control of runoff some distance upstream of the point of discharge to offset direct untreated discharges of the remaining (downstream) portions of the roadway. (See later discussion regarding “macro” approach to evaluating storm water management systems).

For existing roadways located on shorelines, causeways, or at the edge of a jurisdictional resource area, a healthy growth of vegetation on the side slopes adjacent to the resource should be established and maintained. If the toe of embankment is at the edge of a water body, the designer should consider preserving and maintaining a “wetland fringe” where feasible, using the plant community’s ability to filter runoff and provide vegetative uptake of nutrients.

Refer to DEP Stormwater Technical Handbook (DEP 1997b, Chapter 2) for additional guidelines related to natural drainage ways, steep slopes, and erodible soils.

3.3.2 Reduce and Minimize Impervious Surfaces If Safe and Feasible

Safety design standards govern pavement widths and configurations, so pavement reduction is generally not an option for reducing highway runoff. While pavement reduction opportunities may be limited in the highway setting, other measures for reducing the volume of runoff may be possible, depending on specific site conditions. However, to the extent feasible, plan highway projects to result in the minimum quantity of runoff that must be handled by the drainage system. Potential measures include:

- Remove abandoned sections of pavement and replace with vegetation;

- Use grassed islands instead of paved islands where the grassed islands can be reasonably maintained in healthy vegetative condition;
- Consider permeable materials instead of paved slopes for stabilization;
- Consider useable shoulders rather than paved shoulders to minimize impervious area; and
- Avoid the mixing of "non-highway runoff" with highway runoff to minimize the amount of storm water to be managed, using strategically placed diversions above cut slopes.

3.3.3 Reproduce Pre-Development Hydrologic Conditions

Because of right-of-way space constraints and technical limits on the use of infiltration measures in connection with roadway pavements, the opportunities to mimic pre-roadway hydrologic conditions may be limited. However, some measures may be applied to modify the hydrologic performance of the highway system, particularly where "open" or "country" type drainage systems are used, including the following:

- Preserve natural drainage systems as much as possible;
- Minimize disturbance of natural channel linings, to take advantage of the treatment capability of existing vegetation. This must be balanced with the need to maintain channel capacity, which may require periodic cleaning of accumulated sediment and debris;
- Incorporate design features to slow velocities to increase time of concentration to the outlet. For instance, where practicable, increase the detention time of storm water in swales through the judicious use of check dams or flat gradients;
- Use shallow gradient channels with vegetated linings where feasible;
- For design conditions that are likely to result in channel bottom scour, consider stone-centered swales with vegetated linings on the upper slopes, and use of stilling basins or check dams within the channel;
- For high energy channel conditions where simple vegetative linings are not anticipated to be stable, consider geotechnically reinforced vegetative linings, or use of stilling basins or check dams within the channel;
- For design conditions requiring structural linings, consider riprap or other lining that results in the lowest velocity of flow, while still meeting channel capacity requirements. Consider porous structural linings on upper slopes to allow infiltration and to promote growth of some vegetation (e.g., open cell concrete revetment materials, planted riprap);
- Generally, only use paved channels when other types of lining will not provide for stability and capacity within the constraints of the site;
- Provide energy dissipation measures where lined channels discharge to vegetated channels or natural drainage ways;
- Evaluate the benefits and disadvantages of disconnecting drainage flows to decrease volumes and velocities of storm water runoff at drainage discharge outlets. This approach may shunt smaller, more dispersed amounts of storm water off the roadway with less erosive force and more opportunity for infiltration and natural detention/retention. Flow disconnection may not be feasible in all situations due to siting and design constraints. For example, ledge outcrops may prevent dispersing of runoff at the edge of shoulder, adjacent urban development may limit available discharge points, and steep slopes and adjacent topography may limit available locations for suitable down-drains;
- Consider flow spreading when designing highway drainage. Sheet flow is preferable to concentrated flow because of the reasons stated above for flow disconnection. With either strategy, the designer needs to consider the capacity and stability of the discharge path to carry the anticipated flows without erosion;
- Minimize the use of curbs and enclosed drainage systems where feasible to meet drainage and safety objectives with open channels;

- Maximize the use of vegetated buffers between the edge of pavement or gravel shoulder and the storm water conveyance system;
- Take advantage of unique opportunities for storm water storage and treatment facilities (e.g., an old borrow pit site from the original road construction might be an ideal site for a created storm water treatment wetland area);
- Consider opportunities to site BMPs within the median and within the parcels bounded by interchange ramps. The designer/engineer must balance the placement of drainage facilities in these locations with safety requirements of the highway. Also, jurisdictional resources may be located within these areas, and thus constrain the development of BMPs in these locations.

3.3.4 Fit the Development to the Terrain

For existing roads and highways, the opportunity to "fit the development to the terrain" may be limited. Rehabilitation and reconstruction projects are constrained by existing alignment, site conditions, and right of way limitations. For roadway improvement projects, examples of "terrain" strategies include measures such as minimizing encroachment into resource areas and buffers, intercepting off-site runoff, and using slopes for filter strips.

The design professional should review Chapter 2 of DEP Stormwater Management Policy Technical Handbook (DEP 1997b) for guidance on fitting new construction project to the terrain.

3.4 Source Control and Non-structural Approaches

The use of source control and pollution prevention measures can minimize the potential pollutant loads conveyed by highway drainage systems associated with adjacent land uses. For example, non-structural measures such as street sweeping and modern snow and ice control practices, may reduce pollutant loads associated with roadway use and maintenance. Refer to DEP Stormwater Technical Handbook (DEP 1997b) for additional information regarding non-structural techniques including source controls and pollution prevention. MassHighway develops and implements non-structural and source control measures at a statewide and/or programmatic level (rather than project level). Some examples of typical types of source control and non-structural storm water approaches employed by MassHighway are further described below:

- Street Sweeping -- Street sweeping reduces the sediment and associated pollutants entrained in runoff and ultimately discharged to receiving resources. Most public roadways and highways are swept on an annual basis as warranted, with an emphasis on high sand accumulation areas and locations adjacent to sensitive receiving waters. Most street sweepers currently in use are mechanized rotary brush sweepers;

- Snow and Ice Control -- Deicing controls for all State-jurisdictional roadways will be consistent with the practices outlined in the Snow and Ice Control Generic Environmental Impact Report (GEIR). Specific recommendations include: optimize the management of road sand for snow and ice control operations by using sand only where it is most effective, such as intersections, sharp curves, low volume roads, and steep grades, and by pre-wetting sand so that smaller amounts can be applied to achieve maximum effectiveness. Existing MassHighway non-structural measures include: designating areas as "Reduced Salt Zones" and installing "reduced salt area" warning signs (for motorists) along roadways near drinking water reservoirs, and covering stockpiled de-icing materials at maintenance facilities to prevent contamination to storm water runoff. In addition, the DEP Snow Removal Policy provides additional guidance for stockpiling snow, such as avoiding wetlands and Zone II well protection areas.

- Management of Pesticides, Fertilizers, and Herbicides – Through the rare and controlled use of fertilizers, herbicides, and pesticides, MassHighway minimizes the introduction of potential pollutants into storm water runoff along its highways. Specifically, MassHighway rarely uses fertilizers (except for new plantings) and pesticides. Also, MassHighway applies only limited amounts of herbicides to roadside vegetation, along high-traffic volume and high-speed interstate and primary roadways, where the safety of motorists and maintenance personnel precludes the use of mechanical methods. MassHighway's Vegetation Management Plan (for the years 2003-2007), as approved by the Department of Agricultural Resources, provides strict operational guidelines for herbicide application, such as avoiding sensitive areas (e.g., surface waters, water supply wells, farmland) and suspending operations during adverse weather conditions.

- Policy Regarding Tie-ins – MassHighway has a policy not to accept tie-ins by off-site properties into roadway drainage systems. Discharges of treated water from construction de-watering operations, into the State drainage system, must have a discharge permit from the EPA and authorization from MassHighway. Sanitary sewer connections are not allowed and, if found, will be removed. Construction de-watering and other related temporary discharges, such as effluent from a groundwater treatment system, are considered adequately regulated and will be allowed if these discharges have been approved through the EPA's NPDES or the State's hazardous waste regulations.

- Public Education -- Public education provides a means to reduce pollutant loads from adjacent land uses that may be conveyed by roadway drainage systems. Programs aimed at proper household hazardous waste disposal or lawn maintenance may also reduce pollutant loads in roadway drainage systems. In addition, public education can be employed to encourage use of mass transit, carpooling, and other measures to reduce traffic, and therefore also reduce pollutant source loading on roadways. Some communities have developed programs for stenciling brief warnings on the pavement at catch basins, to discourage dumping of oil and other substances into the storm drain system. MassHighway funds training programs through the MassHighway Training Assistance Program (MTAP) and Baystate Roads. These programs provide training to MassHighway and municipal departments of public works staff, and include workshops and seminars addressing storm water management resource protection issues.

- Litter Pick-up – MassHighway participates in the nationwide program -- *Adopt-a-Highway* -- whereby organizations and businesses adopt a stretch of highway, and participate in litter control and other enhancement projects. The program provides an opportunity for environmentally conscious groups and corporations to participate in keeping Massachusetts roads litter-free. MassHighway also administers *Project Clean* **–** which supports the enforcement of State litter laws by providing signage within the highway right-of-way, and encouraging roadway users to notify MassHighway of litter and debris along the roadway through Project Clean. By calling #321 on a cellular phone or 1-888-359-9595 on a standard phone, people can act as roving patrollers and keep MassHighway informed of unsightly litter and debris.

- Other measures that may also reduce pollutant loads through source reduction include:
  - Park and Ride Lots

- Mass Transit/Alternative Transportation
- Enforcement of litter laws through signage and support of violator-reporting programs
- Construction Storm Water Pollution Prevention Plans.

Roadway designers can promote source control in project designs (some of which also enhance roadway safety) by considering the following:

- Improvements to roadways and related drainage systems to reduce puddling and icing on the road surface, thereby reducing the need for salt and sand applied for deicing;
- Improvements to roadway surfaces (providing smoother pavements) to facilitate thorough plowing and more complete snow removal, thereby reducing the need for salt and sand application;
- Clearing of vegetation which prevents light penetration to the road surface, to eliminate "cold spots". Otherwise, such cold spots typically require repeated applications of salt and sand to control icing conditions;
- Placement of catch basins, so that plowing operations can keep catch basin inlets clear, reducing the need for sand/salt application;
- Adequate space for snow storage along the roadway, to allow for more effective snow removal by plowing equipment;
- Stabilization of eroding surfaces (e.g., pavement, shoulders, embankments, and ditches) that contribute sediment to storm water;
- Commensurate with the nature and scale of a particular project, identification and elimination of illicit non-storm water discharges into the roadway drainage system;
- Providing scour protection at unprotected drainage outlets. Some existing storm drain outlets may lack erosion protection, resulting in scour at the outfall. Provision of riprap aprons, plunge pools, or other scour protection to correct this condition will help reduce TSS loading to downstream watercourses.
- Reducing roadway widths from MassHighway design standards (i.e., securing design waivers) can reduce the volume and rate of storm water runoff flowing into wetlands by reducing the amount of impervious surfaces.
- Changes to roadway drainage, e.g., collection and re-routing, can reduce storm water loading to sensitive resources. However, re-routing of drainage must be considered in light of potential effects on wetland hydrology.

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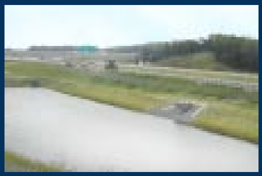
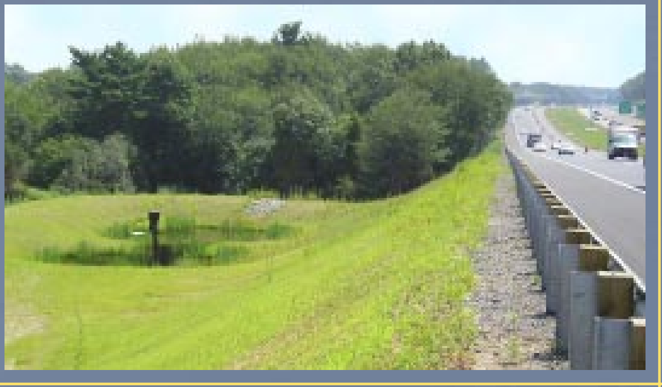
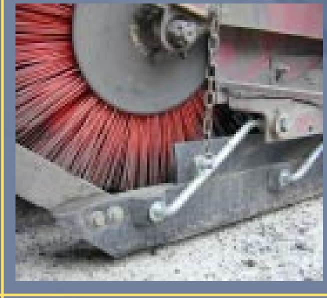


Selecting Storm Water Best Management Practices for Highways and Bridges





Selecting Storm Water Best Management Practices for Highways and Bridges

4.0 SELECTING STORM WATER BEST MANAGEMENT PRACTICES FOR HIGHWAYS AND BRIDGES

This Section discusses the process of screening and selecting Best Management Practices (BMPs) for application to roadway improvement projects. This Section also includes a brief overview of construction-related BMPs (sediment and erosion control practices), and a discussion of operation and maintenance considerations.

General summaries, basic design criteria, and design references for various BMPs are provided in Section 5.0 of this Handbook.

In the process of selecting and designing BMPs, the designer should evaluate and develop storm water controls within the overall project context. As discussed in Section 3.1, this “macro” approach considers the entire drainage system (or a sub-drainage area with multiple outlets) under study, rather than individual outlets. This holistic approach offers flexibility in meeting storm water management objectives, because it allows addressing project storm water effectiveness on a project-wide basis, rather than at individual outlets. This Section provides additional guidance on applying this approach to the development of BMP systems for meeting peak rate control, storm water recharge, and water quality treatment objectives.

Within this overall design strategy, the following process is recommended for screening and selection of BMPs.

4.1 Screening and Selecting Storm Water Best Management Practices (BMPs) for Roadway Projects

The evaluation and selection of BMPs is typically an iterative process taking into consideration site constraints, cost-effectiveness, and resource protection. To help facilitate the evaluation of Storm Water BMPs for the roadway setting, this Section outlines a screening process for selecting the most practicable BMP or group of BMPs for a roadway improvement project. The process screens BMPs according to key factors affecting BMP **feasibility**. The designer then evaluates the feasible BMPs for their **suitability** to meet storm water management objectives (i.e., peak rate control, recharge, and water quality treatment). If more than one feasible BMP or combination of BMPs can meet storm water objectives, then the designer ranks the candidate BMPs (short list of acceptable alternatives meeting all applicable criteria) according to cost-effectiveness, and chooses the system to advance to final design. Designers should use this screening process to document the analysis of alternatives for addressing storm water management objectives.

On roadway projects covered under “Redevelopment” (Standard 7 of the DEP Stormwater Management Policy), the designer should first evaluate whether existing untreated storm water discharges can be eliminated. Removing an existing untreated storm water outlet would achieve an improvement over existing conditions under Standard 1. Once this alternative has been considered, then the designer should proceed with screening BMPs for possible application at the remaining outlets.

In this screening process, the designer evaluates BMPs based on the following sets of criteria:

1. **Feasibility Factors**
   a. Physical
   b. Installation and Operational
   c. Regulatory Restrictions
   d. Location Within Watersheds of Critical Areas
   e. Land Uses With Higher Potential Pollutant Loads

2. **Storm Water Management Suitability Objectives**
   a. Peak Rate Control
   b. Recharge
   c. Water Quality Control

Application of these criteria involves an assessment of the "practicability" of candidate BMPs. Under the DEP Stormwater Management Policy, Standard 3 (Recharge) and Standard 7 (Redevelopment Projects, which applies to many roadway improvement projects) specifically refer to the implementation of applicable measures "to the maximum extent practicable". The Policy states:

> *"To the extent practicable" means the applicant has made all reasonable efforts to meet the standards, including evaluation of alternative BMP designs and their locations."*

This screening process provides a methodical approach for conducting this evaluation, to arrive at the most appropriate storm water management design for a roadway improvement project.

In the road and highway setting, the term "practicability" also involves an evaluation of BMPs in terms of the following considerations:

- Does the system allow for effective drainage of the highway surface and sub-base, consistent with standard engineering practice for roadway design, and with the objectives of public safety and roadway structural integrity?
- Has the system been documented to achieve storm water management objectives effectively and efficiently in the highway setting?
- Does the system have a cost for initial installation and ongoing operation, repair, and maintenance, commensurate with the overall project scope, available funding, and the sensitivity of the receiving watercourse?

The designer should ask these questions as he/she proceeds with each step of the evaluation of BMPs. Sections 4.2 and 4.3 describe the screening categories in further detail.

After screening the list of available BMPs according to the above criteria, the designer will have a list of BMPs that potentially comply with the DEP Stormwater Management Policy; meet other regulatory objectives; can be implemented within the physical constraints of the project; and are practicable to construct, operate, and maintain. As discussed in Section 4.4, the designer will then rank these remaining BMPs according to cost-effectiveness, and select the most practicable BMP (or combination of BMPs) for advancement to final design. BMPs will be chosen to meet storm water management requirements, while being commensurate with the overall project scope of work and project costs.

Figure 4-1 presents a checklist that summarizes the criteria for screening BMPs.

Figure 4-1. BMP Screening Checklist – Instructions

Use the following two-part checklist to screen the list of potential types of BMPs for applicability for each project Storm Water Discharge (or for a system of discharges where the "macro" approach is applied). **Part 1** of the checklist identifies BMPs that are **feasible**, based on Feasibility Factors described in this chapter. For the list of feasible BMPs identified in Part 1, **Part 2** identifies which BMPs are **suitable** for accomplishing each applicable storm water management objective. This screening process can be used to document the storm water management alternatives analysis for a project.

Part 1: Feasibility Factors

1. Use the information compiled for the project to determine which categories of feasibility factors apply. Place a check mark (where indicated) under each category that applies to the project. If a particular category does not apply to the project, cross out the entire column of the worksheet corresponding to that set of factors. (For example, if the project watershed does not contain land uses with a higher potential pollutant load, then the two columns under that heading can be eliminated from consideration).
2. For each type of BMP listed, review the applicable feasibility factors, and determine if the BMP type can meet each applicable set of feasibility criteria. If the BMP type can comply with the applicable criteria, check the box corresponding to that Feasibility Category. If the BMP type cannot meet applicable criteria, leave the box blank. Refer to the text in this chapter for an explanation of the feasibility factors. (For example, if an extended detention basin is not feasible because the slope is too steep for installation, leave the box next to "Extended Detention Basin" blank under "Physical Feasibility Factors".)
3. Every box for a BMP type under applicable Feasibility Categories must be checked, for the BMP type to be **feasibl**e. In that case, circle the letter "Y" in the final column. If any box is left blank (the BMP cannot meet applicable criteria), circle the letter "N" in the last column. (Note: if a BMP fails to meet criteria under any one Feasibility Category, it is not necessary to proceed with review of other categories. For example, BMPs eliminated according to physical feasibility criteria do not need further evaluation under any of the remaining feasibility factors.)
4. Use the "Remarks" column to identify the particular factor (if any) that precludes the use of the BMP type. Attach a supporting narrative, as appropriate.

Part 2: Storm Water Management Suitability

1. In most cases, a project will need to meet each of the listed Storm Water Management Objectives. However, on some projects, particular objectives may not apply (for example, discharges to waters subject to tidal action do not require control of peak discharge rates). If a particular Objective does not apply to the project, cross out the entire column of the worksheet corresponding to that objective.
2. If any special objectives apply to the project (management objective not specifically covered in the Stormwater Policy), indicate this in the Special Objectives column, and attach a narrative describing this objective. (For example, on a particular project, it may be desirable to control some other pollutant than just TSS.)
3. In the first column of Part 2, list the feasible BMPs identified in **Part 1**. For each BMP listed, determine whether it can meet each applicable objective. For each objective the BMP meets, check the corresponding box. (For example, a deep sump catch basin can provide some degree of TSS removal, so check the box under "TSS Removal". In most cases, deep sump catch basins will not meet other storm water objectives, so those boxes will be left blank.)
4. In most cases, a BMP will meet at least one Objective. If a particular objective has been eliminated, certain BMPs that can meet only that objective will be eliminated. If no box has been checked under "Storm Water Management Objective", then the type of BMP is not suitable and can be eliminated from further consideration. (For example, if the discharge is to tidal waters, peak rate control is not an objective. In that case, a conventional detention basin that has no water quality or recharge functions would not meet any other objective, and would be eliminated as a suitable BMP).
5. At the bottom of each column, note the number of BMPs that are both **feasible** and **suitable** for meeting each Storm Water Management Objective. If no feasible BMP can meet a particular Objective, then it is not practicable to meet that objective for the particular Storm Water Discharge under study.

Ranking and Selection of Remaining BMPs

The above process will result in a short list of BMPs that are **feasible** and **suitable** for the particular project Storm Water Discharge:

1. If only one type of BMP remains for a particular objective (e.g., quality control), that BMP type will advance to final design.
2. If more than one BMP type remains on the list for a particular objective, then the designer must determine whether one BMP or a combination of BMPs is needed to achieve full compliance with the applicable Policy Standard. If there are multiple BMP combinations providing similar levels of compliance, the designer may rank and select candidate BMPs based on cost-effectiveness.

Figure 4-1. BMP Screening Checklist – Part 1: Feasibility Factors

Type of Storm Water Best Management Practice (BMP)	Feasibility Category						Remarks	Feasible BMP? (See Note 2)
	Physical Feasibility Factors	Installation and Operational Factors	Regulatory Restrictions	Location in Critical Areas	Land Uses With Higher Potential Pollutant Loads			
					Not Critical Area	Critical Area		
Use a Check Mark (√) to Indicate Whether Feasibility Category Applies to Project →	√	√						
Source Control	o	o	o	o	o	o		**Y/N**
Conventional Drainage Channel	o	o	o	o	o	o		**Y/N**
Water Quality Swale	o	o	o	o	o	o		**Y/N**
Outlet Sediment Trap	o	o	o	o	o	o		**Y/N**
Vegetated Filter Strip	o	o	o	o	o	o		**Y/N**
Deep Sump Catch Basin	o	o	o	o	o	o		**Y/N**
Sediment Forebay	o	o	o	o	o	o		**Y/N**
Detention Basin	o	o	o	o	o	o		**Y/N**
Extended Detention, Pond, or Wetland System	o	o	o	o	o	o		**Y/N**
Recharge Basin, Trench, or Bed	o	o	o	o	o	o		**Y/N**
Leaching Catch Basin, Leaching Basin, Dry Well, or Recharge Galley	o	o	o	o	o	o		**Y/N**
Sand or Organic Filter	o	o	o	o	o	o		**Y/N**
Water Quality Inlet	o	o	o	o	o	o		**Y/N**

Notes:

1. If the Type of BMP meets applicable feasibility criteria, place a check in the box. If a BMP does not meet feasibility criteria for the project being evaluated, leave the box blank.
2. Circle "Y" to indicate a BMP type is **Feasible**. A BMP type is considered feasible if it complies with the criteria under <u>all</u> applicable feasibility categories. If <u>any</u> box under an <u>applicable</u> feasibility category is left blank (BMP type cannot comply with that feasibility criteria), then the type of BMP is eliminated from further consideration; in that case, circle "N". State reason for elimination under "Remarks".

Figure 4-1. BMP Screening Checklist – Part 2: Storm Water Management Suitability

List Feasible Best Management Practices Identified in Part 1	Storm Water Management Objective[1]: Peak Rate Control – 2-Year Storm	Peak Rate Control – 10-Year Storm	Peak Rate Control – 100-Year Flood Elevation	Recharge	Quality Control – TSS Removal	Quality Control – Percent TSS Removal[2]	Special Objective[3]	Remarks
	o	o	o	o	o		o	
	o	o	o	o	o		o	
	o	o	o	o	o		o	
	o	o	o	o	o		o	
	o	o	o	o	o		o	
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	o	o	o	o	o		o	
	o	o	o	o	o		o	
	o	o	o	o	o		o	
Indicate Number of BMPs that can meet Storm Water Objective[4]								

Notes:

1. Place a check in the box to indicate the type of BMP is suitable for meeting the storm water objective. If not suitable for the project being evaluated, leave the box blank.
2. Indicate percent TSS removal achieved by BMP.
3. Describe the Special Objective under “Remarks” and/or in an attached narrative. Examples include but are not limited to: minimizing storm water discharges within Zone II Groundwater Protection Areas, minimizing bacteria in storm water discharges to shellfish beds, minimizing thermal impacts of storm water discharges to cold-water fisheries.
4. Indicate the total number of feasible BMPs that can meet each storm water objective. If “0”, then achieving the storm water objective is not practicable. If “1” or greater, then at least one of the candidate BMPs will advance to the design phase. If greater than “1”, then select from among the BMPs based on achievement of objective to “maximum extent practicable”. If multiple BMPs (or combinations) achieve equivalent levels of compliance with the objective, then they may be ranked and the final selection may be based on cost-effectiveness.

4.2 Feasibility Factors

The roadway planner/designer should evaluate BMPs relative to several categories of criteria, to determine if a particular BMP is feasible in a particular project setting. These factors include the following:

4.2.1 Physical Factors

Under this set of criteria, designers will screen the candidate BMPs relative to actual physical conditions at a site. **Table 4-1. Physical Feasibility Factors for Screening BMPs** lists physical factors that may affect the design and construction of roadway improvements, including associated drainage system components. Basic site and BMP suitability factors are described in Chapter 4 of DEP's Stormwater Technical Handbook (DEP 1997b). Special considerations relative to roadway drainage design are identified in Table 4-1.

4.2.2 Installation and Operational Factors

This category of screening criteria addresses implementation factors involved in BMP selection. These factors include construction feasibility, safety considerations, accessibility for inspection, and operation and maintenance considerations. **Table 4-2. Installation and Operational Factors for Screening BMPs** lists the installation and operational factors that must be considered in roadway improvement projects, and identifies key issues to consider in screening BMPs for feasibility of use in the roadway setting.

4.2.3 Regulatory Restrictions

Under this category of criteria, the designer assesses the candidate BMPs for any attributes that affect their design or preclude their use, because of regulatory restrictions (other than the requirements of the DEP Stormwater Management Policy). BMPs may be restricted as they relate to common site features that may be regulated under State or federal law. These restrictions fall into one of three general categories:

1. Areas where the siting of a BMP or supporting structure would be expressly *prohibited* by statute or regulation;

2. Areas where the siting of a BMP or supporting facilities is *restricted* and is only allowed on a case by case basis. State and/or federal permits shall be obtained and the applicant will need to supply additional documentation to justify locating the BMP within the regulated area; and

3. Areas where the siting of BMPs will require specific *setbacks* of fixed distances from certain site features.

[Text continues on Page 4-12]

Table 4-1. Physical Feasibility Factors for Screening BMPs

Physical Factor	Considerations for Roadway Drainage Design
Compatibility with Engineering Design Practice	BMPs must allow for the effective drainage of the highway surface and sub-base, consistent with standard engineering practice for roadway design, and with the objectives of public safety and roadway structural integrity.
Slope	Location of a highway and development of the longitudinal highway profile are greatly dependent on topography. Longitudinal profile depends on alignment standards for safety, drive-ability, and drainage. Cross section is dependent on safety standards, slope stability, and available right-of-way. As a result of these factors, existing topography and required finished slope grades can constrain the amount of space available for installation of drainage facilities. Slopes can thus affect the choice of closed drainage over open drainage, the selection of water quality BMPs, and the selection of structural surfaces versus vegetation for stabilization. Slopes can also affect the choice of BMPs because of BMP design considerations; for instance, steep slopes may constrain the siting of a detention basin, because a sufficient storage volume would require an excessively high impoundment berm. Flat slopes may also restrict certain BMPs, if those BMPs need more hydraulic head than available given site topography.
Depth to Groundwater	Roadways may require sub-drains to control the effect of groundwater levels on the pavement structure. Such activities may also be required to control the effect of local groundwater levels on the sub-structure of the road. To the extent these actions use up available right of way, the choice of BMPs may be limited. Certain BMPs require minimum clearances to groundwater. For example, recharge BMPs must have at least two feet of clearance (and sometimes more) between the infiltration surface and seasonal high groundwater. Where such clearances are not available, recharge BMPs may not be practicable.
Depth to Bedrock	The presence of bedrock close to the surface in a roadway right-of-way can significantly affect the choice of drainage system, BMP type, and location.
Soil Characteristics	The structural properties of underlying soils, as well as permeability, erodibility, and frost susceptibility are important considerations in the design of the highway cross section (i.e., embankment, cut slopes, and pavement structure), the choice of type of drainage system, and type of BMP. Certain soils will not offer practicable locations for certain BMPs. For instance, recharge BMPs cannot be located in Hydrologic Group D soils, and may be problematic in other soils as well (e.g., where receiving soils are prone to clogging under anticipated design conditions).
Natural Resources (Wetlands, Mature Trees, Upland Wildlife Habitat, Critical Areas, Vegetated Buffers)	The location of highway improvements and the selection and design of associated structures (such as storm water BMPs) must be balanced with other public resource protection objectives. These other objectives often include minimizing the disruption of other natural features in the landscape, including “critical areas” as defined under the Policy. Designers should note that there may be cases where BMPs must be sited in close proximity to, or even within, such natural resources of concern, to achieve the offsetting environmental benefits of storm water treatment. In such cases, designers must be cognizant of regulatory requirements that may apply (see discussion in Section 4.2.3). Also in such cases, designers should discuss the proposed activity during the early design stages with the appropriate regulatory agencies and other stakeholders.

Table 4-1. Physical Feasibility Factors for Screening BMPs

Physical Factor	Considerations for Roadway Drainage Design
Existing Development and Structures	Density, land-use type, types of structures, presence of historic structures, presence of archaeological resources, and other man-made features in the landscape, also affect the location of highway improvements and the selection and design of drainage system components. For example, the presence of a major building and its foundation in close proximity to the right-of-way can significantly limit the choice of drainage facilities for both conveyance and treatment.
Existing Utilities	Roadway rights-of-way are frequently shared by other utilities, including above-ground power and communications systems, and below-ground power, communications, gas, water, sewer, and storm drain conduits. Also, existing utilities may be located outside the right-of-way but in close proximity to the roadway. In addition, adjacent properties may contain water supply wells and on-site sewage disposal systems. The presence of these facilities may limit the extent to which the existing roadway drainage system can be modified, and can constrain the placement of new BMPs. In some cases, these facilities may preclude use of certain BMPs (e.g., recharge BMPs should not be placed within the zone of influence of a water supply well).
Rights-of-Way, Property Lines, Easements	Available right-of-way can constrain the choice of storm water management facilities and their locations. Some easements for construction are temporary, until construction is complete, which can preclude the siting of BMPs in these areas. Acquisition of additional permanent right-of-way for implementation of BMPs may be constrained by available funding, by the short time frames of certain types of highway projects (e.g., for operational or funding reasons), and by landowner opposition. The designer should evaluate the candidate list of BMPs based on whether sufficient space within the right-of-way is available to accommodate each storm water management measure. Space must be available to accommodate the BMP, ancillary structures, grading requirements, safety setbacks, and applicable regulatory setbacks. Space also needs to be provided for operation and maintenance access. Designers may need to consider whether additional right-of-way can be reasonably obtained, given the project scope, location, sensitivity of receiving water, nature of other adjacent land uses, and project funding. BMPs that cannot fit within available right-of-way (including practicable takings) will need to be eliminated from the list of candidate storm water management measures. If right-of-way is determined to be unavailable, this should be documented as part of the project's analysis of design alternatives.
Sites with Potential Releases of Hazardous Materials	The presence of these sites along a roadway can affect right-of-way acquisition decisions, as well as the choice and design of storm water management facilities. The presence of known or potential "discharge plumes" that have migrated through soils under the roadway can also affect these design decisions.

Table 4-1. Physical Feasibility Factors for Screening BMPs

Physical Factor	Considerations for Roadway Drainage Design
Drainage Area	Certain BMPs have recommended minimum drainage areas considered suitable for the practices. For example, the minimum area recommended for an Extended Detention Basin is 4.1 hectares (10 acres, unless the extended detention outlet control can be designed to prevent clogging). BMPs that are not sustainable by the contributing area can be eliminated from further consideration. (Refer to guidelines for specific BMPs in Chapter 5.) However, the designer should note that the minimum drainage areas recommended for some BMPs (such as ponds and wetlands) should not be considered inflexible limits and may be increased or decreased depending on water availability (base flow or groundwater) or the mechanisms employed to prevent clogging of outlet structures. Certain BMPs have recommended maximum drainage areas considered suitable for the practices. For example, the maximum area recommended for a subsurface recharge system (trench or bed) is 2.0 hectares (5 acres). If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway may be allowed, or more than one practice can be installed.
Available Hydraulic Head	Most BMPs depend on gravity flow for their operation, and many will require minimum operating depths for their effective function. The designer must consider the required operating head of a BMP in the screening process, as well as in design. If multiple BMPs will be used, the combined hydraulic head requirement must be considered, and compared to the available vertical clearance at the site. Furthermore, some BMPs have underground structures, piping, or other components. The depth of cover over these components must be considered in determining whether BMPs can be installed within available vertical clearances.

Table 4-2. Installation and Operational Factors for Screening BMPs

Installation or Operational Factor	Considerations for Roadway Drainage Design
Construction Feasibility	Road improvement projects can be complex to design and construct. Even though the general site conditions discussed in Section 4.2.1 and Table 4-1 may be favorable for a certain BMP, other factors may preclude the BMP because of difficulties in constructing the facility. Some examples include: • The installation of deep sump catch basins or other underground structures at the edge of pavement or shoulder may be restricted by the presence of other underground utilities; • Existing traffic must be accommodated during road improvement projects. Space within the right-of-way may be required to route traffic around the construction. This may temporarily (or in some cases, permanently) preclude the use of that space for siting a particular BMP or type of BMP; • Along existing roads, candidate locations for BMPs are sometimes identified at the toe of slope of the roadway embankments. However, these areas are frequently inaccessible to construction equipment, because of the height and slope of the existing embankment. In these cases, installation of the BMPs in otherwise suitable locations may be precluded by the limitations on construction or maintenance access. Designers will need to review actual construction conditions on each project, for particular conditions that may affect the choice of BMPs.
Adequate Safety	Safety is of paramount concern in the roadway setting. Designers must evaluate BMPs for their compatibility with vehicular safety requirements. Depending on particular site conditions, this may rule out the use of certain BMPs, or affect their siting and design if they are used. Along heavily used roadways (such as limited access highways and urban arterial roadways), designers should consider the safety implications posed by BMPs that require frequent maintenance. BMPs should be selected and sited so that maintenance crews can access and service the measures, with an absolute minimum of disturbance to traffic flow. For example, installation of a device that requires closing a lane of traffic for routine maintenance should be avoided – particularly if there is an alternative BMP with lower maintenance requirements, or that can be sited in a less disruptive location. In addition, other public safety requirements will need to be considered. For example, in many residential settings, the provision of BMPs that have permanent open pools of water may either be precluded from further consideration because of public safety concerns (e.g., accidental drowning), or require special design requirements and access controls (e.g., protective fencing).
Ease of Inspection	BMPs require periodic inspection, to monitor performance and to identify conditions that might interfere with the proper function of the storm water management system. Preference should be given to BMPs that can be easily observed by roadway maintenance personnel. Routinely employed BMP measures with which maintenance personnel are familiar, and which can be easily observed, are more likely to receive routine attention than devices that are difficult to access or to observe.

Table 4-2. Installation and Operational Factors for Screening BMPs

Installation or Operational Factor	Considerations for Roadway Drainage Design
Operational Considerations	The designer should give preference to BMPs that require no special operational measures. Designers should avoid BMPs that have flow controls that require frequent adjustments or that otherwise require the regular presence of personnel to keep the facility operational. BMPs should also be selected and designed to be compatible with local emergency response procedures for spill containment, especially in "critical areas". BMPs selected for roadway use should have full documentation of performance in the highway setting.
Maintenance Considerations	Designers should give preference to BMPs that are simple to maintain, can be maintained with the routine procedures and equipment typically used by the party responsible for maintenance, and require the least maintenance over the long-term. The following criteria should be considered: • Frequency of scheduled maintenance required by the selected BMP; • Chronic maintenance problems (such as clogging) associated with any BMP, as reported in the literature or experienced by the designer or implementing agency personnel; • Reported failure rates for any particular BMP; • The need for special equipment or procedures to accomplish routine maintenance (for example, some enclosed structures will require confined-space entry procedures under OSHA). Many roadway projects implemented by MassHighway involve sections of roadways maintained by local communities. Where a project will be designed and constructed by one agency, but operated and maintained by another agency, written agreements should clearly specify responsibilities for maintenance.
Life-Cycle Cost	The designer should select BMPs that meet project objectives (including regulatory requirements), but that are also cost-effective. Roadway improvement projects are primarily publicly funded, as well as maintained by public agencies. The designer should screen BMPs for those with life-cycle costs (including installation, operation, maintenance, and repair) commensurate with available funding. BMPs with extraordinary costs of installation or maintenance may be deleted from further consideration.

Typical areas that are subject to regulatory restrictions include, but are not limited to:

- Areas regulated under the Massachusetts Wetlands Protection Act;
- Wetlands and waterways subject to federal permitting under the Federal Clean Waters Act (Section 404);
- Public Surface Water Supplies and their protection zones (see, for example, 314 CMR 4.00 and 350 CMR 11.00);
- Public Groundwater Supplies and their aquifer protection zones;
- Areas near private wells;
- Areas governed by the Massachusetts regulations of Hazardous Waste (310 CMR 30) and the Massachusetts Contingency Plan (MCP, 310 CMR 40);
- Existing on-site sewage disposal systems;
- Other areas that may impose siting restrictions, setback requirements, or unique design constraints on the proposed BMP, to comply with State and federal regulatory requirements (e.g., Section 4(f) lands used for public recreation, park, or wildlife purposes).

Specific regulations and requirements are not listed in this Handbook. Designers must check applicable State and federal regulatory statutes and regulations, and consult with the appropriate regulatory agencies, to ascertain applicable requirements that affect the selection and design of BMPs.

4.2.4 Location within Watersheds of Critical Areas

The design of urban BMPs is fundamentally influenced by the nature of the downstream water body that will be receiving the storm water discharge. Consequently, designers must determine the characteristics of the watershed in which their project is located prior to design.

The DEP Stormwater Management Policy, Standard 6, identifies certain BMPs as suitable for “critical areas”, which are defined in the policy to include the following:

- Outstanding Resource Waters (ORWs), e.g., surface water drinking supplies and certified vernal pools, as defined by the Surface Water Quality Standards (314 CMR 4.00),
- Shellfish beds,
- Swimming beaches,
- Cold water fisheries, and
- Recharge areas for public water supplies.

If the roadway improvement site falls within a watershed of one of these areas, then the DEP Stormwater Policy Handbook, Volume 1, indicates that the following BMPs are suitable:

- Extended detention basins,
- Wet ponds,
- Constructed wetlands,
- Water quality swales,
- Sand filters,
- Organic filters,
- Infiltration basins,
- Infiltration trenches,
- Deep sump and hooded[1] catch basins (used with other BMPs).

1 For further discussion on the use of hoods in the roadway setting, see “General Information” and “Design Criteria” for Deep Sump Catch Basins in Section 5.1.

In Critical Areas, MassHighway recommends the following BMPs in addition to those cited by the DEP:

- Vegetated Filter Strips,
- Leaching Catch Basins and Leaching Basins.

Note, however, that within recharge areas for public water supplies, the application of recharge BMPs must be considered on a case by case basis. In some areas, such as the Cape Cod sole source aquifer, the benefits to groundwater quantity may outweigh the risks associated with introducing the pollutants in storm water into the ground.

The selection of BMPs for critical areas should generally be limited to those identified in the above discussion. Alternative BMPs can be used if their performance is equivalent and can be documented.

Designers should also note that the DEP Stormwater Management Policy identifies restrictions on the use of certain BMPs within the watersheds of the following:

- Surface and Groundwater Drinking Water Supplies,
- Shellfish Growing Area or Public Swimming Beach,
- Cold Water Fisheries.

Designers should refer to the Stormwater Policy Handbook, Volume 1 for a tabulation of the restrictions.

In addition to noting the specific DEP Stormwater Management Policy provisions, designers of roadway improvements should recognize the special nature of "Critical Areas" (especially surface water drinking water reservoirs and other ORWs). In general, roadway improvements in these areas warrant additional efforts to protect water quality (i.e. a higher standard for "practicability") than may apply in other less sensitive areas. Designers should carefully consider candidate BMPs, and the provision of space to site these BMPs (including potential additional right-of-way acquisition), to achieve storm water management objectives in these areas.

The DEP Stormwater Management Policy uses TSS removal as an indicator for BMP performance. In some critical areas, however, TSS may not be the only parameter (or even the primary parameter) of concern. For example:

- In shellfish growing areas and public swimming beaches, bacterial contamination is of concern. Therefore, designers should evaluate BMPs for their ability to capture bacteria or limit their growth. BMP technologies that retain water under conditions that promote bacteria growth (such as enclosed spaces that can become "septic" during extended no-flow periods) should be avoided in these areas.

- In cold water fisheries, water temperature is a critical parameter. Therefore, if a BMP discharges directly to temperature sensitive waters, the BMP should not retain water in such a manner that raises its temperature (as may occur in a shallow wet pond, for instance). Alternatively, BMPs can sometimes be designed to account for the temperature effects; for example, in a deeper wet pond, water can be discharged from lower levels of the pond, or re-introduced to the downstream resource area through groundwater recharge.

4.2.5

Land Uses With Higher Potential Pollutant Loads

The DEP Stormwater Management Policy identifies certain land uses that potentially have higher storm water runoff pollutant loads (refer to Standard 5 of the Policy). The list of such land uses does not include roads and highways.

However, portions of certain ancillary land uses (such as roadway maintenance depots) may fall on this list. Also, owners of properties outside the right-of-way, but draining to the roadway system, may engage in land uses that fall on this list. If a project involves handling storm water runoff from land uses other than roads and highways, designers should refer to the DEP Stormwater Management Policy Handbook, Volume 1, to determine if the project is covered by Standard 5.

To the extent that Standard 5 applies to the project, designers should consider source reduction and pretreatment measures.

Also, the Policy indicates the following BMPs may be used only if sealed or lined:

- Detention basins,
- Wet ponds,
- Constructed wetlands,
- Sand or organic filters.

If the project falls within the watershed of a "critical area" (Standard 6) and also under Standard 5, then the Policy precludes the following BMPs:

- Infiltration trenches,
- Infiltration basins,
- Dry wells.

4.2.6 Short List of BMPs Meeting Feasibility Criteria

After screening BMPs according to the feasibility factors, the designer will have a short list of BMPs that can be implemented within the site's constraints, other regulatory requirements, and installation and maintenance factors. These **feasible** BMPs must then be evaluated for their ability to accomplish storm water objectives. This **suitability** screening process is described further in the next section of this chapter.

4.3 Storm Water Management Suitability

In this phase of the screening process, the designer evaluates feasible BMPs for their **suitability** – the ability of BMPs to meet storm water management objectives. In this process, the designer will consider the question:

> *What are the applicable storm water management objectives, and can the BMP meet these objectives at the site (or is a combination of BMPs needed)?*

To complete this process, the designer of a particular project will evaluate how the storm water objectives of peak rate control, recharge, and water quality treatment will be addressed by the project.

Section 3.1 outlines the use of a "macro" approach for storm water management design on a project-wide basis. Using this approach, the designer will determine the following:

1. Existing outlets that may be eliminated or recombined, to reduce the number of outlets requiring treatment;
2. New outlets that will be required to handle storm water discharge requirements;
3. Specific outlets that will be used to meet the objectives of peak rate control, recharge, and water quality treatment. As discussed in Section 3.1, not every outlet will necessarily have a treatment BMP.
4. For each outlet that will be used to meet one or more storm water objective, the designer will then screen the list of **feasible** BMPs for those measures capable of providing the appropriate type and level of storm water management (peak rate control, recharge, and quality control).

This evaluation may further narrow the list of available BMP options that can be applied at each particular outlet. This evaluation will also provide the designer an understanding whether a single BMP or some combination of BMPs will serve project objectives and meet storm water sizing criteria and each outlet. A sequence of BMPs (or "treatment train") frequently will be required to meet project objectives.

Under the Storm Water Management Suitability Criteria, designers will screen BMPs for their ability to meet the following objectives:

4.3.1 Peak Rate Control (Standard 2)

Standard 2 of the DEP Stormwater Management Policy deals with controlling peak rates of storm water discharge. To develop the most practicable system of BMPs for addressing peak rate control, designers must determine the extent of control needed for the project, select the most effective locations for such control, and then screen BMPs for suitable measures to achieve this objective.

Designers should first consider the need for peak rate control by addressing the following questions:

1. Is the project's storm water discharge to waters subject to tidal action? If so, then peak rate control is not needed to comply with the Stormwater Management Policy.
2. Is peak rate control warranted in the particular project setting (other than waters subject to tidal action)? The extent of peak rate control provided will depend on factors such as:
   a. The relative increase in impervious area;
   b. Proximity to areas prone to flooding during frequent storm events (e.g., adjacent properties with known storm water flooding problems);
   c. Whether the project will result in increased flooding offsite during the 100-year frequency event (if there is no impact on offsite flooding during the 100-year design event, then controlling the 100-year frequency discharge will not be necessary); and
   d. The size of the contributing roadway sub-watershed relative to the size of the overall watershed of the receiving water.
3. Can the project design meet peak rate control objectives by combining outlets, modifying conveyance capacity, or selectively controlling certain outlets?

Designers should consider these questions in the context of the overall project and affected watersheds. This "macro" approach, discussed further in Section 3.1, results in a design of the overall highway drainage **system** (instead of individual outlets) to:

- Provide control of peak rates (if needed) at critical control points (such as capacity sensitive resource areas or structures); and
- Prevent increased levels of flooding downstream or upstream of the project.

Selected drainage outlets may be provided with peak rate control facilities, but not necessarily all outlets.

Once the need for and extent of peak rate control are defined for each outlet, then candidate BMPs are evaluated for their ability to control peak discharge rates for the 2-year and 10-year frequency, 24-hour design storms. The BMPs should also be evaluated relative to their influence, if any, on off-site flood elevations during the 100-year frequency design event. The finding that a particular BMP cannot control peak rates does not necessarily mean that it should be eliminated from consideration (because it may serve another function such as pretreatment, recharge, or water quality treatment), but may indicate that more than one practice may be needed at a site.

4.3.2 Recharge (Standard 3)

DEP Stormwater Management Policy Standard 3 addresses minimizing the loss of annual groundwater recharge as a result of development. Designers will need to determine the extent to which recharge is practicable for the project, and then screen the list of feasible BMPs for suitable options. In some cases, the design of recharge systems will be precluded by physical suitability criteria (e.g., groundwater elevations, depth to bedrock), or other factors discussed in this Chapter.

To evaluate the extent to which recharge will be provided on a highway project (assuming recharge BMPs meet feasibility criteria) the following process is recommended:

1. Determine if there is a net increase in impervious area as a result of the project. If impervious area is not increased, then a recharge BMP is not necessary.
2. Determine if the project will discharge runoff from one or more "land uses with higher potential pollutant loads" (as defined by DEP's Stormwater Management Policy) to a "critical area." If this is the case, certain infiltration measures are precluded from use by this feasibility criterion, as discussed in Section 4.2.5.
3. If recharge is a suitable objective based on the above analysis, then
    a. Determine if there is space within existing right-of-way to place recharge BMPs;
    b. If insufficient space, and additional right-of-way cannot be acquired, then recharge for this particular setting shall be considered “not practicable”;
    c. If sufficient space, then consider BMPs designed specifically for recharge for the project;
    d. If recharge BMPs are not feasible, consider other BMPs which have an incidental infiltration function (such as water quality swales or vegetated buffer strips);
    e. If these other BMPs are not feasible, then recharge for the project will be considered “not practicable”.

If recharge measures appear applicable, based on the analysis outlined above, the list of feasible BMPs must then be screened for alternative measures that can achieve the recharge objectives. (This list of candidate BMPs will have been evaluated in terms of the other Feasibility Factors described earlier in this chapter.)

4.3.3

TSS Removal (Standard 4)

Standard 4 of the DEP Stormwater Management Policy deals with management of storm water quality. Standard 4 specifies a reduction in the Total Suspended Solids (TSS) load in the contributing runoff. For new development, the Standard calls for an average annual TSS removal of 80%. For redevelopment projects, the standard needs to be met to the maximum extent practicable.

To select BMPs for the most practicable system for addressing this quality control standard, designers should determine (using the "macro" approach, as appropriate) the outlet locations to be served by TSS reduction BMPs. The designer then reviews the short list of feasible BMPs for suitable measures to achieve this objective at each of the designated outlets. The use of BMPs in series ("treatment trains") may be required to meet storm water objectives.

To address the TSS removal standard under the Stormwater Management Policy, designers should also consider the sensitivity of the receiving water (discussed under *Location Within Watersheds of Critical Areas*), and the nature of the land use relative to pollutant potential (discussed under *Land Uses with Higher Potential Pollutant Loads*). The factors considered under those criteria may preclude the use of some BMPs, apply constraints to the design of particular BMPs, and affect the appropriate sizing rule applicable in the project setting (1.0 inches times impervious area for "critical areas", 0.5 inches times impervious area in other settings).

The designer should also consider whether:

1. The project design can meet quality control objectives by combining outlets for treatment in a minimum number of devices; or
2. Segments of the drainage system can be separated so that smaller scale treatment devices can be employed; or
3. Certain outlets can be selectively treated, to offset impacts at remaining outlets that may not be provided with specific water quality treatment measures.

Storm water BMPs should be evaluated either singly or in combination with other BMPs for their ability provide for TSS removal to the maximum extent practicable. In screening the BMPs, designers should consider the sizing requirements identified in the Stormwater Management Policy. The Policy lists BMPs for which DEP presumes TSS removal rates for the purposes of evaluation under the Policy. The designer should refer directly to the Policy for the applicable TSS removal rates. These removal rates are also summarized in Section 5.0 of this Handbook.

If a particular BMP does not appear on the list in the Policy guidance, then the designer will need to provide documentation of the anticipated treatment performance of the device. Also, even for the listed BMPs, a higher TSS removal rate may be credited to a BMP if the designer provides satisfactory documentation that the higher performance level can be achieved. In documenting the performance of a BMP measure, the designer should be careful to evaluate performance based on particle settling or trapping characteristics. In assessing BMP technologies, designers should consider available evaluation protocols and resources. These include product evaluations performed by the Massachusetts Strategic Envirotechnology Partnership (STEP), and a Six-state Memorandum of Agreement (currently under development) detailing protocols for testing and verifying performance of storm water treatment technologies.

4.4 Prioritizing and Selecting BMPs

Based on the screening criteria discussed above, the designer will develop a short list of BMPs that are considered suitable for the project, based on storm water management objectives, physical constraints, operational considerations, and regulatory guidelines and requirements. The process is designed to account for feasibility constraints and resource protection goals in the development of a list of candidate BMPs. If more than one alternative system is considered viable, then the designer must select from the remaining alternatives.

From the “short-list” of suitable BMPs, the designer should choose the most economical system, compatible with storm water management objectives. Life-cycle costs, including initial construction as well as operation and maintenance, should be considered during BMP selection and design.

For simple projects, the analysis of the relative cost-effectiveness of BMPs can be qualitative, based on designers’ experience and descriptions in the engineering literature. For more complex projects, designers may wish to follow a more formal analysis of cost-effectiveness in comparing BMPs. It may be necessary to combine installation costs with the costs of repair and maintenance using amortization methods typically used for engineering life-cycle cost comparisons.

Based on the ranking the BMPs by cost-effectiveness, the designer will select the BMP system that will advance to final design for the project.

4.5 Erosion and Sediment Control BMPs for Highway Construction

In addition to selection and design of permanent storm water management BMPs, an important step in controlling storm water runoff quality from the site is the proper implementation of erosion and sediment controls during construction. Without proper controls the erosion of soil disturbed by construction can be a significant source of runoff pollutants (e.g., solids, nutrients, and other trace contaminants).

Standard #8 of the DEP Stormwater Management Policy requires the implementation of erosion and sediment controls during construction. Requirements also apply under the U.S. EPA Storm Water NPDES program (discussed in Section 3.2.8 of this Handbook).

For MassHighway projects, the designer should refer to current MassHighway design manuals as the primary reference for designing and implementing erosion and sediment controls. Additional guidance may be found in the publication, *Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas*, (March 1997)[1], prepared by the Franklin, Hampden, Hampshire Conservation Districts (Northampton, Massachusetts) for use by planners, designers, and municipal officials.

Also, several neighboring states have adopted BMP manuals for erosion and sediment controls. A number of control measures are included in many of these manuals. Other measures are either unique to each manual or treated a little differently. All of these manuals are useful sources of information for designers dealing with site-specific erosion/sediment control. Reference should be

1 This handbook may be obtained from the Boston office of the Massachusetts DEP. DEP also intends to post the handbook on its web site at www.state.ma.us/dep.

made to those guidance documents for application information and design criteria and details. These references include:

Connecticut	Guidelines for Soil Erosion and Sediment Control (Revised 1988)
Maine	Erosion and Sediment Control Handbook for Construction: Best Management Practices (1991)
New Hampshire	Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire (1992)
New York	Guidelines for Urban Erosion & Sediment Control (1991)
Rhode Island	Soil Erosion and Sediment Control Handbook (1989)

The following is a listing of the erosion and sediment control BMPs of particular interest for roadways. These BMPs are listed by the two major categories of Erosion Control (to prevent the suspension of sediment) and Sedimentation Control (to trap sediment once it becomes suspended in runoff). The designer should emphasize erosion control measures as the "first line of defense" against the suspension and transport of soil material into waterways and other wetland resource areas.

4.5.1 Erosion Controls (Temporary Measures)

1. Timing and sequencing of construction specifically for erosion control, including measures to limit the extent and time of exposure of soils;
2. Limiting the area of alteration to the minimum required for construction of proposed work;
3. Timely planting of temporary seed mixes and mulches;
4. Erosion control blanket products (reinforced with natural and synthetic materials) for use on steep slopes, erodible soils;
5. New synthetic "mulch" products (soil stabilizers) available for use in critical areas where standard mulching techniques are not workable;
6. Organic compost mulch products available from proprietary sources for use in critical areas requiring aggressive stabilization;
7. Providing temporary diversion berms or channels along or across access roads and roads under construction (commensurate with topographic conditions and construction traffic);
8. Strategic use of temporary check dams in ditches and installed channels;
9. Provision of temporary slope drains or "chutes" to control flow over the tops and faces of embankments;
10. Erosion control treatment of stockpiled soil materials;
11. Regular inspection, maintenance, and repair of erosion controls during construction.

4.5.2 Erosion Controls (Permanent Measures)

1. Diversion berms at tops of steep cut slopes;
2. Slopes constructed with intermediate terraces, with provision for down-drains;
3. Stable down-drains (e.g., armored drainage way) to convey water down embankments;
4. Permanently installed organic compost mulch products available from proprietary sources for use in critical areas requiring aggressive stabilization;
5. Pervious slope stabilization and revetment materials (such as lattice-type masonry units, synthetic cellular grid systems, rip rap and modified rock fill) for use in areas requiring aggressive stabilization measures;

6. Stable slopes for inside detention basin embankments (because of periodic inundation, these slopes frequently need to either be flatter, or provided with different cover treatments, than upland slopes in similar soil materials);
7. Closed drainage systems for slope and soil conditions that may be susceptible to erosion;
8. Timely planting of permanent vegetation, proper selection of seed mixes appropriate to the highway setting (based on vegetation function and application conditions);
9. Bio-engineering materials and methods for critical area stabilization (especially steep slopes, stream banks, shorelines);
10. Vegetated buffers near wetlands and watercourses;
11. Strategic use of permanent check dams in drainage channels.

4.5.3 Sediment Controls

1. Siltation barriers (e.g., silt fences and/or hay bales between construction areas and resource areas, siltation barriers at catch basin inlets where appropriate);
2. Use of temporary silt traps and sediment basins, including temporary use of permanent BMPs such as detention basins, where feasible. Temporary use of permanent structures should only occur where temporary use will not interfere with future permanent function of the facility. For example, a future infiltration basin should not, in general, be used for sediment trapping during construction;
3. Sediment barriers placed around stockpiled soil materials;
4. Regular inspection, maintenance, and repair of sediment controls during construction.

4.6 BMP Operation and Maintenance

For a project subject to the DEP Stormwater Management Policy, Standard 9 requires the storm water management system to have an operation and maintenance plan to ensure that the system functions as designed. The plan should identify the system owner, the parties responsible for operation and maintenance, a schedule for inspection and maintenance, and the maintenance tasks to be undertaken.

Various state and local departments are responsible for the operation and maintenance of drainage structures and BMPs associated with the thousands of miles of public roadways in the state. Funding for ongoing operation and maintenance activities is provided through public process.

For projects on roadways where the municipality retains the responsibility for maintenance, the Design Engineer should coordinate with the appropriate Municipal Officer to develop a maintenance program for the storm drainage system. The Engineer should obtain written certification from the Municipality that it accepts responsibility for performing this maintenance program.

Periodic inspection is an important component of an operation and maintenance plan. Moreover, DEP (1997a) states that BMPs for roadways should be easy to maintain and have low frequency maintenance requirements.

MassHighway recommends the following practices for the routine operation and maintenance of roadway drainage systems and BMPs, consistent with the provisions of the *NPDES Storm Water Management Plan for MassHighway Owned and Operated Highways* (MassHighway SWMP):

1. Maintain records that document catch basin inspection and cleaning (as well as any maintenance activities for other drainage structures), including: executed contracts, certificates of completion, contractor invoices, or other types of maintenance logs.
    a. Develop a centralized database for keeping records on inspection and maintenance of catch basins. This will include developing a statewide map of its drainage systems, on a project by project basis as individual roadway projects are proposed and issued environmental permits. MassHighway will collect data on the accumulation of debris (including the frequency of cleaning catch basins, and any drainage problems) for representative areas, and determine if the current inspection and cleaning schedule should be altered for particular areas.
    b. The schedule will target areas that are in most need of cleaning, with an emphasis on locations adjacent to sensitive receiving waters (e.g., public drinking water reservoirs), while corresponding to MassHighway's limited maintenance budgets.
    c. Upon completion of the review, the Standard Operating Procedure (SOP) for catch basin cleaning will be updated, as necessary;
2. Sweep roadways on an annual basis after winter deicing applications as warranted, with an emphasis on high sand accumulation areas and locations adjacent to sensitive receiving waters;
3. Note problems and take appropriate corrective actions to maintain outlets and BMPs in good working condition;
4. Take appropriate control measures to avoid discharge of materials to receiving wetland and water resources during cleaning and maintenance activities (e.g., avoid side-casting sediments from ditch cleaning into adjacent wetlands);
5. Install, inspect and maintain construction BMPs to ensure appropriate sediment control is provided throughout construction and until the site is stabilized.
6. The inspection and cleaning for other storm water BMPs are included in Section 5, BMP Design Criteria, herein.

Routine tasks (e.g., sediment removal from drainage swales, catch basin cleaning in the buffer zone) for the operation and maintenance of existing and future BMPs, conveyance systems, drainage structures, and outlets described above are non-jurisdictional under the Wetlands Protection Act. As such, these activities do not require filing of a Notice of Intent or Request for Determination of Applicability under the regulations of the Act. Care should be exercised so that removed material from such maintenance activities is not disposed within jurisdictional areas or where it may impact a resource area.

Moreover, maintenance of wetlands created and used for the purpose of storm water management or conveyance does not require filing a Notice of Intent (NOI) under the Wetlands Protection Act and regulations, "provided that the work is limited to the maintenance of the storm water management system and conforms to an Order of Conditions issued after April 1, 1983 and that the area is not altered for other purposes" (see 310 CMR 10.02(3)).

In the context of roadways and highways, such "wetlands" may include basins or ponds, swales, drainage ditches, depressions, or other structures or features used or intended for use in the conveyance, control or treatment of roadway runoff.

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BMP Design Criteria

5.0 BMP DESIGN CRITERIA

A number of structural BMPs are described in the DEP Stormwater Management Technical Handbook (DEP 1997b). In the previous Section, an approach for evaluating and selecting BMPs for a given highway project was described.

This Section provides a brief summary of each BMP (including appropriate design references) basic design criteria for each BMP, and a schematic (typical) example of each BMP.

Other BMPs and alternative design approaches may yield equivalent or better performance. It should be noted that BMPs should conform to the DEP design guidelines (DEP 1997b) if the design professional intends to use the presumptive treatment efficiencies listed in the DEP Stormwater Management Policy. If other BMPs or design/sizing approaches are used, an independent demonstration (e.g., using models or other empirical reference data) should be provided to demonstrate achievable treatment efficiencies.

A number of innovative technologies for managing storm water have been introduced in recent years, and new technologies are anticipated. The general BMP categories listed below do not include a separate category for "innovative technologies". Generally, such technologies fall within one or more of the categories listed below (e.g., water quality inlets, filter systems). The designer of a particular project should use applicable information from the following pages to assist in evaluating innovative technologies and screening them for potential use. In assessing these technologies, designers should also consider available evaluation protocols and resources. These include product evaluations performed by the Massachusetts Strategic Envirotechnology Partnership (STEP), the Technology Acceptance and Reciprocity Partnership (TARP), and the Environmental Technology Verification (ETV) program. These programs verify that an innovative technology will function as described in its assessment report (including potential sources of data error), provided that the site conditions are similar to those in which the treatment performance was evaluated.

5.1 BMP General Information and Design Criteria

The BMPs in the following pages are organized by general categories as follows:

In addition, Section 5.2 offers the following guidelines and information regarding devices and structures that are used in conjunction with the BMPs described under the above categories:

Design Criteria for Selected Supplemental Structures and Devices

SOURCE CONTROLS

GENERAL INFORMATION

Description:
Source controls consist of measures to minimize the types and concentrations of pollutants in storm water runoff. These practices help control pollutants by:

- preventing the deposition of potential pollutants on the land surface where they would come into contact with runoff (e.g., judicious use of fertilizers on vegetated areas, and avoidance of use of herbicides and pesticides);
- removing deposited materials prior to contact with runoff (e.g., street sweeping); and
- minimizing the volume of storm water runoff coming into contact with potential pollutants (e.g., diversion of runoff from undeveloped areas away from impervious surfaces).

Examples of source controls applicable for roadway improvement projects include, but are not limited to:

- Street sweeping (refer to General Information sheet on this practice);
- Implementation of temporary and permanent erosion control measures on erosion-prone slopes adjacent to roadways;
- Snow and ice management practices (in conformance with MassHighway GEIR for Snow and Ice Control);
- Highway improvements that contribute to the prevention of spills (refer to Section 3.2.6 of this Handbook);
- Implementation of other non-structural measures discussed in Section 3.4 of this Handbook;
- Drainage improvements that prevent runoff from undeveloped areas from coming into contact with roadway pavements, thus minimizing the quantity of runoff requiring treatment by structural BMPs.

Applicable DEP Stormwater Management Policy Performance Standards	Standards #4, #5. Refer to DEP Stormwater Management Policy for specific guidelines for source controls under these standards. Street Sweeping is the only nonpoint pollutant source control measure for which DEP provides a credit for TSS removal. Qualitatively, provision of source controls on a "Redevelopment" project provides an "improvement over existing conditions". Quantification of this benefit generally is not required.	
TSS Removal	DEP Credit:	Up to 10% for street sweeping (see Street Sweeping General Information). No specific credit for other measures.
Relative Cost	Varies with practice.	
Potential Constraints to Use	Varies with practice.	
Other Considerations	Varies with practice.	
Primary Reference		

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STREET SWEEPING

GENERAL INFORMATION	
Description: Street sweeping is a non-structural method of controlling pollutants in storm water. It is essentially a source reduction practice. It involves the use of mechanical or vacuum pavement cleaning equipment (and sometimes, manual labor), to remove particulates from the pavement surface prior to wash-off by storm water runoff. To be effective in controlling storm water pollution, sweeping must be conducted regularly, and must be performed by a method that picks up fine-grained particulates (clays, silts, fine sands), as well as coarse materials (sand and gravel) and debris.	
Applicable DEP Stormwater Management Policy Performance Standards	Standard #4. Street Sweeping is the only nonpoint pollutant source control measure for which DEP provides a credit for TSS removal.
TSS Removal	DEP Credit: Up to 10%. Street sweeping program needs to be specified in an Operations and Maintenance Plan that ensures sweeping on a regular basis. Estimated Range from Literature: <5% to >50%; varies widely with frequency of sweeping and type of cleaning equipment
Relative Cost	Capital Cost: High (street cleaning equipment) Maintenance: Low to high; varies widely with frequency of sweeping and type of equipment
Potential Constraints to Use	• Equipment availability • Limitations on use imposed by high traffic volumes on certain roadways • On street parking in highly developed urban areas
Other Considerations	• Vacuum sweepers are generally more effective than mechanical (brush or broom) sweepers • Dry weather sweeping is generally more effective than wet weather sweeping • Early spring is the optimal time for street sweeping • Pollutant removal rates are directly related to frequency of sweeping; generally street sweeping program must be aggressive to obtain effective pollutant reduction. Refer to Primary Reference and other literature for additional information on removal effectiveness as a function of frequency and type of equipment.
Disposal of Street Sweepings	Dispose of street sweepings in accordance with Reuse and Disposal of Street Sweepings, MA DEP Bureau of Waste Prevention, Final Policy #BWP-94-092.
Primary Reference	Young, et. al., 1996

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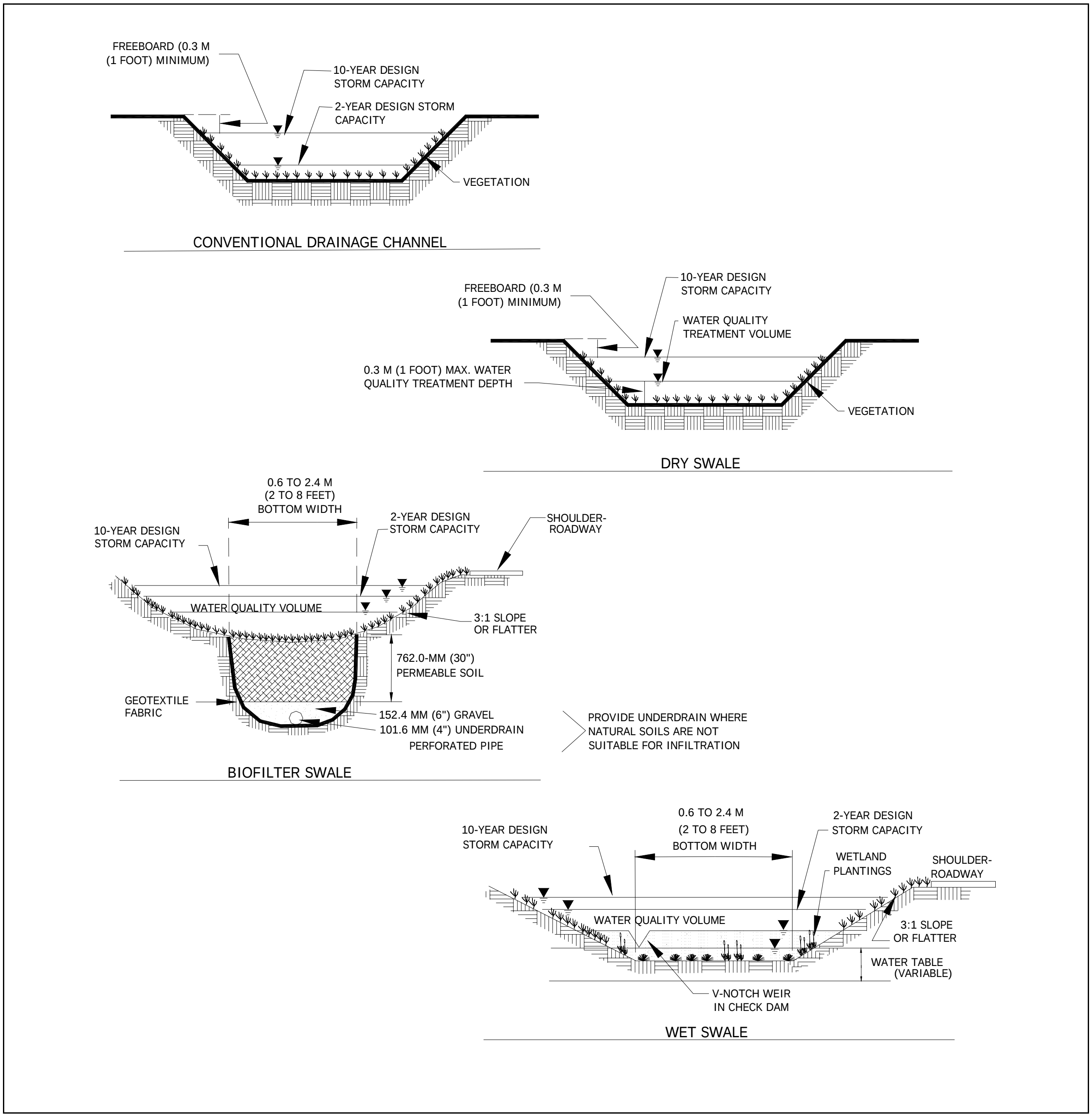
CHANNEL SYSTEMS

GENERAL INFORMATION	
Description: Channel systems include open channels in two general categories: 1. Conventional drainage channels with non-erosive surfaces designed primarily for **storm water conveyance** (water quality treatment is secondary). 2. Water Quality Swales, designed primarily to provide **storm water treatment**, with the secondary function of conveying flows. They include Dry Swales, Bio-filter Swales, and Wet Swales. They are generally shallow, vegetated, earthen channels. Depending on site conditions, pollutant removal occurs by filtration through vegetation, infiltration into underlying soils, and physical settling (if residence time is sufficient). Check dams may enhance pollutant removal. Water Quality Swales are well suited for treatment of roadway runoff. Separate Design Criteria summaries follow for Conventional Drainage Channels, and each of the three types of Water Quality Swales. For all channels, geometry, slope, and lining materials are designed for capacity and stability under design flow conditions. Some channel designs include the use of **Check Dams**. Criteria for Check Dams are included under **Design Criteria for Selected Supplemental Structures and Devices**.	
Applicable DEP Stormwater Management Policy Performance Standards	Standard #4 (if specific criteria are met) Standard #2, in some instances, where channels may be designed with sufficient capacity to control peak discharges. Standard #3, in some instances, where channels may be designed to infiltrate runoff (e.g., bio-filter swales located in suitable soils).
TSS Removal	DEP Credit: 25% for Conventional Drainage Channels meeting specific criteria: • Design for non-erosive velocity for 2-year storm • Design with check dams 70% for Water Quality Swales Estimated Range from Literature: Varies for conventional drainage channels. 60-83% for water quality swales.
Cost	Construction: Low Maintenance: Low
Potential Constraints to Use	• Depth to bedrock • Slope • Soil conditions (such as erodibility, permeability) • Not well suited to highly urbanized setting (limited rights-of-way)
Other Considerations	• Swales generally are less expensive than curb/gutter systems, but require more land • May be used in combination with other BMPs for pre-treatment or discharge conveyance • If properly designed and maintained, drainage channels may last indefinitely
Maintenance Requirements	• Mowing of embankments for vegetated channels • Periodic sediment removal • Re-seeding and/or re-stabilization of eroded areas
Primary Design References	Current MassHighway Design Manuals Young, et. al., 1996 Claytor and Schueler, 1996



Examples of Channel Systems

CONVENTIONAL DRAINAGE CHANNEL

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	No size limit on contributing area, but size may be limited by velocity criteria applicable to the channel.
Storm frequency for DEP TSS removal credit	Minimum design storm = 2-year frequency
Conveyance Capacity	Refer to highway drainage design manual for design storm frequency to meet capacity criteria.
Maximum permissible velocity	Maximum velocity for stability of a channel depends on its lining. Vegetated channel stability depends on soils type and grass species. The permissible velocity in a grassed channel can be increased through the use of geosynthetic materials, also known as Turf Reinforcement Materials (TRMs). Channels may also be lined with riprap or with fabricated revetment systems, such as interlocking concrete block revetments. Consult design literature for further guidance on channel linings.
Maximum longitudinal gradient	Depends on lining and anticipated velocities. Grassed waterways (without use of TRMs) are generally prone to excessive erosion when their gradients exceed 5%.
Check Dams	Refer to separate design criteria listing for Check Dams (Design Criteria for Supplemental Structures and Devices).
Stabilization	For vegetated channels, seed in accordance with NRCS standards; species tolerant to frequent inundation are required. Erosion control blankets recommended during establishment of vegetation. Consult design literature for reinforcement using TRMs. Consult design literature for stabilization using "bio-engineering" methods. For lined channels, consult technical literature for design of riprap or synthetic revetments.
Outlet protection	Scour protection required at discharge point, unless channel discharges directly to a conduit or a properly lined channel.

DRY SWALE

DESIGN CRITERIA	
Design Parameter	**Criteria**[1]
Distinguishing characteristics from other Water Quality Swales	• Complete drawdown between storm events • Treats by detention, to promote settling and vegetative filtration, with secondary infiltration • Sized based on residence time
Contributing Drainage Area	No size limit on contributing area, but size may be limited by velocity criteria applicable to the swale.
Design flow: **Treatment** **Conveyance capacity**	 Estimate the peak flow for the storm that produces the water quality volume (see corresponding permissible velocity) 10-year storm (see corresponding maximum permissible velocity)
Design depth: **Treatment** **Conveyance**	 Max. 0.30 meter (1.0 foot) is recommended for depth of treatment flow. Size to convey 10-year storm event with one foot of freeboard.
Water Quality Treatment Capacity	Design for hydraulic residence time for treatment flow, as identified below.
Hydraulic Residence Time (Treatment Design Flow)	Optimal greater than 9 minutes (>80% TSS removal). Minimum = 5 minutes (~60% TSS removal).
Maximum permissible velocity: **Treatment** **Conveyance**	 Less than 0.30 meters/second (1.0 fps) for treatment design flow. Less than 0.91 meters/second (3.0 fps) for peak discharge during 10-year storm.
Maximum longitudinal gradient	Channel gradient should be as close to zero as possible. Maximum gradient recommended is 5%.
Channel shape	Trapezoidal or parabolic
Side slopes	3:1 or flatter
Bottom width	0.6 to 2.4 meters (2 to 8 feet).
Soils	Soils suitable for establishing vegetation.
Stabilization	Seed in accordance with NRCS standards; species tolerant to frequent inundation required. Erosion control blankets recommended during establishment of vegetation.
Pretreatment	Required. Use sediment forebay and check dam, or other suitable method of pretreatment.
Outlet protection	Scour protection required at discharge point, unless channel discharges directly to a conduit or a properly lined channel.

1 Adapted from Young, et. al., 1996.

BIOFILTER SWALE

DESIGN CRITERIA	
Design Parameter	**Criteria**[1]
Distinguishing characteristics from other Water Quality Swales	• Complete drawdown between storm events • Treats by retention and complete infiltration of the water quality volume, or by detention and filtration of the water quality volume (this latter option requires an underdrain for the swale) • Sized based on the Water Quality Volume
Contributing Drainage Area	No direct limit on size of contributing area, but area may be limited by other sizing criteria applicable to the swale.
Design flow for conveyance capacity and stability	10-year storm
Conveyance Capacity	Size to convey 10-year storm event with one foot of freeboard.
Water Quality Treatment Capacity	Design to retain and infiltrate prescribed water quality volume. Use check dams or other design measure to achieve required water quality storage capacity.
Recharge Treatment Capacity	Design to retain and infiltrate prescribed recharge volume.
Maximum permissible velocity	Less than 3.0 fps for peak discharge during 10-year storm.
Maximum longitudinal gradient	Channel gradient should be as close to zero as possible. Maximum gradient recommended is 5%.
Channel shape	Trapezoidal or parabolic
Side slopes	3:1 or flatter
Bottom width	0.6 to 2.4 meters (2 to 8 feet).
Check Dams	Refer to separate design criteria listing for Check Dams (Design Criteria for Supplemental Structures and Devices).
Soils	• Natural soil bed 762.00 mm (30”) deep; approximately 50% sand/50% loam. • If natural soils do not permit infiltration, design with underdrain (for water quality treatment function). In this case, swale does not meet recharge standard.
Stabilization	Seed in accordance with NRCS standards; species tolerant to frequent inundation required. Erosion control blankets recommended during establishment of vegetation.
Pretreatment	Required. Use sediment forebay and check dam, or other suitable method of pretreatment.
Outlet protection	Scour protection required at discharge point, unless channel discharges directly to a conduit or a properly lined channel.

1 Adapted from Young, et. al., 1996.

WET SWALE

DESIGN CRITERIA	
Design Parameter	**Criteria**[7]
Distinguishing characteristics from other Water Quality Swales	• Drawdown to level of seasonal high groundwater between storm events • Treats by detention, to promote physical settling, vegetative filtration, and vegetative nutrient uptake. Infiltration through side-walls of channel may be secondary. • Sized based on the Water Quality Volume
Contributing Drainage Area	No direct limit on size of contributing area, but area may be limited by other sizing criteria applicable to the swale.
Design flow	For conveyance capacity and stability: 10-year storm
Conveyance Capacity	Size to convey 10-year storm event with one foot of freeboard.
Water Quality Treatment Capacity	Design to detain or retain prescribed water quality volume above anticipated level of seasonal high groundwater. If detention is used, size for at least 24-hour draw-down time. If retention is used, size based on infiltration capacity of side walls. Use check dams or other design measure to achieve required water quality storage capacity. If detention, provide outlet control for required draw-down time.
Maximum permissible velocity	Less than 0.91 meters/second (3.0 fps) for peak discharge during 10-year storm.
Maximum longitudinal gradient	Channel gradient should be as close to zero as possible. Maximum gradient recommended is 5%.
Channel shape	Trapezoidal or parabolic
Side slopes	3:1 or flatter
Bottom width	0.6 to 2.4 meters (2 to 8 feet).
Soils	Use wet swales where water table is at or near the soil surface, or where soil types are poorly drained. Soils underlying completed swale should be saturated most of the time. Retention-type swales can only be used where side slopes of swale are suitable for infiltration.
Stabilization	Seed in accordance with NRCS standards; flood tolerant species required; need to use wetland-adapted species in the saturated portion of the swale. Erosion control blankets recommended during establishment of vegetation.
Pretreatment	Required. Use sediment forebay and check dam, or other suitable method of pretreatment.
Outlet protection	Scour protection required at discharge point, unless channel discharges directly to a conduit or a properly lined channel.

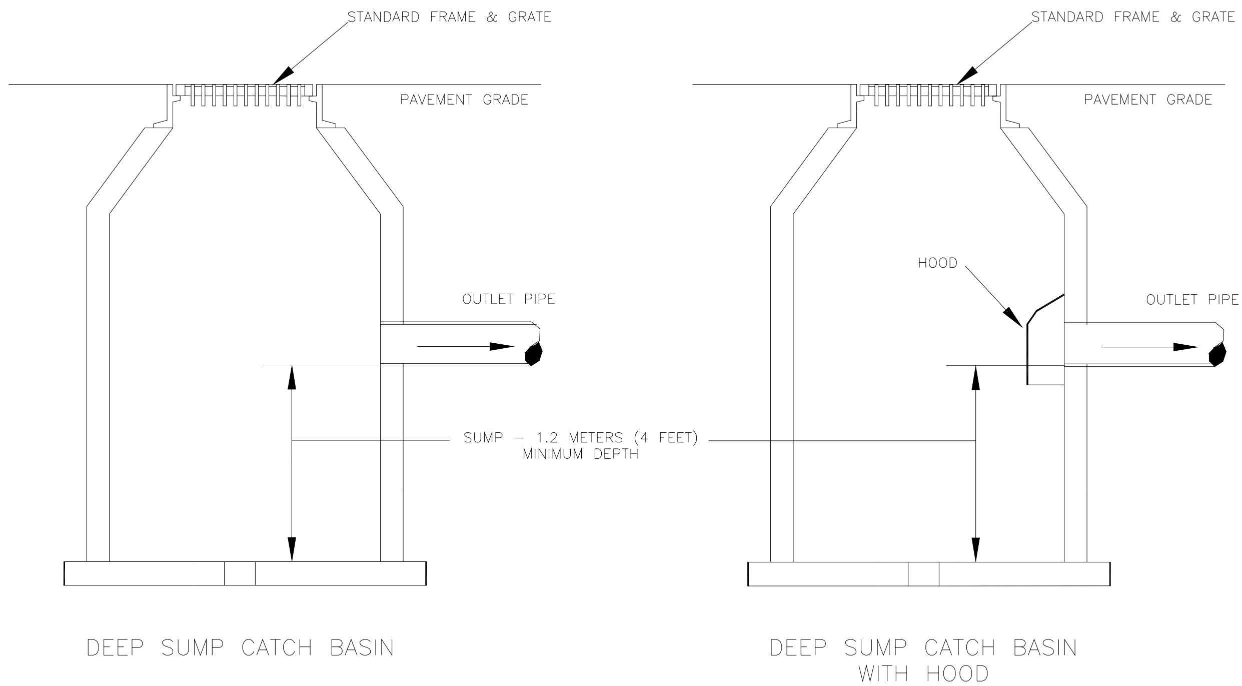
DEEP SUMP CATCH BASIN

GENERAL INFORMATION	
Description: Deep sump catch basins are modified versions of the inlet structures typically installed in a piped storm water conveyance system. Deep sumps provide capacity for sediment accumulation. Deep sump catch basins are most effective if placed "off-line" – that is, if they do not have inlet pipes. Flow-through basins are more susceptible to sediment re-suspension. Deep sump catch basins can serve as pre-treatment for other BMPs. For new or redevelopment projects, MassHighway will evaluate on a case-by-case basis whether catch basins can be used to replace drop inlets. Deep sumps will be incorporated into the drainage system (for both catch basins and drop inlets), employing off-line operation, to the maximum extent practicable. Potential site constraints include hydraulic grade line, bedrock, and high water tables. Hoods may be prone to damage and displacement during cleaning in the highway setting. However, hoods provide benefits in high-litter areas,as well as for spill containment. Hoods must be used for new and redevelopment activities in those areas specified under Design Criteria (see next page).	
Applicable DEP Stormwater Management Policy Performance Standards	• Standard #4 (partial treatment for TSS removal): • Generally, deep sump catch basins are used for pretreatment of runoff prior to discharge to other BMPs; however, in a redevelopment project, deep sump catch basins may be the primary form of treatment feasible. • Standard #3 (recharge): in some cases, Leaching Catch Basins can be used for recharge. See criteria for Leaching Catch Basins/Leaching Basins.
TSS Removal	**DEP Credit:** 25% **Estimated Range from Literature:** Up to 45%, depending on flow conditions (Pitt and Field, 1998)
Relative Cost	Construction: Low to moderate (depends on number of catch basins per acre Maintenance: Moderate
Potential Constraints to Use	• Depth to bedrock • High groundwater • Presence of utilities • Soil conditions that limit depth of excavation because of stability
Other Considerations	• Requires regular maintenance • Appropriate as retrofit in existing piped collection and conveyance systems • Most local/state highway departments own or have access to equipment needed to maintain catch basins
Maintenance Requirements	• Periodic sediment removal (as discussed in Section 4.6) • Inspection of inlets and outlets (noting the presence or absence of hoods, if applicable); periodic removal of debris • Disposal of sediment in accordance with DEP policy[1]
Primary Design Reference	MassHighway *Construction and Traffic Standard Details* (Metric Edition, 1996) Current MassHighway Design Manuals

1 Refer to "Reuse and Disposal of Contaminated Soil at Massachusetts Landfills", Department of Environmental Protection Policy # COMM-97-001.

DEEP SUMP CATCH BASIN

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	Refer to MassHighway Design Manuals
Minimum sump depth	1.2 meters (4 feet) below invert of outlet pipe.
Inlet grate	Design and placement of inlet grates may require consideration of the capacity of grates to pass design flows. Refer to MassHighway Drainage Manual for design of catch basin inlet capacity. Upgrading stand-alone drop inlets with catch basin drop inlets should be considered in order to prevent litter from entering the drainage system. Moreover, although down-gradient manholes are necessary whenever there is a bend in the piping of a drainage system, they do not function as storm water treatment BMPs and therefore have no TSS removal credit.
Hood	For highways owned or constructed by MassHighway, the following requirements apply: 1. Hoods must be used in catch basins provided for new and redevelopment activities in the following areas: a. Along roadways in commercial areas; b. Within rest areas; c. In MassHighway maintenance yards; d. Along highways where no other containment device is provided for a discharge to a critical area. However, for recharge areas of public groundwater supplies, hoods are required only within the boundary of a delineated Zone II or within 0.5 miles of the wellhead, whichever is closer to the wellhead. MassHighway may propose alternative plans that afford equivalent protection based on risk of spills and proximity to sensitive resources, subject to review and approval by the authority reviewing the project for compliance with the DEP Stormwater Management Policy. 2. Hoods within catch basins are not required in other locations along highways owned or constructed by MassHighway.



CATCHBASIN MATERIALS AND FABRICATION VARIES. SEE DRAWINGS IN MASSHIGHWAY "CONSTRUCTION AND TRAFFIC STANDARD DETAILS" (METRIC EDITION 1996).

Examples of Deep Sump Catch Basins

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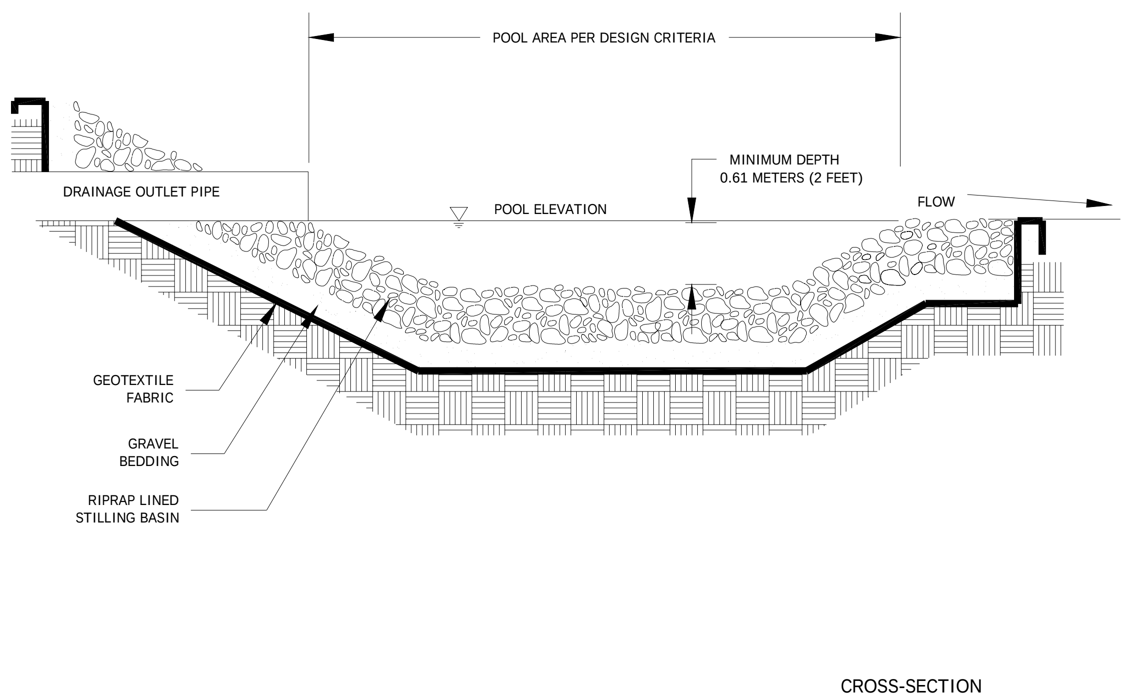
OUTLET SEDIMENT TRAP

GENERAL INFORMATION		
Description: An Outlet Sediment Trap is a small basin lined with riprap or other suitable non-erosive lining, and located at the end of an outlet pipe, paved waterway, or channel outlet. The Outlet Sediment Trap is designed similar to a plunge pool, to dissipate the energy of incoming runoff. It is also sized to detain the runoff for initial settling of coarse particulates. Outlet Sediment Traps may be used for pretreatment of runoff before it discharges to another BMP, or they may be used as a BMP at the outlet of a drain system without further downstream treatment. This device can be employed where insufficient space is available to install another type of BMP, and where the device can be inspected and cleaned on a regular basis.		
Applicable DEP Stormwater Management Policy Performance Standards	Standard #4 (TSS Removal)	
TSS Removal	DEP Credit:	25% for "Sediment Traps/Forebays" meeting a specified sizing rule. However, an alternative sizing method is provided in this fact sheet.
	Estimated Range from Literature:	Data Not Available
	Estimated Range :	35% to 45% (based on modeling with P-8 Urban Catchment Model)
Relative Cost	Construction: Low Maintenance: Low to moderate	
Potential Constraints to Use	• Depth to bedrock	
Other Considerations	• Recommended for use where space requirements preclude the use of other BMPs • Should be designed for stability as an energy dissipation device. • Where feasible, design to minimize short-circuiting between inlet and outlet ends of the trap.	
Maintenance Requirements	• Inspect annually; • Removal of debris from outlet structures as needed; • Remove and dispose of accumulated sediment based on inspection.	
Design References	• Current MassHighway design manuals, applicable sections on design of plunge pools.	

OUTLET SEDIMENT TRAP

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	No minimum or maximum drainage area specified for this device.
Minimum Area (Top of Pool)	100 square feet per acre of contributing impervious area. Minimum area of 50 square feet.
Minimum Depth	24 inches
Interior slopes	2:1 or flatter recommended.
Other	• Trap should also be designed as a plunge pool for dissipating flow velocities at the drainage system outlet (refer to MassHighway Design Manual and Drainage Manual). • Stabilize interior surface of trap with properly designed riprap or other suitable lining for stability under anticipated flow conditions • Exit velocities from the trap shall be non-erosive. • Maintenance access should be provided



Example of Outlet Sediment Trap

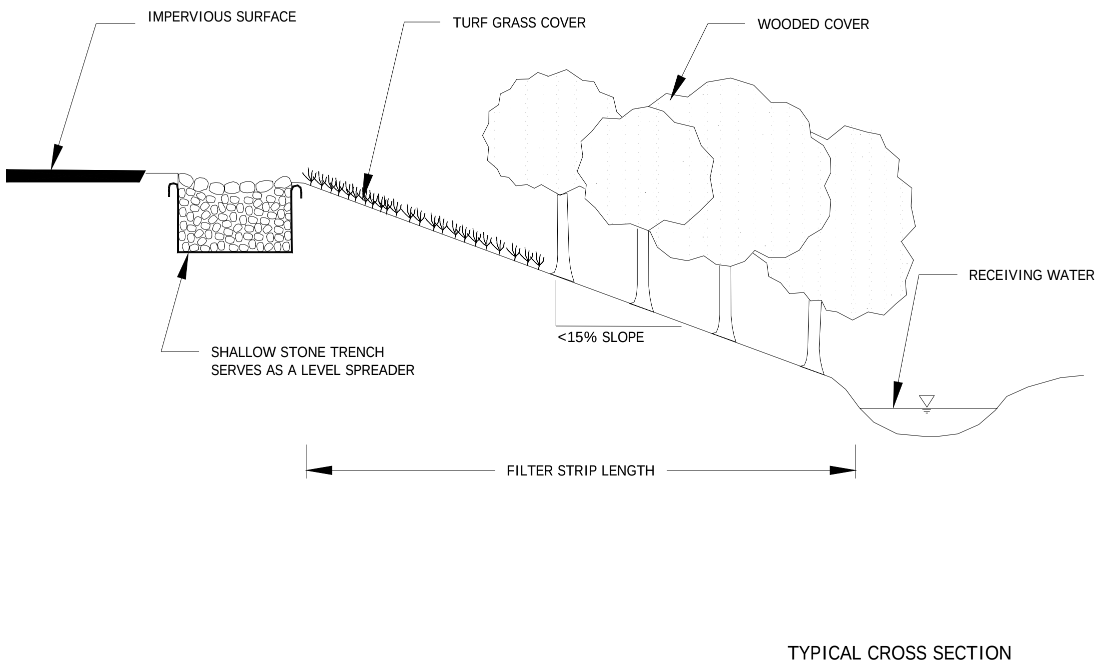
VEGETATED FILTER STRIP

GENERAL INFORMATION	
Description: Filter strips are vegetated areas of land that have gradual slopes and are designed to accept runoff as overland sheet flow. Vegetation slows runoff, allowing for some infiltration and promoting settling of particles. Runoff from an adjacent impervious area must be evenly distributed across the filter strip; a level spreader may be used to accomplish this. Filter strip vegetation may be grass, shrubs, or woods.	
Applicable DEP Stormwater Management Policy Performance Standards	Standard #4. Filter strips may provide some incidental benefits in the control of peak flows and promotion of infiltration.
TSS Removal	DEP Credit: Not specified. Vegetated filter strips are not currently included in the Stormwater Policy BMP listing. Designer will need to document removal efficiencies. Estimated Range from Literature: 40 – 90%
Relative Cost	Construction: Low Maintenance: Low
Potential Constraints to Use	• Cannot be used where slope shape, gradient, or length results in concentrated flow and channelization (flow must be sheet flow)
Other Considerations	• May help to control peak flows and promote infiltration, by reducing velocity of runoff, and providing dispersion of runoff over the land surface as sheet flow. • Effectiveness dependent on shallow diffuse flow • Low maintenance requirements • Can be used as part of runoff conveyance system in combination with other BMPs • Limited feasibility in highly urbanized environment
Maintenance Requirements	• For grassed buffer strips that will be mowed, mowing should maintain a height of at least 101.60-152.40 mm (4-6 inches) of dense grass cover, and should receive the minimum fertilizer application to maintain grass in a healthy condition. • Natural succession by native grass species and shrubs may be allowed to occur if desirable. • May require periodic repair, regrading, and sediment removal, and reseeding to correct erosion and prevent channelization • Periodic manual removal of sediment accumulated near the top of the strip may be required to maintain original grade and prevent formation of a “berm” that would inhibit distribution of runoff as sheet flow.
Primary Design References:	• Young, et. al., 1996.

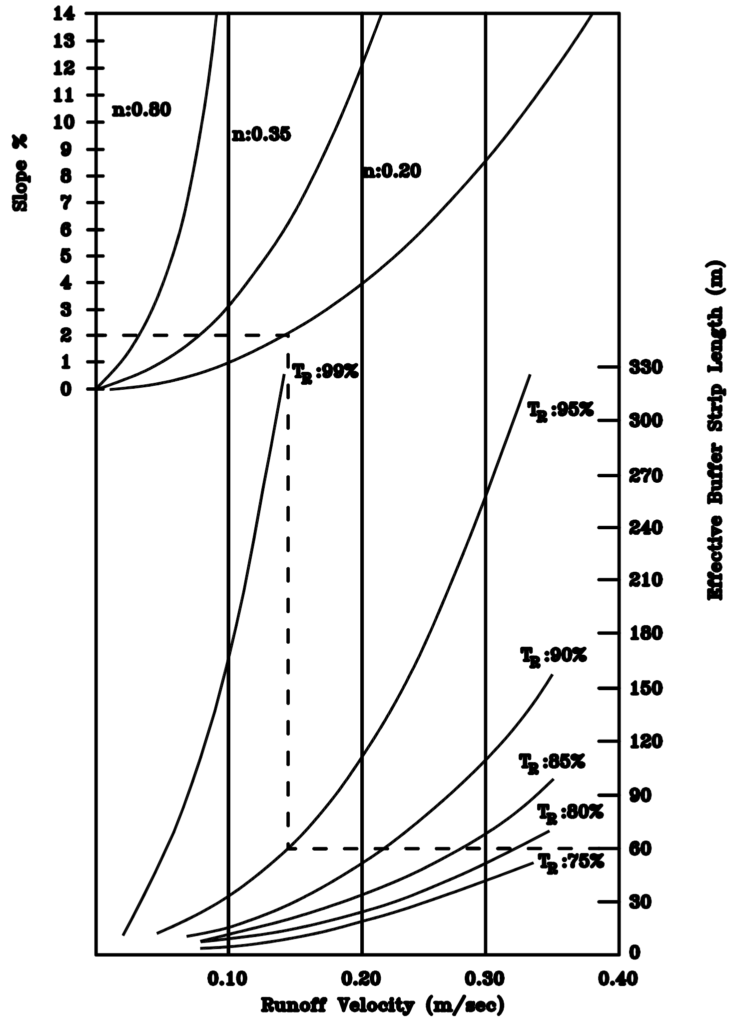
VEGETATED FILTER STRIP

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	No minimum drainage area required. Maximum drainage area will be limited by flow depth and velocity.
Storm frequency for design flow	6-month, 24 hour storm
Average design flow depth	Less than 12.70 mm (0.5 inch) for design flow condition (must be sheet flow)
Maximum normal velocity **Maximum permissible velocity**	Less than 0.30 meters/second (1.0 fps) for design flow[1]. Less than 0.90 meters/second (3.0 fps) for peak discharge during 10-year storm.
Hydraulic Residence Time (Design flow)	Optimal greater than 9 minutes. Minimum = 5 minutes
Maximum slope	15% (6.7:1) maximum less than 5% (20:1) generally preferred
Length of strip required for treatment (In direction of storm water flow)	Determine from one of attached charts, based on TSS removal required. Options: 1. FHWA Methodology, adapted from Wong & McCuen 2. Maine DEP lookup tables
Minimum length of filter strip	6.1 meters (20 feet) (in direction of flow through the filter strip)
Maximum length of filter strip	Filter strips do not have a maximum length for habitat, aesthetic benefits. However, for filter effectiveness for water quality treatment evaluation, only the first 76.2 meters (250 feet) is considered. Lengths greater than 76.2 meters (250 feet) are prone to concentration and rechannelization of flow.
Minimum width of filter strip	0.2 x L where L = the length of the flow path of sheet flow over the upstream impervious surface, OR 2.4 meters (8 feet) (whichever is greater)
Shape of filter strip slope	Slope must be planar or convex in shape, so that flows do not tend to concentrate and channelize.
Distribution of runoff over filter strip	Locate at edge of suitable planar or convex-sloped contributing area; otherwise, provide a level spreader designed to convert flows to sheet flow at top of edge of the filter strip
Stabilization	Seed and mulch disturbed areas according to State Erosion Control guidance manual; preserve existing vegetation where natural growth will be retained. Disturbed areas steeper than 4:1 should be protected during establishment with erosion control blankets
Pretreatment	For buffers with “bare soil” contributing areas, runoff should be treated with a sediment control BMP prior to discharge to buffer strip.

1 Flow velocities computed using Manning’s equation, assuming hydraulic radius equals depth. Manning’s n equals 0.20 for mowed grass slope, 0.24 for infrequently mowed grass slope, higher value based on literature for wooded slope.



Example of Vegetated Filter Strip



Removal Rates (T_R) for buffer strips (Wong and McCuen, 1982).

Multiplicative adjustments in length for various soil types:

Soil Type	***Buffer Strip Length***
Coarse Silt	1.0 x length from nomograph
Fine Silt	4.9 x length from nomograph
Medium Silt	1.3 x length from nomograph
Fine Sand	0.02 x length from nomograph
Medium Sand	0.005 x length from nomograph

Nomograph for Determining Length of Vegetated Filter Strip

From: Young, et. al., 1996

Buffer Removal Efficiencies

(Percent removal of TSS, i.e., 0.40 is 40% removal)

Use the table below for all Soil Types (no soil survey required)

	"WOODED" BUFFER WIDTH [a]					"NON-WOODED" BUFFER WIDTH [a]					"SEEDED" BUFFER WIDTH [a]				
BUFFER SLOPE	**25'**	**50'**	**100'**	**150'**	**250'**	**25'**	**50'**	**100'**	**150'**	**250'**	**25'**	**50'**	**100'**	**150'**	**250'**
0-3%	0.30	0.50	0.65	0.75	0.85	0.10	0.20	0.40	0.60	0.80	0.05	0.10	0.20	0.30	0.40
3-8%	0.20	0.35	0.55	0.65	0.75	0.00	0.15	0.35	0.50	0.65	0.00	0.05	0.15	0.25	0.35
8-15%	0.10	0.25	0.45	0.60	0.70	0.00	0.05	0.25	0.45	0.60	0.00	0.00	0.10	0.20	0.30
15-30%	0.05	0.20	0.30	0.45	0.55	0.00	0.00	0.10	0.20	0.40	0.00	0.00	0.05	0.10	0.20

Use the two tables below when on-site Soil Survey Information is available for the site.

HYDROLOGIC GROUP A & B SOILS

	"WOODED" BUFFER WIDTH [a]					"NON-WOODED" BUFFER WIDTH [a]					"SEEDED" BUFFER WIDTH [a]				
BUFFER SLOPE	**25'**	**50'**	**100'**	**150'**	**250'**	**25'**	**50'**	**100'**	**150'**	**250'**	**25'**	**50'**	**100'**	**150'**	**250'**
0-3%	0.50	0.60	0.80	0.90	0.95	0.10	0.50	0.60	0.70	0.80	0.05	0.25	0.30	0.35	0.40
3-8%	0.30	0.50	0.70	0.85	0.95	0.00	0.30	0.50	0.65	0.80	0.00	0.15	0.25	0.30	0.40
8-15%	0.20	0.40	0.60	0.80	0.90	0.00	0.20	0.45	0.45	0.80	0.00	0.10	0.20	0.20	0.40
15-30%	0.20	0.25	0.40	0.55	0.70	0.00	0.05	0.10	0.20	0.40	0.00	0.00	0.05	0.10	0.20

HYDROLOGIC GROUP C & D SOILS

(HSG D soils with a water table at or near the surface and having a surface connection to a water body may not qualify for a buffer removal efficiency.)

	"WOODED" BUFFER WIDTH [a]					"NON-WOODED" BUFFER WIDTH [a]					"SEEDED" BUFFER WIDTH [a]				
BUFFER SLOPE	**25'**	**50'**	**100'**	**150'**	**250'**	**25'**	**50'**	**100'**	**150'**	**250'**	**25'**	**50'**	**100'**	**150'**	**250'**
0-3%	0.30	0.50	0.65	0.75	0.85	0.10	0.20	0.40	0.60	0.80	0.05	0.10	0.20	0.30	0.40
3-8%	0.20	0.35	0.55	0.65	0.75	0.00	0.15	0.35	0.50	0.65	0.00	0.05	0.15	0.25	0.35
8-15%	0.10	0.25	0.45	0.60	0.70	0.00	0.05	0.25	0.45	0.60	0.00	0.00	0.10	0.20	0.30
15-30%	0.05	0.20	0.30	0.45	0.55	0.00	0.00	0.10	0.20	0.40	0.00	0.00	0.05	0.10	0.20

a. The *width* referred to in these tables should be considered as the length of treatment or flow along the fall-line.

Charts for Determining Filter (Buffer) Strip Lengths
Based on Soils and Vegetation Type

Adapted from Maine DEP, 1995

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DETENTION/RETENTION BASIN SYSTEMS:

The following pages present General Information and Design Criteria fact sheets for a variety of detention and retention basin systems. In common, these BMPs provide for the temporary storage of storm water, to provide for peak rate control, water quality treatment, groundwater recharge, or a combination of two or more of these functions.

Detention systems involve the storage of water and its controlled release to downstream drainage systems or receiving waters. Retention systems involve the storage of water and its release primarily by infiltration.

Generally, the storage of storm water is accomplished in basins excavated into the ground surface or created by construction of impoundments, using berms or dams. The fact sheets which follow are generally based on such "reservoir" type detention/retention facilities. While it is possible to construct enclosed structures at or below the ground surface to store storm water, the storage volumes involved are usually large, making such structures cost-prohibitive. Therefore, these fabricated types of structures are not covered in detail in this guidance document.

Most detention/retention basins that are used for water quality treatment will be preceded by a sediment forebay (the forebay may actually be incorporated within the overall basin, in some cases). Therefore, information on sediment forebays is included in this Section.

Fact sheets are provided for the following BMPs:

- Sediment Forebay
- Detention Basin
- Extended Detention Basin
- Wet Pond
- Enhanced Wet Pond
- Constructed Storm Water Wetlands
- Recharge Basins

Note that while separate fact sheets are provided for each of these types of basins, features of two or more types of basins may be combined into a particular BMP. For instance, a constructed wetland may have a wet pond component, an extended detention component, and a peak rate control (conventional detention) component.

Construction of these BMPs frequently requires the use of an embankment (berm or dam) to impound water during storm events. Design of these embankments requires the application of specific engineering practices to provide for embankment stability, outlet control, overflow contingencies, and other features. Some general design guidelines for impoundment structures are included in this guidance document under the Section entitled: **Design Criteria for Selected Supplemental Structures and Devices.**

Designers of detention and retention systems should also consider the need for fencing or other appropriate measures to restrict unauthorized access to the basins, and to address potential safety concerns.

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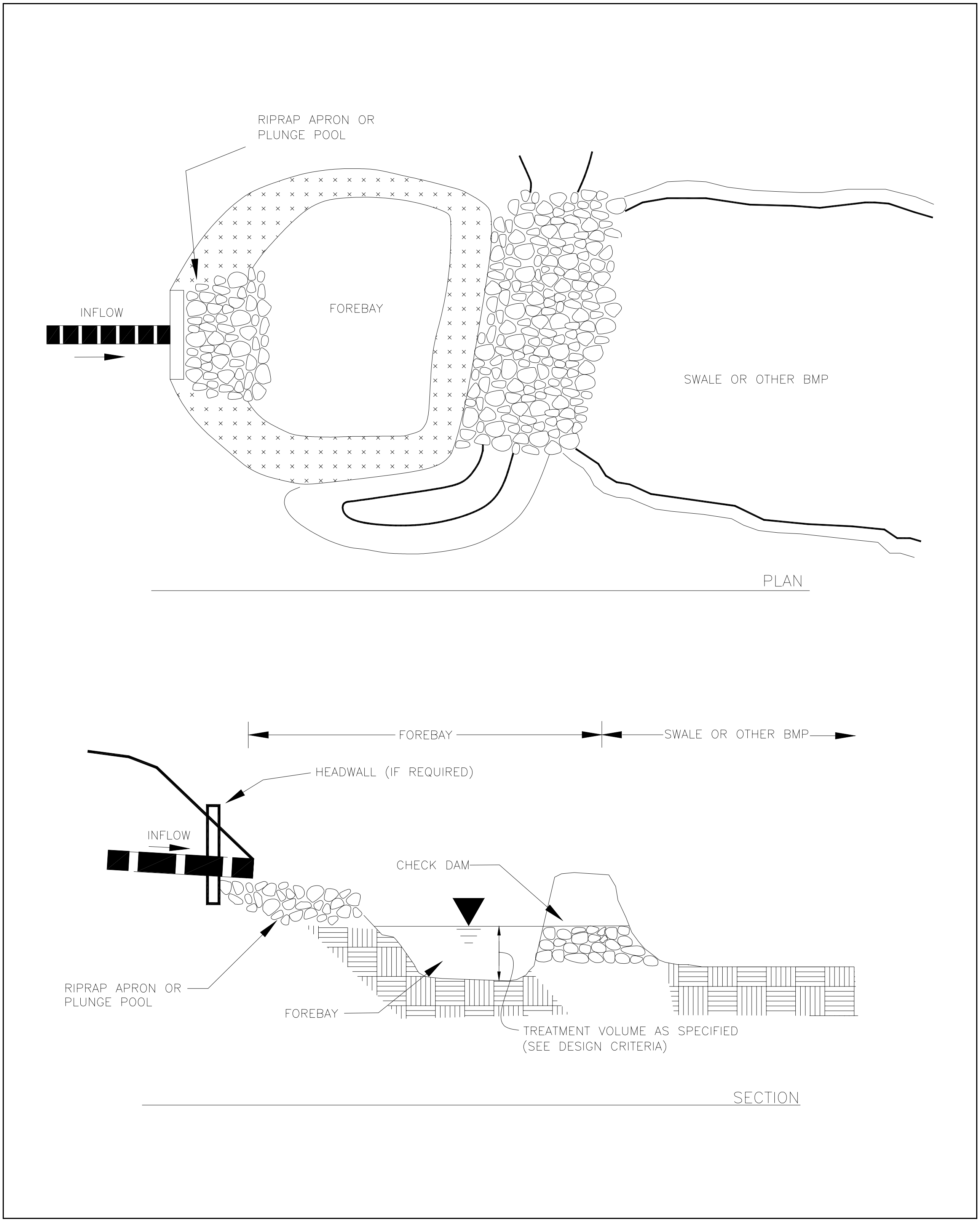
SEDIMENT FOREBAY

GENERAL INFORMATION	
Description: A sediment forebay is an impoundment, basin, or other storage structure designed to dissipate the energy of incoming runoff, and detain the runoff for initial settling of coarse particulates. Forebays are usually used for pretreatment of runoff before it discharges to the primary water quantity and quality control BMP. Forebays are frequently integrated into the design of larger storm water management structures.	
Applicable DEP Stormwater Management Policy Performance Standards	This BMP is intended as an integral component of several other BMPs, and may contribute to compliance with Standards #2, #3, and #4, depending on design.
TSS Removal	DEP Credit: 25% Estimated Range from Literature: Separate data on the performance of forebays is limited.
Relative Cost	(Data not available)
Potential Constraints to Use	• Depth to bedrock
Other Considerations	• Sediment forebays for detention/retention basin type systems are generally incorporated into the basin design, using intermediate berm (see example illustration) • Forebays can also be constructed as underground structures, but these are not encouraged in the highway setting, if a surface basin is feasible, because of cost and maintenance considerations. • Forebays help reduce the sediment load to downstream BMPs. Therefore, forebays will typically require cleaning on a more frequent basis than those BMPs.
Maintenance Requirements	• Inspect at least annually; • Periodic mowing of embankments (generally two times per year) to control growth of woody vegetation on embankments; • Removal of debris from outlet structures at least once annually; • Remove and dispose of accumulated sediment based on inspection. Recommend installation of a staff gage or other measuring device, to indicate depth of sediment accumulation and level at which clean-out is required.
Design References	• Young, et. al., 1996 • DEP Stormwater Management Policy, for TSS removal credit

SEDIMENT FOREBAY

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	No minimum or maximum drainage area specified for this device.
Volume[1]	2.54 mm (0.1 inch) per impervious acre specified by DEP Stormwater Management Policy, for TSS removal credit [Note: FHWA reference suggests sizing forebay to equal 5 to 10% of Water Quality Volume (Young, et. al., 1996)]
Storm frequency for design flow	Design conveyance capacity for compatibility with BMP to which it discharges. Design should consider flow velocity, to minimize re-suspension of trapped sediments.
Interior embankment slopes	3:1 or flatter recommended Steeper slopes may be allowable if special engineering treatment is provided for surface and structural stability.
Other	• Maintenance access should be provided • Embankment design to be engineered to meet applicable safety standards • Stabilize exposed earth slopes and bottom of basin using seed mixes recommended by NRCS. • Exit velocities from the forebay shall be non-erosive.

1 Volume requirements listed in literature do not clearly differentiate between storage volume for accumulated sediment, and operating volume for the forebay. Citations also do not provide good references for the derivation of the required volume. Designer is advised to research the design literature for further guidance on sizing forebays.



Example of Sediment Forebay

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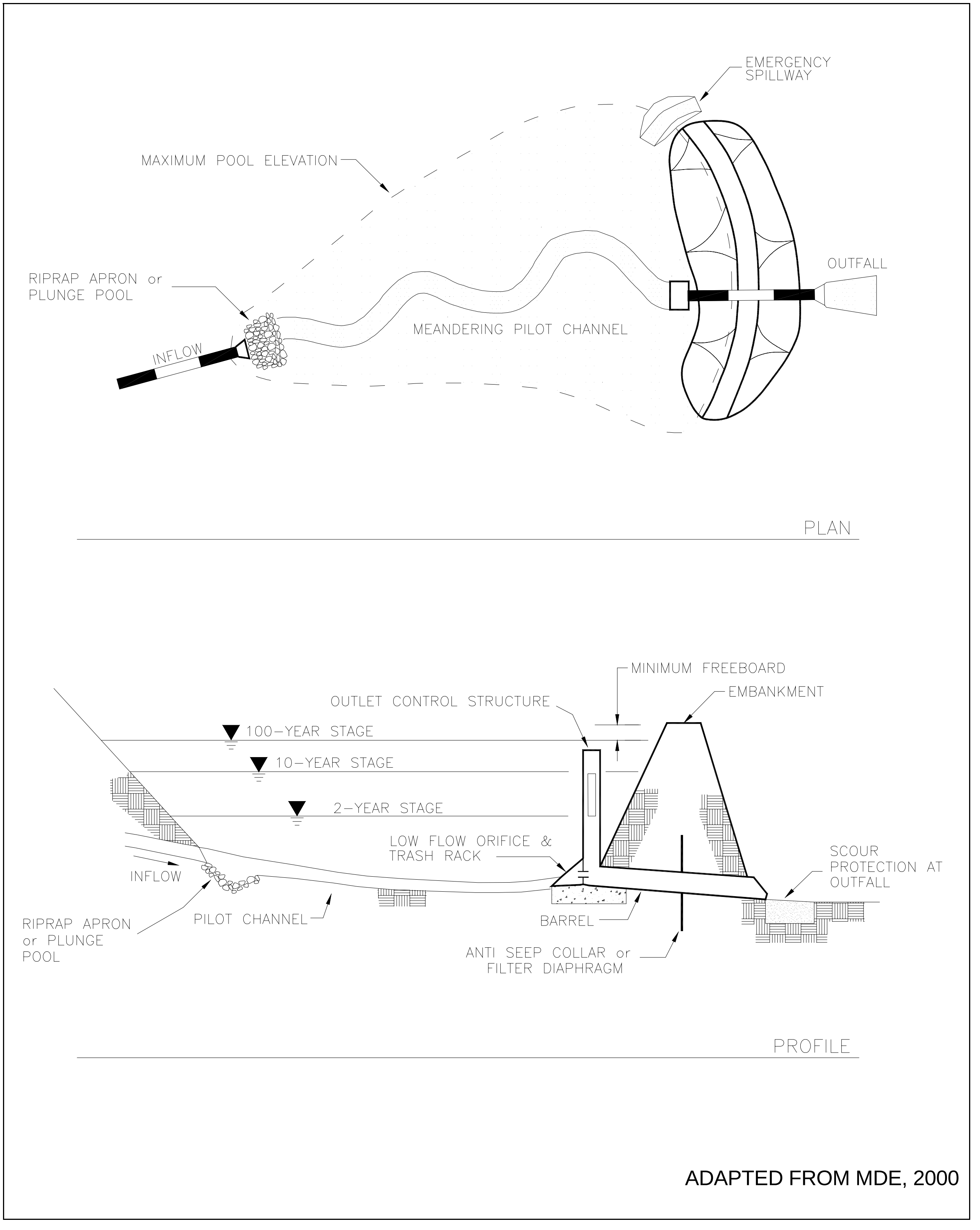
DETENTION BASIN

GENERAL INFORMATION	
Description: Conventional detention basins are storm water storage basins designed to control peak runoff rates under 2 and 10 years storms as well as to safely pass the 100 year storm. They are not specifically designed to provide extended dewatering times, wet pools, or measures for infiltration, and thus provide only incidental water quality treatment. Generally, outlet structures are provided to hydraulically control discharge rates. Sometimes, flow control can be accomplished by simply using an outlet pipe of the appropriate size, but this approach typically cannot be used to control multiple design storm events.	
Applicable DEP Stormwater Management Policy Performance Standards	Standard #2 (Conventional detention basins that do not provide extended dewatering times, wet pools, or measures for infiltration, are not anticipated to meet Stormwater Policy criteria for recharge or water quality treatment)
TSS Removal	DEP Credit: No credit for conventional detention basin. Estimated Range from Literature: Minimal; intended primarily for peak rate control.
Relative Cost	Construction: Low to moderate Maintenance: Low to moderate
Potential Constraints to Use	• Depth to groundwater (although groundwater levels may be controlled by design of outlet and design of embankment treatment) • Depth to bedrock (excavation cost)
Other Considerations	• May be combined with created wetlands, wet ponds, extended detention or infiltration features to provide for water quality treatment
Maintenance Requirements	• Periodic mowing of embankments • Removal of woody vegetation from embankments • Removal of debris from outlet structures
Primary Design Reference	Current MassHighway Design Manuals

DETENTION BASIN

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	No specific upper or lower limits on drainage area
Storage Volume Requirements	Storage volume as required to achieve control of peak rates, to meet Stormwater Policy Standard #2. May also require flood storage volume to prevent increase in off-site flooding for 100-year storm.
Storm frequencies for design flow	2-year and 10-year, 24-hour design storms for peak rate control. Capacity to safely pass 100-year frequency storm. No increase in elevation of downstream flood plain for 100-year frequency storm.
Minimum drawdown time for flood pool	No minimum time specified. Time will be as required to control peak discharges to comply with Standard #2.
Primary spillway	Multiple stage outlet structure or structures designed to achieve peak discharge control for selected design storms.
Emergency spillway[1]	Required for any basin with embankment (dam); spillway should be constructed in existing ground (not in embankment section).
Length to width ratio	No specific requirement.
Interior embankment slopes	3:1 or flatter recommended Steeper slopes may be allowable if special engineering treatment is provided for surface and structural stability.
Bottom slope	Grade interior of basin for positive drainage between storm events: • Minimum bottom slope for drainage: 2% • Consider use of pilot channel to facilitate drainage.
Other	• Maintenance access should be provided. This includes provisions for access to interior of basin for maintenance. • Embankment design to be engineered to meet applicable safety standards • Stabilize exposed earth slopes and bottom of basin using seed mixes recommended by NRCS.

1 Emergency spillway design: Where applicable safety standards do not specify design criteria for spillway, this guidance document recommends that the design provide capacity for conveyance of the 100-year flood routed through the basin (starting with basin at lower pool elevation) with the primary spillway non-functioning. Provide minimum 1-foot of freeboard to embankment crest with emergency spillway flowing at design capacity.



Example of Detention Basin

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EXTENDED DETENTION BASIN

GENERAL INFORMATION	
Description: An extended detention basin provides a storage volume above the invert of the lowest outlet, to temporarily detain a portion of storm water runoff for an extended time period (up to 24 hours after a storm). By draining this volume over a period of about 24 hours, the basin provides pollutant removal by allowing time for settling of particulate fractions. Extended detention can be combined with conventional detention for control of peak rates, as well as the extended draw-down of the water quality volume. An extended detention component can be incorporated into the design of a wet pond or created storm water wetlands, to provide enhancement of the treatment function of those BMPs. Dry extended detention ponds have a greater risk of sediment re-suspension than do extended detention wet ponds, or extended detention wetlands, and generally do not provide as effective soluble pollutant removal. Extended detention may be designed as an on-line or off-line system	
Applicable DEP Stormwater Management Policy Performance Standards	Standards #2, #4 In some cases, dry extended detention basins can incorporate recharge functions to meet Standard #3.
TSS Removal	DEP Credit: 70% Estimated Range from Literature: 60 - 80%
Relative Cost	Construction: Moderate Maintenance: Moderate
Potential Constraints to Use	• Depth to groundwater (although groundwater levels may be controlled by design of outlet and design of embankment treatment) • Depth to bedrock (excavation cost)
Other Considerations	• Can also be designed to control peak rates • Design for extended draw-down and for control of high frequency storms can help reduce bank/channel erosion • May increase water temperature, which may be of concern for watersheds with cold-water fisheries • Sediment and debris may accumulate quickly
Maintenance Requirements	• Periodic mowing of embankments • Removal of woody vegetation from embankments • Removal of debris from outlet structures • Removal of accumulated sediment
Primary Design Reference	Schueler, 1987 Young, et. al., 1996

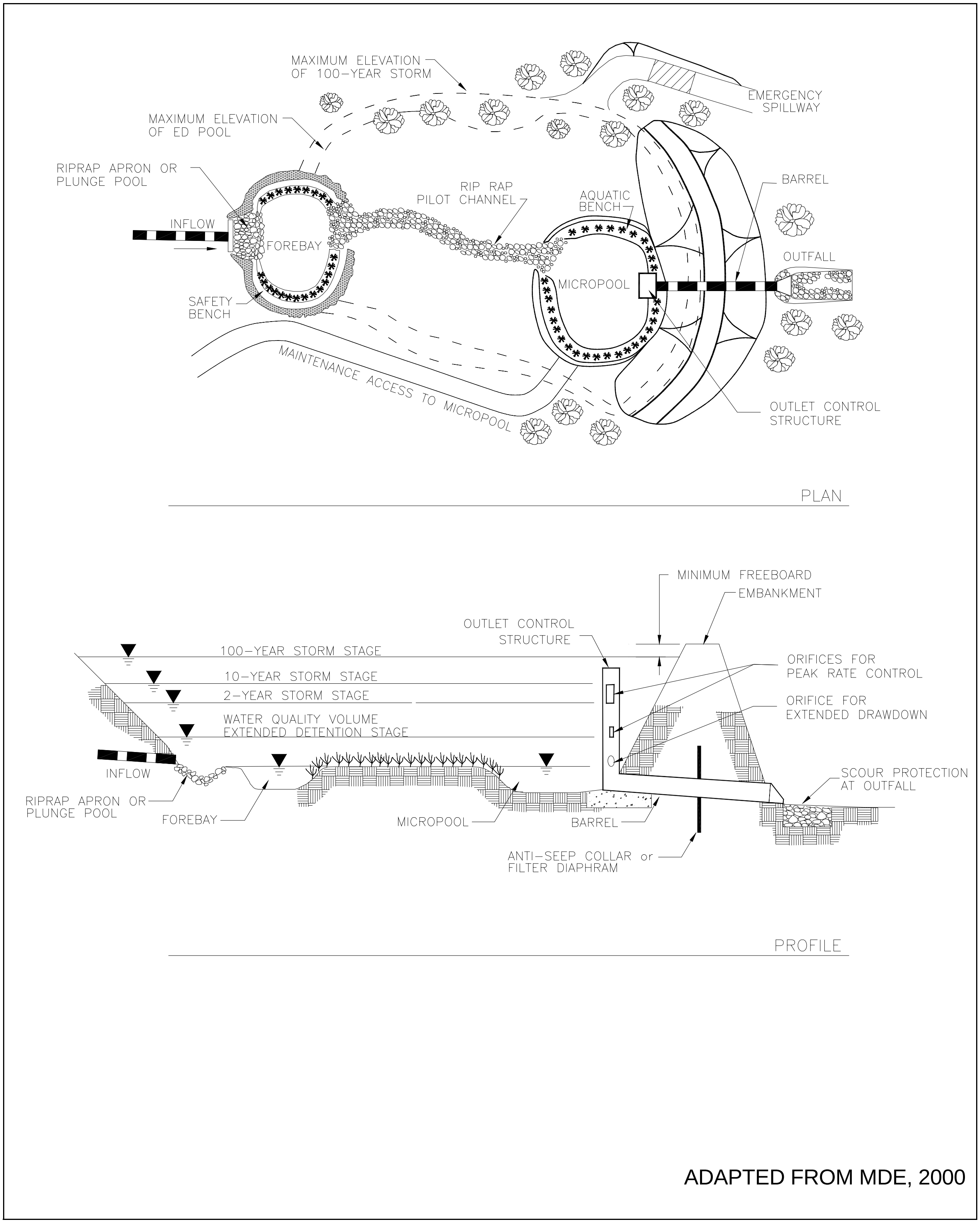
EXTENDED DETENTION BASIN

DESIGN CRITERIA

Design Parameter	Criteria
Contributing Drainage Area	Greater than 4.1 ha (10 acres) suggested Lesser area may be feasible if lower stage outlet control can be designed to prevent clogging
Storage Volume Requirements	Multi-stage design: • Lowest stage = extended detention = water quality storage volume • Upper stages = flood control volume for peak rate control
Extended Detention Volume (lower stage)	Equals prescribed water quality volume per Standard #4 (12.70 mm (0.5 inch) or 25.40 mm (1.0 inch) sizing rule, as applicable)
Flood Control Pool Volume (upper stages)	Equals volume required to control peak discharge rates per Standard #2, determined from hydrologic/hydraulic modeling.[1]
Minimum draw-down time for extended detention (lower stage)	24 hours (minimum) to draw down (completely dewater) the lower stage of the basin (equal to prescribed water quality volume). A more conservative design is to provide for draw down of approximately half of the volume in the first 24 hours, with the remaining volume dewatered within an additional 24 to 48 hours.
Minimum dewatering time for flood pool (upper stage)	As required to meet peak discharge control requirements
Primary spillway	Multiple stage outlet structure or structures designed to achieve peak discharge control for upper stages, and required dewatering time for lower stage.
Emergency spillway[2]	Required for any basin with embankment (dam); constructed in existing ground (not in embankment section).
Length to width ratio	2:1 minimum; greater ratio preferred where feasible: consider internal berms, baffles, or other measures to increase effective length and minimize short-circuiting of flows.
Interior embankment slopes	3:1 or flatter recommended Steeper slopes may be allowable if special engineering treatment is provided for surface and structural stability.
Pretreatment	Strongly recommended: sediment forebay or other pretreatment BMP suggested.
Micro-pool	• Provide micro-pool adjacent to outlet, to help prevent resuspension and flushing of sediment from the basin: • Approximate volume: 10% of treatment volume • Approximate area: 5% of surface area of water quality pool
Other	• Provide maintenance access, including access to basin interior • Stabilize slopes as indicated for other impoundment-type BMPs • Design embankment to meet applicable safety standards • Provide method to drain lowest stage in the event of outlet clogging

1 Detention/retention basins with highly restricted discharge rates should <u>not</u> be designed using TR-55 manual calculation procedure or various computer adaptations of that procedure. The model truncates the rising limb of the input hydrograph, ignoring a significant volume of runoff from the earlier hours of the 24-hour design storm. This volume can occupy a significant portion of basin volume when the outlet structure is designed for a highly constricted release rate for lower stages. The designer should also use a hydrodynamic method of pond routing; the graphic method of pond sizing provided in TR-55 is useful for rough sizing estimates during the conceptual design process, but a routing model such as TR-20 should be used for final design.

2 See Detention Basin Design Criteria, Footnote 1.



Example of Extended Detention Basin

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WET POND

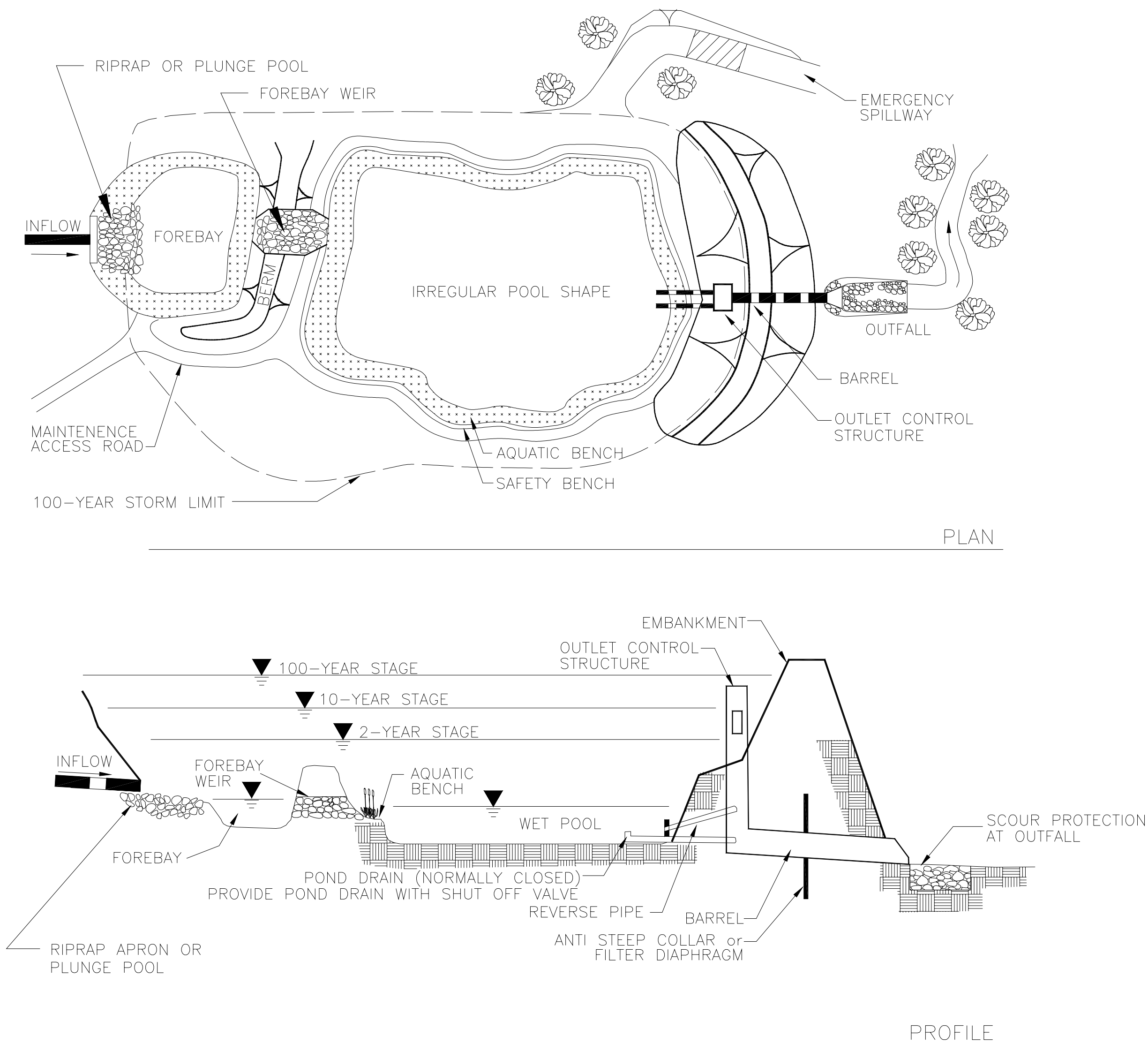
GENERAL INFORMATION	
Description: A wet pond has a permanent pool of water located below the outlet invert. Pollutant removal is accomplished through settling as well as biological uptake or decomposition. Wet ponds may be enhanced with wetland features or combined with extended detention (see criteria for Enhanced Wet Pond). Wet ponds are suitable for on-line or off-line treatment.	
Applicable DEP Stormwater Management Policy Performance Standard	Standard #4 Wet ponds can also meet Standard #2, when provided with conventional detention features for upper stages.
TSS Removal	DEP Credit: 70% Estimated Range from Literature: 60 - 90%
Relative Cost	Construction: Moderate to high Maintenance: Moderate
Potential Constraints to Use	• Depth to bedrock • Soils (permeability) • Downstream cold-water fisheries
Other Considerations	• Lining may be required, depending on soil type and natural groundwater elevation, to maintain standing water • Safety/liability issues must be considered relative to establishing permanent pool • May be designed with conventional detention basin features, to control peak rates • May contribute to thermal impacts
Maintenance Requirements	• Mowing of embankments • Periodic inspection and removal of debris/trash from outlet structures • Periodic sediment removal (typically on the order of 15 – 25+ years)
Primary Design Reference	Schueler, 1987 Young, et. al., 1996

WET POND

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	Greater than 4.1 ha (10 acres) suggested; Lesser area may be feasible if surface and groundwater hydrology will sustain the permanent pool, or if perimeter and bottom vegetation can be provided to address aesthetic issues associated with extended periods of draw-down during dry seasons.
Storage Volume Requirements	Multi-stage design: • Lowest stage = permanent wet pool volume • Upper stages = flood control volume for peak rate control
Permanent Wet Pool Volume	Equals the prescribed water quality volume per Standard 4 (12.70 mm (0.5 inch) or 25.40 mm (1.0 inch) sizing rule, as applicable). This assumes no "extended detention" feature is provided (see Enhanced Wet Pond)
Flood Control Volume (upper stages)	Equals volume required to control peak discharge rates per Standard 2, determined from hydrologic/hydraulic modeling.[1]
Minimum dewatering time for flood pool (upper stage)	As required to meet peak discharge control requirements
Depth of Permanent Pool	Minimum depth: 0.9 meters (3 feet) Average depth: 0.9 to 1.8 meters (3 to 6 feet) recommended Maximum depth: 2.4 meters (8 feet)
Primary spillway	Multiple stage outlet structure or structures designed to achieve peak discharge control for upper stage, with invert set to control maximum permanent pool elevation
Emergency spillway[2]	Required for any basin with embankment (dam); constructed in existing ground (not in embankment section); see Note (b).
Length to width ratio	3:1 minimum for permanent pool; greater ratio preferred where feasible: consider internal berms, baffles, or other measures to increase effective length and minimize short-circuiting of flows.
Interior embankment slopes	3:1 or flatter recommended Steeper slopes may be allowable if special engineering treatment for stability is provided
Pretreatment	Strongly recommended: sediment forebay or other pretreatment BMP suggested.
Other	• Provide maintenance access, including access to basin interior • Stabilize slopes as indicated for other impoundment-type BMPs • Design embankment to meet applicable safety standards • Consider providing a method to dewater permanent pool for maintenance • Maintain required setbacks from septic system components, property lines and wells • Recommend 10:1 or flatter "safety bench" at or just below permanent pool level around perimeter of pool.

1 See Extended Detention Basin Design Criteria, Footnote 1.

2 See Detention Basin Design Criteria, Footnote 1.



ADAPTED FROM MDE, 2000

Example of Wet Pond

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ENHANCED WET POND

GENERAL INFORMATION	
Description: An Enhanced Wet Pond has a permanent pool of water located below the outlet invert. An enhanced wet pond also has one or more features in addition to the permanent pool to provide for water quality treatment, either through physical removal processes (settling, filtration, infiltration) or through biological processes (vegetative filtering and nutrient uptake). Not all potential enhancement features will be employed for a given pond. The following information and design criteria lists some potential enhancement measures that may be considered for improving the performance of a wet pond system. It also has either an additional volume above this elevation that is designed as "extended detention", or wetland features to enhance pollutant removal. Enhanced Wet Ponds are suitable for on-line or off-line treatment.	
Applicable DEP Stormwater Management Policy Performance Standard	Standard #4 Enhanced Wet Ponds can also meet Standard #2, when provided with conventional detention features for upper stages.
TSS Removal	DEP Credit: 70% The DEP Stormwater Management Policy guidelines do not distinguish between enhanced wet ponds, simple wet ponds, or simple extended detention. If the designer wishes to obtain TSS removal credit for greater than 70%, then the design submittal must document the greater removal efficiency using modeling or other evidence of BMP performance. Estimated Range from Literature: 60 - 90%
Relative Cost	Construction: Moderate to high Maintenance: Moderate
Potential Constraints to Use	• Depth to bedrock • Soils (permeability) • Downstream cold-water fisheries
Other Considerations	• Lining may be required, depending on soil type and natural groundwater elevation, to maintain standing water • Safety/liability issues must be considered relative to establishing permanent pool • May be designed with conventional detention basin features, to control peak rates • May contribute to thermal impacts
Maintenance Requirements	• Mowing of embankments • Periodic inspection and removal of debris/trash from outlet structures • Periodic sediment removal (typically on the order of 15 – 25+ years)
Primary Design Reference	Schueler, 1987 Young, et. al., 1996

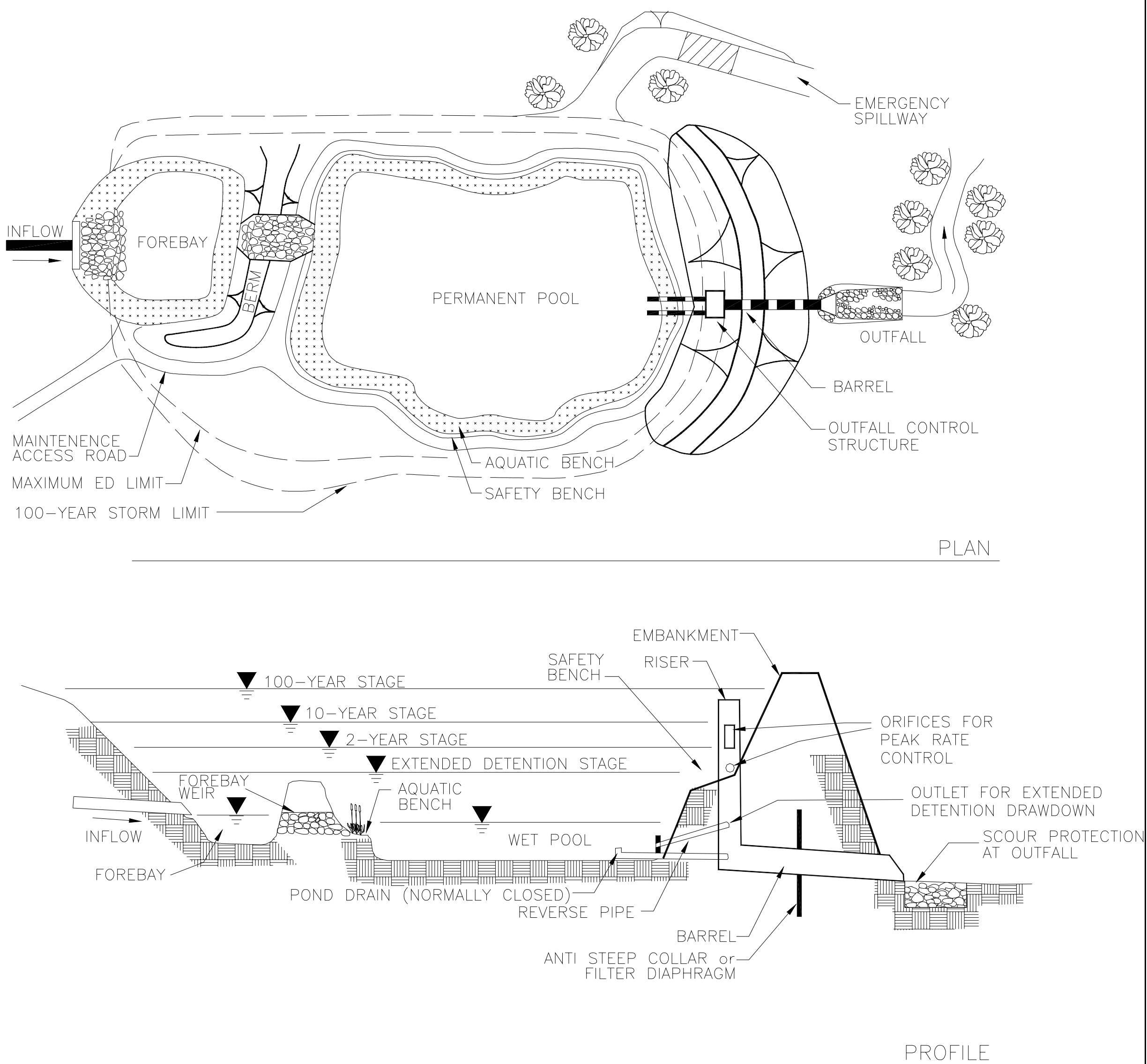
ENHANCED WET POND

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	Greater than 4.1 ha (10 acres) suggested Lesser area may be feasible if surface and groundwater hydrology will sustain the permanent pool
Storage Volume Requirements	Multi-stage design: • Permanent wet pool volume • lower stage of flood volume = an extended detention volume • upper stages = additional flood control volume for peak rate control
Permanent Wet Pool Volume	If no extended detention feature is provided, the permanent pool volume should equal the prescribed water quality volume per Standard #4 (12.70 mm (0.5 inch) or 25.40 mm (1.0 inch) sizing rule, as applicable) If extended detention feature is provided, then the combined volume of the permanent pool and extended detention volume should equal the prescribed water quality volume.
Enhanced Detention Pool Volume (Flood pool lower stage)	See Criterion for permanent wet pool volume.
Flood Control Volume (Upper stages)	Equals additional volume required to control peak discharge rates per Standard #2, determined from hydrologic/hydraulic modeling.[1]
Minimum dewatering time for enhanced detention pool volume	Objective is to achieve 12 to 24-hour drawdown time, or even greater, depending on design. Modeling of treatment performance will be required to document the additional TSS removal rate achieved.
Minimum dewatering time for flood pool (upper stage)	As required to meet peak discharge control requirements
Depth of Permanent Pool	Minimum depth: 0.9 meters (3 feet) Average depth: 0.9 to 1.8 meters (3 to 6 feet) recommended Maximum depth: 2.4 meters (8 feet)
Primary spillway	Multiple stage outlet structure or structures designed to control: • permanent pool elevation at required elevation • draw-down of enhanced detention pool volume at required dewatering rate (12-24 hours) • peak discharges to comply with Standard #2
Emergency spillway[2]	Required for any basin with embankment (dam); constructed in existing ground (not in embankment section).
Length to width ratio	3:1 minimum for permanent pool Further enhancement provided by greater ratio: consider internal berms, baffles, or other measures to increase effective length and minimize short-circuiting of flows.
Interior embankment slopes	3:1 or flatter recommended Steeper slopes may be allowable if special engineering treatment for stability is provided

1 See Extended Detention Basin Design Criteria, Footnote 1.

2 See Detention Basin Design Criteria, Footnote 1.

DESIGN CRITERIA	
Design Parameter	**Criteria**
Other potential physical enhancements that may be considered.	• Provision of a series of treatment cells, divided by submerged berms, with wetland plantings and open water pools to provide an internal "treatment train" within the pond • Provision of filter berms between cells, using fine-grained sands or other filter media to achieve pollutant removal from base flow through the pond • In suitable soils, providing for side-wall infiltration above the level of the permanent pool
Potential wetland enhancements	• Aquatic bench around perimeter of pond, minimum width 3.0 meters (10 ft), depth 152.40 mm to 457.20 mm (6 inches to 18 inches) • Intermediate submerged "berms" or islands with deep and shallow marsh plantings to provide vegetative uptake and to lengthen flow path through wet pool
Other	• Provide maintenance access, including access to basin interior • Stabilize slopes as indicated for other impoundment-type BMPs • Design embankment to meet applicable safety standards • Consider providing a method to dewater permanent pool for maintenance • Maintain required setbacks from septic system components, property lines and wells • Recommend 10:1 or flatter "safety bench" at or just below permanent pool level around perimeter of pool.



ADAPTED FROM MDE, 2000

Example of Enhanced Wet Pond

CONSTRUCTED STORM WATER WETLANDS

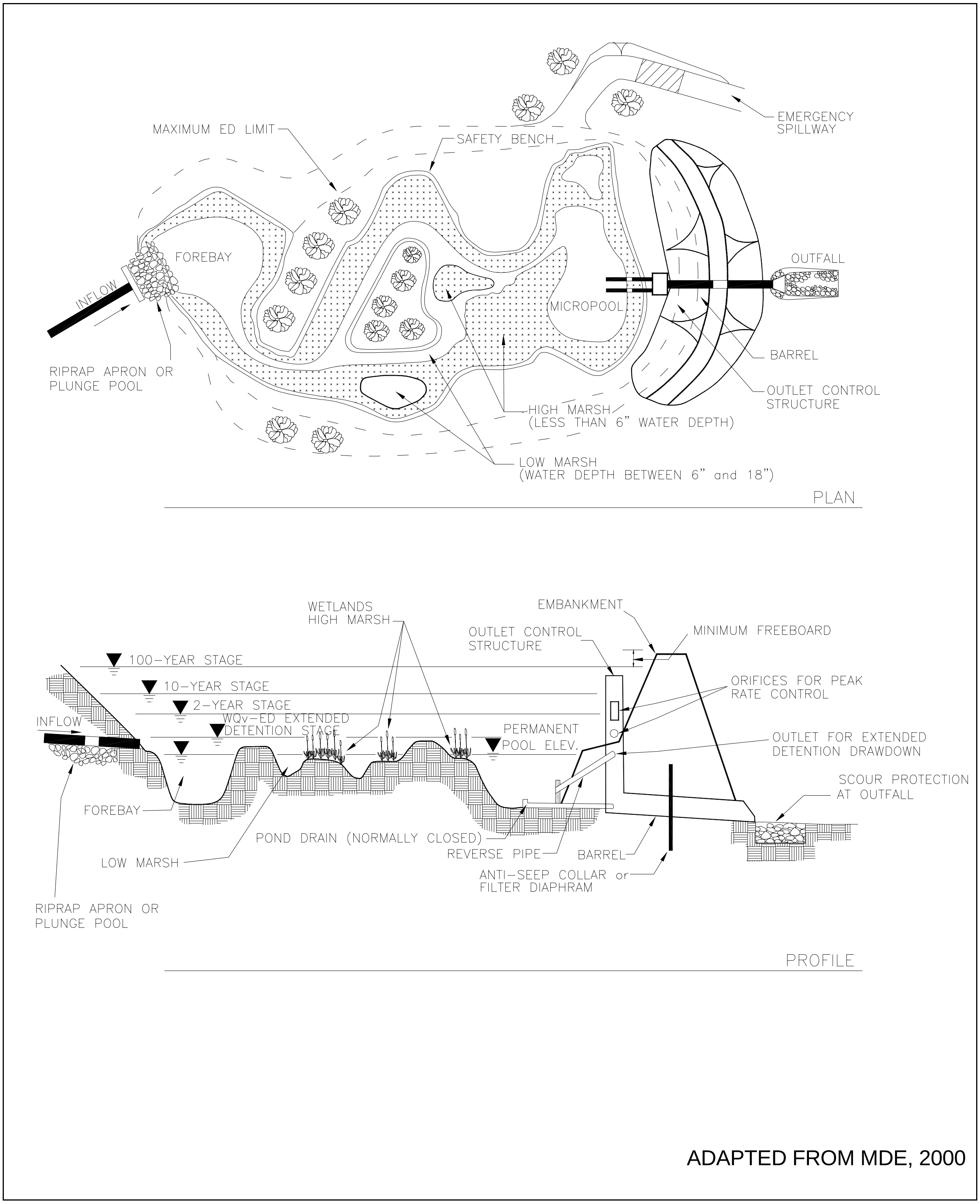
GENERAL INFORMATION	
Description: Constructed storm water wetlands are shallow pools that create conditions suitable for the growth of wetland plants. These systems maximize pollutant removal through vegetative uptake, soil binding, bacterial decomposition, and enhanced settling of particulates. Created wetlands may be combined with wet ponds and/or extended detention, to enhance their performance. Created wetlands are suitable for on-line or off-line treatment (assuming adequate hydrology can be maintained with off-line systems). Regulatory permits do not allow Constructed Storm Water Wetlands to also serve as "Replication Wetlands".	
Applicable DEP Stormwater Management Policy Performance Standards	Standards #2, #4
TSS Removal	DEP Credit: 80% Estimated Range from Literature: 65 - 90%
Relative Cost	Construction: Moderate to High Maintenance: Moderate
Potential Constraints to Use	• Depth to bedrock • Depth to ground water • Sufficient contributing area and or groundwater elevation to maintain hydrology
Other Considerations	• Should include pre-treatment forebay to prevent excessive sedimentation • Large area requirements • May serve as source of bacteria with heavy waterfowl use • May contribute to thermal impacts • Can provide moderate to high phosphorous removals (40-90%) • May develop mono-culture of invasive plant species over time
Maintenance Requirements	• Mowing of embankments • Removal of sediment from pre-treatment structures or forebay areas • Re-planting as necessary to maintain complete vegetation cover • Periodic inspection and removal of debris/trash from outlet structures
Primary Design References	Young, et. al., 1996 Schueler, 1987 Schueler, et. al., 1992

CONSTRUCTED STORM WATER WETLANDS

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	Greater than 4.0 hectares (10 acres) suggested; Lesser area may be feasible if surface and groundwater hydrology will sustain the permanent pool
Storage Volume Requirements	Multi-stage design: • Permanent wet pool volume • If extended detention feature is provided, then lower stage of flood volume = an extended detention volume • upper stages = additional flood control volume for peak rate control
Permanent Wet Pool Volume	If no extended detention feature is provided, the permanent pool volume should equal the prescribed water quality volume per Standard #4 (12.7 mm (0.5 inches) or 25.4 mm (1.0 inch) sizing rule, as applicable) If extended detention feature is provided, then the combined volume of the permanent pool and extended detention volume should equal the prescribed water quality volume.
Flood Control Volume (upper stages)	Equals volume required to control peak discharge rates per Standard #2, determined from hydrologic/hydraulic modeling.[1]
Minimum dewatering time for flood pool (upper stage)	As required to meet peak discharge control requirements
Primary spillway	Multiple stage outlet structure or structures designed to achieve peak discharge control for upper stages, with invert set to control maximum permanent pool elevation
Emergency spillway[2]	Required for any basin with embankment (dam); constructed in existing ground (not in embankment section)
Length to width ratio	3:1 minimum for permanent pool; greater ratio preferred where feasible: consider internal berms, baffles, or other measures to increase effective length and minimize short-circuiting of flows.
Interior embankment slopes	3:1 or flatter recommended Steeper slopes may be allowable if special engineering treatment for stability is provided
Other	• Provide maintenance access, including access to basin interior • Stabilize slopes as indicated for other impoundment-type BMPs • Design embankment to meet applicable safety standards • Maintain required setbacks from septic system components, property lines and wells • If wet pond feature is included, provision of 10:1 or flatter “safety bench” is recommended, at or just below permanent pool level around perimeter of pool. • Method of dewatering lower pool for maintenance may be a desirable feature. However, care must be exercised during operation of this feature, as an extended drawdown of this pool could adversely affect wetland plantings.

1 See Extended Detention Basin Design Criteria, Footnote 1.

2 See Detention Basin Design Criteria, Footnote 1.



Example of Constructed Storm Water Wetlands

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RECHARGE BASIN

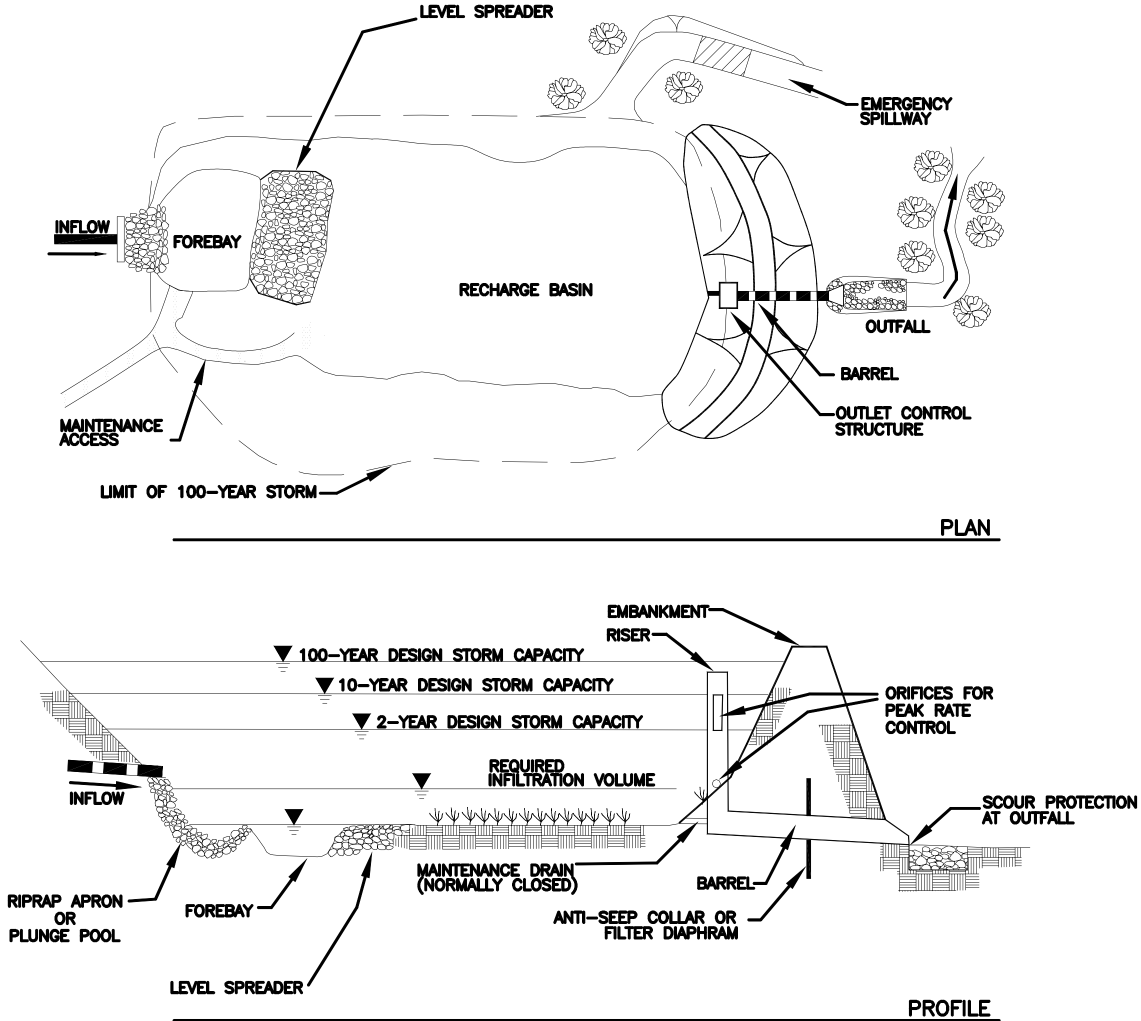
GENERAL INFORMATION	
Description: Recharge basins temporarily store runoff, but release at least a portion of that runoff by infiltrating the water into the ground. The recharge volume is stored below the lowest outlet of the basin, and allowed to infiltrate into the underlying soils over a period of time following a storm event. The storage volume above this level may be released by an outlet structure designed to bypass all excess flows, or to control the release rates of discharge as for a conventional detention basin or extended detention basin. Recharge Basins may be designed on-line or off-line.	
Applicable DEP Stormwater Management Policy Performance Standards	Standards #3 and #4. If sufficient additional storage and appropriate outlet structures are provided, recharge basins may also be used to meet Standard #2.
TSS Removal	DEP Credit: 80% Estimated Range from Literature: >90%
Relative Cost	Construction: Moderate to high; varies depending on types soils of contributing drainage area, soils at site of system, storage depth, and type of outlet structure Maintenance: Moderate to high
Potential Constraints to Use	• Depth to groundwater • Depth to bedrock or other impermeable stratum • Suitability of site soils for infiltration
Other Considerations	• May be combined with detention or extended detention • Pre-treatment must be provided, to prevent clogging of soils surface by sediments in the influent storm water. • Frequent maintenance may be required, to remove accumulated sediment and restore infiltrative capacity. • Recharge systems can provide high levels of treatment of other pollutants, in addition to TSS removal.
Maintenance Requirements	• Inspect a minimum of twice annually. • Periodic mowing of embankments • Removal of woody vegetation from embankments • Removal of debris from outlet structures • Clean forebay as required. • Clean basin of accumulated sediment as required. • Clean flow control structures at least once annually, or as indicated by inspection. • Maintain vegetation in healthy condition.
Primary Design References	MA DEP Technical Bulletin, (pending) Schueler, 1987 Schueler, et. al., 1992 Young, et. al., 1996

RECHARGE BASIN

DESIGN CRITERIA	
Design Parameter	**Criteria**[1]
Contributing Drainage Area	No specific upper or lower limits on drainage area
Storm frequency for design flow	Varies with system. Recharge systems are sized for recharging an annual volume, not an event storm.
Annual Recharge Volume	Compute annual recharge volume using methodology specified in DEP Technical Bulletin (see Primary Design References), or use an alternative method conforming to accepted engineering practice.
Required Storage Volume	Compute storage volume using methodology specified in DEP Technical Bulletin.
Design Recharge Rate	Determine recharge rate based on soil texture/hydrologic group as specified in Technical Bulletin, confirmed by on-site field testing; or use an alternative method conforming to accepted engineering practice.
Design Safety Factor	Surface systems shall be sized with a safety factor of 1.0 times the design recharge rate.
Maximum Draw-down Time	The basin should be designed to drain the design storage volume in 48 hours or less, using the design recharge rate times the applicable safety factor.
Maximum Depth of System	Depth of system shall be equal to or less than the depth permitting draw-down in the required time.
Depth to Bedrock or Impermeable Stratum	Minimum 0.6 meters (2 feet) below bottom of system, unless engineering analysis demonstrates that lesser separation is feasible.
Depth to seasonal high groundwater	Small systems: Minimum 0.6 meters (2 feet) below bottom of system. Large systems: Groundwater mounding analysis may be required.
Pretreatment	Pre-treatment system required; provide 25% TSS removal prior to discharge to a surface recharge system. Use forebay or equivalent measure.
Velocity Dissipation at Inlet	Provide measures to dissipate velocity of flows into the recharge basin, to prevent erosion of basin interior.
Setback from slab foundation	3.0 meters (10 feet)
Setback from cellar foundation	6.1 meters (20 feet)
Setback from slope >15%	4.6 meters (15 feet) (top edge of system to top of slope), or as required for impoundment stability. Distance may need to be greater where potential for "break-out" and resulting slope instability may be a problem.
Setback from on-site sewage disposal system	15.2 meters (50 feet) (or greater, if required under 310 CMR 15.000 [Title 5])
Setback from private well	30.5 meters (100 feet)
Setback from groundwater supply	Zone I radius; additional setback may be required depending on hydro-geologic conditions
Setback from surface water supply	Zone A, and 30.5 meters (100 feet) from tributaries

1 Several of the design criteria regarding setbacks from slopes, foundations, and other site features have been adapted from the requirements for on-site sewage disposal systems described in Massachusetts Title 5 (310 CMR 15.000). However, storm water quantities and flow durations differ markedly from the hydraulic loadings to septic systems. The design engineer should be aware of these differences, and may need to consider additional setbacks to provide for slope stability, protect structures, and provide for the satisfactory performance of the recharge system.

DESIGN CRITERIA	
Design Parameter	**Criteria**[1]
Performance under frozen conditions.	Recharge basins should be designed to either: • Provide for capture and recharge of required annual volume during the period April to December; or • Provide for capture and recharge during the entire year, with provisions for introduction of recharged storm water into the ground under frozen conditions (e.g., through use of wick drains, leaching galleries, or chambers, or other measures).
Construction of infiltration surface	The infiltration surface shall be constructed to preserve and enhance the capability of the soil to pass flows from the basin into the groundwater. Consider measures such as: • Minimizing trafficking by heavy construction equipment • Use of a minimum thickness of topsoil required to establish plantings • Using a planted surface, rather than crushed stone or sand surface
Protection During Construction	Runoff from disturbed areas shall not be discharged to the recharge basin. The contributing site shall be completely stabilized, prior to placing the recharge basin in service.
Access for maintenance, repair, and rehabilitation	Design shall consider accessibility to system, and capability to replace system components, to provide for eventual repair and rehabilitation of the system.
Other	• Provide maintenance access, including access to basin interior • Stabilize slopes as indicated for other impoundment-type BMPs • Design embankment to meet applicable safety standards • Provide emergency spillway as indicated for other impoundment-type BMPs • Consider providing method to drain lowest stage in the event of clogging of infiltration surface, so that surface can be rehabilitated.



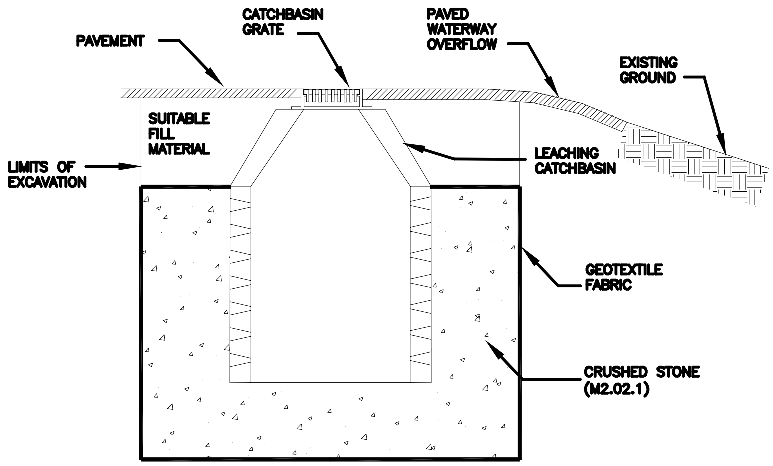
Example of Recharge Basin

LEACHING CATCH BASIN / LEACHING BASIN

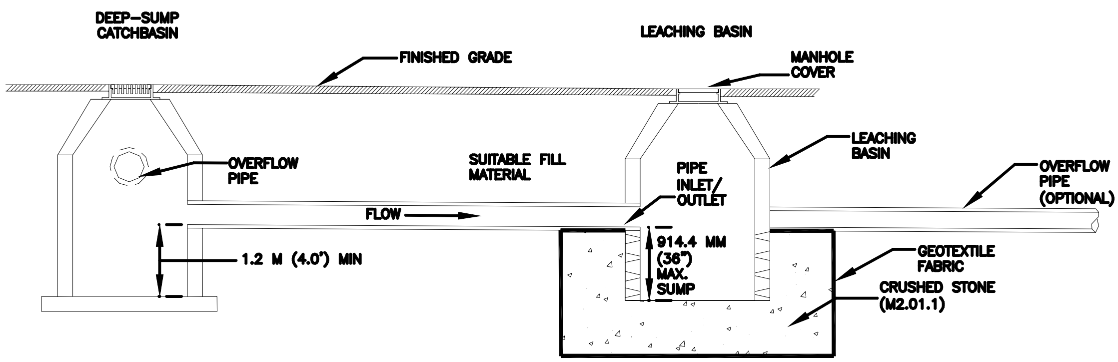
GENERAL INFORMATION	
Description: A leaching catch basin is a catch basin that is fabricated of barrel and riser sections that permit the infiltration of runoff into the ground. A leaching basin is a similar device, installed adjacent to a deep sump catch basin that provides pretreatment (see illustration). Because of this pretreatment, the catch basin/leaching basin combination is preferable to the leaching catch basin, where feasible. The basins are generally set in an excavation lined with a geotextile. 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. Leaching catch basins should be used as "off-line" devices (that is, they should not generally be piped in series as "flow-through" devices). Leaching catch basins and leaching basins should only be used in areas with highly permeable soils. Designers should also provide for the safe overflow of these devices in severe storm events, or in the event of clogging of the soils surrounding the device.	
Applicable DEP Stormwater Management Policy Performance Standards	• Standards #3, #4: • Standard #2 (peak rate control), if sufficient number of leaching catch basins are provided to handle the 10-year frequency storm.
TSS Removal	DEP Credit: 80% Estimated Range from Literature: >90%
Relative Cost	Construction: Low to moderate (depends on number of catch basins per acre Maintenance: Moderate (annual cleaning required)
Potential Constraints to Use	• Depth to bedrock or other impermeable substratum • Depth to groundwater • Soils must be well-drained to permit infiltration • Leaching catch basins should only be used where the water discharged will not compromise the integrity of the road base
Other Considerations	• Requires regular maintenance • Not recommended where sediment loading is likely to result in clogging of infiltration surface • Leaching catch basins do not provide pretreatment of runoff. A deep sump catch basin does provide for pretreatment prior to discharge to a leaching basin unit
Maintenance Requirements	• Inspection (typically annually, or more frequently as indicated by structure performance) • Periodic sediment and debris removal (typically annually) • Rehabilitation in the event of failure due to clogging
Primary Design Reference	MA DEP Technical Bulletin, (pending) MassHighway Design Manual, MassHighway *Construction and Traffic Standard Details* (Metric Edition, 1996).

LEACHING CATCH BASIN / LEACHING BASIN

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	Less than 0.4 ha (1.0 acre). For roadways, the tributary area for each catch basin will be much less than this, based on typical spacing of basins along a roadway.
Storm frequency for design flow	Varies with system. To comply with Standard #3, recharge systems are sized for recharging an annual volume, not an event storm. To comply with Standard #2 (peak rate control), size must be determined based on hydraulic/hydrologic modeling.
Annual Recharge Volume	Compute "annual recharge loss" using methodology specified in DEP Technical Bulletin (see Primary Design References),
Required Storage Volume	Compute storage volume required to compensate for "annual recharge loss" using methodology specified in DEP Technical Bulletin or use an alternative method conforming to accepted engineering practice. For peak rate control, compute required storage by accepted runoff estimation/routing practice for required design storm.
Stone Void Space	When the void space in crushed stone is used for storage, the specified stone should be uniformly sized. A porosity (volume of voids divided by total volume of bed) of 0.39 or less should be used for design.
Geotextile	The stone material surrounding the basin must be encapsulated by a geotextile fabric designed to prevent the migration of fine soil particles into the void spaces in the stone. Geotextile materials shall meet applicable MassHighway standard specifications, and must be selected based on an analysis of on-site soils conditions.
Depth to Bedrock or Impermeable Stratum	Minimum 0.6 meters (2 feet) below bottom of system.
Depth to Seasonal High Groundwater	Minimum 0.6 meters (2 feet) below bottom of system, unless engineering analysis demonstrates that lesser separation is feasible.
Structural design loading	Structural components should be designed for dead and live loads appropriate to their location. The minimum design load shall be H-20 loading.
Inlet grate	Design and placement of inlet grates may require consideration of the capacity of grates to pass design flows. Refer to MassHighway Drainage Manual for design of catch basin inlet capacity.
Provision for Overflow	Design and placement of leaching catch basins should consider the impact of runoff that exceeds the capacity of the device, either because of the magnitude of the event, or the clogging of the infiltration surface. Provisions for overflow might include redundant devices, paved "chutes" to discharge excess runoff to an acceptable outlet, or other measure.
Setbacks	Refer to Design Criteria for Recharge Wells and Galleys for recommended setbacks from surface water supplies, wells, foundations, septic systems, and steep slopes.
Other	Leaching catch basins are most effective as "beginning of system" or "off-line" devices (no inlet pipes)



LEACHING CATCH BASIN



CATCH BASIN WITH LEACHING BASIN

Examples of Leaching Catch Basin; Catch Basin with Leaching Basin

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SUBSURFACE RECHARGE SYSTEMS
(Other than Leaching Catch Basins and Leaching Basins)

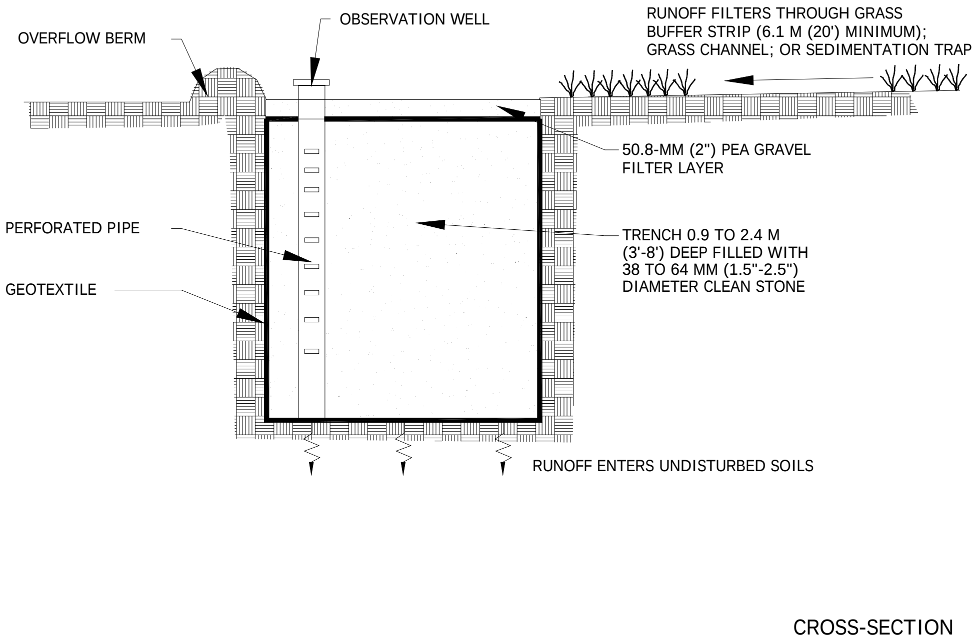
GENERAL INFORMATION	
Description: Subsurface recharge systems may include trenches, beds, galleys, or dry wells. Such systems have sufficient storage capacity so as to permit the gradual infiltration of runoff. Pollutant removal is provided by filtration through the soil matrix. Pre-treatment is required to prevent failure of infiltration systems due to sediment accumulation. Subsurface systems (other than leaching catch basins or leaching basins – see previous fact sheets) will rarely be used in the highway setting. These systems have historically had significant failure rates, and site constraints often limit the effective use of infiltration. Recharge BMPs should generally be designed as off-line systems. Separate Design Criteria summaries follow this table, for **Recharge Trenches and Beds** and **Recharge Dry Wells and Galleys**.	
Applicable DEP Stormwater Management Policy Performance Standards	Standard #3 (recharge) Standard #2, in some instances, where system volume is sufficient for flood storage. While underground recharge systems may be used to comply with Standard #4, pretreatment is required to remove 43.75% TSS prior to discharge to an underground recharge system.
TSS Removal	DEP Credit: 80% Estimated Range from Literature: >90%
Relative Cost	Construction: Moderate to high Maintenance: High
Potential Constraints to Use	• Depth to bedrock or other impermeable substratum • Depth to groundwater • Soils • Slope
Other Considerations	• Recharge systems can provide high levels of treatment of other pollutants, in addition to TSS removal • High failure rates (particularly without sufficient pre-treatment); replacement/rehabilitation (with a cost about equal to initial construction) may be required • Frequent maintenance may be required
Maintenance Requirements	• Inspect at least twice annually • Regular sediment removal from pre-treatment systems to prevent clogging • Rehabilitation in the event of failure due to clogging • Periodic removal of debris/trash from flow control structures
Primary Design References	MA DEP Technical Bulletin, (pending) Schueler, 1987 Young, et. al., 1996

RECHARGE TRENCHES AND BEDS

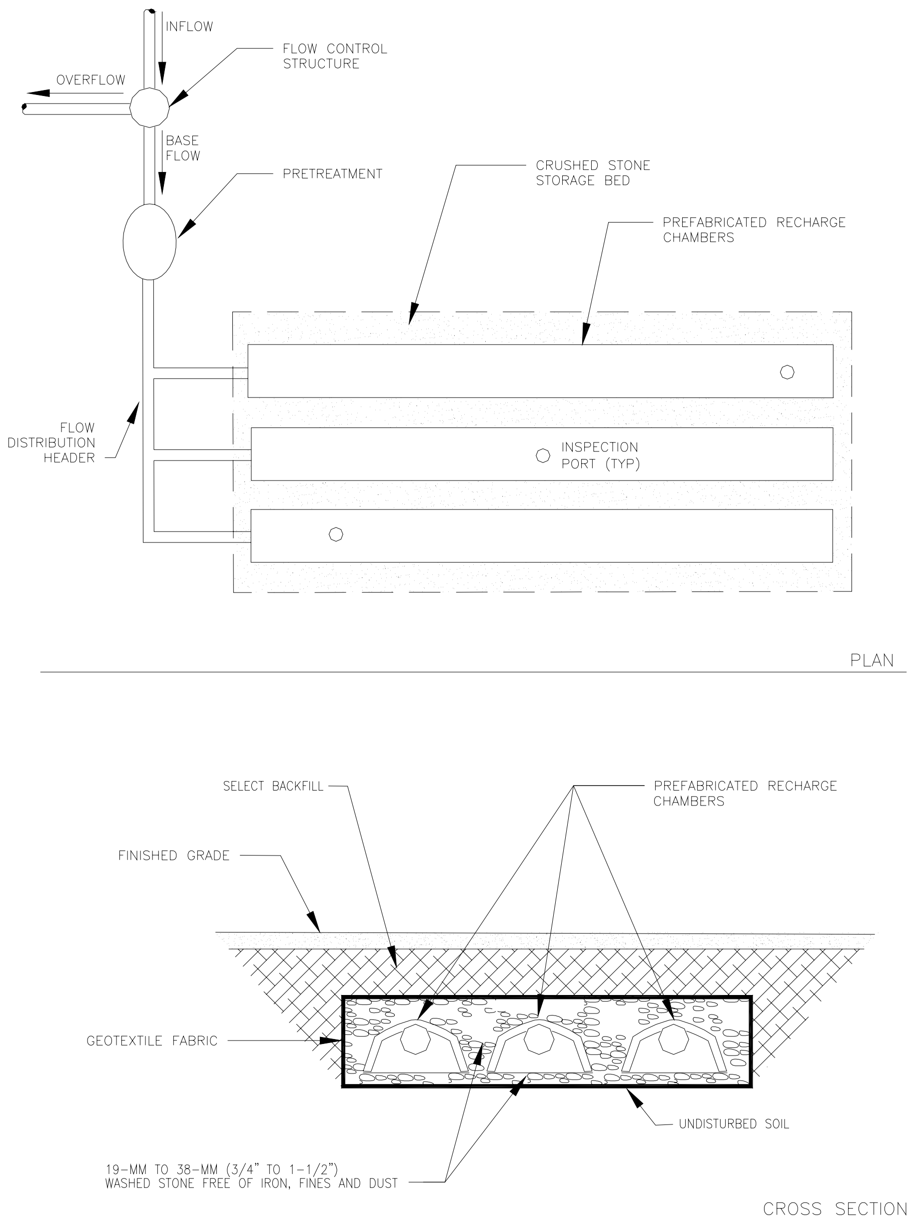
DESIGN CRITERIA	
Design Parameter	**Criteria**[1]
Contributing Drainage Area	< 2.0 ha (5 acres)
Storm frequency for design flow	Varies with system. Recharge systems are sized for recharging an annual volume, not an event storm.
Annual Recharge Volume	Compute annual recharge volume using methodology specified in DEP Technical Bulletin (see Primary Design References), or use an alternative method conforming to accepted engineering practice.
Required Storage Volume	Compute storage volume using methodology specified in DEP Technical Bulletin.
Design Recharge Rate	Determine recharge rate based on soil texture/hydrologic group as specified in Technical Bulletin, confirmed by on-site field testing; or use an alternative method conforming to accepted engineering practice.
Design Safety Factor	The DEP does not require a safety factor for sizing the volumes or areas of underground systems. However, this manual recommends designers consider a safety factor to allow for the potential clogging of underground systems.
Maximum Draw-down Time	The system should be designed to drain the design storage volume in 48 hours or less, using the design recharge rate times the applicable safety factor.
Maximum Depth of System	Depth of system shall be equal to or less than the depth permitting draw-down in the required time.
Stone Void Space	When the void space in crushed stone is used for storage, the specified stone should be uniformly sized. A porosity (volume of voids divided by total volume of bed) of 0.39 or less should be used for design.
Geotextile	The crushed stone material must be isolated from adjacent in-situ soils by a geotextile fabric designed to prevent the migration of fine soil particles into the void spaces in the stone. Geotextile materials shall meet applicable MassHighway standard specifications, and must be selected based on an analysis of on-site soils conditions.
Provisions for Overflow or Bypass	An underground system should be designed as an “off-line” system, or otherwise provided with an overflow or by-pass to safely convey flows that exceed the system capacity.
Depth to Bedrock or Impermeable Stratum	Minimum 0.6 meters (2 feet) below bottom of system, unless engineering analysis demonstrates that lesser separation is feasible.
Depth to seasonal high groundwater	Small systems: Minimum 0.6 meters (2 feet) below bottom of system. Large systems: Groundwater mounding analysis may be required.
Pretreatment	Pre-treatment system required; provide 43.75% TSS removal prior to discharge to an underground recharge system.
Velocity Dissipation at Inlet	Provide measures to dissipate velocity of flows into the device, to prevent erosion within the structure; generally, velocities $\leq$ 0.61 meters/second (2 fps) are recommended..
Setback from slab foundation	3.0 meters (10 feet)

1 Several of the design criteria regarding setbacks from slopes, foundations, and other site features have been adapted from the requirements for on-site sewage disposal systems described in Massachusetts Title 5 (310 CMR 15.000). However, storm water quantities and flow durations differ markedly from the hydraulic loadings to septic systems. The design engineer should be aware of these differences, and may need to consider additional setbacks to provide for slope stability, protect structures, and provide for the satisfactory performance of the recharge system.

DESIGN CRITERIA	
Design Parameter	**Criteria**[1]
Setback from cellar foundation	6.1 meters (20 feet)
Setback from slope >15%	4.6 meters (15 feet) (top edge of system to top of slope), or as required for impoundment stability. Distance may need to be greater where potential for "break-out" and resulting slope instability may be a problem.
Setback from on-site sewage disposal system	7.6 meters (25 feet) (or greater, if required under 310 CMR 15.000 [Title 5])
Setback from private well	30.5 meters (100 feet)
Setback from groundwater supply	Zone I radius; additional setback may be required depending on hydro-geologic conditions
Setback from surface water supply	Zone A, and 30.5 meters (100 feet) from tributaries
Construction of infiltration surface	The infiltration surface shall be constructed to preserve and enhance the capability of the soil to pass flows from the basin into the groundwater. Consider measures such as minimizing trafficking by heavy construction equipment
Structural design loading for chambers	If structural chambers are used to construct the bed or trench, they should be designed for dead and live loads appropriate to their location. The minimum design load shall be H-20 loading.
Inspection access	Underground systems should be provided with access ports, man-ways, or observation wells to enable inspection of water levels within the system. At a minimum, provide two (2) observation wells (152.40 mm (6-inch) diameter perforated PVC or HDPE risers) per trench or bed; for beds greater than 372.0 square meters (4,000 square feet) in area, provide one (1) well for each 186.0 square meters (2,000 square feet) (minimum of three wells). The inspection port should be accessible at-grade (i.e. not buried).
Access for maintenance, repair, and rehabilitation	Design shall consider accessibility to system, and capability to replace system components, to provide for eventual repair and rehabilitation of the system.
Protection During Construction	Runoff from disturbed areas shall not be discharged to the recharge structure. The contributing site shall be completely stabilized, prior to placing the recharge structure in service.
Other	Recharge trenches and beds should be "off-line" devices, with provisions for the bypassing or overflow of storms exceeding the storage capacity of the trench or bed.



Example of Recharge Trench



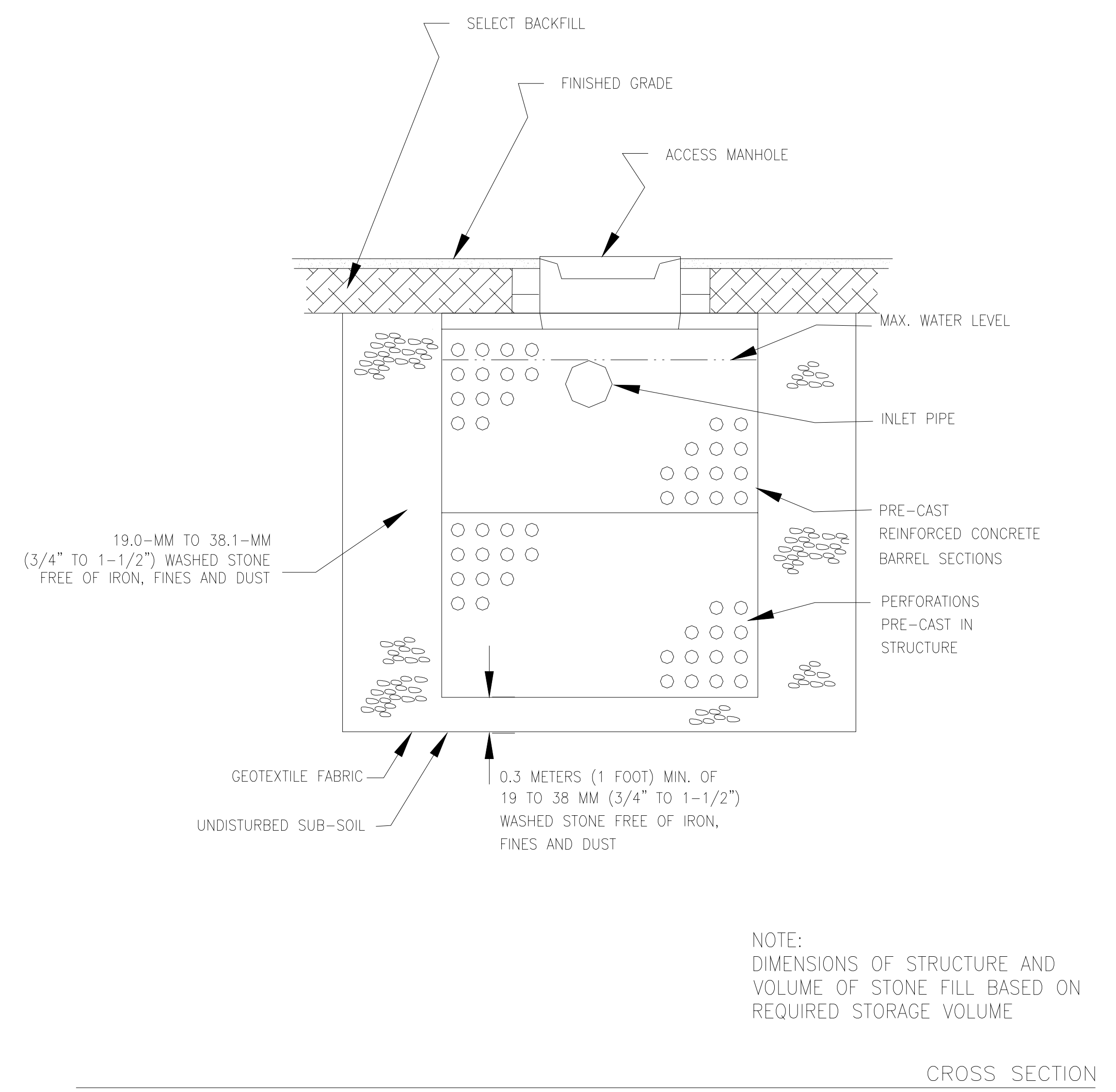
Example of Recharge Bed

RECHARGE DRY WELLS AND GALLEYS

DESIGN CRITERIA	
Design Parameter	**Criteria** [1]
Contributing Drainage Area	Contributing area will be limited by the size of well or galley used. These devices are typically used for discharging roof top runoff, or small parking areas. Designer will need to relate size and number of units to the volume of runoff to be treated.
Storm frequency for design flow	Varies with system. Recharge systems are sized for recharging an annual volume, not a storm event.
Annual Recharge Volume	Compute annual recharge volume using methodology specified in DEP Technical Bulletin (see Primary Design References), or use an alternative method conforming to accepted engineering practice.
Required Storage Volume	Compute storage volume using methodology specified in DEP Technical Bulletin.
Design Recharge Rate	Determine recharge rate based on soil texture/hydrologic group as specified in Technical Bulletin, confirmed by on-site field testing; or use an alternative method conforming to accepted engineering practice.
Design Safety Factor	The DEP does not require a safety factor for the design of underground systems. However, this manual recommends designers consider a safety factor to allow for the potential clogging of underground systems.
Maximum Draw-down Time	The system should be designed to drain the design storage volume in 48 hours or less, using the design recharge rate times the applicable safety factor.
Maximum Depth of System	Depth of system shall be equal to or less than the depth permitting draw-down in the required time.
Stone Void Space	When the void space in crushed stone is used for storage, the specified stone should be uniformly sized. A porosity (volume of voids divided by total volume of bed) of 0.39 or less should be used for design.
Geotextile	The crushed stone material must be isolated from adjacent in-situ soils by a geotextile fabric designed to prevent the migration of fine soil particles into the void spaces in the stone. Geotextile materials shall meet applicable MassHighway standard specifications, and must be selected based on an analysis of on-site soils conditions.
Provisions for Overflow or Bypass	An underground system should be designed as an “off-line” system, or otherwise provided with an overflow or by-pass to safely convey flows that exceed the system capacity.
Depth to Bedrock or Impermeable Stratum	Minimum 0.6 meter (2 feet) below bottom of system, unless engineering analysis demonstrates that lesser separation is feasible.
Depth to seasonal high groundwater	Small systems: Minimum 0.6 meter (2 feet) below bottom of system. Large systems: Groundwater mounding analysis may be required.
Pretreatment (roofs)	Pre-treatment of residential roof runoff not required. Pre-treatment of commercial and industrial building roof runoff may need to be considered, on site-specific basis.
Pretreatment (other areas)	Pre-treatment system required; provide TSS removal rate specified by DEP prior to discharge to an underground recharge system.

1 Several of the design criteria regarding setbacks from slopes, foundations, and other site features have been adapted from the requirements for on-site sewage disposal systems described in Massachusetts Title 5 (310 CMR 15.000). However, storm water quantities and flow durations differ markedly from the hydraulic loadings to septic systems. The design engineer should be aware of these differences, and may need to consider additional setbacks to provide for slope stability, protect structures, and provide for the satisfactory performance of the recharge system.

DESIGN CRITERIA	
Design Parameter	**Criteria**[1]
Velocity Dissipation at Inlet	Provide measures to dissipate velocity of flows into the device, to prevent erosion within the structure; generally, velocities $\leq$ 0.61 meters/second (2 fps) are recommended.
Setback from slab foundation	3.0 meters (10 feet)
Setback from cellar foundation	6.1 meters (20 feet)
Setback from slope >15%	4.6 meters (15 feet) (top edge of system to top of slope), or as required for impoundment stability. Distance may need to be greater where potential for “break-out” and resulting slope instability may be a problem.
Setback from on-site sewage disposal system	7.6 meters (25 feet) (or greater, if required under 310 CMR 15.000 [Title 5])
Setback from private well	30.5 meters (100 feet)
Setback from groundwater supply	Zone I radius; additional setback may be required depending on hydro-geologic conditions
Setback from surface water supply	Zone A, and 30.5 meters (100 feet) from tributaries
Structural design loading	Structural components should be designed for dead and live loads appropriate to their location. The minimum design load shall be H-20 loading.
Inspection access	Each well or galley unit should be provided with an access port, man-way, or observation well to enable inspection of water levels within the system. The inspection port should be accessible at-grade (i.e. not buried).
Maintenance access	If inspection port does not provide access, additional manhole access should be provided to each well or galley chamber.
Protection During Construction	Runoff from disturbed areas shall not be discharged to the recharge structure. The contributing site shall be completely stabilized, prior to placing the recharge structure in service.
Other	Recharge dry wells and galleys should be “off-line” devices, with provisions for bypassing or overflow of storms exceeding the design capacity of the devices.



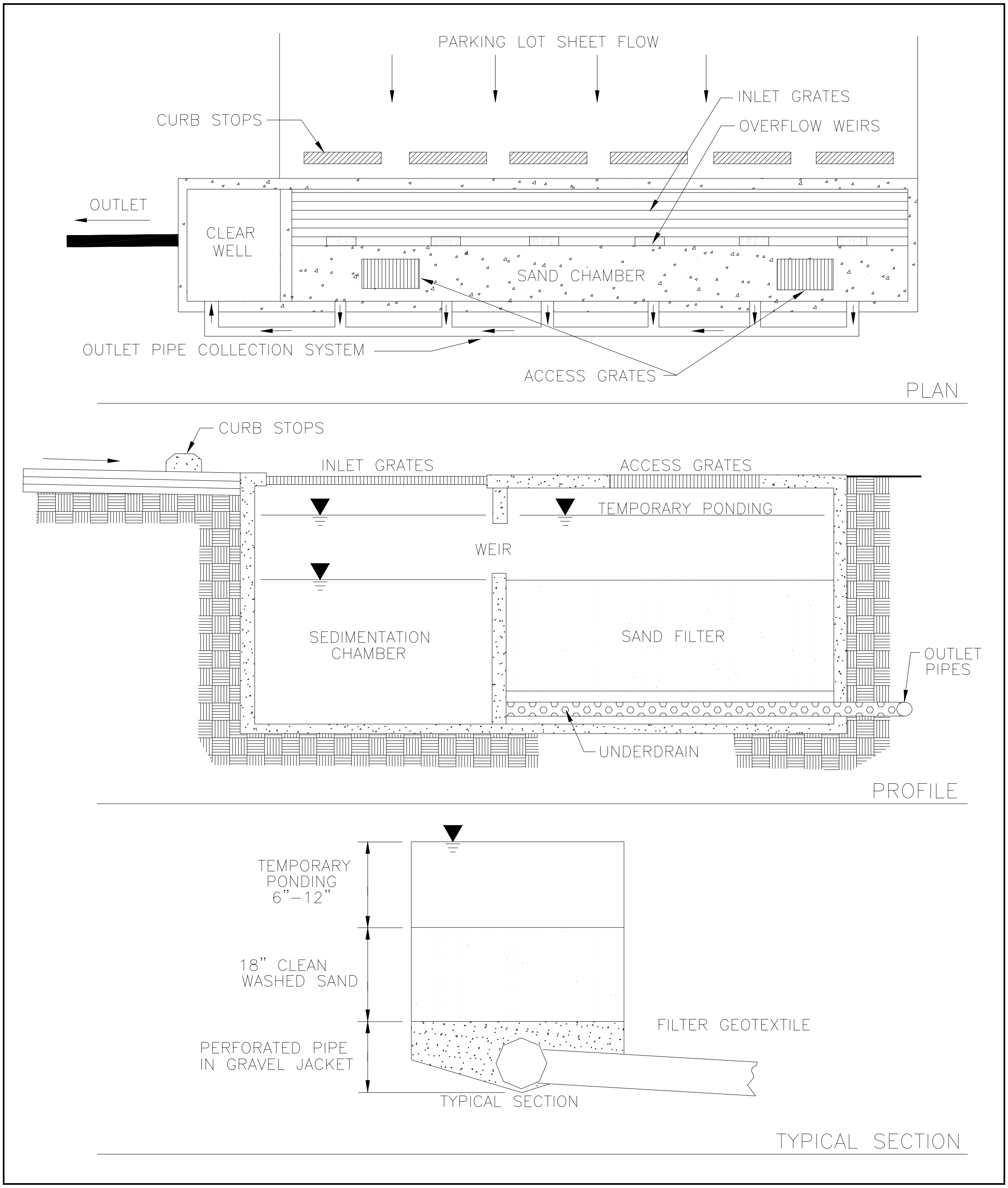
Example of Recharge Galley

FILTER SYSTEMS

GENERAL INFORMATION	
Description: Sand filters and organic filters are a relatively new storm water treatment application. Filter beds are designed to receive the first flush of runoff, which is then strained through a filter media and collected in underdrains for discharge. The basic type of system is a **sand filter**, using specially graded sand for the filter media. These systems may be enhanced to include peat or other organic materials (**organic filters**) or iron shavings to enhance nutrient removal. To date, extensive application of this technology has been limited to the mid-Atlantic and southwestern US. There is a lack of documentation regarding performance in the Northeast climate; system performance may be adversely affected by freezing weather. Sand filters and organic filters should not generally be used as on-line systems. These systems generally require a high level of maintenance on an ongoing basis.	
Applicable DEP Stormwater Management Policy Performance Standards	Standard #4.
TSS Removal	DEP Credit: 80% Estimated Range from Literature 75-95%
Relative Cost	Construction High Maintenance High
Potential Constraints to Use	• Depth to Bedrock • Depth to Groundwater • Freezing Weather • Susceptibility to failure due to clogging of the filtration surface
Other Considerations	• Highly adaptable to urbanized areas • Should be designed as off-line device • Requires pretreatment to prevent premature clogging of filter media • 1 to 8 feet of available head required for most applications • Limited documentation regarding performance in the Northeast • Requires frequent manual maintenance
Maintenance Requirements	• Requires regular raking, surface sediment removal, and removal of trash, debris, and leaf litter from the filtration surface • Requires frequent sediment removal from pre-treatment systems
Primary Design References	Young, et. al., 1996 Claytor & Schueler, 1996

SAND FILTER

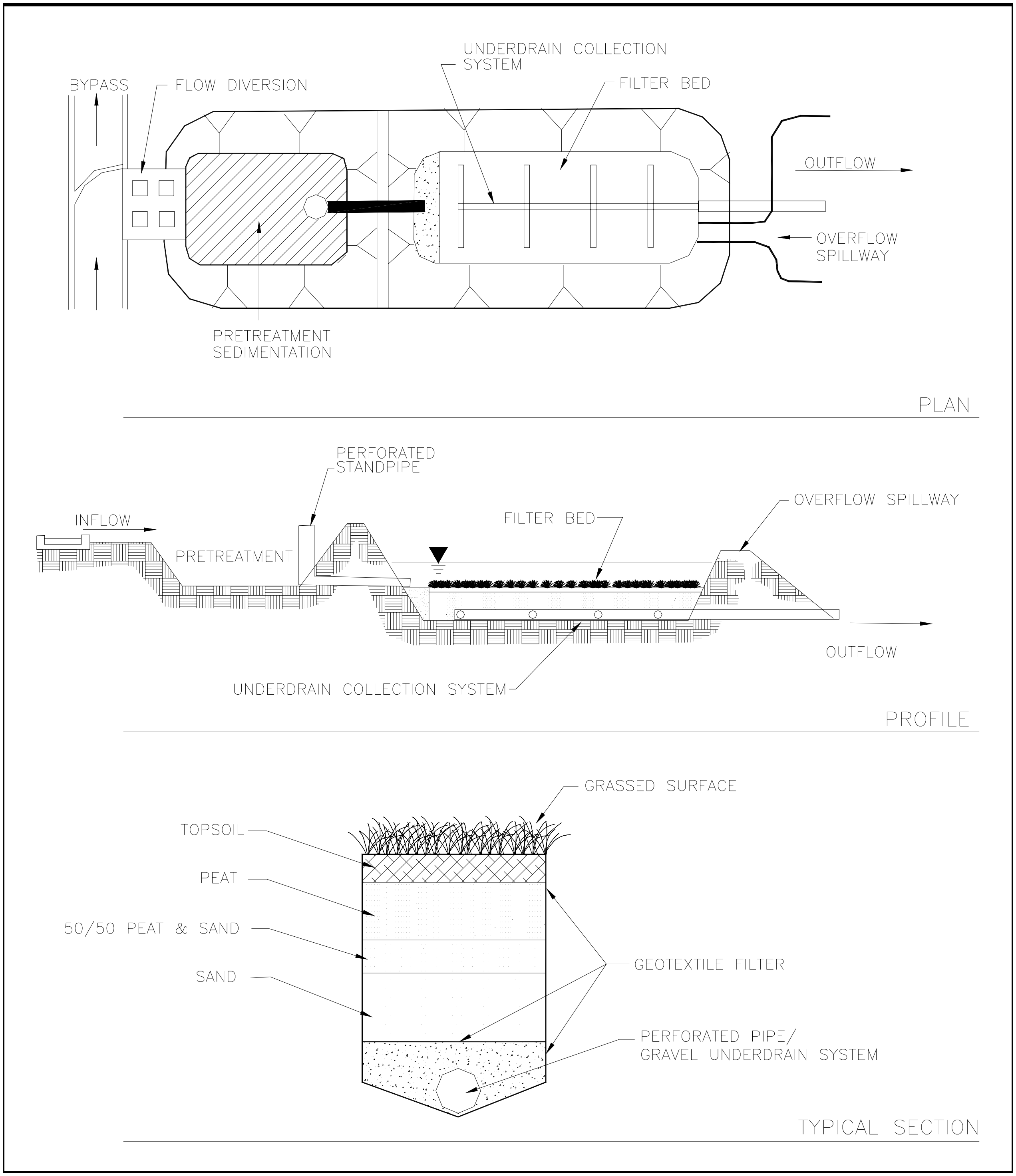
DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	2 to 5 acres recommended (Claytor & Schueler, 1996)
Design flow rate	Refer to Claytor & Schueler for sizing procedure.
Required Storage Volume	Refer to Claytor & Schueler for sizing procedure.
Maximum Draw-down Time	Sand filters shall drain in 24 hours or less.
Maximum Water Column Depth of System	Depth of system above filter bed shall be equal to or less than the depth permitting draw-down in the required time.
Thickness of filter media	18” to 24” typical, placed over 6” to 12” gravel bed. Design varies with type and configuration of underdrain.
Filter media	Sand: Provide documentation of sizing criteria (including calculations), based on literature, source availability, and hydraulic loading rate. Include documentation of k-value. Gravel: (For underdrain bedding) Provide documentation of sizing criteria (including calculations), including source availability, sizing for compatibility with filter media, sizing for compatibility with underdrain orifice size. Filter fabric: (For separation of layers, where required): provide documentation of criteria for selection (including calculations).
Depth to Bedrock or Impermeable Stratum	Where filter is designed as a recharge structure: • Minimum 4 feet below bottom of system, unless engineering analysis demonstrates that lesser separation is feasible. Where filter is under-drained for surface discharge: • No specific separation requirement.
Depth to seasonal high groundwater	Where filter is designed as a recharge structure: • Small systems: Minimum 2 feet below bottom of system. • Large systems: Groundwater mounding analysis may be required. Where filter is under-drained for surface discharge: • No specific separation requirement.
Pretreatment	Provide sedimentation basin sized per Claytor & Schueler, 1996.
Inspection access	Each chamber of the filter unit should be provided with an inspection well, to enable inspection of water levels within the system. This inspection access should be installed through the full depth of the filter media and bedding, to allow observation of whether filter media is properly draining. The inspection port should be accessible at-grade (i.e. not buried).
Maintenance access	If inspection port does not provide access, additional manhole access should be provided to each chamber.
Protection During Construction	Runoff from disturbed areas shall not be discharged to the filter structure. The contributing site shall be completely stabilized, prior to placing the filter structure in service.
Other	Recommended as off-line structure. Provide ability to isolate filter from conveyance system for maintenance and rehabilitation.



Example of Sand Filter

ORGANIC FILTER

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	2 to 5 acres recommended (Claytor & Schueler, 1996)
Design flow rate	Refer to Claytor & Schueler for sizing procedure.
Required Storage Volume	Refer to Claytor & Schueler for sizing procedure.
Maximum Draw-down Time	Sand filters shall drain in 24 hours or less.
Maximum Water Column Depth of System	Depth of system above filter bed shall be equal to or less than the depth permitting draw-down in the required time.
Thickness of filter media	Typical design: 18” organic media/sand media mixture, placed over 6-inch sand bed, placed over 6” to 12” gravel bed. Design varies with type and configuration of underdrain; provide documentation.
Filter media	Organic media: Provide documentation of type of media, material specifications, laboratory k-value, target pollutants, and information regarding pollutant removal effectiveness. Sand: Provide documentation of sizing criteria (including calculations), based on literature, source availability, and hydraulic loading rate. Include documentation of k-value. Gravel: (For underdrain bedding) Provide documentation of sizing criteria (including calculations), including source availability, sizing for compatibility with filter media, sizing for compatibility with underdrain orifice size. Filter fabric: (For separation of layers, where required): provide documentation of criteria for selection (including calculations).
Depth to Bedrock or Impermeable Stratum	Where filter is designed as a recharge structure: • Minimum 4 feet below bottom of system, unless engineering analysis demonstrates that lesser separation is feasible. Where filter is under-drained for surface discharge: • No specific separation requirement.
Depth to seasonal high groundwater	Where filter is designed as a recharge structure: • Small systems: Minimum 2 feet below bottom of system. • Large systems: Groundwater mounding analysis may be required. Where filter is under-drained for surface discharge: • No specific separation requirement.
Pretreatment	Provide sedimentation basin sized per Claytor & Schueler, 1996.
Inspection access	Each chamber of the filter unit should be provided with an inspection well, to enable inspection of water levels within the system. This inspection access should be installed through the full depth of the filter media and bedding, to allow observation of whether filter media is properly draining. The inspection port should be accessible at-grade (i.e. not buried).
Maintenance access	If inspection port does not provide access, additional manhole access should be provided to each chamber.
Protection During Construction	Runoff from disturbed areas shall not be discharged to the filter structure. The contributing site shall be completely stabilized, prior to placing the filter structure in service.
Other	Recommended as off-line structure. Provide ability to isolate filter from conveyance system for maintenance and rehabilitation.



Example of Organic/Sand Filter

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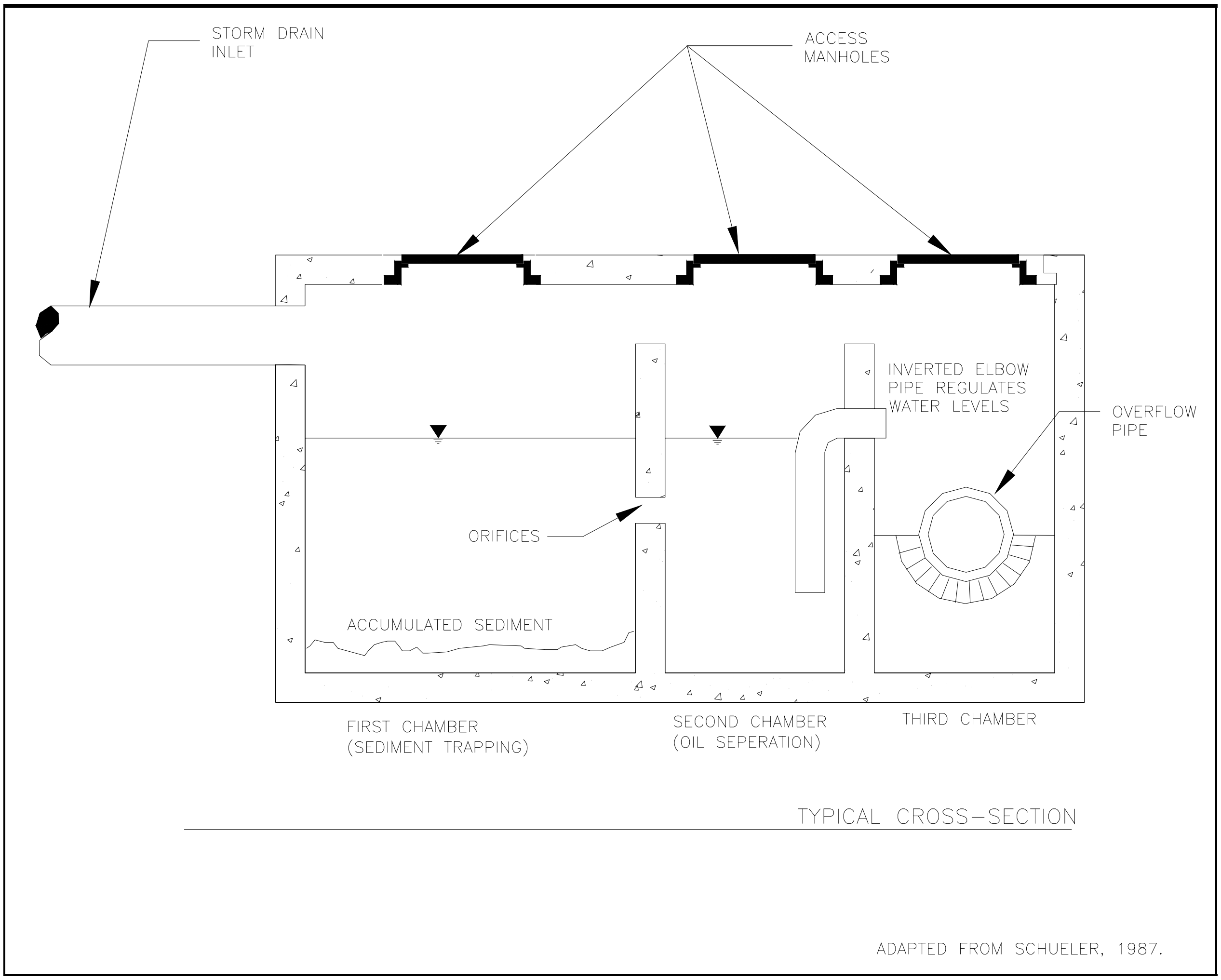
WATER QUALITY INLET (Oil/Grit Separator)

GENERAL INFORMATION	
Description: Water quality inlets are underground storage tanks with multiple chambers designed to remove heavy particulates, floating debris, and some hydrocarbons from storm water runoff. They are frequently used to pre-treat storm water discharged to other BMPs. The typical device comprises a concrete tank with three chambers: sediment chamber, oil trapping chamber, and outlet chamber. Flow between chambers is controlled by orifices, weirs, and inverted elbows. Some proprietary products introduce other components or features for collecting sediment, trapping floatables, and controlling flows. Water quality inlets are underground devices, which affects cost of installation, ease of inspection, and accessibility for routine maintenance. Inspection and maintenance may require use of "confined space" safety procedures. Sediments and liquid removed during maintenance may require special disposal practices because of contamination by hydrocarbons. The device is susceptible to flushing during major storm flow events, which displaces accumulated sediments.	
Applicable DEP Stormwater Management Policy Performance Standards	Standard #4.
TSS Removal	DEP Credit: 25% Estimated Range from Literature: Varies
Relative Cost	Construction: Moderate to high Maintenance: Moderate to high
Potential Constraints to Use	• Cost and frequency of maintenance. • Potential requirements for special procedures for maintenance access, disposal of sediments. • Limits on available hydraulic head.
Other Considerations	• Recommended as off-line device. • Potential for use as pre-treatment device. • Accumulated sediments subject to flushing by high flows, limiting the effectiveness of the device. • Generally suitable only for coarse sediment removal. Fine sediments, dissolved pollutants, and bacteria not treated. • Retention of water within the device for extended periods can result in conditions conducive to growth of anaerobic microorganisms.
Maintenance Requirements	• Requires frequent cleaning to remove accumulated sediments. • Inspection and maintenance may require use of "confined space" safety procedures. • Frequency of maintenance may pose traffic safety concerns when devices must be located in close proximity to high-traffic roadways. • Disposal of sediments and liquids removed during maintenance may be subject to special disposal practices.
Primary Design References	Schueler, 1987 Schueler, et. al., 1992

WATER QUALITY INLET (Oil/Grit Separator)

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	Generally less than 0.4 hectare (1.0 acre). May vary depending on particular design of device.
Design flow rate	Recommended that device should pass the 2-year frequency design storm without hydraulic interference; provide for by-pass of larger design flows, to prevent re-suspension of captured sediments
Required Storage Volume	0.1 inch times contributing impervious area, to comply with DEP Stormwater Management Policy. Some proprietary devices may have alternative sizing requirements; consult manufacturer's data.
Depth	Permanent pool depth retained in settling chamber should be minimum 4 feet in depth.
Access	Each chamber of inlet should have manhole access for inspection and maintenance.
Other	Use for off-line treatment only. Larger storm flows should be designed to by-pass this type of device. Consider device for pretreatment upstream of other BMPs. Provide ability to isolate filter from conveyance system for maintenance and rehabilitation. Where structure is located below the seasonal high groundwater elevation, design structure to prevent floatation.



Example of Water Quality Inlet

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5.2 Design Criteria for Selected Supplemental Structures and Devices

This Section offers the following guidelines and information regarding devices and structures that are used in conjunction with the BMPs described in Section 5.1:

Flow Splitter

General Design of Impoundment Structures

Check Dam

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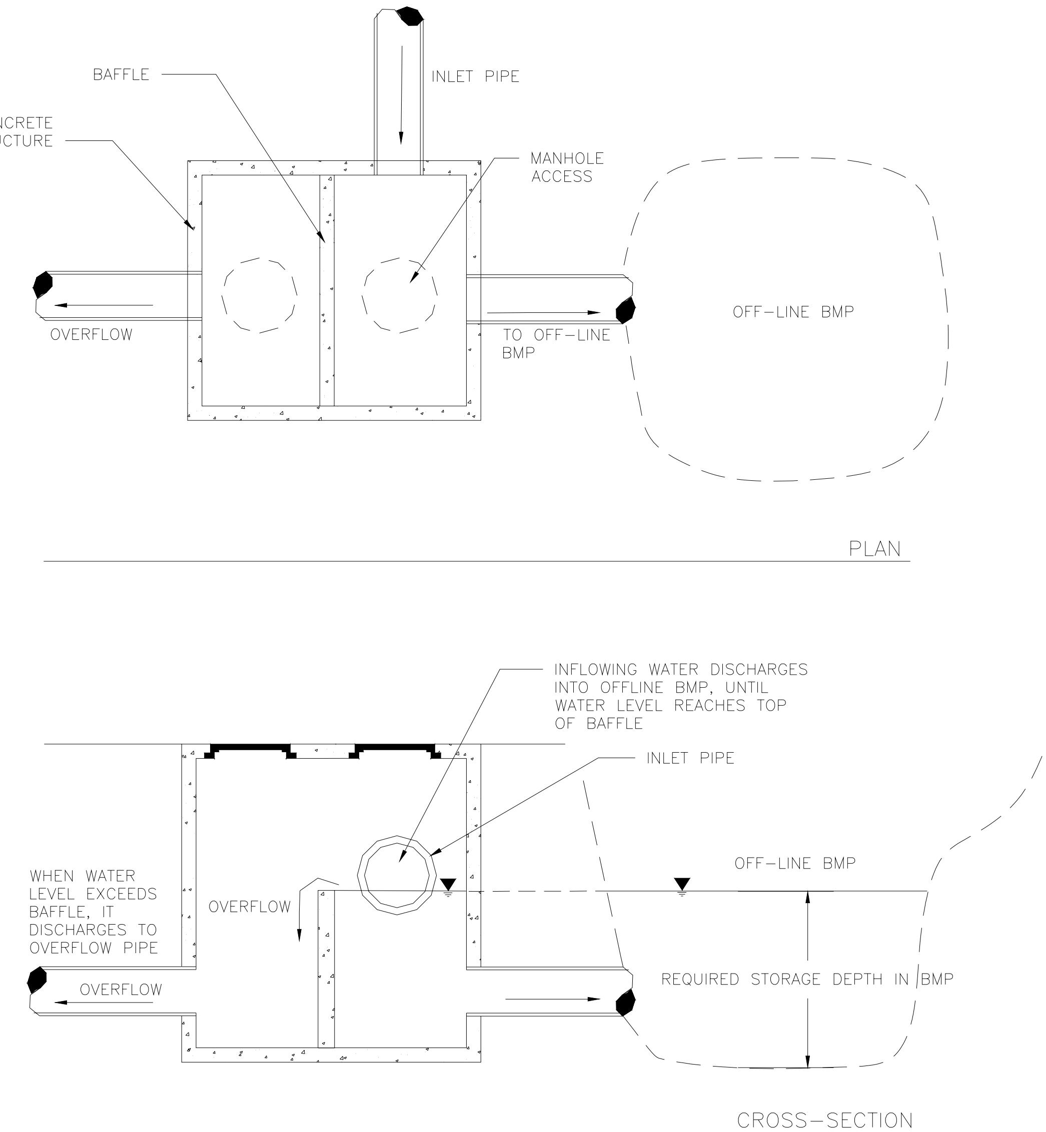
FLOW SPLITTER

GENERAL INFORMATION	
Description: A flow splitter is an engineered structure used to divide flow into two or more parts, and divert these parts to different places. The design of a flow splitter uses specifically designed structures, pipes, orifices, and weirs set at specific elevations to control the direction of flow. An illustration of a simple type of flow splitter is provided in the accompanying figure. Typically, when managing storm water flows, such a structure is used to direct initial storm water flows to an "off-line" BMP. The splitter is placed at an elevation coordinated with the elevation of the treatment BMP, so that the elevation of water in the BMP governs the elevation in the flow splitter. As shown in the example illustration, storm water flows to the BMP until it reaches a pre-determined elevation. Once storm water reaches that elevation, a weir (or other hydraulic feature) directs additional flow to an alternative outlet. This simple type of flow splitter works on hydraulic principles, and requires no mechanical components or instrumentation.	
Applicable Stormwater Policy Standards	No specific standard applies to flow splitters. Flow splitters are essentially hydraulic devices that distribute flows to two or more components of a storm water management system.

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	No minimum or maximum drainage area applies.
Hydraulic capacity	Design to be consistent with the hydraulic capacities of the devices receiving discharge from the splitter; Design must be performed by design professional familiar with hydraulic principals; Design must account for head-losses at all transitions within the structure and inlet and outlet conduits; Design must account for tailwater and headwater conditions affecting the device.
Outlets	Outlets must discharge to stable areas.
Structural loads	Splitter structures must be designed to sustain anticipated dead and live loads. Generally, minimum design load will be H-20 loading, but this may vary with location of structure relative to traffic, as well as with local code requirements.
Access	Construct splitters in accessible locations. Because splitters involve transition of flows to multiple outlets, some of which may be smaller than the inlets, accessibility for routine and emergency cleaning and removal of debris is necessary.



Example of Flow Splitter

IMPOUNDMENT STRUCTURES
SUGGESTED DESIGN CONSIDERATIONS FOR SMALL DAMS

NOTE: *The design of Storm Water Management BMPs frequently involves the development of containment basins to store runoff from the contributing watershed. In some instances, these basins can be constructed by excavation. More frequently, impoundments are required to develop the needed storage capacity. Generally, the impoundments are created by earthen embankments, with ancillary discharge control structures.*

These structures should be designed by professional engineers versed in the analysis and design of impoundments, and based on site specific information relative to watershed hydrology, site soils conditions, hydraulic behavior of receiving waters, hydraulic characteristics of inlet and outlet structures, and other parameters. In some instances, the design of the structures will be subject to regulatory review and licensing under governmental dam safety statutes, rules, and regulations.

The following are some suggested general guidelines for parameters typically applied to the design of the relatively small impoundments used for storm water management. However, this listing is not necessarily complete, and may not apply to particular site conditions. The design engineer on any particular project is responsible for research of applicable design standards, including regulatory requirements and codes, selection of methodologies, and performance of the analyses, calculations, and design procedures required to meet accepted engineering practice for the design of impoundments. Users of the following assume all risk associated with the application of this information to the design of impoundment structures.

DESIGN GUIDELINES	
Design Parameter	**Guidelines**
Applicable Stormwater Policy Standards	No specific Standard applies. Impoundments are frequently required to develop BMPs to generally conform to the nine standards of the Policy.
Applicable Massachusetts Reservoir and Dam Safety Standards	302 CMR 10.00: Dam Safety, promulgated pursuant to the authority granted the Department of Environmental Management in M.G.L. c.253, Section 44. Generally, 302 CMR 10.00 applies to any artificial barrier greater than 1.8 meters (6 feet) in height, or which impounds more than 18,500 cubic meters (15 acre-feet) of water. Refer to those Rules and Regulations for specific requirements.
Design References	*Earth Dams and Reservoirs*, Technical Release No. 60, U.S. Department of Agriculture, Soil Conservation Service Engineering Division, Revised Oct. 1985. Any of a number of design references published in cooperation with the Soils Conservation Service (now the Natural Resource Conservation Service). Examples include the following: • *Guidelines for Soil Erosion and Sediment Control*, the Connecticut Council on Soil and Water Conservation, Revised 1988. • *Stormwater Management and Erosion and Sediment Control Handbook for Urban and Developing Areas in New Hampshire*, Prepared by Rockingham County Conservation District for the New Hampshire Department of Environmental Services, in cooperation with USDA Soil Conservation Service, 1992.

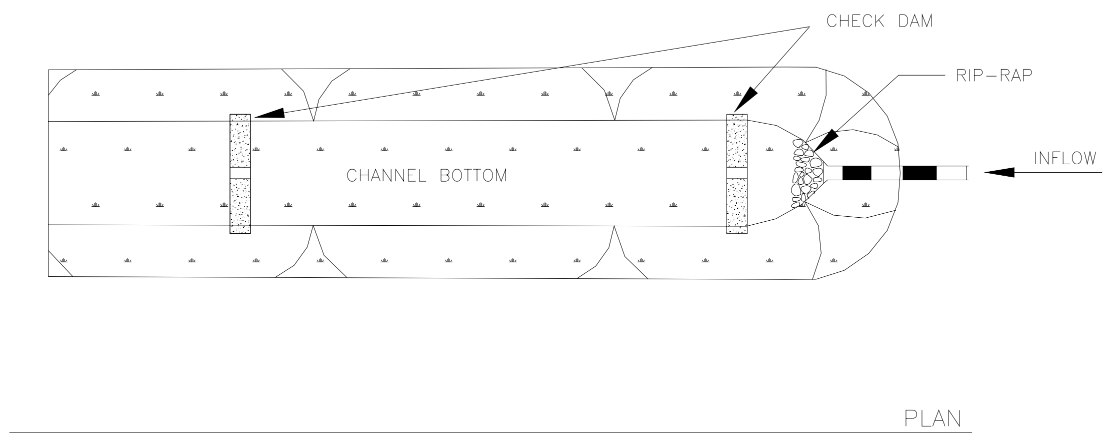
DESIGN GUIDELINES	
Design Parameter	**Guidelines**
Major Design Components	Embankment • Top width per design reference guidelines for structural stability and access • Side slopes for surface and structural stability • Suitable foundation conditions • Freeboard capacity during maximum design flood • Construction materials for stability • Seepage Control • Allowance for post-construction settlement • Surface Stabilization (vegetation, armor, etc.) • Provisions for controlling undesirable vegetation on embankment slopes • Where pipes or other conduits penetrate the embankment, provisions for “drainage diaphragm(s)” (specially designed layers of free-draining soil materials) or anti-seep collar(s) to prevent “piping” along exterior surface of conduit Principal Spillway (Outlet Structure) • Capacity for controlled release of design storms (multiple-stage control of peak discharges) • Capacity for overflow in storms exceeding design capacity of impoundment • Provisions for intercepting and managing trash and debris • Provisions for intercepting and managing floating pollutants • Accessibility for routine maintenance and emergency servicing • Provisions to prevent piping along exterior of conduit (see embankment guidelines) Emergency Spillway • Location to protect integrity of embankment (generally, the emergency spillway shall not be located in the embankment, but in undisturbed original ground) • Capacity to pass the routed design emergency storm (frequently, the 100-year event, but may be other event based on applicable regulation) • Adequate freeboard above emergency impoundment stage Other • Provisions for drawdown and maintenance of permanent pools • Provisions for cleaning of forebays, cleaning and interior maintenance of basin • Provisions for lining if needed for maintaining permanent water levels, or preventing direct discharge of stored runoff into sub-soils • Provisions for contingency response to spills of oil or hazardous materials, which may be discharged into the basin

CHECK DAM

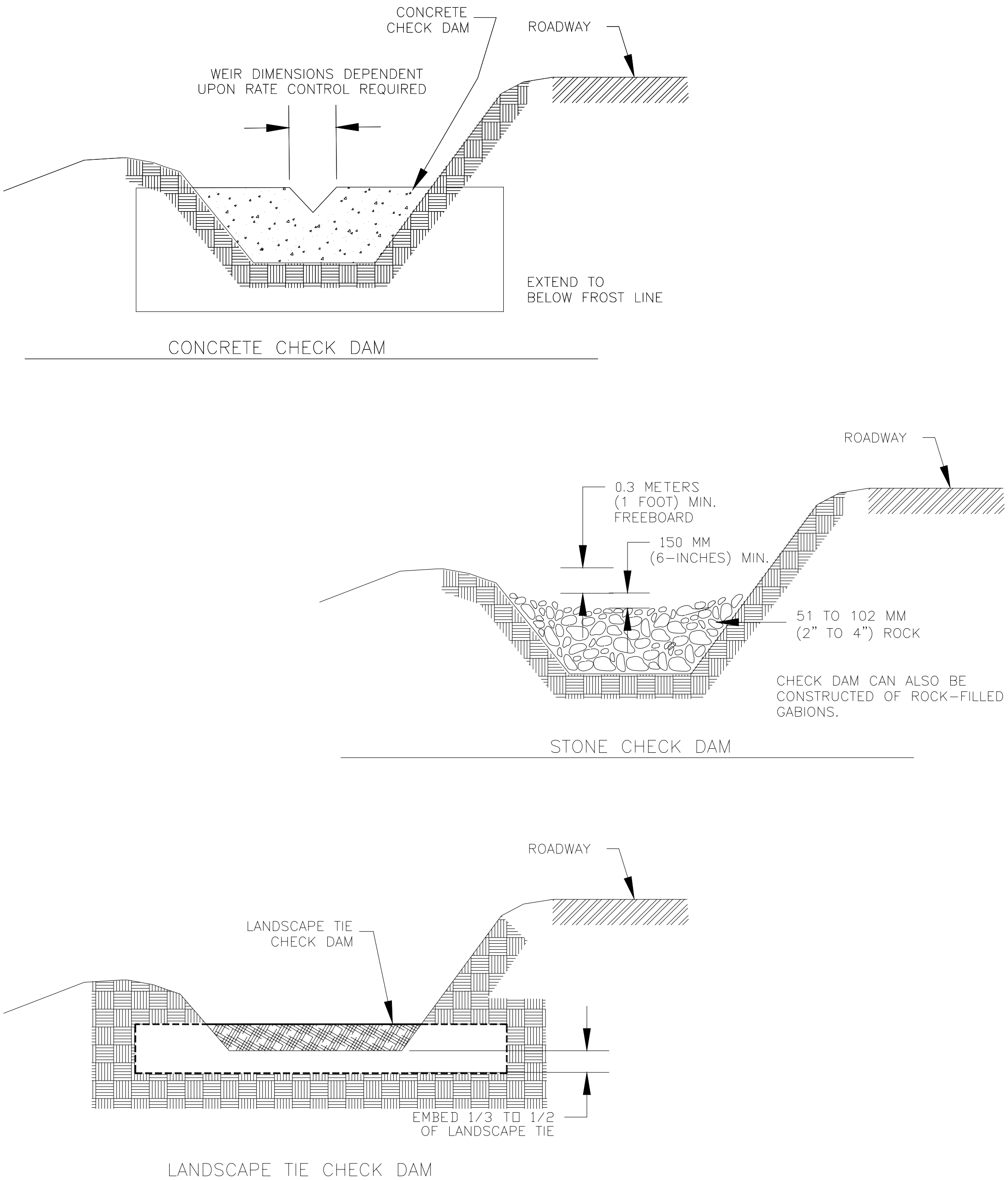
GENERAL INFORMATION	
Description: A check dam is a small dam constructed across a drainage ditch, swale, or channel to reduce the velocity of flow in the channel. The check dam impounds a shallow pool of water, allowing sediments to settle. Check dams are used in channel-type BMPs to increase residence time in the channel, enhancing TSS and other pollutant removal through physical settling, and in certain soils, through infiltration. Check dams may be constructed of stone fill materials, gabions, concrete weirs, wood landscaping ties, and other materials.	
Applicable Stormwater Policy Standards	No specific standard applies to check dams. Check dams are used in various types of drainage channel systems, including conventional drainage channels and water quality swales.
TSS Removal	No separate credit for TSS removal is provided for check dams. These devices are considered as components of other BMPs (see Channel Systems), as well as erosion and sediment control devices.
Relative Cost	Construction: Low to Moderate, depending on materials used Maintenance: Low
Other Considerations	• May be used on a temporary basis for sediment and erosion control during construction and stabilization of the contributing site • Applicable to the relatively flat gradients associated with water quality treatment channels, to enhance residence time and associated pollutant removal • Also applicable in steeper-gradient channels for providing grade control, to slow flow velocities and provide erosion protection • Must be designed so that water overflowing top of structure does not erode channel embankments at the check dam abutments.
Maintenance Requirements	• Inspect at least once annually. • Remove accumulated sediment upstream of check dam as indicated by inspection • Repair scour at downstream toe as indicated by inspection • Maintain and repair check dam as indicated by inspection.
Primary Design References	Massachusetts Erosion and Sediment Control Guidelines for Urban and Suburban Areas (1997) MassHighway Drainage Manual Young, et. al., 1996

CHECK DAM

DESIGN CRITERIA	
Design Parameter	**Criteria**
Contributing Drainage Area	Recommended maximum drainage area of 0.8 hectare (2 acres). This may vary depending on design of structure.
Height of Check Dam	Maximum of 0.61 m (2 feet)
Spacing of Check Dams	Generally, check dams are spaced so that the elevation of the toe of each check dam equals the top elevation of the check dam immediately downstream.
Freeboard	Check dams act as weirs within the channel. They should be designed so that, when the channel design flow is passing over the top of weir, the height of adjacent channel embankment above top of dam equals the depth of flow plus a minimum freeboard of 0.30 m (1 foot).
Abutment Protection	Check dams should be shaped to direct flow away from the connection of the dam to the embankment, or the dam should be embedded into the embankment, so as to prevent scour of the embankment and the resulting undercutting and channelization around the end of the dam.
Scour Protection	The channel at the downstream toe of the check dam may require riprap or other lining to prevent scour resulting from water passing over the structure.
Construction Materials	Stone fill materials, gabions, concrete weirs, landscape timbers, and logs may be used to construct check dams. Refer to design references. Dams must be designed for stability under anticipated hydraulic conditions. Earth check dams are not recommended.



Plan View of Drainage Swale Showing Typical Check Dam Placement



Examples of Check Dams

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Massachusetts Statutes

MGL 30, Sections 61-62H	Massachusetts Environmental Policy Act (MEPA)
MGL 91, Sections 1-63	Waterways (Massachusetts Public Waterfront Act) (Chapter 91)
MGL 92, Section 107A	Massachusetts Watershed Protection Act
MGL 131, Section 40	Massachusetts Wetlands Protection Act (WPA)

Massachusetts Regulations

301 CMR 11.00	MEPA Regulations
310 CMR 10.00	Wetlands Protection
310 CMR 15.00	The State Environmental Code, Title 5: Standard Requirements for the Siting, Construction, Inspection, Upgrade and Expansion of On-site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage
314 CMR 3.00	Surface Water Discharge Permit Program
314 CMR 4.00	Massachusetts Surface Water Quality Standards
314 CMR 5.00	Ground Water Discharge Permit Program
314 CMR 6.00	Ground Water Quality Standards
314 CMR 9.00	401 Water Quality Certification for Discharge of Dredged or Fill Material, Dredging, and Dredged Material Disposal in Waters of the United States within the Commonwealth
350 CMR 11.00	Watershed Protection