Attachment 6:

MassDOT TMDL Method

Description of MassDOT's TMDL Method in BMP 7R

Introduction

The Massachusetts Department of Transportation (MassDOT) owns and operates stormwater collection systems along its roadways throughout Massachusetts. In urbanized areas, discharges from these stormwater collection systems are regulated under a Municipal Separate Storm Sewer Systems (MS4) National Pollutant Discharge Elimination System (NPDES) general permit issued by the United States Environmental Protection Agency (USEPA). This permit requires that MassDOT's MS4 discharges to impaired waterbodies must be consistent with any State or EPA established Total Maximum Daily Loads (TMDLs) for that water body and any applicable Waste Load Allocations (WLAs).

MassDOT has developed a NPDES Storm Water Management Plan (SWMP; MassHighway, 2008) pursuant to the requirements of its NPDES general permit. The SWMP includes several protocols used to address pollutant loading from MassDOT's stormwater discharges to the State's impaired waterbodies. For those impaired waterbodies with an established TMDL, MassDOT's uses the following assessment methodology, as described in BMP 7R of the SWMP:

1. Identify waters with TMDLs to which MassDOT's urbanized roadways may potentially discharge stormwater
2. Conduct a desktop review and, if necessary, site survey of waters with TMDLs with applicable WLAs to determine if there are direct stormwater discharges from MassDOT urban areas.
3. Assess whether WLAs for stormwater discharges are being met
   - 3a. Calculate the relevant areal WLA
   - 3b. Calculate loading from MassDOT stormwater
   - 3c. Assess WLA relative to loading from MassDOT
4. Consider control measures for pollutants of concern listed in TMDL reports that do not contain stormwater WLAs
5. Select, design and implement BMPs
6. Document the results of the assessment and the progress on implementation

This report is intended to elaborate on the assessment methodology described in BMP 7R of the SWMP and includes detailed step-by-step instructions for each component thereof. MassDOT has termed this methodology "MassDOT's TMDL Method."

MassDOT's TMDL Method

MassDOT's TMDL Method has been developed exclusively for assessing discharges to impaired waterbodies with TMDLs for pollutants typically found in highway stormwater runoff as part of MassDOT's Impaired Waters Program. These pollutants include, but are not limited to, total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and zinc (Zn). MassDOT has developed additional procedures for assessing compliance with TMDLs for pathogens.

MassDOT developed a supplementary worksheet to assist in performing the calculations required for each assessment and documenting the necessary information. This report provides guidance for completing the TMDL Method assessment both with and without the use of the supplementary worksheet. However, we strongly recommended using the TMDL worksheet. Screenshots are included throughout this report and as Attachment 1 at the end of the report to illustrate various user inputs (shaded in blue) and worksheet outputs (shaded in yellow). Note that the worksheet is currently set up to only assess TMDLs for total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), and zinc (ZN).

MassDOT's TMDL Method uses the TMDL reports and associated guidance published by MassDEP and USEPA. MassDEP's TMDL reports can be accessed at the following URL: http://www.mass.gov/dep/water/resources/tmdls.htm. USEPA's guidance on developing, implementing, and complying with TMDLs can be accessed at the following URL: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/index.cfm.

Several steps of MassDOT's TMDL Method require the user to perform a desktop analysis to develop an understanding of local flow patterns within the watershed of the subject TMDL waterbody and within MassDOT's right-of-way. The desktop analysis is intended to be completed in a Geographic Information System (GIS) environment in order to simultaneously analyze multiple sets of geospatial data. It is recommended that the user be familiar with ESRI's ArcGIS or equivalent GIS software before performing an assessment using the methodology described herein.

Figure 1 summarizes MassDOT's TMDL Method. The following sections describe in detail the steps necessary to complete an assessment of MassDOT's stormwater discharges to an impaired waterbody under the jurisdiction of a State- or USEPA-established TMDL using MassDOT's TMDL Method.

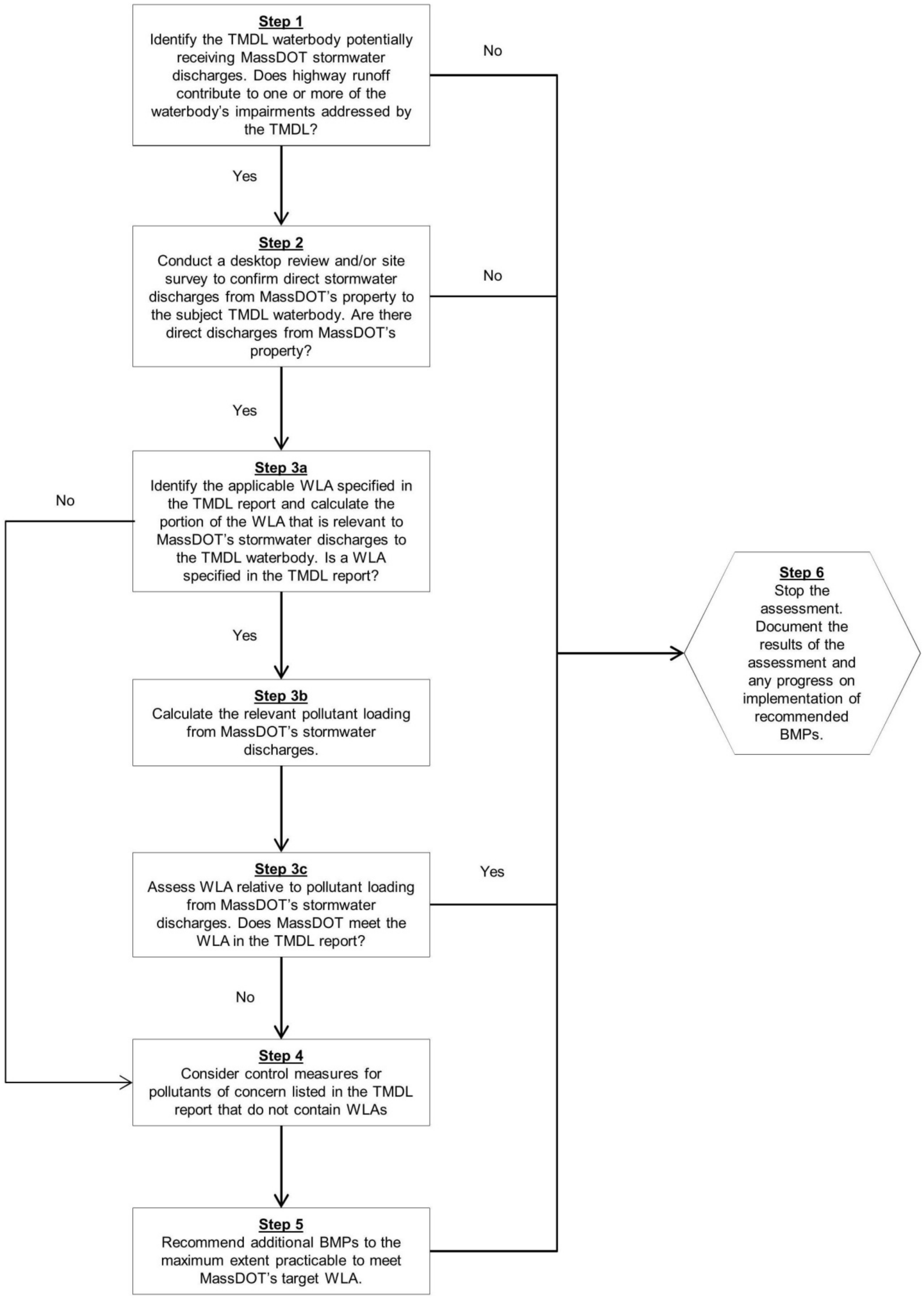

Figure 1. Flow Chart Illustrating MassDOT's TMDL Method

Step 1. Identify Waters with TMDLs to Which MassDOT's Urbanized Roadways May Potentially Discharge Stormwater

Identify the waterbody that potentially receives stormwater from one or more of MassDOT's urbanized roadways. Urbanized roadways are defined as those which fall within the urbanized areas identified in the Massachusetts 2000 Urban Boundaries datalayer downloaded from MassGIS. Identify impairment(s) to the subject waterbody using MassDEP's most recent *Final Massachusetts Integrated List of Waters* and verify that a TMDL has been finalized to address one or more of the impairments. Read the TMDL report(s) corresponding to the impairment(s). If runoff from MassDOT's property does not have the potential to contribute to the impairments addressed by the TMDL, then proceed to Step 6 and document the basis for doing so. If no TMDL has been developed for the impairments to the subject waterbody, or if the TMDL is still in draft form, then select a different assessment methodology. Otherwise, proceed to Step 2.

Step 2. Conduct Desktop Review and/or Site Survey of Waters with TMDLs with Applicable WLAs

After determining that runoff from MassDOT's property may contribute to the impairment(s) addressed by the TMDL under Step 1, confirm that there are direct stormwater discharges from MassDOT's property to the subject waterbody. Perform a desktop analysis to establish flow patterns within the watershed to the subject waterbody. Identify any stormwater outlets from MassDOT's property and review local topography to verify the waterbody receives discharges from the stormwater outlets. Data sources for the desktop analysis should include construction or as-built plans, aerial imagery, 1:24,000 scale USGS topographic maps, and other GIS datasets which may be of use.

If the desktop analysis does not provide a clear understanding of the flow patterns within the watershed to the subject waterbody, or if the desktop analysis reveals possible direct discharges to the subject waterbody from MassDOT's property, then conduct a field visit to obtain further clarification of flow patterns and verify the results of the desktop analysis. If the desktop analysis confirms that there are no stormwater discharges from MassDOT's property to the subject waterbody, then proceed to Step 6 and thoroughly document the basis for doing so. Otherwise, proceed to Step 3.

Step 3. Assess Whether WLAs for Stormwater Discharges Are Being Met

Where MassDOT urban area directly discharges to a water body with an applicable WLA, assess whether the WLA is being met through existing stormwater control measures or if additional control measures may be necessary. This assessment will be conducted using the steps outlined below.

In cases where no WLA is specified, the TMDL report may provide specific recommendations for BMPs to address stormwater runoff from roadways and/or highways or may provide specific performance requirements for highway dischargers. Skip this step and proceed to Step 4 if no WLA is specified in the TMDL report.

Step 3a. Calculate the Relevant Areal WLA

TMDL reports typically specify a single WLA for stormwater discharges within the watershed of the TMDL waterbody or specify a WLA for each of the various land use categories within the watershed (e.g. "commercial," "industrial," etc.). They generally do not specify a WLA for stormwater from MassDOT's property. As a result, calculate the portion of the applicable WLA that is relevant to MassDOT's stormwater discharges to the TMDL waterbody.

Calculate the Target Areal WLA

Review the TMDL report to identify the specified stormwater WLA(s). If the TMDL report specifies s single WLA for stormwater discharges within the watershed of the TMDL waterbody, use the WLA and the total watershed area covered by the WLA to calculate the target areal WLA as shown below. If the TMDL report instead specifies a WLA for each land use category within the watershed, select the category under which roadways and highways are included. If the TMDL report does not specifically state this information, then use the more stringent WLA associated with either the “commercial” or “industrial” land use categories.

Using the selected WLA and its corresponding area, calculate the target areal WLA as follows:

$$Target\ Areal\ WLA\ (lb/ac/yr) = \frac{WLA\ (lb/yr)}{Area\ Covered\ by\ WLA\ (ac)}$$

This calculation may be performed using the TMDL worksheet. Refer to the section in the worksheet titled “TMDL Waste Load Allocation (WLA) Calculations.” A screenshot of this portion of the TMDL worksheet is shown below and in Attachment 1 at the end of this report.

TMDL Waste Load Allocation (WLA) Calculations

Land Use for MassDOT's Directly Contributing Property	Commercial/Industrial	
WLA for Land Use	23	lb/yr
Area Covered By WLA	95	ac
Target Areal WLA	**0.24**	lb/ac/yr

The user must input values for the WLA specified in the TMDL report for the appropriate land use category (lb/yr) and the area covered by the WLA (ac). The worksheet will then return a value for the target areal WLA (lb/ac/yr). The user should also document the WLA location within the TMDL report in the fields provided in the worksheet.

Calculate the Target WLA for MassDOT

Next, calculate the relevant WLA for MassDOT. Delineate the pervious and impervious areas of MassDOT’s property that contribute stormwater directly to the subject waterbody. Data sources for this delineation should include construction or as-built plans, aerial imagery, 1:24,000 scale USGS topographic maps, the Impervious Surface datalayer downloaded from MassGIS, and other GIS datasets which may be of use. Confirm the delineated boundaries by performing a site visit. This should be incorporated into the site visit required under Step 2.

Enter the impervious and pervious area (in acres) in the section in the worksheet titled “Pre-BMP Loading Calculations for MassDOT’s Directly Contributing Property.” The worksheet will return values for total area (ac). A screenshot of this portion of the TMDL worksheet is shown below and in Attachment 1.

Pre-BMP Loading Calculations for MassDOT's Directly Contributing Property

Impervious Area	35.0 ac
Pervious Area	40.0 ac
Total Area	75.0 ac

Multiply the target areal WLA by the total area of MassDOT's property that contributes stormwater directly to the subject waterbody to obtain the target WLA for MassDOT's directly contributing property. This calculation should be performed as follows:

$$\begin{aligned} Target\ WLA\ for\ MassDOT\ (lb/yr) \\ &= Target\ Areal\ WLA\ (lb/ac/yr) \\ &\times Total\ Area\ of\ MassDOT's\ Directly\ Contributing\ Property\ (ac) \end{aligned}$$

This calculation may be performed using the TMDL worksheet. Refer to the section in the TMDL worksheet titled "Loading from MassDOT's Directly Contributing Property Relative to TMDL WLA." A screenshot of this portion of the TMDL worksheet is shown below and in Attachment 1.

Loading from MassDOT's Directly Contributing Property Relative to TMDL WLA

Total Estimated Load (calculated above)	80 lb/yr
→ WLA for MassDOT's Directly Contributing Property	18 lb/yr
MassDOT's Required Load Reduction	**62** lb/yr

The worksheet automatically returns a value for the Target WLA for MassDOT (identified as the "WLA for MassDOT's Directly Contributing Property" in the worksheet) when the user inputs values for Target Areal WLA and for MassDOT directly contributing impervious and pervious areas.

Step 3b. Calculate Loading from MassDOT Stormwater

This step is broken up into two parts as described below. First, calculate the estimated loading of the pollutant of concern from MassDOT's property to the subject waterbody. Then, quantify the pollutant mitigation provided by any existing BMPs.

Calculate MassDOT's Total Estimated Pre-BMP Pollutant Load

If the TMDL worksheet is used for the assessment, the user must first input the site name, subject impaired waterbody, and select the relevant pollutant from the drop-down list as shown below.

Site Name	Sample Water Body
Impaired Water	MA12345-Sample
Pollutant	TP

Use the delineation developed in Step 3a and the loading rates for pervious and impervious areas listed in Table 1 below to calculate MassDOT's total estimated pre-BMP pollutant load to the subject waterbody for the pollutant(s) of concern. This calculation should be performed as follows:

$$MassDOT's Total\ Estimated\ Pre-BMP\ Pollutant\ Load\ (lb/yr) = \\ Impervious\ Area\ (ac) \times Impervious\ Loading\ Rate\ ((lb/ac)\ /\ yr) + \\ Pervious\ Area\ (ac) \times Pervious\ Loading\ Rate\ (lb\ /\ ac\ /\ yr)$$

Table 1. Loading Rates for MassDOT's Pervious and Impervious Property

	Loading Rate (lb/acre/yr)	
Pollutant	Impervious	Pervious
Total Nitrogen (TN)[1]	13.7	2.5
Total Phosphorus (TP)[2]	1.6	0.6
Total Suspended Solids (TSS)[3]	1,000	420
Zinc (ZN)[3]	2.1	0.7

[1] Impervious loading rate derived from USGS document SIR 2009-5269, *Quality of stormwater runoff discharged from Massachusetts highways, 2005–07: U.S. Geological Survey Scientific Investigations Report 2009–5269* (Smith & Granato, 2010). Pervious loading rate derived from AECOM's *Lake Loading Response Model* (2011) assuming a value equal to the median N export coefficient for the "Open 2 (Meadow)" land use category.

[2] Impervious loading rate derived from USGS document SIR 2009-5269, *Quality of stormwater runoff discharged from Massachusetts highways, 2005–07: U.S. Geological Survey Scientific Investigations Report 2009–5269* (Smith & Granato, 2010). Pervious loading rate derived using the loading rate for "Hayland" provided in the USEPA document EPA 440/5-80-011, *Modeling phosphorus loading and Pond response under uncertainty: a manual and compilation of export coefficients* (Reckhow, 1980).

[3] Both impervious and pervious loading rates derived from the USEPA's *Stormwater Best Management Practices (BMP) Performance Analysis* (USEPA, 2010b). The impervious loading rate is equal to that provided for the "Commercial" land use category. The pervious loading rate is equal to that provided for the "High-Density Residential" land use category.

This calculation may be performed using the TMDL worksheet. Refer to the section in the TMDL worksheet titled "Pre-BMP Loading Calculations for MassDOT's Directly Contributing Property". A screenshot of this portion of the TMDL worksheet is shown below and in Attachment 1. The screenshot provided is for a phosphorus TMDL.

Pre-BMP Loading Calculations for MassDOT's Directly Contributing Property

Impervious Area	35.0	ac
Pervious Area	40.0	ac
Total Area	75.0	ac
Estimated Loading Rate for Impervious Area	1.6	lb/ac/yr
Estimated Loading Rate for Pervious Area	0.6	lb/ac/yr
Total Estimated Pre-BMP Loading Rate	**1.1**	**lb/ac/yr**
Total Estimated Pre-BMP Load	**80**	**lb/yr**

The worksheet will return values for the estimated loading rate for impervious area (lb/ac/yr), estimated loading rate for pervious area (lb/ac/yr), total estimated pre-BMP loading rate (lb/ac/yr), and total estimated pre-BMP load (lb/yr) in the section titled "Pre-BMP Loading Calculations for MassDOT's Directly Contributing Property".

Quantify the Treatment Provided by Existing BMPs

Perform a desktop analysis to identify any existing BMPs that may address direct stormwater discharges from MassDOT's property to the subject waterbody. This may be incorporated into the desktop analysis required under Step 2. Data sources for the desktop analysis should include construction or as-built plans, aerial imagery, 1:24,000 scale USGS topographic maps, and other GIS datasets which may be of use. Review design plans, as-built plans, permit applications, and any other available documentation for the following BMP-specific information:

- BMP dimensions (depth, width, length, etc.)
- Inlet structures (type, orifice size, invert elevations, etc.)
- Outlet structures (type, orifice size, invert elevations, etc.)
- Contributing watershed information (size, land cover, etc.)

Record this information for field-verification and use in calculations in subsequent parts of this step.

Identify the soils at each BMP location using the United States Department of Agriculture's Natural Resources Conservation Service (NRCS) SSURGO-Certified Soils data, which can be obtained from the MassGIS website. Use the information included in the data later to determine the soil type and associated Hydrologic Soil Group (HSG) at each location.

Delineate the impervious and pervious areas of MassDOT's property contributing stormwater runoff to each BMP using a combination of original construction plans or as-built plans, showing surface and subsurface conveyance system, aerial imagery, and USGS topographical maps.

Then verify the data collected during the desktop analysis with a site visit. Confirm the presence, type, function, and characteristics (dimensions, inlet and outlet structures, wet or dry conditions, and working condition) of existing BMPs. Verify the drainage patterns and watershed boundaries delineated during the desktop analysis and evaluate the watersheds of newly identified BMPs. This may be incorporated into the site visit required under Step 2.

Classify existing BMPs based on the guidance provided as Attachment 2 at the end of this report. The guidance also provides detailed explanation on the formulas used in the TMDL worksheet that drive the calculations shown below in this section.

To determine the pre-BMP pollutant load for the pollutant(s) of concern for each catchment area draining to a BMP, multiply the pervious and impervious watersheds to each BMP by the corresponding loading rates listed in Table 1. This calculation should be performed as follows:

$$\begin{aligned} &Pre - BMP\ Pollutant\ Load\ (lb/yr) \\ &\qquad = Impervious\ Area\ (ac) \times Impervious\ Loading\ Rate\ (lb/ac/yr) \\ &\qquad + Pervious\ Area\ (ac) \times Pervious\ Loading\ Rate\ (lb/ac/yr) \end{aligned}$$

Finally, to determine the pollutant load reduction provided by each existing BMP, assign a pollutant load reduction credit to each BMP using the percent reduction values specified in Table 2 included as Attachment 3 at the end of this report. Multiply the pre-BMP pollutant load for the catchment area draining to that BMP calculated above by the corresponding percent reduction values to obtain the load reduction provided by each existing BMP. This calculation should be performed as follows:

$$\begin{aligned} &BMP\ Pollutant\ Load\ Reduction\ (lb/yr) \\ &\qquad = Pre - BMP\ Pollutant\ Load\ (lb/yr) \times Percent\ Reduction\ \ (\%) \end{aligned}$$

This calculation may be performed using the TMDL worksheet. Refer to the section in the TMDL worksheet titled "Load Reduction Provided by MassDOT BMPs under Existing Conditions." A screenshot of this portion of the TMDL worksheet is shown below and is included as Attachment 1.

Load Reduction Provided by MassDOT BMPs under Existing Conditions

BMP Name	BMP Type	Soil Classification	**All BMPs** Directly Contributing Watershed IC Area (square feet)	**BMPs in Series** Remaining IC Area from Upstream BMP (square feet)	**All BMPs** Directly Contributing Watershed Pervious Area, Excluding BMP area (square feet)	**All Storage BMPs** BMP Storage Volume (cubic feet)	**All BMPs** BMP Surface Area (square feet)	**Extended Detention BMPs** Basin Head (calculate in feet using Ia or 0.5 inch storm, whichever greater)	**Extended Detention BMPs** Orifice Diameter (inches)	**Porous Pavement BMPs** Thickness of Filter Course (inches)	Pre-BMP Load (lb/yr)	
Sample Existing BMP 1	Infiltration Basin	D	60,000		5,000	6,000	6,000	1	2	48	2.36	92%
Sample Existing BMP 2	Vegetated Filter Strip	A - Loamy Sand 2.41 in/hr	18,000		1,500	-	2,000	-	-		0.71	78%
Ex -BMP-3	Extended Detention Basin	A - Loamy Sand 2.41 in/hr	35,000		5,000	4,000	5,000	1	1	-	1.42	12%
Ex -BMP-4	Porous Pavement	B - Loam 0.52 in/hr	40,000		-	-	40,000	-	-	18	2.02	69%
Ex -BMP-5												
Sample Series - Ex BMP 1a	Infiltration Basin	A - Loamy Sand 2.41 in/hr	20,000	-	2,000	1,500	800	-	-	-	0.77	97%
Sample Series - Ex BMP 1b	Infiltration Swale	A - Loamy Sand 2.41 in/hr	1,500	1,204	200	800	450	-	-	-	0.08	100%
Ex -BMP-8												
Ex -BMP-9												
Ex -BMP-10												
Ex -BMP-11												
Ex -BMP-12												

Populate this field with remaining IC area from upstream BMP1

Add Post-BMP Load from upstream BMP 1

For B
Depth
where

The user must input values for the following:

- BMP name
- BMP type
- soil classification of the BMP area
- directly contributing watershed from impervious area (sf)
- directly contributing watershed from pervious area (sf)
- BMP surface area (sf)

For storage BMPs, the user must also input the BMP storage volume (cf). For BMPs in series, the user must also input the impervious area remaining after pollutant load reduction credits from the upstream BMP have been applied (sf). For extended detention BMPs, the user must also input the total basin head (ft) and the outlet orifice diameter (in). And for porous pavement BMPs, the user must also input the thickness of the filter course (in).

The TMDL worksheet will return values for the following and is shown in the screenshot below:

- pre-BMP pollutant load (lb/yr)
- percent load reduction provided by the BMP
- total load reduction provided by the BMP (lb/yr)
- post-BMP pollutant load (lb/yr)
- depth of runoff treated by the BMP (in)
- resulting percent removal of contributing watershed impervious area
- effective impervious area reduction provided by the BMP (sf)

Pre-BMP Load (lb/yr)	Load Reduction %	Load Reduction (lbs/yr)	Post-BMP Load (lbs/yr)	TMDL Lookup Code	Depth of Runoff Treated by BMP (inches)	Drawdown Time (days, for Extended Detention Basin only)	Storage Credit (Extended Detention Basin only)	Drawdown Credit (Extended Detention Basin only)	Resulting % Removal of Contributing Watershed IC	Effective IC Area Reduction (square feet)	IC Look-up Code	BMP Input Notes (information sources, assumptions, measurements, treatment train, etc.)
2.36	92%	2.16	0.19	2087	1.1	N/A	N/A	N/A	76%	45,818	1087	
0.71	78%	0.56	0.15	2162	0.3	N/A	N/A	N/A	68%	12,157	1162	
1.42	12%	0.18	1.25	2052	1.2	4.41	37%	90%	33%	11,520	1052	
2.02	69%	1.39	0.63	2134	N/A	N/A	N/A	N/A	0%	-	1134	
0.77	97%	0.75	0.02	2082	0.9	N/A	N/A	N/A	94%	18,796	1082	
0.08	100%	0.08	0.00	2102	3.0	N/A	N/A	N/A	100%	1,500	1102	

For BMPs in series,
Depth Treated = BMP 2 Storage Volume / (BMP 2 IC Watershed+ BMP 2 Surface Area + BMP 1 IC Out);
where BMP1 IC Out = (BMP1 IC Watershed - BMP1 Effective IC Area Reduction)

For extended detention BMPs, the TMDL worksheet will also return values for drawdown time (days) and the corresponding storage and drawdown percent removal credits (these two values are multiplied together to obtain the total percent removal of contributing watershed impervious area).

If there are existing BMPs owned by MassDOT that receive stormwater from non-MassDOT property, calculate the pollutant load reduction provided by these BMPs using the same methodology as described above but include both MassDOT and non-MassDOT area in the watershed to determine the percent of pollutant removal the BMP provides. Then use this percentage removal to determine the pollutant reduction specifically for MassDOT property. These calculations can be performed using the TMDL worksheet. Refer to the section titled "Credit for Non-MassDOT Property Treated by Existing MassDOT BMPs."

The TMDL worksheet summarizes the pollutant load reduction provided by existing BMPs in the "MassDOT's Load Reduction Summary" section of the worksheet shown in the screenshot below and in Attachment 1. Note that this section of the TMDL worksheet also includes pollutant load reductions provided by recommended BMPs, which will be discussed in Step 5.

MassDOT's Load Reduction Summary

Reduction Provided by Existing BMPs	4.75	lb/yr
Credit for Non-MassDOT Property Treated by MassDOT BMPs	3.62	lb/yr
Reduction Provided by Proposed BMPs	3.62	lb/yr
Reduction provided by Existing and Proposed BMPs	**11.98**	**lb/yr**

Step 3c. Assess WLA Relative to Loading from MassDOT

This step analyzes the results from Steps 3a and 3b to determine if existing conditions provide enough pollutant treatment or if more pollutant treatment is necessary to meet the target WLA.

First, determine MassDOT's required load reduction by subtracting the target WLA for MassDOT calculated in Step 3a from MassDOT's total estimated pre-BMP pollutant load calculated in the first part of Step 3b. This calculation should be performed as follows:

$$\begin{aligned} &Required\ Load\ Reduction\ (lb/yr) \\ &\qquad = Total\ Estimated\ Pre - BMP\ Pollutant\ Load\ (lb/yr) - Target\ WLA\ (lb/yr) \end{aligned}$$

The worksheet automatically returns this calculation when Steps 3a and 3b are performed. A screenshot of this portion of the TMDL worksheet is shown below and as Attachment 1.

Loading from MassDOT's Directly Contributing Property Relative to TMDL WLA

Total Estimated Load (calculated above)	80	lb/yr
WLA for MassDOT's Directly Contributing Property	18	lb/yr
MassDOT's Required Load Reduction	**62**	**lb/yr**

Next, apply the treatment provided by MassDOT's existing BMPs, quantified in the second part of Step 3b, to the required load reduction. If MassDOT's load reduction provided by existing BMPs is more than or equal to the required load reduction, then MassDOT is in compliance with the TMDL for its discharges to the subject waterbody. When this is the case, proceed to Step 6.

If MassDOT's load reduction provided by existing BMPs is less than the required load reduction, then opportunities for reducing the pollutant load should be considered.

Refer to the section in the TMDL worksheet titled "Loading from MassDOT's Directly Contributing Property Relative to TMDL WLA" for assistance in this determination. A screenshot of this portion of the TMDL worksheet is shown below and as Attachment 1.

Loading from MassDOT's Directly Contributing Property Relative to TMDL WLA

Total Estimated Load (calculated above)	80	lb/yr
WLA for MassDOT's Directly Contributing Property	18	lb/yr
MassDOT's Required Load Reduction	**62**	**lb/yr**
MassDOT's Load Reduction Summary		
Reduction Provided by Existing BMPs	4.75	lb/yr
Credit for Non-MassDOT Property Treated by MassDOT BMPs	3.62	lb/yr
Reduction Provided by Proposed BMPs	3.62	lb/yr
Reduction provided by Existing and Proposed BMPs	**11.98**	**lb/yr**

Since calculations for these items are based upon previous calculations, no input is required from the user.

To determine the target reduction for recommended BMPs, subtract the load reduction provided by existing BMPs from the required load reduction. This value is the remaining pollutant load that recommended BMPs should aim to treat. Proceed to Step 5.

Step 4: Consider Control Measures for Pollutants of Concern Listed in TMDL Reports That Do Not Contain WLAs

For waters with TMDLs where no WLA is specified, MassDOT relies principally on the BMP recommendations or performance requirements for highway dischargers listed in the TMDL report (or in other performance agreements or memoranda of understanding) to determine whether the control measures currently in place are adequate to control the relevant pollutant(s) of concern.

If the subject waterbody is one of the waters with TMDLs where no WLA is specified, review the TMDL report to determine whether existing stormwater control measures are adequate to control the relevant pollutant(s) of concern listed in the TMDL report and to assess the need for additional control measures. Identify existing BMPs. Then compare existing BMPs to the BMP recommendations for roadway and/or highway dischargers listed in the TMDL report. Recommend additional BMPs as outlined in Step 5 to satisfy the requirements of the TMDL and document the assessment and recommendations for BMPs as outlined in Step 6.

Step 5. Select, Design and Implement BMPs

If Steps 3 and 4 determine that additional BMPs may be necessary to meet MassDOT's target WLA, develop recommendations for additional BMPs to the maximum extent practicable and implement the BMP recommendations as described below.

First, determine whether it is practicable to construct additional BMPs to address runoff from MassDOT's directly contributing property to the subject waterbody. There are a variety of data sources that are useful for this purpose, including aerial photography, construction or as-built plans of the existing roadway and stormwater system, SSURGO-certified soils data available through MassGIS, etc. In some instances it may not be practicable to construct any additional BMPs due to site constraints such as lack of available space, presence of underground utilities, presence of incompatible soils, presence of wetlands, etc. When this is the case, proceed to Step 6 and thoroughly document all site constraints hindering the construction of additional BMPs.

If the installation of additional BMPs seems practicable, identify locations where BMPs may be constructed. Select BMPs that may be retrofitted into the existing roadway and stormwater infrastructure but will also provide a significant reduction in pollutant loading to the subject waterbody. Consider the following while selecting additional BMPs:

- The estimated pollutant reduction efficiencies for structural BMPs based on the percent reductions assigned to each in the TMDL worksheet;
- BMP recommendations or performance requirements for highway dischargers listed in the TMDL report (or in other performance agreements or memoranda of understanding);
- The specific potential sources of certain pollutants;
- Existing stormwater and highway infrastructure;
- The nature and extent of site constraints that may limit the scope of BMP construction;
- Any existing literature regarding appropriate BMPs for the pollutant(s) at issue, including any guidance issued by the EPA or MassDEP; and
- The overall magnitude of MassDOT's stormwater discharges and the degree to which its estimated pollutant loads deviate from the WLAs.

Quantify the pollutant reductions provided by the recommended BMPs in the same manner as described for existing BMPs in Step 3b: "Quantify the Treatment Provided by Existing BMPs." First calculate an existing pollutant load from the catchment area that will drain to the recommended BMP, then assign a pollutant load reduction credit to each recommended BMP using the percent reduction values specified in Table 2, and finally multiply the watershed pollutant loads by the corresponding percent reduction values to obtain the pollutant load reduction provided by each recommended BMP.

These calculations can be performed using the TMDL worksheet. Figure 3, included as Attachment 1 shows a screenshot of this portion of the TMDL worksheet for existing BMPs, but it is set up exactly the same for recommended BMPs. The user must input the same type of values as described above for existing BMPs that receive MassDOT stormwater runoff, and the TMDL worksheet will return the same type of values as described above.

Sum the pollutant load reductions provided by the recommended BMPs and compare to MassDOT's required load reduction calculated in Step 3c. As described in Step 3b, the TMDL worksheet summarizes the pollutant load reductions provided by existing and recommended BMPs in the "MassDOT's Load Reduction Summary" section of the worksheet shown in Figure 2. If possible, the pollutant load reduction provided by the existing and recommended BMPs should equal or exceed MassDOT's required load reduction. Considering site-specific limitations, this may not be possible. Recommend additional BMPs only to the maximum extent practicable. Document any site constraints or other limitations preventing MassDOT from meeting the load reduction required to remain consistent with the WLA for the pollutant(s) specified in the TMDL.

After completing Step 5, work with MassDOT to permit and develop construction documents for the recommended BMPs. Proceed to Step 6 to document the results of the assessment.

Step 6. Document Results of Assessment and Progress on Implementation

As described in BMP 7U of MassDOT's SWMP (MassHighway, 2008), MassDOT will include in its reports to the EPA updates on its progress in assessing and mitigating 303(d) impaired waters, including waters with TMDLs.

For waters with TMDLs reviewed using the above methodology, document the results of the assessment in a standardized format. This should include the following:

- the name and segment numbder of the water body with a TMDL
- the underlying pollutant(s) of concern covered by the TMDL
- the applicable WLA
- the estimated load from MassDOT
- any BMP recommendations, performance requirements, or other Performance Agreement or Memorandum of Understanding applicable to the TMDL
- a summary of MassDOT's assessment and/or mitigation plan
- a report on the status of any planned implementation of additional control measures or BMPs

Any relevant calculations, documentation, data sources for the assessment, etc. should be compiled and kept on file. MassDOT's reports to the EPA should clearly document the basis of any conclusions reached as a result of the assessment regarding the need or lack of need for BMPs at specific sites.

Summary

As part of its NPDES MS4 stormwater permit, MassDOT is required to address the discharge of pollutants from its stormwater systems to impaired waterbodies identified in MassDEP's *Final Massachusetts Integrated List of Waters*. MassDOT's SWMP (MassHighway, 2008) identifies several methods for addressing its stormwater discharges to impaired waterbodies depending on whether or not they are covered by a TMDL.

To assess impaired waterbodies that are covered by a TMDL, MassDOT uses the Waste Load Allocation (WLA) as a target for the loading from MassDOT urban areas. MassDOT then calculates the pollutant loading from its property and the pollutant load reduction provided by any existing BMPs and compares the resulting values to the WLA identified in the TMDL report. In cases where MassDOT's pollutant loading exceeds the WLA, MassDOT looks for opportunities to implement additional BMPs. In cases where no WLA is specified in the TMDL report, MassDOT considers whether additional measures are appropriate to be consistent with any BMP recommendations in the TMDL. This method allows MassDOT to identify locations where they are already meeting TMDLs for impaired waters and locations where additional BMPs should be considered.

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Attachment 1

TMDL Worksheet Screenshot

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Site Information

Site Name	Sample Water Body		
Impaired Water	MA12345-Sample		
Pollutant	TP	------>>>> Select Pollutant	

Input
Calculated (TMDL Load Calcs)
Calculated (IC Mitigation Calcs)

NOTE: This spreadsheet has been designed for units consisting of pounds (lb), acres (ac), and years (yr). For all other units, please convert.

1 acre = 43,560 square feet
1 hectare = 2.47105381 acres
1 kilogram = 2.20462262 pounds

Pre-BMP Loading Calculations for MassDOT's Directly Contributing Property

Impervious Area	35.0	ac	
Pervious Area	40.0	ac	
Total Area	75.0	ac	
Estimated Loading Rate for Impervious Area	1.6	lb/ac/yr	------>>>> This field populated based on 'Pollutant' selected above
Estimated Loading Rate for Pervious Area	0.6	lb/ac/yr	------>>>> This field populated based on 'Pollutant' selected above
Total Estimated Pre-BMP Loading Rate	**1.1**	**lb/ac/yr**	
Total Estimated Pre-BMP Load	**80**	**lb/yr**	

TMDL Waste Load Allocation (WLA) Calculations

			TMDL Page No.	TMDL Notes
Land Use for MassDOT's Directly Contributing Property	Commercial/Industrial		62	
WLA for Land Use	23	lb/yr	62	The no's for WLA on p. 62 differ from the model data in the Appendix.
Area Covered By WLA	95	ac	62	The no's for WLA on p. 62 differ from the model data in the Appendix.
Target Areal WLA	**0.24**	**lb/ac/yr**		

Loading from MassDOT's Directly Contributing Property Relative to TMDL WLA

Total Estimated Load (calculated above)	80	lb/yr
WLA for MassDOT's Directly Contributing Property	18	lb/yr
MassDOT's Required Load Reduction	**62**	**lb/yr**
<u>MassDOT's Load Reduction Summary</u>		
Reduction Provided by Existing BMPs	4.75	lb/yr
Credit for Non-MassDOT Property Treated by MassDOT BMPs	3.62	lb/yr
Reduction Provided by Proposed BMPs	3.62	lb/yr
Reduction provided by Existing and Proposed BMPs	**11.98**	**lb/yr**

Figure 2: Screenshot from TMDL Worksheet showing MassDOT's Pollutant Loading Calculations

Load Reduction Provided by MassDOT BMPs under Existing Conditions

BMP Name	BMP Type	Soil Classification	All BMPs Directly Contributing Watershed IC Area (square feet)	BMPs in Series Remaining IC Area from Upstream BMP (square feet)	All BMPs Directly Contributing Watershed Pervious Area, Excluding BMP area (square feet)	All Storage BMPs BMP Storage Volume (cubic feet)	All BMPs BMP Surface Area (square feet)	Extended Detention BMPs Basin Head (calculate in feet using Ia or 0.5 inch storm, whichever greater)	Extended Detention BMPs Orifice Diameter (inches)	Porous Pavement BMPs Thickness of Filter Course (inches)	Pre-BMP Load (lb/yr)	
Sample Existing BMP 1	Infiltration Basin	D	60,000		5,000	6,000	6,000	1	2	48	2.36	92%
Sample Existing BMP 2	Vegetated Filter Strip	A - Loamy Sand 2.41 in/hr	18,000		1,500	-	2,000	-	-		0.71	78%
Ex -BMP-3	Extended Detention Basin	A - Loamy Sand 2.41 in/hr	35,000		5,000	4,000	5,000	1	1	-	1.42	12%
Ex -BMP-4	Porous Pavement	B - Loam 0.52 in/hr	40,000		-	-	40,000	-	-	18	2.02	69%
Ex -BMP-5												
Sample Series - Ex BMP 1a	Infiltration Basin	A - Loamy Sand 2.41 in/hr	20,000	-	2,000	1,500	800	-	-	-	0.77	97%
Sample Series - Ex BMP 1b	Infiltration Swale	A - Loamy Sand 2.41 in/hr	1,500	1,204	200	800	450	-	-	-	0.08	100%
Ex -BMP-8												
Ex -BMP-9												
Ex -BMP-10												
Ex -BMP-11												

Populate this field with remaining IC area from upstream BMP1

Add Post-BMP Load from upstream BMP 1

Pre-BMP Load (lb/yr)	Load Reduction %	Load Reduction (lbs/yr)	Post-BMP Load (lbs/yr)	TMDL Lookup Code	Depth of Runoff Treated by BMP (inches)	Drawdown Time (days, for Extended Detention Basin only)	Storage Credit (Extended Detention Basin only)	Drawdown Credit (Extended Detention Basin only)	Resulting % Removal of Contributing Watershed IC	Effective IC Area Reduction (square feet)	IC Look-up Code	BMP Input Notes (information sources, assumptions, measurements, treatment train, etc.)
2.36	92%	2.16	0.19	2087	1.1	N/A	N/A	N/A	76%	45,818	1087	
0.71	78%	0.56	0.15	2162	0.3	N/A	N/A	N/A	68%	12,157	1162	
1.42	12%	0.18	1.25	2052	1.2	4.41	37%	90%	33%	11,520	1052	
2.02	69%	1.39	0.63	2134	N/A	N/A	N/A	N/A	0%	-	1134	
0.77	97%	0.75	0.02	2082	0.9	N/A	N/A	N/A	94%	18,796	1082	
0.08	100%	0.08	0.00	2102	3.0	N/A	N/A	N/A	100%	1,500	1102	

For BMPs in series,
Depth Treated = BMP 2 Storage Volume / (BMP 2 IC Watershed+ BMP 2 Surface Area + BMP 1 IC Out);
where BMP1 IC Out = (BMP1 IC Watershed - BMP1 Effective IC Area Reduction)

Figure 3: Screenshot from TMDL Worksheet Showing Pollutant Load Reduction Calculations for Existing BMPs

Attachment 2

BMP Classification and Pollutant Reduction Methodology

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Characterizing Existing BMPs

Using the data obtained through the desktop analysis and field verification, characterize existing BMPs according to approximate type, approximate volume of stormwater treated by the BMP, and soil infiltration rate.

MassDOT classifies infiltration basins, infiltration swales, and vegetated filter strips as infiltration BMPs. Infiltration BMPs are designed to infiltrate runoff and therefore mimic the ability of undeveloped vegetated soils to absorb stormwater runoff. This serves to reduce runoff volumes and rates, remove pollutants as water is absorbed in the soils, and restore base flows to the receiving water body. Infiltration BMPs provide the highest pollutant load reduction credits for TN, TP, TSS, and Zn. Therefore, these BMPs are prioritized for use by MassDOT to gain the most pollutant treatment possible.

Additional BMPs that provide TP, TN, TSS, and Zn removal that the TMDL Method supports include: bioretention area / rain gardens; constructed stormwater wetlands; extended detention basins; gravel wetlands; infiltration structures (i.e. trenches or underground stormwater galleys); porous pavement; and wet detention basins. In addition to infiltration BMPs, the extended detention basin is a common BMP that MassDOT implements in the field.

Other BMPs that only provide TSS removal that the TMDL Method supports include: deep sump catch basin; grass channel; oil grit separator; outlet sediment trap (plunge pool); and street sweeping.

Detailed information on infiltration BMPs and extended detention basins is provided below for assistance in classification because they are commonly implemented on MassDOT roadways. For the remaining BMPs, see Table 2 in Attachment 2 for pollutant reduction rates and their data sources. The *Massachusetts Stormwater Handbook* (MassDEP, 2008) and USEPA's *Stormwater Best Management Practices (BMP) Performance Analysis* (USEPA, 2010) should be used for assistance in classification for the remaining BMPs.

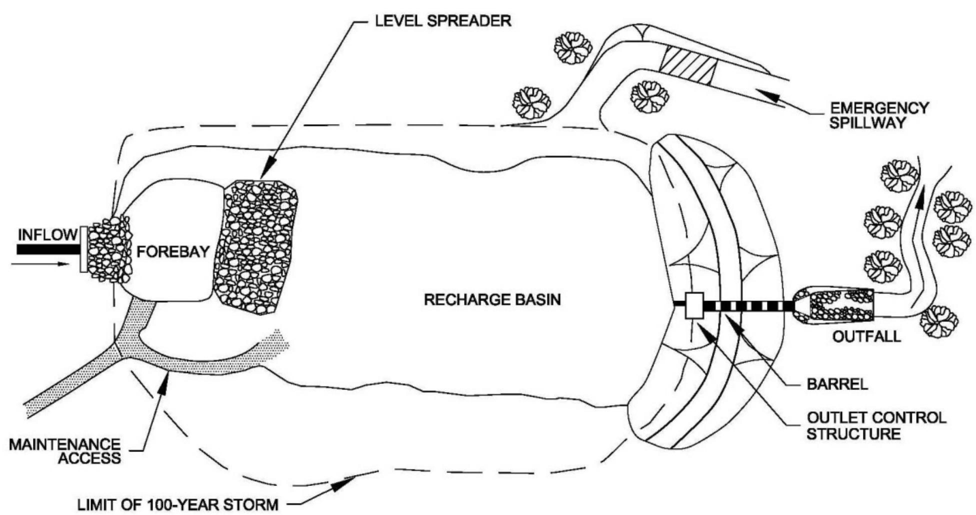
<u>Infiltration Basin:</u> The infiltration basin is a pond designed to intercept runoff and provide both retention and infiltration. Infiltration basins are constructed in permeable soils and should be dry when observed in the field unless recent rain has occurred. Infiltration basins should not have a low level outlet. The storage volume provided by an infiltration basin is calculated as the volume between the floor of the basin and its lowermost outlet. See Figure 4.

<u>Infiltration Swale:</u> The infiltration swale is a vegetated, flat or gently sloped channel designed to provide retention and infiltration within cells defined by impermeable check dams or other structures. Infiltration swales should also be constructed in permeable soils. The storage volume provided by an infiltration swale consists of the volume stored behind the check dam within each cell, therefore conveyance swales with no outlet control or check dams would not be characterized as infiltration swales. See Figure 5.

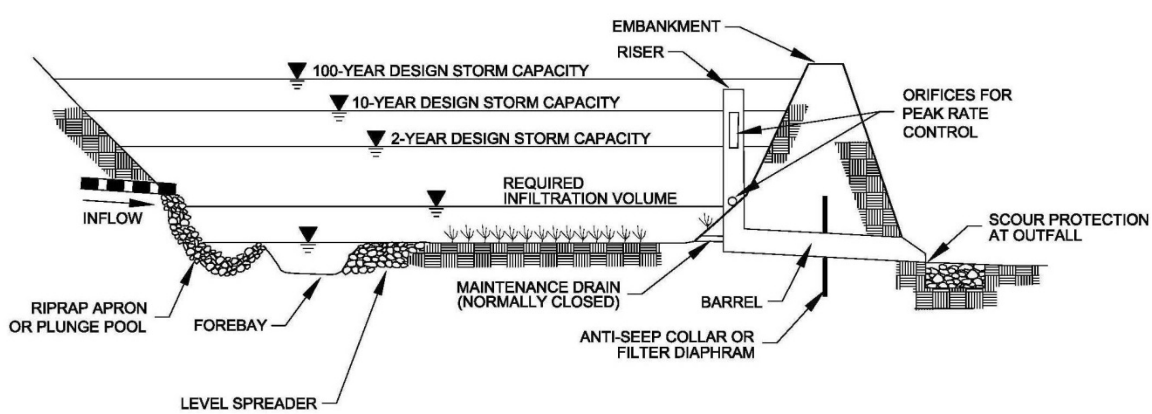
<u>Vegetated Filter Strip:</u> The vegetated filter strip is a flat or gently sloping vegetated area that receives sheet flow from impervious cover. A vegetated filter strip should be between 25 and 75 feet in length (MassDEP Storm Water Handbook, 2008), and should be as wide as the area contributing to the filter strip. See Figure 6.

<u>Extended Detention Basin:</u> The extended detention basin is a wet or dry pond that intercepts and stores runoff and slowly releases it over an extended period. Extended detention basins and their outlet control structure should be sized to store a relatively large volume of runoff and draw down over a period of several days to mimic pre-development contribution to base flows to a receiving water body. An extended detention basin should include a small low-level outlet that discharges runoff at a controlled rate. Observe the level of water in the pond above the lowest outlet. This level

should be appropriate relative to the magnitude of recent rain events and time since the last event. For example, if it has not rained for a week or more, the pond level should be near the low level outlet and conversely if significant rain occurred in the past 24-hours, the pond level should be close to the overflow outlet. The extended detention storage volume provided by this type of basin consists of the volume between the low level outlet of the basin and its overflow, or flood controls outlet. See Figure 7.

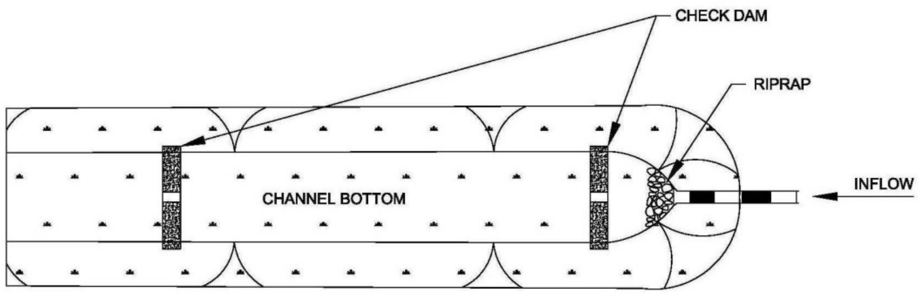


Infiltration Basin Plan View

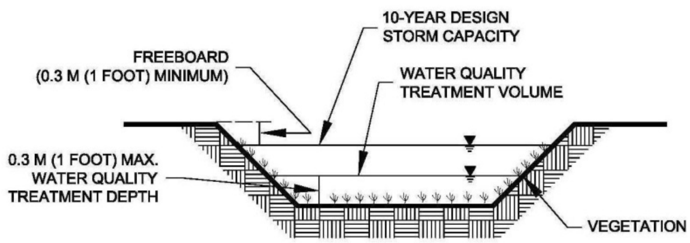


Infiltration Basin Profile View

Figure 4 Typical Infiltration Basin, from MassHighway Storm Water Handbook 2003



Swale Plan View



Swale Profile View

Figure 5 Typical Water Quality Swale with Check Dam, from MassHighway Storm Water Handbook 2003

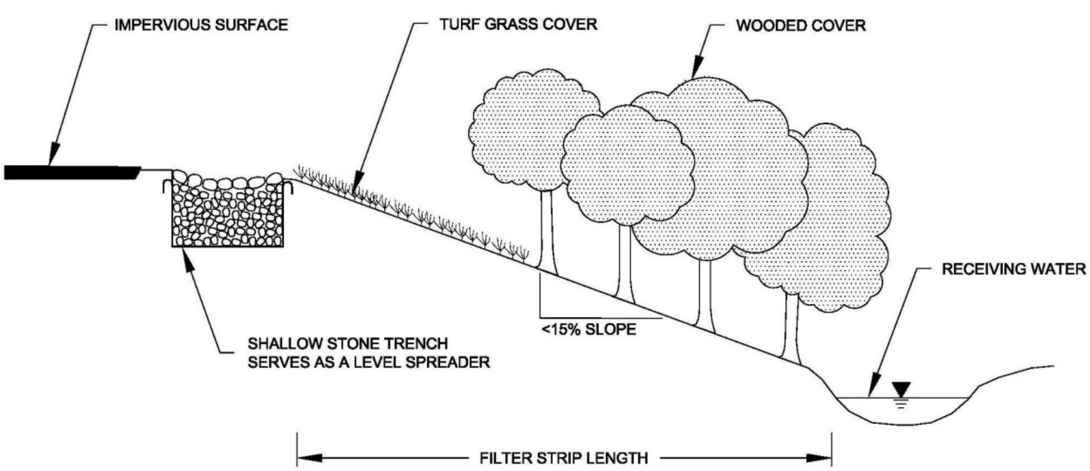
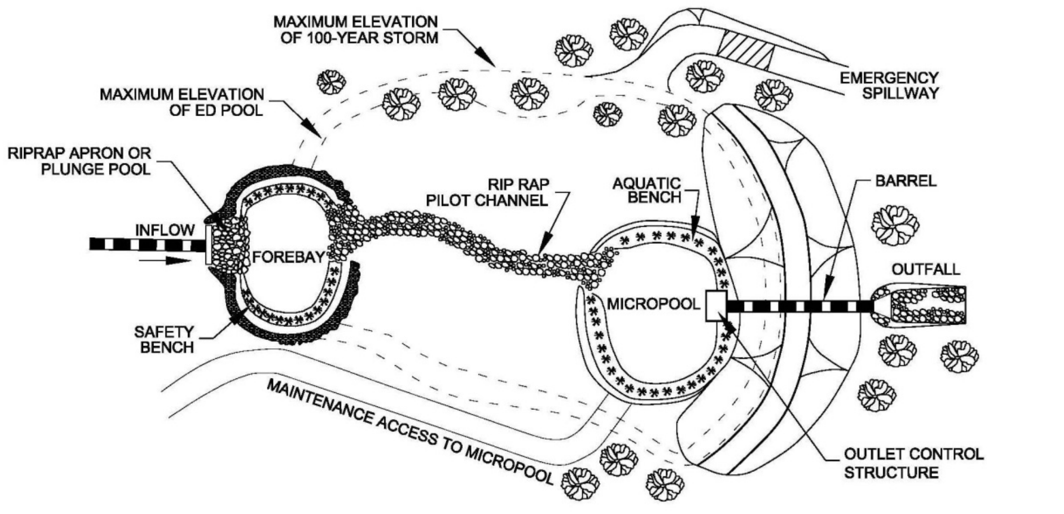
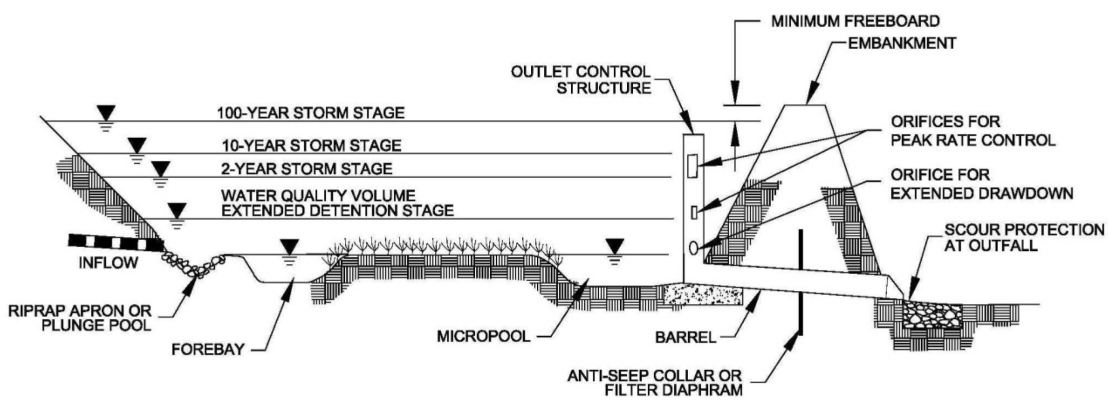


Figure 6 Typical Filter Strip, from MassHighway Storm Water Handbook 2003



Extended Detention Plan View



Extended Detention Profile View

Figure 7 Typical Extended Detention, from MassHighway Storm Water Handbook 2003

Using the above descriptions, the *Massachusetts Stormwater Handbook,* and USEPA's *Stormwater Best Management Practices (BMP) Performance Analysis*, classify each existing BMP.

Calculating Depths of Stormwater Treated for BMPs:

For all BMPs except the extended detention basin, calculate the depth in inches of stormwater runoff treated by each BMP. The depth of stormwater runoff treated will be used to evaluate the BMP's effectiveness of mitigation runoff, and therefore, pollutant load reduction. For BMPs that only remove TSS, this approach differs slightly and will be discussed later. For storage BMPs, perform this calculation by dividing the total storage volume of the BMP by the watershed draining to the BMP.

For a BMP with a storage volume of 1,000 cubic feet and 1.5 acres of contributing area, this calculation is as follows:

$$\frac{1{,}000\ cubic\ feet}{1.5\ acres\ \times\left(\frac{43{,}560\ square\ feet}{1\ acre}\right)}\times\frac{12\ inches}{1\ foot}=0.184\ inches$$

For non-storage BMPs, such as the vegetated filter strip, the calculation is different.

For vegetated filter strips, the depth of stormwater runoff treated is performed by first calculating the initial abstraction (Ia) of the filter strip using the equation below. Estimate the CN using a land cover of open space in good condition (grass cover >75%) for the applicable hydrologic soil group. These CN values from TR-55 are listed in the table below.

Hydrologic Soil Properties Classified by Soil Texture

Texture Class	NRCS Hydrologic Soil Group (HSG)	Infiltration Rate (inches/hour)	CN (Open Space, Good Condition)
Sand	A	8.27	39
Loamy Sand	A	2.41	39
Sandy Loam	B	1.02	61
Loam	B	0.52	61
Silt Loam	C	0.27	74
Sandy Clay Loam	C	0.17	74
Clay Loam	D	0.09	80
Silty Clay Loam	D	0.06	80
Sandy Clay	D	0.05	80
Silty Clay	D	0.04	80
Clay	D	0.02	80

$$Ia=0.2\times\left(\frac{1000}{CN}-10\right)$$

The Ia is the depth of runoff that is initially absorbed by the filter strip. Then multiply the Ia by the area of the filter strip to calculate the volume of water absorbed or treated by the filter strip:

$$Volume\ Treated\ by\ Filter\ Strip=Ia\times Area\ of\ Filter\ Strip$$

Divide this volume by the total contributing area (area of the filter strip plus the impervious watershed draining to the BMP) to obtain the depth of stormwater treated by the filter strip, as follows:

$$Depth\ Treated\ by\ Filter\ Strip = \left(\frac{Volume\ Treated\ by\ Filter\ Strip}{Impervious\ Watershed\ Area + Area\ of\ Filter\ Strip}\right)$$

For a filter strip that is 75 feet long and 20 feet wide with 1.5 acres of contributing impervious watershed area and Hydrologic Soils Group (HSG) A soils, this calculation as follows:

$$Ia = 0.2 \times \left(\frac{1000}{39} - 10\right) = 3.13\ inches$$

$$Volume\ Treated\ by\ Filter\ Strip = 3.13\ inches \times 75\ feet \times 20\ feet$$
$$= 391\ cubic\ feet$$

$$Depth\ Treated\ by\ Filter\ Strip = \left(\frac{391\ cubic\ feet}{65{,}340\ square\ feet + (75\ feet \times 20\ feet)}\right)$$
$$= 0.07\ inches$$

After calculating the depth of stormwater in inches treated by each existing BMP, assign an infiltration rate to each BMP using the data summarized in the above table. To be conservative, unless specific soil evaluation data is available, use the slowest infiltration rate (least infiltration ability) for a given HSG. In areas where several HSGs are present within an existing BMP, use the most conservative (slowest) infiltration rate among those present. If no soil information is available, use HSG C.

Assigning Pollutant Load Reduction Credit to BMPs

For all BMPs except the extended detention basin, assign a percentage of pollutant removal to each BMP based on type, treatment depth, and soil infiltration rate using the removal efficiencies summarized in Table 2, included as Attachment 3. Calculate intermediate values using linear interpolation.

Removal efficiencies for the majority of BMPs are derived from results in the study titled *Storm Water Best Management Practices (BMP) Performance Analysis* (USEPA, 2010b). This study analyzed the long-term ability of several BMPs, to treat for pollutants characteristic of stormwater runoff, including Total Phosphorus (TP), Total Suspended Solids (TSS), and Zinc (Zn). Additionally, the report analyzed the long-term ability of infiltration systems to reduce runoff volumes. The *Massachusetts Stormwater Handbook (*MassDEP, 2008) and the *MassHighway Storm Water Handbook* (MassHighway, 2004) were used to determine removal efficiencies for BMPs where there was no data in the USEPA document. See Table 2 for the source used for each pollutant removal for each BMP.

The range of removal efficiencies summarized in Table 2 is the same for each infiltration BMP (infiltration basin, infiltration swale, or vegetated filter strip) because each acts as an infiltration basin in that they store and infiltrate stormwater and are a direct function of the depth of runoff treated. Calculating the depth of runoff treated for each existing BMP, as outlined above, will provide the appropriate credit regardless of whether the BMP is a storage BMP or a non-storage BMP.

For BMPs that only remove TSS (deep sump catch basins, grass channels, oil grit separators, outlet sediment traps, and street sweeping), the calculation to determine depth of runoff treated by

BMP is necessary for the TMDL worksheet to function appropriately. However, removal efficiency of TSS is the same no matter the depth of runoff treated.

Assigning Pollutant Load Reduction Credit to Extended Detention BMPs

MassDOT based its method for assigning mitigation credit to extended detention basins on guidance provided in USEPA's Storm Water TMDL Implementation Support Manual (ENSR, 2006). The following passage from the manual describes criteria for designing extended detention basins:

"Extended detention BMPs do not exfiltrate runoff but instead slowly release stored runoff over a period of time (days). Detention BMP should be sized to store the full difference between existing and pre-existing 2-inch storm runoff volume. The detention BMP outlet should be designed to draw the full mitigation volume down over a period of 7 to 10 days and to draw down the initial abstraction mitigation volume over a period of 3 to 4 days. These extended drawdown periods are intended to maximize attenuation of flows while allowing for recovery of storage volume for future events."

MassDOT has adapted this guidance to develop a method for estimating pollutant removal for existing and proposed extended detention BMPs. The guidance is clear that extended detention basins that store a large volume of water and release it over several days provide significant pollutant removal. Storing and releasing runoff very slowly after rain events can achieve similar benefits to infiltration-type BMPs, including:

- Control of peak runoff rates
- Replenishment of base flow via extended surface discharges
- Preventing increased frequency of bank full flows
- Minimizing runoff volume impacts
- Water quality enhancement through significantly extended detention times

For extended detention basins, assign pollutant load removal efficiency based on the method outlined below. This method uses two parameters to assess the percentage of pollutant removal to be applied to each extended detention basin: storage capacity (Storage Credit) and drawdown time (Drawdown Credit) with each parameter assigned a percentage of the optimal (100%) credit. Multiplying two percentages together to provides an overall extended detention pollutant removal credit:

Extended Detention Mitigation Credit = Storage Credit X Drawdown Credit

These factors represent the extended detention BMP's ability to store significant volumes of runoff and then release it slowly over several days. Basins that both store large volumes and release them over several days receive high relative credits, while basins that store small volumes or release stored volumes quickly would receive little or no mitigation credit.

Storage Credit

Using the TMDL Implementation Support Manual (2006) as the standard, basins that can store the full 2-inch storm volume receive full (100%) Storage Credit. The 2-inch storm in Massachusetts represents 98 to 99% of all storm events, recurring every one to two years. This recurrence interval is also associated with bank full/channel forming flows. Basins that can store a 2-inch storm have the means to mitigate increased runoff rates, increased bank full discharges, and decreased base flows. Also, while these basins do not reduce total runoff volumes, spreading outflows over several days provides a very similar effect. MassDOT considered two other critical storms to establish Storage Credits for basins that store less than the 2-inch storms:

- Initial abstraction storm: equal to the initial abstraction depth for pre-development conditions, the storm for which no runoff would result under natural conditions. Basins that store this storm provide the ability to mitigate many hydrologic impacts (increased runoff rates, reduced base flow, increased runoff volume), but not for all storms. The initial abstraction storm (0.5 to 1.5 inches, depending on soils) represents 75 to 95% of all storms. MassDOT established a relatively conservative Storage Credit of 50% for basins able to store this volume.
- 0.5-inch storm: The 0.5-inch storm represents approximately 75% of rainfall events in Massachusetts. Basins that store this storm still provide the ability to mitigate many hydrologic impacts (increased runoff rates, reduced base flow, increased runoff volume), but for a smaller fraction of storms. MassDOT established a relatively conservative Storage Credit of 25% for basins able to store this volume.

To determine the Storage Credit portion of the Extended Detention Mitigation Credit, first calculate the pre-development initial abstraction (Ia) runoff depth for the total area of impervious watershed contributing to the subject BMP. Estimate the pre-development curve number (CN) using a land cover of woods in good condition for the applicable hydrologic soil group (HSG). Use the following equation or Table 2 for this calculation:

$$Ia = 0.2 \times \left(\frac{1000}{CN} - 10\right)$$

Table 2 Initial Abstraction for Woods in Good Condition

Hydrologic Soil Group	CN (woods, good condition)	Ia (inches)
A	30	4.25
B	55	1.45
C	70	0.78
D	77	0.53

Next multiply the Ia by the surface area of impervious watershed contributing to the subject BMP to obtain the pre-development Ia volume. This represents the volume of water normally infiltrated into the subsurface before creating runoff under pre-development conditions. Calculate the basin's detention volume and assign the Storage Credit based on the ability of the BMP to hold the volumes specified in Table 3. Take no Storage Credit for basins that store less than 0.5-inch storm volume.

Table 3 Storage Credit for Extended Detention Basins

Storage Volume of Impervious Area	Storage Credit
< 0.5 inch	0%
0.5 inch	25%
Ia depth	50%
2 inch	100%

Drawdown Credit

Based on the TMDL Implementation Support Manual (2006) as the standard, basins that release the Ia storm over 4 days receive full (100%) drawdown credit. Given an average inter-storm interval of 3 days (see Table 5), a 4 day drawdown time is optimal for maximizing detention times but still providing sufficient storage for future storms. Longer times could result in too frequent overtopping, therefore not providing pollutant loading reduction, unless very large detention volumes are provided. Shorter drawdown times would increase periods of no outflow and diminish the benefit of spreading flows over long periods. MassDOT established 1 and 8 day as respective minimum and maximum drawdown times to provide some extended detention benefit, assigning these a storage credit of 25% and then linearly interpolating for other drawdown times between 1 and 4 and 4 and 7 days.

Table 5 Average Storm Information for Massachusetts

Rainfall Depth (inches)	0.01	0.1	0.5	1.0	2.0
Average annual occurrences	122	80	31	11	2
Avg. annual interstorm interval (days)	3.0	4.6	12	32	187
Percentage of storms this depth or smaller (%)	-	35	75	91	98

Source: http://www.nrcc.cornell.edu/page_nowdata.html, 1971-2000 for Massachusetts rainfall stations, Boston Area, Amherst, Ashburnham, Birch Hill Dam, Nantucket, Natick, Newburyport, Northbridge, Sunderland, Tully Lake, and Walpole

For the Drawdown Credit, first calculate the volume of stormwater produced by an Ia storm for the area of impervious watershed draining to the subject extended detention basin. For basins that store less than the Ia volume (calculated for the Storage Credit), use the 0.5-inch storm. Then use the extended detention drawdown plots included in Appendix A to calculate the drawdown time for this volume. When using the extended detention drawdown plots, calculate head by dividing the drawdown volume by the estimated BMP surface area. Assign Drawdown Credit based on the calculated drawdown specified using the credits values listed in Table 6.

Table 6. Drawdown Credit for Extended Detention Basins

Drawdown Time* (days)	Drawdown Credit
< 1	0%
1	25%
2	50%
3	75%
4	100%
5	75%
6	50%
7	25%
>7	0%

** Drawdown time for smaller of Ia storm or largest storm basin holds.*

Calculate Extended Detention Pollutant Load Reduction Credit

Finally, multiply Storage Credit and the Drawdown Credit together to obtain the total pollutant load reduction credit for the subject extended detention basin. Basins that store relatively large volumes and draw these down over several days are credited well, while basins that only do well in one aspect will receive little or no credit. For example, a basin that stores the Ia volume and draws it down over 4 days would receive a mitigation credit of (50% X 100% =) 50% whereas a basin that stores 0.5-inches and draws down in 1 day would receive a credit of (25%X 25% =) 6%.

Quantifying Pollutant Load Reduction Provided by Existing BMPs

After assigning percentages of pollutant load reduction to each BMP, calculate the amount of reduction provided by each. For an infiltration basin treating 0.1 inch of stormwater over its impervious watershed and HSG A soils, the corresponding TP removal efficiency based on Table 2 is 45%. Using this percentage applied to pre-BMP load of 2 lb/yr, the calculation for pollutant load reduction credit is as follows:

$$2\ lb/yr \times 45\% = 0.9\ lb/yr$$

In cases where a cumulative reduction in pollutant load achieved by the existing BMPs is equal to or greater than the target reduction, no further measures are taken and the analysis ends. However, if the reduction in pollutant load achieved by existing BMPs is less than the target reduction, the analysis continues to Step 5.

Attachment 3

Table 2. BMP Pollutant Load Reduction Credits

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Table 2. BMP Pollutant Load Reduction Credits

BMP Type	Pollutant	Soil Type	BMP Storage Over Impervious Area (inches)									Data Source Notes
			0	0.1	0.2	0.4	0.6	0.8	1	1.5	2	
Bioretention Area/Rain Garden	TP	A, B, C, D	0%	19%	33%	53%	64%	71%	76%	84%	89%	1
	TN	A, B, C, D	0%	30%	30%	30%	30%	30%	30%	30%	30%	2a
	TSS	A, B, C, D	0%	44%	69%	91%	97%	98%	99%	100%	100%	1
	Zn	A, B, C, D	0%	68%	88%	95%	96%	96%	97%	98%	99%	1
Constructed Stormwater Wetland	TP	A, B, C, D	0%	40%	40%	40%	40%	40%	40%	40%	40%	2a
	TN	A, B, C, D	0%	20%	20%	20%	20%	20%	20%	20%	20%	2a
	TSS	A, B, C, D	0%	80%	80%	80%	80%	80%	80%	80%	80%	2
	Zn	A, B, C, D	0%	20%	20%	20%	20%	20%	20%	20%	20%	2a
Conveyance Channel	TP	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TN	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TSS	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	Zn	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
Deep Sump Catch Basin	TP	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TN	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TSS	A, B, C, D	0%	25%	25%	25%	25%	25%	25%	25%	25%	2
	Zn	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
Extended Detention Basin	TP	A, B, C, D	0%	3%	6%	8%	9%	11%	12%	13%	14%	1a
	TN	A, B, C, D	0%	15%	15%	15%	15%	15%	15%	15%	15%	2a
	TSS	A, B, C, D	0%	18%	31%	38%	40%	44%	46%	47%	49%	1a
	Zn	A, B, C, D	0%	53%	67%	68%	69%	72%	73%	74%	76%	1a
Grass Channel	TP	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TN	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TSS	A, B, C, D	0%	47%	47%	47%	47%	47%	47%	47%	47%	2
	Zn	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
Gravel Wetland	TP	A, B, C, D	0%	19%	26%	41%	51%	57%	61%	65%	66%	1
	TN	A, B, C, D	0%	20%	20%	20%	20%	20%	20%	20%	20%	2a
	TSS	A, B, C, D	0%	48%	61%	82%	91%	95%	97%	99%	99%	1
	Zn	A, B, C, D	0%	57%	68%	83%	88%	90%	90%	91%	92%	1
Infiltration Basin	TP	A - Sand - 8.27 in/hr	0%	59%	81%	96%	99%	100%	100%	100%	100%	1b
		A - Loamy Sand - 2.41 in/hr	0%	45%	67%	87%	94%	97%	98%	100%	100%	1b
		B - Sandy Loam - 1.02 in/hr	0%	40%	60%	81%	90%	94%	97%	99%	100%	1b
		B - Loam - 0.52 in/hr	0%	38%	56%	77%	87%	92%	95%	98%	99%	1b
		C - Silt Loam - 0.27 in/hr	0%	36%	54%	74%	84%	90%	93%	98%	99%	1b
		C - Sandy Clay Loam - 0.17 in/hr	0%	35%	51%	71%	82%	88%	92%	97%	99%	1b
		D	0%	34%	48%	68%	80%	86%	91%	96%	99%	1b, 1f
	TN	A, B, C, D	0%	50%	50%	50%	50%	50%	50%	50%	50%	2a
	TSS	A - Sand - 8.27 in/hr	0%	79%	95%	100%	100%	100%	100%	100%	100%	1b
		A - Loamy Sand - 2.41 in/hr	0%	70%	88%	98%	100%	100%	100%	100%	100%	1b
		B - Sandy Loam - 1.02 in/hr	0%	67%	84%	96%	99%	100%	100%	100%	100%	1b
		B - Loam - 0.52 in/hr	0%	65%	83%	95%	99%	99%	100%	100%	100%	1b
		C - Silt Loam - 0.27 in/hr	0%	65%	81%	94%	98%	99%	100%	100%	100%	1b
		C - Sandy Clay Loam - 0.17 in/hr	0%	64%	80%	93%	98%	99%	100%	100%	100%	1b
		D	0%	63%	79%	92%	98%	99%	100%	100%	100%	1b, 1f
	Zn	A - Sand - 8.27 in/hr	0%	91%	99%	100%	100%	100%	100%	100%	100%	1b
		A - Loamy Sand - 2.41 in/hr	0%	82%	95%	100%	100%	100%	100%	100%	100%	1b
		B - Sandy Loam - 1.02 in/hr	0%	78%	92%	99%	100%	100%	100%	100%	100%	1b
		B - Loam - 0.52 in/hr	0%	75%	90%	98%	99%	100%	100%	100%	100%	1b
		C - Silt Loam - 0.27 in/hr	0%	73%	88%	97%	99%	100%	100%	100%	100%	1b
		C - Sandy Clay Loam - 0.17 in/hr	0%	71%	86%	96%	98%	99%	100%	100%	100%	1b
		D	0%	69%	84%	95%	97%	98%	100%	100%	100%	1b, 1f
Infiltration Structure	TP	A - Sand - 8.27 in/hr	0%	50%	75%	94%	98%	99%	100%	100%	100%	1c
		A - Loamy Sand - 2.41 in/hr	0%	32%	55%	81%	91%	96%	98%	100%	100%	1c
		B - Sandy Loam - 1.02 in/hr	0%	26%	46%	72%	85%	92%	96%	99%	100%	1c
		B - Loam - 0.52 in/hr	0%	23%	42%	67%	82%	89%	94%	98%	99%	1c
		C - Silt Loam - 0.27 in/hr	0%	20%	37%	62%	78%	86%	91%	97%	99%	1c
		C - Sandy Clay Loam - 0.17 in/hr	0%	17%	33%	57%	73%	83%	89%	97%	99%	1c
		D	0%	14%	29%	52%	68%	80%	87%	97%	99%	1c, 1f
	TN	A, B, C, D	0%	40%	40%	40%	40%	40%	40%	40%	40%	2a, 2b
	TSS	A - Sand - 8.27 in/hr	0%	68%	92%	100%	100%	100%	100%	100%	100%	1c
		A - Loamy Sand - 2.41 in/hr	0%	50%	77%	97%	100%	100%	100%	100%	100%	1c
		B - Sandy Loam - 1.02 in/hr	0%	44%	70%	93%	99%	100%	100%	100%	100%	1c
		B - Loam - 0.52 in/hr	0%	40%	66%	91%	98%	99%	100%	100%	100%	1c
		C - Silt Loam - 0.27 in/hr	0%	36%	61%	88%	97%	99%	100%	100%	100%	1c
		C - Sandy Clay Loam - 0.17 in/hr	0%	32%	56%	84%	95%	98%	99%	100%	100%	1c
		D	0%	28%	51%	80%	93%	97%	98%	100%	100%	1c, 1f
	Zn	A - Sand - 8.27 in/hr	0%	93%	100%	100%	100%	100%	100%	100%	100%	1c
		A - Loamy Sand - 2.41 in/hr	0%	81%	98%	100%	100%	100%	100%	100%	100%	1c
		B - Sandy Loam - 1.02 in/hr	0%	72%	94%	99%	100%	100%	100%	100%	100%	1c
		B - Loam - 0.52 in/hr	0%	65%	90%	98%	99%	100%	100%	100%	100%	1c
		C - Silt Loam - 0.27 in/hr	0%	57%	84%	97%	99%	99%	100%	100%	100%	1c
		C - Sandy Clay Loam - 0.17 in/hr	0%	51%	77%	94%	98%	99%	99%	100%	100%	1c
		D	0%	45%	70%	91%	97%	99%	98%	100%	100%	1c, 1f
Infiltration Swale	TP	A - Sand - 8.27 in/hr	0%	59%	81%	96%	99%	100%	100%	100%	100%	1d
		A - Loamy Sand - 2.41 in/hr	0%	45%	67%	87%	94%	97%	98%	100%	100%	1d
		B - Sandy Loam - 1.02 in/hr	0%	40%	60%	81%	90%	94%	97%	99%	100%	1d
		B - Loam - 0.52 in/hr	0%	38%	56%	77%	87%	92%	95%	98%	99%	1d
		C - Silt Loam - 0.27 in/hr	0%	36%	54%	74%	84%	90%	93%	98%	99%	1d
		C - Sandy Clay Loam - 0.17 in/hr	0%	35%	51%	71%	82%	88%	92%	97%	99%	1d
		D	0%	34%	48%	68%	80%	86%	91%	96%	99%	1d, 1f
	TN	A, B, C, D	0%	10%	10%	10%	10%	10%	10%	10%	10%	2a, 2c
	TSS	A - Sand - 8.27 in/hr	0%	79%	95%	100%	100%	100%	100%	100%	100%	1d
		A - Loamy Sand - 2.41 in/hr	0%	70%	88%	98%	100%	100%	100%	100%	100%	1d
		B - Sandy Loam - 1.02 in/hr	0%	67%	84%	96%	99%	100%	100%	100%	100%	1d

BMP Type	Pollutant	Soil Type	BMP Storage Over Impervious Area (inches)									Data Source Notes
			0	0.1	0.2	0.4	0.6	0.8	1	1.5	2	
Infiltration Swale (cont'd)		B - Loam - 0.52 in/hr	0%	65%	83%	95%	99%	99%	100%	100%	100%	1d
		C - Silt Loam - 0.27 in/hr	0%	65%	81%	94%	98%	99%	100%	100%	100%	1d
		C - Sandy Clay Loam - 0.17 in/hr	0%	64%	80%	93%	98%	99%	100%	100%	100%	1d
		D	0%	63%	79%	92%	98%	99%	100%	100%	100%	1d, 1f
	Zn	A - Sand - 8.27 in/hr	0%	91%	99%	100%	100%	100%	100%	100%	100%	1d
		A - Loamy Sand - 2.41 in/hr	0%	82%	95%	100%	100%	100%	100%	100%	100%	1d
		B - Sandy Loam - 1.02 in/hr	0%	78%	92%	99%	100%	100%	100%	100%	100%	1d
		B - Loam - 0.52 in/hr	0%	75%	90%	98%	99%	100%	100%	100%	100%	1d
		C - Silt Loam - 0.27 in/hr	0%	73%	88%	97%	99%	100%	100%	100%	100%	1d
		C - Sandy Clay Loam - 0.17 in/hr	0%	71%	86%	96%	98%	99%	100%	100%	100%	1d
		D	0%	69%	84%	95%	97%	98%	100%	100%	100%	1d, 1f
Oil Grit Separator	TP	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TN	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TSS	A, B, C, D	0%	25%	25%	25%	25%	25%	25%	25%	25%	2
	Zn	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
Outlet Sediment Trap (Plunge Pool)	TP	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TN	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
	TSS	A, B, C, D	0%	25%	25%	25%	25%	25%	25%	25%	25%	2
	Zn	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	2
Street Sweeping	TP	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	3
	TN	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	3
	TSS	A, B, C, D	0%	10%	10%	10%	10%	10%	10%	10%	10%	3
	Zn	A, B, C, D	0%	0%	0%	0%	0%	0%	0%	0%	0%	3
Vegetated Filter Strip	TP	A - Sand - 8.27 in/hr	0%	59%	81%	96%	99%	100%	100%	100%	100%	1d
		A - Loamy Sand - 2.41 in/hr	0%	45%	67%	87%	94%	97%	98%	100%	100%	1d
		B - Sandy Loam - 1.02 in/hr	0%	40%	60%	81%	90%	94%	97%	99%	100%	1d
		B - Loam - 0.52 in/hr	0%	38%	56%	77%	87%	92%	95%	98%	99%	1d
		C - Silt Loam - 0.27 in/hr	0%	36%	54%	74%	84%	90%	93%	98%	99%	1d
		C - Sandy Clay Loam - 0.17 in/hr	0%	35%	51%	71%	82%	88%	92%	97%	99%	1d
		D	0%	34%	48%	68%	80%	86%	91%	96%	99%	1d, 1f
	TN	A, B, C, D	0%	50%	50%	50%	50%	50%	50%	50%	50%	2a, 2d
	TSS	A - Sand - 8.27 in/hr	0%	79%	95%	100%	100%	100%	100%	100%	100%	1d
		A - Loamy Sand - 2.41 in/hr	0%	70%	88%	98%	100%	100%	100%	100%	100%	1d
		B - Sandy Loam - 1.02 in/hr	0%	67%	84%	96%	99%	100%	100%	100%	100%	1d
		B - Loam - 0.52 in/hr	0%	65%	83%	95%	99%	99%	100%	100%	100%	1d
		C - Silt Loam - 0.27 in/hr	0%	65%	81%	94%	98%	99%	100%	100%	100%	1d
		C - Sandy Clay Loam - 0.17 in/hr	0%	64%	80%	93%	98%	99%	100%	100%	100%	1d
		D	0%	63%	79%	92%	98%	99%	100%	100%	100%	1d, 1f
	Zn	A - Sand - 8.27 in/hr	0%	91%	99%	100%	100%	100%	100%	100%	100%	1d
		A - Loamy Sand - 2.41 in/hr	0%	82%	95%	100%	100%	100%	100%	100%	100%	1d
		B - Sandy Loam - 1.02 in/hr	0%	78%	92%	99%	100%	100%	100%	100%	100%	1d
		B - Loam - 0.52 in/hr	0%	75%	90%	98%	99%	100%	100%	100%	100%	1d
		C - Silt Loam - 0.27 in/hr	0%	73%	88%	97%	99%	100%	100%	100%	100%	1d
		C - Sandy Clay Loam - 0.17 in/hr	0%	71%	86%	96%	98%	99%	100%	100%	100%	1d
		D	0%	69%	84%	95%	97%	98%	100%	100%	100%	1d, 1f
Wet Detention Basin	TP	A, B, C, D	0%	2%	4%	8%	11%	15%	18%	24%	30%	1e
	TN	A, B, C, D	0%	33%	33%	33%	33%	33%	33%	33%	33%	1e, 4a
	TSS	A, B, C, D	0%	30%	44%	60%	68%	74%	77%	83%	86%	1e
	Zn	A, B, C, D	0%	59%	71%	80%	85%	87%	89%	92%	93%	1e

General Notes

1. Where "Soil Type" is specified as "A, B, C, D," removal rates are the same for each hydrologic soil group. Infiltration rates assigned to each hydrologic soil group are as follows:

Soil Type	Infiltration Rate
A - Sand	8.27 in/hr
A - Loamy Sand	2.41 in/hr
B - Sandy Loam	1.02 in/hr
B - Loam	0.52 in/hr
C - Silt Loam	0.27 in/hr
C - Sandy Clay Loam	0.17 in/hr
D	0.00 in/hr

Data Source Notes

1. United States Environmental Protection Agency Region 1/Tetra Tech. March 2010. Stormwater Best Management Practices (BMP) Performance Analysis.
   a. Assumes pollutant load reductions equal to those observed for dry ponds.
   b. Assumes commercial land use.
   c. Assumes pollutant load reductions equal to those observed for infiltration trenches with a commercial land use.
   d. Assumes pollutant load reductions equal to those observed for infiltration basins with a commercial land use.
   e. Assumes pollutant load reductions equal to those observed for wet ponds.
   f. Pollutant load reductions calculated by subtracting the difference in pollutant load reductions between Silt Loam and Sandy Clay Loam from the pollutant load reductions associated with Sandy Clay Loam.

2. Massachusetts Department of Environmental Protection. February 2008. Massachusetts Stormwater Handbook.
   a. Assumes lowest pollutant load reduction within specified range for given pollutant(s).
   b. Assumes pollutant load reductions equal to those observed for infiltration trenches.
   c. Assumes pollutant load reductions equal to those observed for water quality swales.
   d. Assumes pollutant load reductions equal to those observed for infiltration basins.

3. Massachusetts Department of Transportation. May 2004. MassHighway Storm Water Handbook for Highways and Bridges.

4. University of New Hampshire Stormwater Center. 2009. Biannual Report.
   a. Pollutant load reductions for Total Nitrogen assumed to be similar to that for Dissolved Inorganic Nitrogen.