Water Quality Accounting and Crediting for RIDOT RIPDES Compliance

PREPARED FOR

Rhode Island Department of Transportation
Two Capitol Hill
Providence, Rhode Island 02903
401.222.2450

PREPARED BY

1 Cedar Street
Suite 400
Providence, RI 02903

DECEMBER 2018

Submission to EPA: December 14, 2018
Acceptance from EPA: _____

Table of Contents

1

Introduction and Background

The Rhode Island Department of Transportation (RIDOT) operates stormwater systems along its roadways to control runoff. Discharges from stormwater systems in urbanized areas of Rhode Island are regulated by the Rhode Island Department of Environmental Management (RI DEM) through the Rhode Island Pollutant Discharge Elimination System (RIPDES) program. In 2003, RI DEM issued the first General Permit for Stormwater Discharge from Small Municipal Separate Storm Sewer System (MS4) and from Industrial Activity at Eligible Facilities Operated by Regulated Small MS4s (MS4 General Permit). In 2015, the US Department of Justice (DOJ) issued a Consent Decree[1] after EPA audited RIDOT's RIPDES permit compliance and determined that RIDOT needed to implement additional measures to comply with conditions and limitations of the permit.

As part of RIDOT's overall effort to comply with the requirements of the RIPDES MS4 General Permit and the Consent Decree, RIDOT has created a program to assess its stormwater discharges located within watersheds of listed impaired waters with stormwater related impairments (as defined by the Rhode Island Section 303(d) List of Impaired Waters[2]), set reduction targets, implement structural controls, also known as stormwater treatment units (STUs), as well as implement enhanced non-structural controls to reduce its contribution to known water quality impairments. For each waterbody segment impaired for stormwater related pollutants which

[1] United States of America, December 22, 2015. Final Consent Decree. Civil Action No. CV-15-433

[2] RIDEM, March 2018, State of Rhode Island 2016 303(d) List of Impaired Waters. Available at: http://dem.ri.gov/programs/benviron/water/quality/surfwq/pdfs/iwr16.pdf

receive RIDOT runoff, RIDOT will be developing a Stormwater Control Plan (SCP). The SCP will quantify RIDOT roadway's stormwater related pollutant contribution and identify potential stormwater treatment controls and measures that can reduce those contributions.

1.1 Methodology Need

This document serves as a refinement of the methodologies outlined in Appendix 2 and 3 of the Consent Decree to support compliance with the Consent Decree's Section A "Requirements for TMDLs and Impaired Waters" of the Remedial Measures. Appendix 2 of the Consent Decree describes the methods for calculating reduction targets and credits for stormwater controls using impervious cover (IC) as the "pollutant of concern" to be used when a waterbody does not have a finalized Total Maximum Daily Load (TMDL) report developed, has an approved bacteria TMDL, or approved TMDLs do not address all stormwater-related impairments[3] affecting the water body. Appendix 3 of the Consent Decree describes methods for calculating reduction targets and credits using pollutant load and load reductions from stormwater controls when a non-bacteria TMDL has been approved for the given waterbody (i.e. metals or nutrients impairments). The Consent Decree's paragraph 14, and both Appendix 2 and 3, allow RIDOT to develop values for impervious cover metrics and present alternative crediting methods for EPA review and approval. This document serves as RIDOT's request and explanation of enhanced and alternative crediting methods.

VHB developed this methodology to establish defined values and calculations to use for specific scenarios that are appropriate to the highway setting. VHB has compiled the calculation methods and results into a spreadsheet tool (RIDOT's SCP Calculator) to allow RIDOT to easily calculate pollutant loads and to evaluate stormwater control performance without developing individual models of each discharge area, structural control, or non-structural control.

This tool allows for consistency across the program which is essential as RIDOT reviews impaired watersheds across the state over several years and works towards meeting the reduction targets set in the SCPs. This format is flexible and allows results to be updated as additional information is collected and developed.

This methodology is used ***for planning purposes only*** *in compliance with Consent Decree / RIPDES MS4 requirements for impaired waters and TMDLs. RIDOT will follow RIDEM's Rhode Island Stormwater Design and Installation Standards Manual (RISDISM) and RIDOT's Linear Stormwater Manual for projects permitting, design and construction.*

[3] Per the Consent Decree, "Roadway Stormwater-Related Impairments" shall mean impairments for metals (e.g., zinc, lead, copper) other than mercury, nutrients (e.g., phosphorus, nitrogen), organic enrichment, bacteria (e.g., fecal coliform, enterococcus), salinity/chloride, impaired biota, turbidity, hydrocarbons, and total suspended solids (TSS). For impairments that are described as "observed effects," e.g., algal growth or taste/color/odor, the impairment will be treated as a Roadway Stormwater-Related Impairment for nutrients (e.g., phosphorus, nitrogen) or, if applicable, another Roadway Stormwater-Related Impairment pollutant listed in the first sentence above."

1.2 Water Quality Accounting Methodology Overview

For each Waterbody ID or Waterbody ID grouping, as approved by EPA and RIDEM, RIDOT will define reduction targets and recommend structural and non-structural controls to meet those targets. RIDOT will follow the water quality accounting methodology outlined in this report.

The water quality accounting methodology follows these major steps for each watershed:

1. Identify Stormwater-related Pollutant of Concern. The SCP initial desktop evaluation has been completed, which identifies the stormwater impairment(s) for each Waterbody ID based on the 2016 303(d) list. Waterbody IDs that are subject to stormwater-related impairments are listed in Appendix 5 of the Consent Decree. This list is updated, with approval from RIDEM and EPA, to include the most recent 303(d) list, and any updates to TMDLs. Appendix 5 has been further refined by eliminating those waterbodies which are solely impaired by a non-roadway stormwater-related impairment (i.e. mercury). Waterbodies listed in Appendix 5 are required to have Stormwater Control Plans. All stormwater impairments must be verified in the year that the Stormwater Control Plan is required by cross-referencing Appendix 5 with the current Rhode Island Section 303(d) list. If there is more than one stormwater-related impairment, a waterbody must be evaluated for all pollutants of concern within the Stormwater Control Plan. **See Section 2.1.**

2. Determine the Applicable Method. There are two methods the Consent Decree requires to establish reduction targets and account for treatment credits, the TMDL method and the IC method. The TMDL method is chosen for non-bacteria stormwater-related impairments that have an EPA approved TMDL. The IC Method is chosen for all bacteria impairments (TMDL or not), and all non-bacteria impairments without a TMDL. **See Section 2.2.**

3. Quantify Reduction Targets. RIDOT reduction targets are calculated based on RIDOT's relative contribution to the pollutant of concern. RIDOT must establish an accurate watershed and determine their contributing impervious cover in the watershed to determine the reduction target in the Stormwater Control Plan (SCP). In the case where both the TMDL and IC methods are applicable, the SCP will address both reduction targets in the SCP. **See Section 2.3.**

    a. **TMDL Method** – the reduction target for this method is set by the TMDL. RIDOT uses the pollutant reduction percentages presented in the TMDLs along with estimates of RIDOT's current pollutant loads to establish pollutant reduction targets. For example, if the pollutant of concern in the TMDL requires 30% phosphorus

reduction, RIDOT will apply a goal of 30% reduction for phosphorus from RIDOT impervious areas.

b. **IC Method** – the reduction target for this method is set to have the entire watershed mimic a watershed with 10% or less impervious cover. For example, if the watershed is 20% impervious, then dischargers within the watershed, including RIDOT, have a goal of a 50% IC reduction target.

c. **TMDL/IC Method** - In waterbodies that have both bacteria impairment and nutrient or metal TMDL, both methods will be used to calculate reduction targets for each impairment. Both reduction targets will be evaluated independently in the SCP.

4. Quantify Treatment Credit. RIDOT treatment credits are calculated based on the type of treatment (non-structural vs. structural), and key parameters.

   a. Quantify treatment credit of non-structural controls (see Section 3 - Treatment Credits for Non-Structural Controls).

   b. Quantify treatment credit of structural controls based on their relative size and key treatment parameters (see Section 4 - **Error! Reference source not found.**).

These reduction targets and credits will be used within the SCP to assist in quantifying the need for additional treatment and the effectiveness of potential STUs and enhanced non-structural controls, which will ultimately result in more cost-effective water quality improvement.

1.3 Differences from the Consent Decree

This current methodology contains the following key developments and refinements to the methodology presented in the Consent Decree (documented in technical memos provided in Appendix B of this document):

1. Refinement of stormwater-related impairments and the target pollutants of concern. For example, an impairment of oxygen requires nutrient reductions (see section 2.1)
2. Use of custom zinc, total suspended solids (TSS), and nitrogen impervious cover loading rates for highways.
3. The development of a Runoff Reduction Factor and a Flow Factor for use in the IC Method which is intended to provide credit for volume reductions and peak flow reductions.
4. Use of total suspended solids (TSS) <u>and</u> total phosphorus (TP), versus just TP, to develop the Pollutant Factor impervious cover metric.
5. Refinement of how to quantify the Flow Factor.

6. Addition of specific structural and non-structural controls not identified in the Consent Decree and its referenced documents.
7. Additional guidance for crediting treatment of non-RIDOT runoff based on RIDEM and EPA direction.[4]

1.4 Methodology Development

The approaches and values used to develop this methodology are the results of a culmination of meetings, discussions, and research done in conjunction with EPA Region 1 technical staff and RIDEM. As part of the methodology development process, VHB evaluated and performed sensitivity analysis in a SWMM model on certain assumptions, parameters, and scenarios with the objective of developing a comprehensive, simple, RIDOT-specific methodology with minimal inputs to characterize reduction targets, loads, and treatment credits.

It is understood by RIDOT, EPA, and RIDEM that this methodology may continue to be refined as more data is made available or as RIDOT begins implementing the program and further develops their Linear Stormwater Manual. For example, additional control measure types may be evaluated, additional data on specific control measures may become available, or further analysis of pollutants of concern may be developed. This additional information may originate from RIDOT or EPA/RIDEM and trigger an update to this methodology.

[4] EPA/RIDEM "Framework to be utilized by U.S. EPA and RIDEM for Determining Credit for Stormwater Treatment Outside a MS4 Operator's Area of Responsibility" on January 31, 2018

2

Watershed Reduction Targets

Watershed reduction targets are unique for each pollutant of concern and for each Waterbody ID. RIDOT's Stormwater Control Plans address watershed reduction targets that are specifically required by an EPA-approved TMDL via the *TMDL Method* and watershed reduction targets that are not yet defined by RIDEM and EPA via the *IC Method*.

The IC Method was developed specifically for those waterbodies that are impaired due to stormwater-related impairments and a reduction requirement has not yet been specifically defined by a TMDL, or for those waterbodies where bacteria is an impairment (TMDL or not). For these cases, EPA and RIDEM opted for an approach that is based upon studies that demonstrate watersheds with greater than 10% impervious cover exhibit loss of water quality and habitat and are more frequently impaired due at least in part to stormwater.

The following section steps through the application of these methods to determine a quantifiable TMDL pollutant or watershed IC reduction target for each Waterbody ID, and RIDOT's pollutant or IC reduction target based on contribution.

2.1 Identify Stormwater-Related Pollutant of Concern (POC)

The list of impaired waterbodies that RIDOT is required to prepare a Stormwater Control Plan for is identified in Appendix 5 of the Consent Decree. They are grouped by larger watersheds and are listed in prioritization categories. The original Appendix 5 listed in the Consent Decree was based on the 2012 Integrated Report and 303(d) listing. As required by the Consent Decree, RIDOT updates this Appendix when a new 303(d) list is released or a new RIDEM TMDL is approved by the EPA. Appendix 5 may be updated based on new impairments, impairment delisting, changes in alternative management plans, and non-roadway stormwater-related impairment listing.

"Roadway Stormwater-Related Impairments" are defined in the Consent Decree §IV.gg. and identify the impairments RIDOT is required to address in the Stormwater Control Plans. Roadway stormwater-related impairments include metals, nutrients, bacterial, TSS, and others (see CD for full listing). It is important to note that not every pollutant listed in the TMDL or in the impaired waters list is stormwater-related. Therefore, some pollutants that cause or contribute to a waterbody impairment will not be addressed in this document.

Also, important to note is that the pollutant of concern (POC) is not always the same as the impairment listed. The POC is used instead of the listed impairment because it causes the impairment and reducing it will advance the goal of achieving the waterbody's designated use (for example, nutrients are the POC for the impairment of algal growth).

Below is the methodology used to determine the roadway stormwater-related pollutant of concern that requires evaluation by RIDOT in the SCPs. The exact application of this methodology is provided in Appendix A of this document.

- **Metals** – In accordance with the CD, for all metals TMDLs (except mercury), the reduction percentages applied to each metal in the TMDL will use **zinc** as a surrogate. Reductions in zinc are considered satisfactory reductions in all of the other metals. To simplify this process, Appendix 3 of the CD requires BMP Performance curves only for zinc. Therefore, zinc is targeted and tracked as the pollutant of concern.
- **Observed Effects** - Per the Consent Decree definition, impairments that were not explicitly listed as stormwater-related but can be described as "observed effects", such as Chlorophyll-a, Dissolved Oxygen, algal growth, etc, are treated as stormwater-related impairments for **nutrients**.
  For salt-waterbodies (Class SA, SB, SB{a}, etc.), nitrogen will be used as the POC.
  For fresh-waterbodies (Class AA, A, or B, etc.), phosphorus will be the POC.
- **Biological impairments -** Impaired Biota, Organic Enrichment, Benthic-Macroinvertebrate Bioassessments, are considered in the Consent Decree to be stormwater-related impairments and will use the **Impervious Cover** as the POC.
- **Salinity/Chloride** – Consent Decree §VI.11. states "for an impaired waterbody segment that is impaired only for chloride, RIDOT shall implement source controls to reduce direct and indirect discharges of chloride from its MS4 to the

impaired waterbody segment to the maximum extent practicable." This sentence implies that source control is applied when the impairment is "only for chloride". This methodology proposes that RIDOT targets chloride source control whenever the waterbody is chloride impaired regardless if there are additional impairments on the waterbody. Therefore, if there is more than one impairment, one of which is chloride, RIDOT will target both chloride and the POC.

2.2 Determine Applicable Method

During SCP Development, RIDOT will review the most updated 303(d) Integrated Report and applicable EPA-approved TMDLs to determine the stormwater-related impairments and TMDL status. There are two methods the Consent Decree utilizes to establish TMDL pollutant or watershed IC reduction targets, the TMDL method and the IC method, based on the impairment. A third method is not necessarily another method, but a combination of the two and addresses the scenario when both the TMDL and IC method are applicable to the same waterbody.

a) **TMDL Method –** this method is applied to each waterbody/pollutant with an EPA approved non-bacteria stormwater-related TMDL. RIDOT will establish the RIDOT pollutant reduction target based upon pollutant load reduction requirements set forth in the TMDL
b) **IC Method** – this method is applied to any waterbody with a bacteria impairment (TMDL or no TMDL), and to any waterbody with a stormwater-related impairment not assigned a pollutant load reduction in a TMDL (i.e. IC Reduction for bacteria)
c) **TMDL/IC Method** – this method is applied when a waterbody meets both a. and b. above. For example, the waterbody may have a bacteria impairment and may also have a TMDL pollutant load reduction requirement for phosphorus or metals.

For watersheds requiring both the IC Standard and TMDL methodology, RIDOT uses the more stringent reduction target by equating the TMDL pollutant reduction target to the impervious area expected to produce that same amount of pollutant. This impervious area can be compared to the IC reduction target calculated using the IC Standard to determine which methodology equates to the more stringent reduction target.

2.3 Quantifying RIDOT Reduction Targets

To this point the methodology has selected the pollutant of concern and the applicable method to follow. The next step is to identify the TMDL pollutant or watershed IC reduction target and RIDOT's pollutant or IC reduction target. RIDOT's pollutant or IC reduction target is calculated based on RIDOT's relative contribution of the pollutant of concern. RIDOT must establish an accurate watershed delineation and determine the RIDOT contributing impervious cover in the watershed in order to determine the RIDOT

reduction target in the Stormwater Control Plan (SCP). In the case where both the TMDL and IC methods are applicable, the SCP will address both RIDOT reduction targets.

2.3.1 RIDOT Contributing Area

Several challenges must be addressed while accurately determining RIDOT's contribution to the waterbody. The Stormwater Control Plan must quantify the following, which may be an iterative process:

a. RIDOT owned property, or Right-of-way (ROW), must be quantified for each Waterbody ID watershed for both pervious and impervious surfaces. Both the pervious and impervious cover area are used in Reduction Target and/or Treatment Credit calculations.

b. Areas within RIDOT's ROW that do not contribute stormwater to the impaired waterbody. Examples include:

   - Non-discharge areas: In accordance with the Consent Decree, areas within the impaired watershed may be categorized as non-discharge areas. These are areas where flows fully infiltrate into the ground before reaching the waterbody (including its banks) or wetlands adjacent to the waterbody.
   - Combined sewer overflow (CSO) areas: Areas where RIDOT's drainage system flows to a CSO do not discharge untreated stormwater, therefore stormwater runoff from these areas is not included in the RIPDES MS4 regulated area.

c. Difference of RIDOT ROW (a.) and RIDOT areas that do not contribute stormwater to the impaired water (b.), delineated to develop the RIDOT discharging area. The resulting value, presented in the rest of the document is referred to as RIDOT area.

2.3.2 Quantify RIDOT Reduction Target

This section presents the approach to quantifying RIDOT reduction targets for the TMDL and IC methods.

2.3.2.1 The TMDL Method

For this method, the RIDOT reduction target, as a percent reduction of the POC, is set by the TMDL. RIDOT uses the pollutant reduction percentages presented in the TMDLs. For example, if the pollutant of concern in the TMDL requires 30% phosphorus reduction, RIDOT's reduction target is 30% reduction from RIDOT impervious surfaces of phosphorus.

RIDOT's pollutant reduction target (mass/yr) requires understanding of three variables:

- RIDOT Impervious Cover area (RIDOT IC)
- Pollutant Loading Rate
- TMDL Pollutant Reduction Percentage

RIDOT Pollutant Reduction Target (mass/yr) – The RIDOT pollutant reduction target in (lbs/yr) is determined by multiplying the three variables.

$$RIDOT\ Pollutant\ Reduction\ Target\left(\frac{mass}{yr}\right) = \text{RIDOT IC (area)} \times \text{Pollutant Loading Rate}\left(\frac{\frac{\text{mass}}{\text{area}}}{\text{yr}}\right) \times \text{\% TMDL Reduction}$$

where:

RIDOT IC (area) – This area is the impervious area calculated in Section 2.3.1.a RIDOT Contributing Area. This area is the total RIDOT impervious cover that contributes stormwater to the impaired waterbody.

Pollutant Loading Rate (mass/area/yr) – EPA approved RIDOT's amendment to Consent Decree Appendix 3.A.1 to use different pollutant loading rates that better represent pollutant loads from RIDOT roadways. These loading rates shall be used for all RIDOT impervious surfaces in the Stormwater Control Plans. (Technical Justification Memo in Appendix B)

Table 1 Pollutant Loading Rates for Roadway Impervious Cover

	Pollutant Loading Rate, lb/ac/yr			
	(Nutrients) Phosphorus	(Nutrients) Nitrogen	(Metals) Zinc	Total Suspended Solids
Rates used for Consent Decree Compliance*	1.3	8.4	1.23	613

*Values refined from USGS SELDM models.

TMDL Pollutant Reduction Percentage – These values are taken directly from Appendix 1 of the Consent Decree or relevant TMDL. If a new TMDL is approved, RIDOT will verify with RIDEM and EPA as to the percent reductions required by RIDOT. If more than one reduction is required per POC, the highest percent reduction is applied per pollutant grouping above in Table 1, unless the TMDL is for a pollutant not represented by Table 1 above. For example, Appendix 1 of the Consent Decree lists the impairment and pollutant reduction percentages for the Woonasquatucket River reach 10D. This reach has three metals impairments with TMDLs: 35% reduction for dissolved copper, 43% reduction for dissolved lead and 41% reduction for dissolved zinc, which are all metals. In this case, see example below, the highest percent reduction for any of the metals is 43%, therefore this is the required % TMDL reduction. Since zinc is the surrogate metal for all other metals, the required reduction of zinc is 43%.

2.3.3 IC Method

The goal of the IC Method is to reduce the watershed's effective IC area to less than or equal to 10% of the waterbody's total watershed area. It is widely accepted that watersheds with greater than 10% IC show impacts to receiving water health, largely based on the Center for Watershed Protection's 2003 report Impacts of "Impervious Cover on Aquatic Systems"[5]. The calculated Watershed IC Reduction is based on the estimated percent reduction, by all responsible parties, necessary to achieve an effective IC that is less than 10% of the total watershed. The steps for this method are as follows:

1. Calculate **Total Watershed IC** for a given Waterbody ID: The total watershed IC calculation is based on GIS data layers and is a measure of total impervious cover of all parties in the watershed. A watershed's Percent Impervious is available on the RIDEM GIS Map Service website. *Note: at this point in the method, impervious cover is not reduced by existing stormwater treatment structures or disconnected sub-watersheds.*

2. Once the Total Watershed IC is determined, the next step is to compare the watershed's total impervious cover to 10%.

    a. **Watershed IC < 10%** - If the total watershed IC area for an impaired watershed is less than 10%, the **Watershed IC Reduction Target** is zero and RIDOT is not required to implement structural or non-structural controls.

    b. **Watershed IC > 10%** - If the total watershed IC area is greater than 10%, the Watershed IC Reduction Target must be calculated as follows:

$$Watershed\ IC\ Reduction\ Target\ (\%) = \frac{\text{Total Watershed IC } (\%) - 10\%}{\text{Total Watershed IC } (\%)}$$

3. Determine **RIDOT IC Reduction Target (Equivalent Area)**: if the total watershed IC area is greater than 10%, RIDOT must use a combination of structural STUs and non-structural BMPs to reduce the Equivalent Area from RIDOT roadways to 10% or less. RIDOT's IC Reduction Target (Equivalent Area) is defined by the Consent Decree as the overall reduction of IC that is equivalent to eliminating RIDOT's proportional share of the total watershed's target IC reduction. The Equivalent Area is RIDOT's IC area (calculated in Section 2.3.1.a) in the watershed multiplied by the Watershed IC Reduction Target.

$$RIDOT\ IC\ Reduction\ Target\ (Equivalent\ Area) = \text{RIDOT IC (area)} \times \text{Watershed IC Reduction Target } (\%)$$

[5] Center for Watershed Protection, 2003, Impacts of Impervious Cover on Aquatic Systems http://owl.cwp.org/mdocs-posts/impacts-of-impervious-cover-on-aquatic-systems-2003/

Example: Lower Woonasquatucket Watershed 10-D

TMDL / IC Method of reduction Targets

The Lower Woonasquatucket River Segment 10D has a 2007 EPA-approved TMDL for fecal coliform and dissolved metals. Consent Decree Appendix 1 contains RIDOT Pollutant Reduction Percentages for the dissolved metals. Because this WBID has both non-bacteria and bacteria impairments, the combined **TMDL/IC Method** is required**.**

Example TMDL Method

RIDOT IC = 82 acres (from Section 2.3.1.a)

Pollutant Loading Rate = Zinc loading rate = 1.23 lbs/acre/yr (Table 1) (zinc is used as the surrogate metal Section 2.1)

%TMDL Reduction= 43% (highest metal reduction in CD Appendix 1)

$$RIDOT\ Pollutant\ Reduction\ Target\ \left(\frac{mass}{yr}\right)$$

$$= \text{RIDOT IC (area)} \times \text{Pollutant Loading Rate} \left(\frac{\frac{\text{mass}}{\text{area}}}{\text{yr}}\right) \times \text{\% TMDL Reduction}$$

$$= \quad 82\ (\text{ac}) \quad \times \quad 1.23 \left(\frac{\frac{\text{lbs zinc}}{\text{ac}}}{\text{yr}}\right) \quad \times \quad 43\%$$

$$= 43.3 \left(\frac{\text{lbs zinc}}{\text{yr}}\right)$$

Therefore, RIDOT must remove <u>43.3 pounds of zinc</u> from its annual contribution through implementing non-structural BMPs and installing structural STUs.

Example IC Method

Total Watershed IC (%) = 58% (*from RIDEM GIS*)

RIDOT IC = 82 acres (*from Section 2.3.1.a*)

$$Watershed\ IC\ Reduction\ Target\ (\%)$$

$$= \frac{\text{Total Watershed IC (\%)} - 10\%}{\text{Total Watershed IC (\%)}} = \frac{58\% - 10\%}{58\%} = 83\%$$

$$RIDOT\ IC\ Reduction\ Target\ (Equivalent\ Area)$$

$$= \text{RIDOT IC (area)} \times \text{Watershed IC Reduction Target (\%)}$$

$$= 82\ \text{ac} \times 83\%$$

$$= 68\ \text{ac}$$

Therefore, RIDOT must <u>treat an equivalent of 68 acres</u> of impervious cover with the implementation of non-structural BMPs and installation of structural STUs for the Lower Woonasquatucket Watershed of 10-D.

For watersheds requiring both the IC Standard and TMDL methodology, RIDOT uses the more stringent reduction target by equating the TMDL pollutant reduction target to the impervious area expected to produce that same amount of pollutant. This impervious area can be compared to the IC reduction target calculated using the IC Standard to determine which methodology equates to the more stringent reduction target."

Example
COMBINED
TMDL/IC Method

TMDL Method Reduction Target = 44 lbs of zinc / yr

IC Method Reduction Target (Equivalent Area) = 68 ac IC

Pollutant Loading Rate = Zinc loading rate = 1.23 lbs/acre/yr (Table 1)

To determine more stringent target, calculate the equivalent IC reduction for the TMDL method reduction target:

$$\textit{Equivalent IC acres} = \text{TMDL target (lbs/yr)} \ / \ \text{Pollutant Loading Rate from Table 1 (lbs/acre/yr)}$$

$$= 44 \ \frac{\text{lb zinc}}{\text{year}} * \frac{1 \text{ ac IC per year}}{1.23 \text{ lb zinc}} = 36 \text{ equivalent acre IC}$$

TMDL Method equivalent IC (36 ac IC) < IC Method equivalent IC (68 ac IC)

Therefore, the RIDOT reduction target will use the <u>IC Method</u> because it is more stringent.

3

Treatment Credits for Non-Structural Controls

Non-structural controls can provide cost-effective source controls and load reductions. RIDOT's approach to stormwater management includes the prioritization of non-structural controls to target pollutant sources, prior to requiring potential costly and burdensome structural controls.

The Consent Decree allows for treatment credit for "enhanced" non-structural controls and allows RIDOT to develop methods for calculating credits, subject to approval by EPA. RIDOT has developed crediting approaches and values for practices RIDOT can incorporate into Stormwater Control Plans.

This section describes non-structural controls and their crediting approach. Controls that require construction and/or maintenance are included in Section 4 Treatment Credits for Structural Controls.

3.1 Non-Structural Controls

The current suite of non-structural controls presented in this document are focused on reducing direct sources of pollutants. They may be ongoing activities or one-time measures.

Error! Reference source not found. lists the various non-structural controls RIDOT may implement, the pollutants of concern they address, and primary unit the credit is applied against. See Appendix C for more detailed explanation and values for each approach.

Some of these approaches are not fully developed at this time and pilot projects and further research may be used to further define credit approaches as the controls are utilized in RIDOT's compliance program.

Table 2 Non-Structural Controls Categories

Non-Structural Control	Pollutants of Concern	Primary Treatment Unit	EPA Approval Date
Enhanced Street Sweeping and Catch Basin Cleaning	TSS, TP, TN, Zn	Mass of material removed	
Sand Application Elimination	TSS	Mass of material removed	
Leaf Litter Removal	TSS, TP, TN, Zn	Mass of material removed	
Dog and Bird Waste Removal	Bacteria, TP, TN	Number of animals addressed	
Manure Removal	Bacteria, TP, TN	Mass of material removed	
Instream Dredging	TSS, TP, TN, Zn	Mass of material removed	
Streambank Restoration	TSS, TP, TN	Area of bank restored	
Illicit Discharge Elimination	Bacteria, TP, TN	Flow and concentration of discharge removed	

3.2 Credit for the TMDL Method

In general, the pollutant removal for a non-structural control measure is calculated by either:

- Direct measurement or estimate of the pollutant of concern removed
- Measurement or estimate of the bulk material removed along with an estimate of the ratio of material to the pollutant of concern.

Appendix C includes equations and values (as available) for use in developing pollutant removal credits for the TMDL method.

3.3 Credit for the IC Method

Impervious cover treatment credits for non-structural controls can be developed by equating the pollutant removed to the impervious cover area expected to produce that same amount of pollutant.

$$Equivalent\ IC\ area\ treated\ (ac) = \frac{\text{Load Removed (lb)}}{\text{IC Loading Rate } (\frac{\text{lb}}{\text{ac}})}$$

This can be done for the primary pollutants of concern including phosphorus, nitrogen, sediment and zinc using the loading values presented in Table 1 in Section 2 and for bacteria-related impairments and TMDLs using a bacteria load estimate developed using RIDEM's method as presented in the Rhode Island Stormwater Design and Installation Standards Manual (RISDISM) Appendix H for bacteria. Based on a rainfall depth of 48 inches, rainfall correction factor of 0.9, and runoff coefficient of 0.95, the annual bacteria load per acre of impervious highway cover is 71.9 billion colonies.

$$Equivalent\ IC\ area\ treated\ (ac) = \frac{\text{Load Removed (\# colonies)}}{\text{IC Loading Rate } (\frac{\text{\# colonies}}{\text{ac}})}$$

Example

Example calculations of Non-Structural Controls found in Appendix C.

4

Treatment Credits for Structural Controls

As part of Consent Decree tracking and reporting, RIDOT is required to calculate treatment credits for existing and potential structural controls throughout the watershed. Using quantitative credits also assists in prioritizing and understanding the cost-effectiveness of various controls. RIDOT needs to evaluate structural controls for their pollutant removal and IC treatment effectiveness.

The Consent Decree includes guidance to use Best Management Practice (BMP) performance curves and tables developed by EPA for pollutant removal percentages and outlines an approach to evaluate structural controls for IC treatment credits in Appendices 2 and 3.

EPA Region 1 has developed pollutant treatment credits for several structural stormwater control types and pollutants using long-term simulation modeling calibrated to influent/effluent data as described in the report "Stormwater Best Management Practices Performance Analysis"[6].

The treatment credits provided in this document are ***for Planning purpose only,*** *and are based on the EPA-Region 1 approach for the New England NPDES MS4 permits.* ***Treatment credit is based on treatment volume of the STU****.*
This differs significantly from the RISDISM approach of routing a specific design storm (i.e. the 1" storm) through an STU for a presumed treatment credit.

[6] Tetra Tech, Inc., Revised March 2010, Stormwater Best Management Practices (BMP) Performance Analysis. Available at: https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf

EPA's treatment credits include a range of treatment values for a given control based on the relative size (storage volume) of the control compared to its contributing catchment area. This approach is useful because it provides a means of crediting controls that cannot be sized for a prescribed treatment volume.

EPA's treatment values do not include values for IC treatment but the Consent Decree (Appendices 2 and 3) outlines the approach for crediting IC treatment and allows RIDOT to develop the methodology for EPA review and approval.

This section describes the structural control credits used as part of this methodology along with a brief explanation of the approach to their development.

4.1 Structural Controls Categories

RIDOT will implement a variety of structural controls to achieve water quality improvement and compliance with the Consent Decree. Although some controls may be configured or designed differently from each other, their basic water quality treatment mechanisms are similar and therefore the treatment credit of one control can apply to a range of similar controls.

Table 3 lists various structural controls RIDOT may implement, which EPA treatment curve applies to the control, and how they were modeled by VHB for flow attenuation and runoff reduction values (required for the IC Method – see Section 2.4 Watershed Reduction Target). See Appendix E for VHB's sketches of the controls' model representations and assumptions.

This list may change or be expanded in the future as RIDOT continues to implement and adapt their compliance program and develop their Linear Stormwater Manual.

Of note:

- Specific design enhancements or site-specific situations are <u>not</u> accounted for (e.g. additional detention provided by enhanced outlet control, treatment additives included in bioretention soils, etc.).
- Infiltration controls were divided into two general categories based on assumed infiltration rates: shallow and deep. Shallow infiltration controls have relatively shallower water ponding depths and larger surface areas for the same storage volume as a deep infiltration controls which will have deeper water ponding depths and smaller footprints.
- Surface structural controls without underdrains were represented as shallow infiltration.

Table 3 Structural Control Categories

Structural Controls Represented[7]	VHB Category for Modeling Flow and Runoff Reduction Factors	EPA Category for Pollutant Factor TSS, TP, TN, and Zn
Infiltration basin Bioretention basin (w/o underdrain) Bioretention swale (w/o underdrain) Infiltration swale (dry swale with check dams/outlet controls) Porous pavement (w/o underdrain)	Shallow Infiltration (<2 ft effective storage depth)	Infiltration Basin
Infiltration trench, chamber or dry well Leaching catch basin Subsurface infiltration structure Underground infiltration system	Deep Infiltration (>2 ft effective storage depth)	Infiltration Trench
Extended dry detention basin Dry detention pond	Extended Dry Detention	Dry Pond/ Extended Detention Basin
Bioretention basin (w/ underdrain) Bioretention swale (w/underdrain) Non-proprietary tree filter Green roof Media filter drain	Bioretention	Bio-filtration
Sand filter	Bioretention	Sand Filter
Porous pavement (w/ underdrain)	Porous Pavement	Porous Pavement
Wet vegetated treatment system (WVTS) Gravel WVTS	Gravel Wetland	Gravel Wetland System
Wet pond/swale Outlet sediment trap	Wet Pond	Wet Pond
Floodplain reconnection	Site-specific analysis	Gravel Wetland
Urban tree canopy	To Be Developed	See Appendix D
Qualifying pervious area[8]	100% treatment, no further analysis necessary	
Pervious land enhancement	Load, runoff volume and peak rate comparison between current and enhanced land cover. See Appendix D.	
Agriculture buffers	To Be Developed	See Appendix D
Hydrodynamic separators	No flow or runoff reduction.	Various Sources - See Appendix D

[7] Stormwater controls will be updated, expanded and refined as the RIDOT Linear Stormwater Manual progresses.

[8] See Rhode Island Stormwater Design and Installation Standards Manual, Section 4.6 for definition and criteria. Amended March 2015

4.2 Credit for Non-RIDOT Discharges

Per the framework outlined by RIDOT and EPA/RIDEM "Framework to be utilized by U.S. EPA and RIDEM for Determining Credit for Stormwater Treatment Outside a MS4 Operator's Area of Responsibility" on January 31, 2018 (see Appendix I), RIDOT may take treatment credit for treating discharges that do not originate on RIDOT property.

The RIDOT drainage system often receives runoff from non-RIDOT properties. For the purposes of Consent Decree compliance, all drainage that flows to a RIDOT stormwater control will receive full water quality credit. This includes the following non-RIDOT discharges:

- Sheet flow run-on (e.g. private parking lots, adjacent side slopes)
- Municipal interconnections
- Private tie-ins (e.g., churches, commercial properties)

In addition, RIDOT may take treatment credit for sponsoring treatment of solely non-RIDOT property that is in excess of required treatment for new and redevelopment required by the RIDISM.

RIDOT is allowed to identify and treat up to 25% of the total required reductions from non-RIDOT sources without special permission. In order to receive credit for more than 25% of the total reductions, RIDOT must receive approval from RIDEM and EPA via a Stormwater Control Plan or other special request if outside a SCP.

The contributing drainage areas, the RIDOT and Non-RIDOT quantities and the associated credit are tracked in the RIDOT database.

4.3 Credit for Partially Pervious Catchments

In highway settings, the contributing catchment area to a control may potentially contain a significant amount of pervious area due to a grassed right-of-way or other pervious contributions. This differs from the 100% impervious area contributing catchment area assumptions used to generate EPA's pollutant crediting results. VHB performed a sensitivity analysis for a range of catchments with fixed impervious cover and varying amounts of additional pervious cover, over different types of structural controls. The results showed that the additional pervious cover had significant effect on pollutant removal when the impervious cover was less than 50% of the catchment area.

The detailed approach to crediting when the contributing catchment area is less than 50% IC is in Appendix F. Resultant values are incorporated into the following sections, where appropriate.

4.4 Credit for the TMDL Method

The pollutant load reduction credit is calculated based on total load coming into the STU from impervious and pervious cover multiplied by the STU removal percentage from EPA's stormwater treatment performance curves. This is represented by the equation:

$$Pollutant\ Reduction\ \left(\frac{mass}{year}\right) = \left[\text{Impervious Load}\ \left(\frac{\text{mass}}{\text{year}}\right) + \text{Pervious Load}\ \left(\frac{\text{mass}}{\text{year}}\right)\right] \times \text{STU Pollutant Removal (\%)}$$

Impervious Load – This is the impervious load contributing to the STU that is calculated using the same values used to establish the TMDL method reduction targets (Section 2.3.2.1). RIDOT's contributing impervious catchment area is multiplied by the loading rate for the POC. Loading rates are found in Table 1 and are applied to all connected impervious cover areas in the watershed.

Pervious Load - In cases where controls are receiving runoff from RIDOT pervious areas, EPA's Developed Land Pervious HSG B loading rate will be used to be consistent with the assumptions used to developed STU pollutant removals (see Section 4.6). EPA's loading rates based on land use presented in the Massachusetts MS4 permit are used for contributing catchment areas that are not RIDOT property. Table 4 shows the loading rates.

Table 4 Impervious and Pervious Cover Loads

Land Use (Land Cover)	Pollutant Loading Rate, lb/ac/yr			
	Phosphorus	Nitrogen	Zinc	Total Suspended Solids
Impervious				
Commercial	1.8	15	1.4	377
Industrial	1.8	15	1.4	377
Institutional	1.8	15	1.4	377
Residential	2.3	14	0.7	439
Highway (SAME AS TABLE 1)	1.3	8.4	1.23	613
Forest	1.5	11	0.7	649
Open Land	1.5	11	1.0	649
Agriculture	1.5	11	0.7	649
Pervious				
Forest	0.12	0.54	0.02	29
Agriculture	0.45	2.6	0.02	29
Developed Land (HSG B)	0.12	1.2	0.02	29
RIDOT Right-of-Way	0.12	0.9*	0.02	29

*As discussed with EPA, this value was modified from the EPA value. The runoff nitrogen load export rate provided by EPA via their Opti-Tool supporting documentation assumes a 50% fertilized area. To reflect that RIDOT does not fertilize pervious areas, this load was modified to be 75% of the load provided by the EPA.

STU Pollutant Removal Percentages - EPA developed "Performance Curves" of annual average pollutant percent reductions for several types of structural stormwater best management practices based on storage volume (treatment depth) as described in the "Stormwater Best Management Practices Performance Analysis"[9]. These EPA values are the basis for pollutant removal rates presented in the Massachusetts NPDES MS4 permit, cited by the Consent Decree.

These Performance Curves were developed from long-term simulation SWMM models developed with New England precipitation data, hydrograph and simulated pollutant time series discharge. See **Error! Reference source not found.** for their results. EPA's values are based on assumed design configurations and assumed fully impervious contributing catchment area. Section 4.6 discusses how STU credit is altered when the contributing catchment area also includes pervious areas. Performance curves are available for Phosphorus, TSS, Zinc, and Nitrogen in Appendix G.

The steps for calculating STU pollutant removal (%) using EPA's performance curves are:

1. Estimate STU physical storage capacity (storage volume) for the potential STU location and configuration.
2. Calculate STU treatment depth as storage volume divided by the impervious contributing catchment area to the STU.
3. Select the appropriate EPA performance curve. EPA curves are specific to STU type (Table 3), pollutant of concern, and, for infiltration STUs, soil type. Section 4.6 discusses how EPA's curves were adapted for partially pervious catchment areas.
4. Use STU treatment depth to lookup pollutant removal (%) on the performance curve in Appendix G.

[9] Tetra Tech, Inc., Revised March 2010, Stormwater Best Management Practices (BMP) Performance Analysis. Available at: https://www3.epa.gov/region1/npdes/stormwater/assets/pdfs/BMP-Performance-Analysis-Report.pdf

Example: Lower Woonasquatucket Watershed 10-D TMDL Method of STU Treatment Credit

The Lower Woonasquatucket River Segment 10D has a 2007 EPA-approved TMDL for fecal coliform and dissolved metals. The Stormwater Control Plan found a potential site along a developed RIDOT ROW to treat for zinc. Basic planning-level design shows a 1.5 impervious acres and 0.5 pervious acres discharge to an outfall. This outfall could be retrofitted to a shallow infiltration basin. The area has sandy loam soils and the STU can be sized to treat 0.4 inches of runoff.
Note the STU Catchment Area is >50% IC (1.5 IC acres / 2 acres = 75%).

Example TMDL Method

Impervious Load = Impervious Catchment * Table 4 value for Land Use/Pollutant
= 1.5 acres * 1.23 lb/ac/yr = 1.85 lb/yr

Pervious Load = Pervious Catchment * Table 4 value for Land Use/Pollutant
= 0.5 acres * 0.02 lb/ac/yr = 0.01 lb/yr

STU Pollutant Removal = 0.99 (Appendix G, based on Pollutant, %IC, STU type, & Treatment Depth)
= 99%

$$Pollutant\ Reduction\ \left(\frac{mass}{year}\right) = \left[\text{Impervious Load}\ \left(\frac{\text{mass}}{\text{year}}\right) + \text{Pervious Load}\ \left(\frac{\text{mass}}{\text{year}}\right)\right] \times \text{STU Pollutant Removal (\%)}$$

$$Pollutant\ Reduction\ (\text{Zinc}) = \left[1.85\ \left(\frac{\text{lbs}}{\text{year}}\right) + 0.01\ \left(\frac{\text{lbs}}{\text{year}}\right)\right] \times 99\% = 1.84\ \left(\frac{\text{lbs}}{\text{year}}\right)$$

Therefore, this one STU removes 1.8-pounds of zinc per year, and RIDOT must remove 41.5 more pounds of zinc from its annual contribution through implementing additional non-structural BMPs and installing structural STUs.

4.5 Credit for the IC Method

IC treatment is estimated through a value known as the Pervious Cover Factor. This factor, which estimates how similar the discharge is to that of a completely pervious watershed, is made up of both water quality and water quantity calculations. The goal of this method is to promote solutions in the stormwater control plans that address all/most of the characteristics of urban stormwater runoff that cause biological, physical and chemical impairments. This factor is applied to the impervious cover treated (i.e., impervious catchment area) and results in an equivalent area reduced (acres). This method is applied for each STU until the incremental reductions achieve the final RIDOT IC reduction target (Equivalent Area from Section 2.3.3). Each STU or enhanced non-structural BMP reduces the equivalent impervious cover by the pervious cover factor and the impervious area that is treated. Therefore, the Equivalent IC Area that is reduced by a given control can be calculated as follows:

$$Equivalent\ Area\ Reduced\ (area) = \text{IC Treated (area)} \times \text{Pervious Cover Factor}$$

IC Treated (area) – the impervious catchment area that discharges to an STU, or the area that is treated by an enhanced non-structural BMP.

Pervious Cover Factor – The pervious cover factor numerates the quality of the stormwater discharge and quantifies its similarities to a pervious watershed. The comparison is measured for phosphorus, TSS, volume, and flow. The pervious cover factor is a value between zero and one and is represented as a decimal. Zero represents a watershed discharge that behaves as though it is completely impervious (e.g. failing grade, no treatment) and one represents a watershed discharge that behaves as though it is completely pervious (e.g. perfect grade, full treatment).

The Pervious Cover Factor is calculated in the formula below. Note the four main factors and that they are equally weighted. Two factors measure water quality benefits and two factors measure runoff (volume) and flow. Pre-calculated Factors to be used in equations are in Appendix H.

$$Pervious\ Cover\ Factor = \frac{[\text{Pollutant Factor TP} + \text{Pollutant Factor TSS} + \text{Runoff Factor} + \text{Flow Factor}]}{4}$$

4.5.1 The Pollutant Factor TP and Pollutant Factor TSS

These pollutant factors utilize EPA's pollutant removal estimates calculated for many structural controls (see Table 3 for a listing of controls and a guide to choose the correct curve for each control). The Consent Decree initially only allowed crediting TP removal. However, it was agreed that adding TSS into the crediting methodology captured a wider range of pollutants that will better represent highway runoff. Whereas,

phosphorus represents nutrient control of smaller particles, and TSS represents larger particles and shear mass/volume of pollutant discharges. The curves utilized for the pollutant removal percentage (TSS, TP) are found in Appendix G. The steps for calculating STU pollutant removal (%) using EPA's performance curves are explained in Section 4.4.

Once the pollutant removal percentage for TSS and TP is extracted from the curves found in Appendix G, the percent removal is converted into the Pollutant Factor. In order calculate the Pollutant Factor, the EPA percent removals are divided by 0.9. This is consistent with the Consent Decree assumption that a 90% reduction in a pollutant load is equivalent to a pervious cover pollutant load and therefore producing a Pollutant Factor of 1.0. Pollutant Factor (TSS, TP) may be calculated using Appendix G STU Pollutant Removal values or pre-calculated values may be found in Appendix H.

$$Pollutant\ Factor\ (TSS, TP) = \frac{\text{STU Pollutant Removal}}{0.9} \leq 1$$

4.5.2 Development of the Runoff Factor and the Flow Factor

Since the Runoff and Flow Factor values were not included in the IC description section of the Consent Decree, VHB developed long-term continuous simulation models of each structural control. EPA provided VHB with the SWMM input and climate files used in the development of their pollutant reductions and recently updated for their Stormwater Nutrient Management Optimization Tool (Opti-Tool)[10]. The VHB models used IC watershed runoff time series output from EPA's models as input to VHB's simulation of the controls. VHB configured storage nodes and links within SWMM to represent the various controls categories. The configurations were reviewed and agreed upon with EPA.

The current analysis includes structural controls sized for treatment depths up to of 2 inches, consistent with EPA's pollutant results. Future analysis may include quantifying the runoff reduction and peak rate control of larger STUs, which would further enhance the Runoff and Flow Factors and provide additional IC treatment.

Once the configuration was accepted, VHB ran the models for the 1992-2014 time period using the EPA's climate file which includes 1-hour precipitation data from the Boston Logan rain gage. A one-acre watershed was simulated to create values on a per-acre basis, which allows these values to be easily scalable. These models were used to develop the Runoff Factors and Flow Factors for each control as described in the following sections. Technical Memos of how the factors were developed and approved by EPA are included in Appendix B.

[10] EPA Region 1's Stormwater Nutrient Management Optimization Tool (Opti-Tool) https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=289305

4.5.2.1 Runoff Factor

The Runoff Factor can also be thought of as volume reduction. The total volume generated to a discharge point from a watershed increases as the impervious cover increases. Mitigating this issue, and bringing the overall volume of the discharge closer to a completely pervious watershed, requires retention and infiltration. The Runoff Reduction as a percentage was calculated by comparing volume of water discharged from a given control to the runoff volume of the IC watershed input over the entire time series to calculate the annual average runoff reduction for a given control.

$$Runoff\ Reduction\ (\%) = \frac{\text{Control Discharge} - \text{Total IC Runoff}}{\text{Total IC Runoff}}$$

The Runoff Factor is then calculated as the runoff reduction percentage divided by 0.9.

$$Runoff\ Factor = \frac{\text{Runoff Reduction (\%)}}{0.9}$$

Pre-calculated Runoff Factor values based on STU type and treatment depth are found in Appendix H.

4.5.2.2 Flow Factor

The flow factor aims to provide credit for reducing flow from impervious cover. Impervious flows, depending upon the impervious cover, can be destructive to natural systems, create stream bank and outfall erosion, flushing out natural sedimentation, degrading macroinvertebrates, and exacerbating flooding.

The flow factor measures how closely a control mimics flows from a pervious watershed (which represents a flow factor score of 1.0). The bigger the control, the more closely the control will mimic a pervious watershed, resulting in a higher score. The flow factor is calculated by comparing a given control's outflow with flow from both an impervious watershed and flow from a pervious watershed for eight water quality storm depths. The control's score for each of the eight water quality storm depths are averaged to produce a single flow factor.

$$Flow\ Factor = \frac{\Sigma_1^8(\text{Interpolate } Q_{STUi}\,[(Q_{100\%\ IC\ i},0),(Q_{0\%\ ICi},1)])}{8}$$

where Qi represents the flow at a point i (one of 8 probability intervals) along the flow duration curve either from the control's outflow (STU) or a 100% or 0% IC watershed.

Pre-calculated Flow Factor values based on STU type and treatment depth are found in Appendix H.

Example: Lower Woonasquatucket Watershed 10-D
IC Method of STU Treatment Credit

The Lower Woonasquatucket River Segment 10D has a 2007 EPA-approved TMDL for fecal coliform and dissolved metals.

The Stormwater Control Plan found a potential site along a developed RIDOT ROW to treat for IC. Basic planning-level design shows a 1.5 impervious acres and 0.5 pervious acres discharge to an outfall. This outfall could be retrofitted to a shallow infiltration basin. The area has sandy loam soils and the STU can be sized to treat 0.4 inches of runoff.

$$Equivalent\ Area\ Reduced\ (area) = \text{IC Treated (area)} \times \text{Pervious Cover Factor}$$

IC Treated (area) = 1.5 impervious acres

$$Pervious\ Cover\ Factor = \frac{[\text{Pollutant Factor TP} + \text{Pollutant Factor TSS} + \text{Runoff Factor} + \text{Flow Factor}]}{4}$$

Pollutant Factor TP, TSS = Appendix H based on STU type, Treatment Depth
= STU Pollutant Removal from Appendix G,
based on Pollutant, %IC, STU type, Treatment Depth / 0.9

Example
IC Method

$$Pollutant\ Factors\ (TP) = \frac{\text{STU Pollutant Removal}}{0.9} = \frac{0.81}{0.9} = 0.9$$

$$Pollutant\ Factors\ (TP) = \frac{\text{STU Pollutant Removal}}{0.9} = \frac{0.96}{0.9} = 1.0$$

Runoff Factor = Appendix H based on STU type, Treatment Depth = 0.78

Flow Factor = Appendix H based on STU type, Treatment Depth = 0.53

$$Pervious\ Cover\ Factor = \frac{[0.9 + 1.0 + 0.78 + 0.53]}{4} = 0.80$$

$$Equivalent\ Area\ Reduced\ (area) = IC\ Treated\ (area) \times Pervious\ Cover\ Factor$$

$$Equivalent\ Area\ Reduced\ (area) = 1.5\ \text{ac} \times 0.80 = 1.2\ \text{ac}$$

Therefore, this one STU treats 1.2 acres of impervious cover, and RIDOT must treat 66.8 more acres in the Watershed through implementing additional non-structural BMPs and installing more structural STUs.

4.6 Credit for Controls In Series

In some cases, one or more structural stormwater control may exist in a series (also known as a "treatment train"). In general, RIDOT prefers to capture the first flush over larger portions of their impervious cover verses installing multiple controls in series to provide additional treatment, mostly due to limited ROW and site constraints such as utilities. Pollutant removal efficiencies for specific pollutants decrease for each subsequent control in the treatment train, due to the removal of coarser-grained particles by the prior control. Controls further in the treatment train receive a greater amount of finer particulates, resulting in decreased removal efficiencies for pollutants associated with finer particles. For this methodology the most effective control will receive the full calculated treatment credit. Additional controls in series will receive 75% of the treatment credit. The overall credit is therefore the full credit for the most effective control plus 75% of the credit for the other controls in the series. This value is based on the Rhode Island Stormwater Design and Installation Standards Manual[11] discount rate for controls in series and, after discussion with EPA, was incorporated into the methodology for the least effective control.

[11] RIDEM. Rhode Island Stormwater Design and Installation Standards Manual. Amended March 2015. Available online at: http://www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

APPENDICES

Appendix A – Consent Decree Impairments, Roadway Related Stormwater, and Pollutant of Concern

Potential Impairments	RIDEM 303(d) List[12]	TMDL[13]	Stormwater Impairment	Applicable reduction targets
Metals				
Aluminum	X	X	X	Zinc
Cadmium	X	X	X	Zinc
Copper	X	X	X	Zinc
Iron	X	X	X	Zinc
Lead	X	X	X	Zinc
Zinc	X	X	X	Zinc
Mercury	X	X	X	N/A
Mercury in Fish Tissue	X			N/A
Bacteria				
Enterococcus	X	X	X	Impervious Cover (IC)
Fecal Coliform	X	X	X	IC
E. Coli		X	X	IC
Nutrients				
Total Nitrogen	X		X	Nitrogen
Total Phosphorus	X	X	X	Phosphorus
Excess Algal Growth	X	X	X	Saline (N), Fresh (P)
Chlorophyll-a			X	Saline (N), Fresh (P)
Organic Enrichment			X	Organic Material
Total Organic Carbon	X	X	X	Organic Material?

[12] RIDEM, March 2018, State of Rhode Island 2016 303(d) List of Impaired Waters. Available at: http://dem.ri.gov/programs/benviron/water/quality/surfwq/pdfs/iwr16.pdf

Only stormwater-related impairments as defined by the Consent Decree: United States of America, December 22, 2015. Final Consent Decree. Civil Action No. CV-15-433

[13] Approved as of December 13. 2017 according to RIDEM: http://www.dem.ri.gov/programs/water/quality/restoration-studies/reports.php

Potential Impairments	RIDEM 303(d) List[12]	TMDL[13]	Stormwater Impairment	Applicable reduction targets
Dissolved Oxygen	X	X	X	Saline (N), Fresh (P)
Observed Effects				
Taste, Color and Odor		X	X	Saline (N), Fresh (P)
Misc Impairments				
Benthic-Macroinvertebrate Bioassessments	X		X	
Impaired Biota			X	
Non-Native Aquatic Plants[14]	X			
Chloride			X	Chloride application
Total Suspended Solids	X	X	X	TSS
Turbidity	X		X	TSS
Hydrocarbons			X	
Ambient Bioassays	X			
Sediment Bioassay	X			N/A
Dioxin	X			N/A
Dioxin in Fish Tissue				N/A
PCB	X			N/A
PCB in Fish Tissue	X			N/A
Total Organic Carbon	X			
Whole Effluent Toxicity	X			N/A
Temperature, Water	X		X	Temp (if Roadway is named)
Other Flow Regime Alterations	X		X	Flow (if Roadway is named)
Eurasian Water Milfoil, Myriophyllum spicatum	X			
Chronic Aquatic Toxicity	X			

[14] No TMDL required. Impairment is not a pollutant.

Appendix B – Technical Memos Documenting Refinements and Developments to Consent Decree Methodology

Technical memos on the following topics will be added to this appendix as they are developed:

1. Refinement of stormwater-related impairments and the target pollutants of concern.
2. Use of custom zinc, total suspended solids (TSS), and nitrogen impervious cover loading rates for highways.
3. The development of a Runoff Reduction Factor and a Flow Factor for use in the IC Method which is intended to provide credit for volume reductions and peak flow reductions.
4. Use of total suspended solids (TSS) and total phosphorus (TP), versus just TP, to develop the Pollutant Factor impervious cover metric.
5. Refinement of how to quantify the Flow Factor.
6. Addition of specific structural and non-structural controls not identified in the Consent Decree and its referenced documents.
7. Additional guidance for crediting treatment of non-RIDOT runoff based on RIDEM and EPA direction.

Appendix C – Non-Structural Control Treatment Approaches

This Appendix provides additional information on the development of non-structural control treatment credits.

Enhanced Street Sweeping and Catch Basin Cleaning

Description: Enhanced street sweeping removes debris, sediment, and associated pollutants from road surfaces, which improves the quality of stormwater runoff. Similarly, enhanced catch basin cleaning reduces the volume of sediment and associated pollutants entering the drainage system.

Pollutants Addressed: Phosphorus, Nitrogen, TSS, Metals

Calculation Approach: Methodology from the Florida Stormwater Association Assessment Tool, developed for the Florida Department of Environmental Protection[15] was used to calculate nutrient, total suspended solids, and metal treatment credit for enhanced street sweeping and catch basin cleaning practices. The volume of solids collected and ratios of solids to pollutants of concern is used to estimate load reduction for each sweeping activity or load per catch basin cleaning using the following equation:

$$Annual\ Load\ Reduction\ \left(\frac{lb}{yr}\right) = Volume\ of\ Solids\ (ft^3) * Bulk\ Density\left(\frac{lb}{ft^3}\right) * \ Annual\ Frequency * Ratio\ \left(\frac{Pollutant\ lb}{TSS\ lb}\right)$$

where:

- Volume of solids = volume of dry (less than 2% moisture content by weight) solids collected per sweeping or catch basin cleaning event, ft^3
- Bulk density = dry bulk density of solids, assumed to be 85 lb/ft^3
- Annual frequency = number of sweeping or catch basin cleaning events per year
- Ratio = ratio of pollutant to TSS

[15] Bateman, Michael. 2012. Methodology for Calculating Nutrient Load Reductions Using the FSA Assessment Tool. https://www.dep.state.fl.us/water/stormwater/npdes/docs/methodology-calculating-reduction-credits.pdf

Estimates for the ratios of different nutrients and metals to total suspended solids were developed from the data provided in Table 16 of the USGS Report *Quality of Stormwater Runoff Discharged from Massachusetts Highways, 2005-07*[16]. **Table C-1** presents these values which are estimates of typical roadway sediments.

Table C- 1 Pollutant to Total Suspended Solids Ratio

TP/TSS	TN/TSS	Zn/TSS
0.0007	0.0070	0.0012

Sand Application Elimination

Description: This measure includes reducing pollutant loading through the reduction of sanding and use of alternative roadway treatments instead of sand during winter storm operations.

Pollutants Addressed: TSS

Calculation Approach: The removal of pollutants through the reduction or elimination of sanding operations involves determining the annualized mass of sand that is removed and/or not applied (which can be estimated from roadway miles and/or data from past operations). To estimate the load that was being delivered to the receiving water before the removal of sand, a delivery factor (to be developed) is then applied. The formula is as follows:

$$Pollutant\ Reduction\ \left(\frac{lb}{yr}\right) = Mass\ of\ sand\ eliminated\ \left(\frac{lb}{yr}\right) * Delivery\ Factor$$

Leaf Litter Removal

Description: The regular gathering, removal, and disposal of landscaping wastes, organic debris, and leaf litter from impervious surfaces reduces nutrient loading to stormwater runoff.

Pollutants Addressed: Phosphorus

Calculation Approach: EPA's Method of crediting, outlined in the Massachusetts MS4 General Permit Appendix F Attachment 2[17] credits phosphorus reduction based

[16] Smith, Kirk P., and Gregory E. Granato. "Quality of Stormwater Runoff Discharged from Massachusetts Highways, 2005–07." Scientific Investigations Report, vol. 2009-5269, 2010, pp. 135–182., pubs.usgs.gov/sir/2009/5269/disc_content_100a_web/sir2009-5269_s508.pdf. United States Geological Survey Prepared in cooperation with the U.S. Department of Transportation Federal Highway Administration and the Massachusetts Department of Transportation

[17] Massachusetts MS4 General Permit. Appendix F Attachment 2. https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/appendix-f-2016-ma-sms4-gp.pdf

on impervious area and loading rate. This method includes the following equation and inputs:

$$Phosphorus\ Load\ Reduction\ \left(\frac{lb}{yr}\right) = Area\ (ac) * Phosphorus\ Load\ Export\ Rate\ \left(\frac{\frac{lbs}{ac}}{yr}\right) * Phosphorus\ Reduction\ Factor\ (\%)$$

where:

- Area = impervious area cleaned (ac)
- Phosphorus Load Export Rate, assumed to be 1.3 lb/ac/yr for highway directly connected impervious cover
- Phosphorus reduction factor = 5% (this value may be further refined based on Vermont Department of Environmental Conservation's ongoing research)
- Assumes collection at least once per week from September 1 to December 1 of each year

Dog and Bird Waste Removal

Description: Eliminating animals waste sources that cause direct loading of pollutants to waterbodies via closed drainage systems without overland treatment or directly loaded to waterbodies. Examples of measures that would help prevent pollutant loading include dog park maintenance and avian bridge deterrents.

Pollutants Addressed: Phosphorus, Nitrogen, Bacteria

Calculation Approach: Estimation of pollutant removal was based on an annualize mass of waste produced by an individual animal, an equivalent number of animals making deposits that will impact the waterbody of interest, and waste quality. The formula is as follows:

$$Pollutant\ Removed\ \left(\frac{lb}{yr}\right) = Number\ of\ Animals * Mass\ of\ Waste\ per\ Animal\ \left(\frac{lb}{yr}\right) * \frac{Pollutant\ (lb)}{Waste\ (lb)}$$

The "number of animals" variable approximates the equivalent number of animals that the waste is removed for (animal-year). For this methodology, it may take more than 1 animal visiting a site to produce the daily waste of one animal. For example, if the removal of the equivalent daily waste of 10 dogs occurs each day at a dog park, the number of animals would be 3,650 for a year, even if the actual number of visiting animals was much higher. These numbers could be estimated or a study/survey could be undertaken to estimate the number of animals at the site of interest, as well as the individual animal's time spent at the site. Estimate annual

loading (lbs/animal/year) are listed in the **Error! Reference source not found.**. Three representative values of birds are included: a small-size bird, such a pigeon), a medium-sized bird (such as a duck), and a large-sized bird (such as a Canada goose).

Table C- 2 Phosphorus Loading by Animal

Animal	Load (lb/animal/year)	lbs P/lb waste
Dog	273.8[18]	0.0025[19]
Canada Goose (Large Bird)	65.7[20]	0.0187[21]
Duck (Medium Bird)	17.0	0.0187
Pigeon (Small Bird)	6.7	0.0187

Manure Removal

Description: Removal of uncovered manure piles near waterways reduces the loading of pollutants that migrate via stormwater runoff. This method estimates the reduction of pollutant loading based on the mass of removed manure.

Pollutants Addressed: Phosphorus, Nitrogen, Bacteria

Calculation Approach: The formula for removal credit from manure removal multiplies an annualized mass of removed waste and ratio of the mass of pollutant of interest per mass of waste to yield a total potential mass of the constituent of interest. To estimate the load that was being delivered to the receiving water before the removal of the manure, a delivery factor is then applied to account for losses via leaching and, in the case of nitrogen, volatilization. The formula is as follows:

$$Pollutant\ Removed\left(\frac{lb}{yr}\right) = Waste\ Removed\ (lb/yr) * \left(\frac{Pollutant\ (lb)}{Waste\ (lb)}\right) * Delivery\ Factor$$

Error! Reference source not found. includes data from NRCS[22] to estimate the phosphorus and nitrogen content of varying livestock wastes. These values are given in pounds of constituent per pound of manure.

[18] "Fact Sheet: Pet Waste & Water Quality." Rensselaer Land Trust (Renstrust.org), Rensselaer Land Trust, www.renstrust.org/images/projects/FactSheetPetWaste.pdf.

[19] *Design, Testing, and Implementation of a Large-Scale Urban Dog Waste Composting Program*, led by a team of researchers from Concordia University.

[20] Scherer, Nancy M., et al. "Phosphorus Loading of an Urban Lake by Bird Droppings." Lake and Reservoir Management, vol. 11, no. 4, 1995, pp. 317–327., doi:10.1080/07438149509354213. Values for annualized bird waste from Table 1.

[21] *Phosphorus Loading of an Urban Lake by Bird Droppings*, prepared in 1995 by KCM, Inc.

[22] "Estimating Moist Bulk Density by Texture." Estimating Moist Bulk Density by Texture | NRCS Soils, Natural Resources Conservation Service, 2018, www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr10/tr/?cid=nrcs144p2_074844.

Table C- 3 Nutrient Content of Various Livestock Waste

Livestock Type	Total Manure (lb/day/1000 lb animal)	Nitrogen (lb/day/1000 lb animal)	Phosphorus (lb/day/1000 lb animal)	lbs P/ lbs Manure
Beef Cow	59.1	0.31	0.11	0.0019
Dairy Cow	80.0	0.45	0.07	0.0009
Hogs/Pigs	63.1	0.42	0.16	0.0025
Chickens (Layers)	60.5	0.83	0.31	0.0051

Delivery factors for the manure piles are based on potential losses of phosphorus, nitrogen, and bacteria through biological processes, leaching and gaseous emissions in addition to the delivery of pollutants via runoff. Further research is needed to develop these delivery factors.

Site-specific discharge concentrations could be developed using leachate sampling. The development of this methodology would best be served by a pilot project to aid in deciding how to properly credit nutrient removal.

Dredging

Description: Pollutants that have been discharged to and accumulating in receiving waters can be removed directly via dredging. The method calculates an estimate of mass of removed pollutant based on the mass of removed dry sediment.

Pollutants Addressed: TSS, Phosphorus, Nitrogen, Metals

In addition to removal of these pollutants, dredging provides a number of benefits including improvements to the navigability of waterways, potential removal of contaminated material, improved flushing and circulation of waterbodies, and encouragement of habitat reestablishment by exposing historic sediments.

Calculation Approach: Estimates for the ratios of different nutrients and metals to total suspended solids were developed from the data provided in Table 16 of the USGS Report *Quality of Stormwater Runoff Discharged from Massachusetts Highways,*

2005-07[23]. **Error! Reference source not found.** presents these values which are estimates of typical roadway sediments.

Table C- 4 Pollutant to Total Suspended Solids Ratio

TP/TSS	TN/TSS	Zn/TSS
0.0007	0.0070	0.0012

These ratios can be used for initial estimates of pollutants removed, but can be supplemented with site-specific sediment sampling to acquire updated ratios.

The following formula quantifies pollutant removal based on the pollutant to TSS ratios:

$$Pollutant\ Removed\ (lb) = (TSS\ Removed\ (lb) * \left(Ratio\ \left(\frac{lb\ Pollutant}{lb\ TSS}\right)\right)$$

Streambank Restoration

<u>*Description:*</u> This measure includes reducing pollutant loading from eroding streambanks. An annual volume of prevented sediment erosion is calculated using an area of eroding streambank, field-observed annual depth of erosion, and soil bulk density.

<u>*Pollutants Addressed:*</u> TSS, Phosphorus, Nitrogen, and Metals

<u>*Calculation Approach*</u>: The formula is based on Protocol 4 of the Urban Stormwater Work Group and Chesapeake Bay Partnership guidelines on stream restoration techniques,[24] as well as EPA Region 5 guidance for the state of Michigan.[25] The

[23] Smith, Kirk P., and Gregory E. Granato. "Quality of Stormwater Runoff Discharged from Massachusetts Highways, 2005–07." Scientific Investigations Report, vol. 2009-5269, 2010, pp. 135–182., pubs.usgs.gov/sir/2009/5269/disc_content_100a_web/sir2009-5269_s508.pdf. United States Geological Survey Prepared in cooperation with the U.S. Department of Transportation Federal Highway Administration and the Massachusetts Department of Transportation

[24] Schueler, Tom, et al. "Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects." Chesapeake Stormwater Network, Chesapeake Stormwater Network & Center for Watershed Protection, 17 Jan. 2014, www.chesapeakebay.net/documents/Final_CBP_Approved_Stream_Restoration_Panel_report_LONG_with_appendices_A-G_02062014.pdf.

[25] Harding, Russell J., and John Engler. Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual. Michigan Department of Environmental Quality, Surface Water Quality Division, Nonpoint Source Unit, 1999. EPA Region 5 Manual

formula takes an area of erosion, soil bulk density based on soil type, and lateral recession rate (LRR) that estimates the depth of material that erodes from the bank. The formula is as follows:

$$Annual\ Load\ Reduction\ \left(\frac{lb}{yr}\right) = \left(Bulk\ Density\ of\ Soil\left(\frac{lbs}{ft^3}\right)\right) * \left(Eroding\ Bank\ Area(ft^2)\right) * \left(Bank\ Erosion\ Rate\ \left(\frac{ft}{yr}\right)\right) * \left(\frac{Pollutant\ (lb)}{TSS\ (lb)}\right)$$

Where:

- Bulk density is based on moist bulk density values which can be provided by NRCS[26] or site-specific information as available.
- The eroding bank area can be estimated in the field visually and with measuring tools. The area can be estimated as a trapezoid, with a top length, bottom length, and height of the eroding area.
- Bank erosion rate, or lateral recession rate (LRR) is an estimate of the depth of soil eroding away from a bank or gully in a year. Approximations of rates from the EPA Region 5 Manual, including representative "midpoints" for each category of erosion, can be found in the tables below

[26] "Estimating Moist Bulk Density by Texture." Estimating Moist Bulk Density by Texture | NRCS Soils, Natural Resources Conservation Service, 2018, www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/office/ssr10/tr/?cid=nrcs144p2_074844.

Table C- 5 Lateral Recession Rate for Stream/Ditch Banks

LRR (ft/yr)	Midpoint (ft/yr)	Category	Description
0.01 - 0.05	0.03	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.06 - 0.2	0.13	Moderate	Bank is predominantly bare with some rills and vegetative overhang.
0.3 - 0.5	0.4	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross section becomes more U-shaped as opposed to V-shaped.
0.5+	0.5	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

Table C- 6 Lateral Recession Rate for Roadbanks and at Road/Stream Crossings

LRR (ft/yr)	Midpoint (ft/yr)	Category	Description
0.01 - 0.05	0.03	Slight	Some bare roadbank but active erosion not readily apparent. Some rills but no vegetative overhang. Ditch bottom is grass or noneroding.
0.06 - 0.15	0.105	Moderate	Roadbank is bare with obvious rills and some vegetative overhang. Minor erosion or sedimentation in ditch bottom.
0.16 - 0.3	0.23	Severe	Roadbank is bare with rills approaching one foot in depth. Some gullies and overhanging vegetation. Active erosion or sedimentation in ditch bottom. Some fenceposts, tree roots, or culverts eroding out.
0.3+	0.3	Very Severe	Roadbank is bare with gullies, washouts, and slips. Severe vegetative overhang; fenceposts, powerlines, trees and culverts eroded out. Active erosion or sedimentation in ditch bottoms.

The formula multiplies eroding area and depth to generate a volume, and then multiplies that volume by a soil bulk density to get a mass of eroding soil per year.

The most accurate soil quality information (mass constituent/mass soil) can be developed by sampling at the site and performing laboratory analysis of soil samples. Soil nutrient content is dependent on a number of circumstances and is highly variable across regions. Consultation with USDA may be helpful to develop a set of typical values for Rhode Island soils. Further development of this methodology would benefit from a pilot project to establish nutrient concentrations in soil.

Illicit Discharge Elimination

Description: Illicit discharges include non-stormwater discharges entering the stormwater system. Eliminating these discharges reduces loads of pollutants that were in those discharges.

Pollutants Addressed: Phosphorus, Nitrogen, Metals, and Bacteria

Calculation Approach: The removal of pollutants through elimination of illicit discharges involves the annual illicit discharge flow multiplied by pollutant concentrations in the discharge of interest. A draft formula approximating this removal has been created and is as follows:

$$Pollutant\ Reduction\ \left(\frac{lb}{yr}\right) = Annual\ Illicit\ Flow\ \left(\frac{volume}{yr}\right) * Pollutant\ Concentration\left(\frac{lb}{volume}\right)$$

Annual illicit flow can be approximated via direct measurement of the illicit flow and/or receiving drainage system during dry conditions and/or when the illicit connection is actively discharging. Illicit discharge water quality can be most reliably quantified by site-specific sampling of the discharge. An approximation based on the illicit source can also be used.

Appendix D – Select Structural Control Treatment Approaches

This Appendix provides additional information on the development of select structural control treatment credits.

Urban Tree Canopy

Description: Vegetation, specifically trees, improves water quality runoff in urban areas by filtering runoff as it passes through the ground as well as through uptake nutrients and other contaminants.

Pollutants Addressed: TSS, Phosphorus, Nitrogen

Calculation Approach: The Pollutant Load Reduction Credit Tool,[27] developed by the Center for Watershed Protection, quantifies an annual reduction in nutrient and sediment loads due to urban tree planting on a per tree basis. The credit is designated by climate zone, underlying land cover (hydrologic soil group if pervious cover), and tree type (small, medium, or large broadleaf deciduous; small or large coniferous evergreen; or unknown).[28]

Optimal load reduction for phosphorus, nitrogen, and TSS for the Northeast climate zone are shown in **Error! Reference source not found.**. Qualifying conditions must be met for optimal credit to be taken, which include the development of a maintenance plan, leaf litter pickup program (for trees planted over impervious cover) and the consultation of a qualified professional on the selection of appropriate species, site preparation, and siting to provide sufficient soil volume. If qualifying conditions are not met, a reduced credit equal to 70% of optimal credit is given.

Table D- 1 Pollutant Load Reductions for Urban Tree Planting

Underlying Soil Type/Land Cover	Load Reduction (lb/year/tree)		
	TN	TP	TSS
Broadleaf Deciduous - Large			
HSG-A, pervious	0.0020	0.0003	0.19
HSG-B, pervious	0.0067	0.0012	0.65
HSG-C, pervious	0.0116	0.0020	1.12
HSG-D, pervious	0.0153	0.0026	1.48

[27] Center for Watershed Protection. 2017. Pollutant Load Reduction Credit. Crediting Framework Product #3 for the project Making Urban Trees Count: A Project to Demonstrate the Role of Urban Trees in Achieving Regulatory Compliance for Clean Water. Center for Watershed Protection, Ellicott City, MD.

[28] Hynicka, J. and D. Caraco. 2017. Relative and Absolute Reductions in Annual Water Yield and Non-Point Source Pollutant Loads of Urban Trees. Crediting Framework Product #2 for the project Making Urban Trees Count: A Project to Demonstrate the Role of Urban Trees in Achieving Regulatory Compliance for Clean Water. Center for Watershed Protection, Ellicott City, MD.

Underlying Soil Type/Land Cover	Load Reduction (lb/year/tree)		
	TN	TP	TSS
Unknown soil type, pervious	0.0116	0.0020	1.12
Impervious cover	0.0094	0.0016	0.91
Broadleaf Deciduous - Medium			
HSG-A, pervious	0.0039	0.0007	0.38
HSG-B, pervious	0.0133	0.0023	1.28
HSG-C, pervious	0.0229	0.0039	2.21
HSG-D, pervious	0.0301	0.0052	2.90
Unknown soil type, pervious	0.0229	0.0039	2.21
Impervious cover	0.0187	0.0032	1.81
Broadleaf Deciduous - Small			
HSG-A, pervious	0.0008	0.0001	0.08
HSG-B, pervious	0.0026	0.0004	0.25
HSG-C, pervious	0.0043	0.0007	0.41
HSG-D, pervious	0.0055	0.0010	0.53
Unknown soil type, pervious	0.0043	0.0007	0.41
Impervious cover	0.0033	0.0006	0.31
Coniferous Evergreen - Large			
HSG-A, pervious	0.0034	0.0006	0.32
HSG-B, pervious	0.0112	0.0019	1.08
HSG-C, pervious	0.0187	0.0032	1.81
HSG-D, pervious	0.0243	0.0042	2.34
Unknown soil type, pervious	0.0187	0.0032	1.81
Impervious cover	0.0178	0.0031	1.72
Coniferous Evergreen - Small			
HSG-A, pervious	0.0012	0.0002	0.11
HSG-B, pervious	0.0043	0.0007	0.42
HSG-C, pervious	0.0077	0.0013	0.74
HSG-D, pervious	0.0102	0.0018	0.98
Unknown soil type, pervious	0.0077	0.0013	0.74
Impervious cover	0.0100	0.0017	0.96
Unknown Tree Type			
HSG-A, pervious	0.0039	0.0007	0.38
HSG-B, pervious	0.0133	0.0023	1.28
HSG-C, pervious	0.0229	0.0039	2.21
HSG-D, pervious	0.0301	0.0052	2.90
Unknown soil type, pervious	0.0229	0.0039	2.21
Impervious cover	0.0187	0.0032	1.81

Floodplain Reconnection

Description: Floodplain reconnection is the development of additional/enhanced floodplain for a given stream corridor. The floodplain allows for storage and treatment of riverine flows.

Pollutants Addressed: TSS, Phosphorus, Nitrogen, and Metals

Calculation Approach: This calculation method is based on the information presented in the Chesapeake Bay Program's stream restoration crediting document[29]. The Chesapeake Bay Program approach (Protocol 3) is based on pollutant reduction in the additional floodplain and the existing pollutant load in the stream. The calculation accounts for the percentage of rainfall treated on an annual basis, as the floodplain area will only be accessed when water levels are high enough as a result of certain rainfall events. The equation estimating removal credit is as follows:

$$Pollutant\ Removed\ \left(\frac{lb}{yr}\right) = Pollutant\ Reduction\ in\ Gravel\ Wetland\ (\%) * Stream\ Watershed\ Load\ \left(\frac{lb}{yr}\right) * Annual\ Rainfall\ Treated\ (\%)$$

Where:

$$Stream\ Watershed\ Load\ \left(\frac{lb}{yr}\right) = \text{Stream}\ Watershed\ Area\ (ac) * \text{Watershed}\ Load\ \text{by Landuse}\left(\frac{lb}{ac}\right)$$

Pollutant reduction percentage in the wetland is based on the EPA treatment curves that calculate removal rates based on the depth of rainfall treated. The Chesapeake Bay protocol uses the treatment credit for a created wetland, which EPA Region 1 currently assigns the gravel wetland treatment curve.

The stream watershed loads are based on a watershed acreage and EPA's load by land use from the Massachusetts MS4 permit (**Error! Reference source not found.** of this report) to calculate an annualized load of pollutant into the stream of interest.

The percent of annual rainfall treated is the anticipated percent of annual rainfall expected to flow though the new floodplain . Using a hydraulic modeling program such as HEC-RAS, the minimum rainfall event that overtops into the proposed

[29] Schueler, Tom, et al. "Recommendations of the Expert to Define Removal Rates for Individual Stream Restoration Projects ." Chesapeake Stormwater Network, Chesapeake Stormwater Network & Center for Watershed Protection, 17 Jan. 2014, www.chesapeakebay.net/documents/Final_CBP_Approved_Stream_Restoration_Panel_report_LONG_with_appendices_A-G_02062014.pdf.

floodplain areas must be calculated. This, along with site-specific rainfall records are used to estimate the percent of annual runoff treated.

Because of the complex nature of generating location-specific values for the percent of annual rainfall treated, it is anticipated that the methodology will be further developed when a pilot project is performed.

Pervious Land Enhancement

Description: Improving pervious cover soil and vegetation quality can provide water quality benefits. The introduction of quality soils and vegetation provides peak rate attenuation of stormwater runoff, reduction of stormwater runoff volume, and improved water quality treatment.

Pollutants Addressed: TSS, Nitrogen, Phosphorus, and Metals

Calculation Approach: The treatment calculation involves the calculation of pre and post runoff, peak rates, and pollutant loads that discharge the area of interest.

EPA's pollutant loading by land use presented in the Massachusetts MS4 permit can be used for calculated loads based on current and enhanced land cover/soil types and using the difference as the pollutant load reduction.

VHB will use its developed long-term continuous simulation models using EPA's SWMM described in Section 4 to estimate the difference in runoff volume and peak rate in the current and enhanced parcels.

Specific values and assumptions will be added to this document as this measure is implemented.

Agriculture Buffers

Description: Agriculture buffers are vegetated areas placed between agricultural land uses and receiving waters such as ponds, wetlands, and rivers. The methodology is based on the Chesapeake Bay Program's Recommendations of the Expert Panel to Reassess Removal Rates for Riparian Forest and Grass Buffers Best Management Practices[30]. The method is based on runoff quality and reduction efficiency based on the geological setting of the buffer.

Pollutants Addressed: TSS, Phosphorus, Nitrogen, and Bacteria. Metals if suspected as present on agricultural land.

Calculation Approach: The Chesapeake Bay Program developed and recommended reduction efficiencies for a number of scenarios. These efficiencies can be applied to

[30] Belt, Ken, and Et. al. "Recommendations of the Expert Panel to Reassess Removal Rates for Riparian Forest and Grass Buffers Best Management Practices." Forestry Workgroup and Chesapeake Stormwater Network, Oct. 2014, www.chesapeakebay.net/documents/Riparian_BMP_Panel_Report_FINAL_October_2014.pdf.

pollutant concentrations in agricultural runoff to generate an approximate load reduction to a waterbody of interest as follows:

$$Load\ Reduction\ \left(\frac{lb}{yr}\right) = Annual\ Runoff\ Volume\ \left(\frac{volume}{yr}\right) * Pollutant\ Concentration \left(\frac{lb}{volume}\right) * Load\ Reduction\ \left(\frac{Efficiency}{100}\right)$$

Published pollutant concentrations can be used to characterize pollutant concentrations based on crop type and fertilizing approaches or site-specific data may be used. These values can be identified as this measure is implemented to RIDOT.

Removal efficiencies are proposed in the Chesapeake Bay Program report mentioned above, and are based on geologic conditions and buffer type:

> Forest Buffer: linear wooded areas adjacent to a body of water and managed to reduce the impacts of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals, to supply food, cover, and thermal protection to fish and other wildlife. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with 35 feet minimum width required.
>
> Grass Buffer: linear strips of grass or other non-woody vegetation maintained between the edge of fields and a water body that help filter nutrients, sediment and other pollutants from runoff. The recommended buffer width for riparian grass buffers (agriculture) is 100 feet, with a 35 feet minimum width required.

Error! Reference source not found. shows the recommended removal efficiencies of different geologic settings and buffer combinations. These values were developed for the Chesapeake Bay area and further review is needed to apply these Chesapeake Bay values to Rhode Island.

Table D- 2 Chesapeake Bay Program Proposed Load Reduction Efficiencies

Geographic Setting	Forest (One Side) (%)			Grass (One or Both Sides) (%)		
	TN	TP	TSS	TN	TP	TSS
Inner Coastal Plain	65	42	56	46	42	56
Outer Coastal Plain (well-drained)	31	45	60	21	45	60
Outer Coastal Plain (poorly-drained)	56	39	52	39	39	52
Tidal Influenced	19	45	60	13	45	60
Piedmont (schist/gneiss)	46	36	48	32	36	48
Piedmont (sandstone)	56	42	56	39	42	56
Valley and Ridge (karst)	34	30	40	24	30	40
Valley and Ridge (sandstone/shale)	46	39	52	32	39	52
Appalachian Plateau	54	42	56	38	42	56

VHB will use its developed long-term continuous simulation models using EPA's SWMM described in Section 4 to estimate the peak rate and runoff reductions to estimate equivalent IC treatment.

Specific values and assumptions will be added to this document as this measure is implemented.

Proprietary Technologies

Description: RIDEM's Stormwater Technical Review Committee has reviewed and accepted proprietary technologies for treatment credit based on the Technology Acceptance Reciprocity Partnership (TARP) protocol including:

- General hydrodynamic separators
- The Jellyfish Filter is a membrane filter that serves as a flow through treatment practice.[31]
- The Modular Wetland System – Linear (MWS-Linear) is a modular precast concrete structure which includes a pre-treatment and wetland chamber.[32]

[31] RIDEM. Alternative Stormwater Technology Certification (Jellyfish Filter). Issued November 23, 2015. Available online at: http://www.dem.ri.gov/programs/benviron/water/permits/swcoord/pdf/jellyfishcert.pdf

[32] RIDEM. Alternative Stormwater Technology Certification (MWS Linear 2.0 Biofiltration System). Issued November 23, 2015. Available online at: http://www.dem.ri.gov/programs/benviron/water/permits/swcoord/pdf/mwscert.pdf

› The Stormceptor system is a precast concrete structure designed to remove hydrocarbons and sediment from stormwater.[33]

Pollutants Addressed: TSS, Phosphorus, Nitrogen, Metals

Calculation Approach:

For general hydrodynamic separators the approach uses TSS credits provided by RIDEM and Virginia Department of Environmental Quality's total phosphorus reduction credits based on the TSS removal from TARP Protocol studies, according to the **Error! Reference source not found.**. Hydrodynamic separators are eligible to receive 25% credit for TSS in the Rhode Island Stormwater Design and Installation Standards Manual[34]. This TSS credit correlates to a total phosphorus reduction of up to 10% using the values in **Error! Reference source not found.**.

Table D- 3 Summary of Testing Procedure with Associated Percent TP Removal Efficiencies[35]

Testing Protocol Followed	Chemical Parameter	Certification	% TSS Removal	% TP Removal
TARP	TSS	Required	<50%	Up to 10%
			≥ 50%	Up to 20%
			≤ 80%	Up to 40%

For propriety technologies, pollutant reductions given by RIDEM based on TARP results are shown in **Error! Reference source not found.**. Zinc removal values could be calculated based on typical ratios of TSS to zinc. Pollutant, flow and runoff factors used to determine effective IC reductions are shown in **Error! Reference source not found.** (proprietary devices are assumed to provide no reduction in runoff volume or peak rates).

Table D- 4 Pollutant Reduction for Proprietary Technologies

Type	TSS Reduction (%)	TP Reduction (%)	TN Reduction (%)
Hydrodynamic Separators	25	10	0
Jellyfish Filter	85	50	50
MWS-Linear	85	64	45
Stormceptor	75	0	0

[33] RIDEM. Alternative Stormwater Technology Certification (Stormceptor Stormwater Treatment System). Issued November 23, 2015. Available online at: http://www.dem.ri.gov/programs/benviron/water/permits/swcoord/pdf/stormceptorcert.pdf

[34] RIDEM. Rhode Island Stormwater Design and Installation Standards Manual. Amended March 2015. Available online at: http://www.dem.ri.gov/pubs/regs/regs/water/swmanual15.pdf

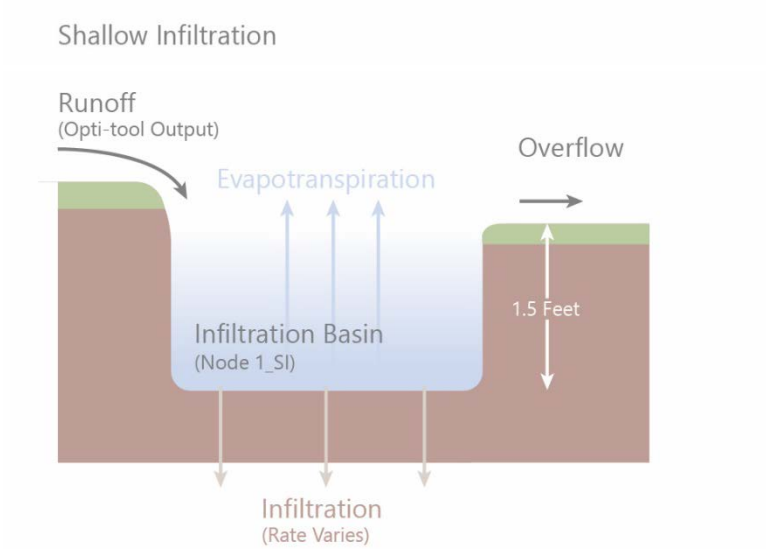
[35] Guidance Memo No. 14-2009 Interim Use of Stormwater Manufactured Treatment Devices (MTDs) to Meet the New Virginia Stormwater Management Program (VSMP) Technical Criteria, Part IIB Water Quality Design Requirements. 2014. Virginia Department of Environmental Quality. http://www.vwrrc.vt.edu/swc/documents/GM14-2009.Interim_Use_Of_SW_MTDs_To_Meet_New_VSMP_Criteria.pdf

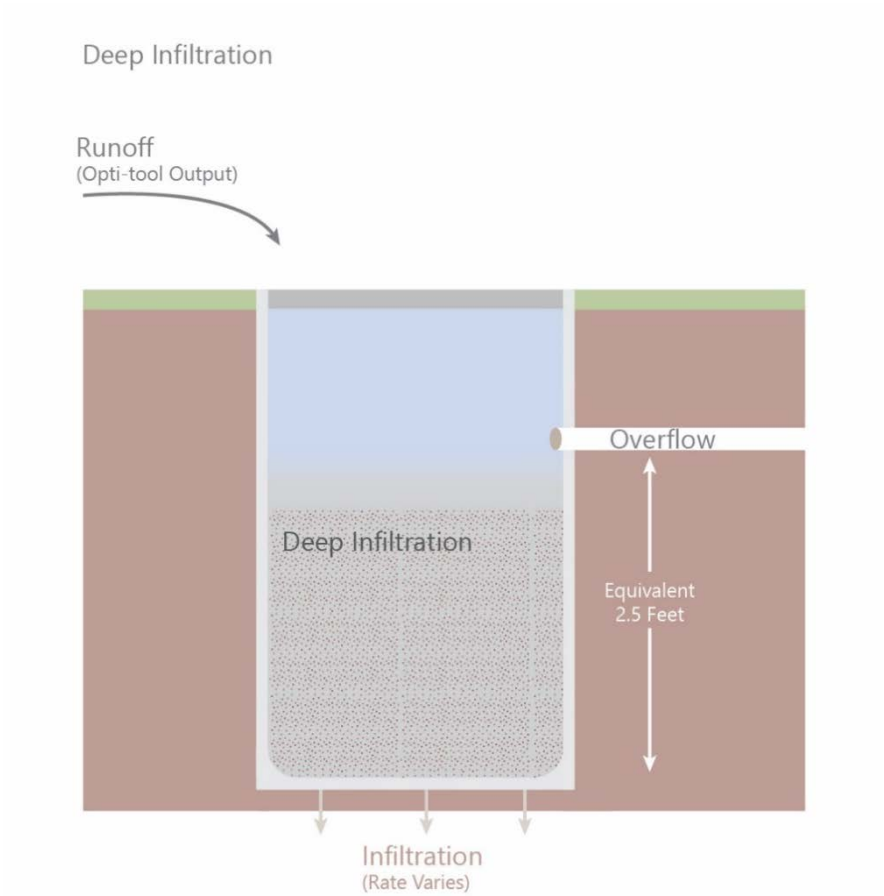
Table D- 5 Effective IC Reduction for Proprietary Technologies

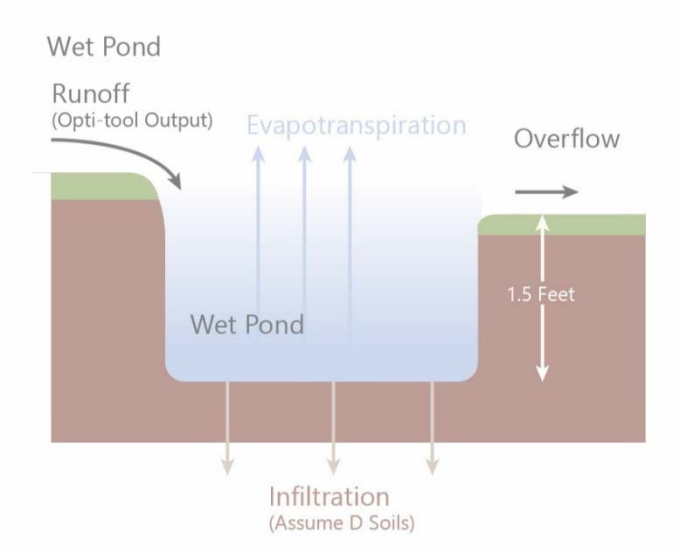
Type	TSS Reduction (%)	TSS Factor	TP Reduction (%)	TP Factor	Flow Factor	Runoff Factor	Pervious Cover Factor
Hydrodynamic Separators	25	0.28	10	0.11	0	0	0.097
Jellyfish Filter	85	0.94	50	0.56	0	0	0.37
MWS-Linear	85	0.94	64	0.71	0	0	0.41
Stormceptor	75	0.83	0	0	0	0	0.21

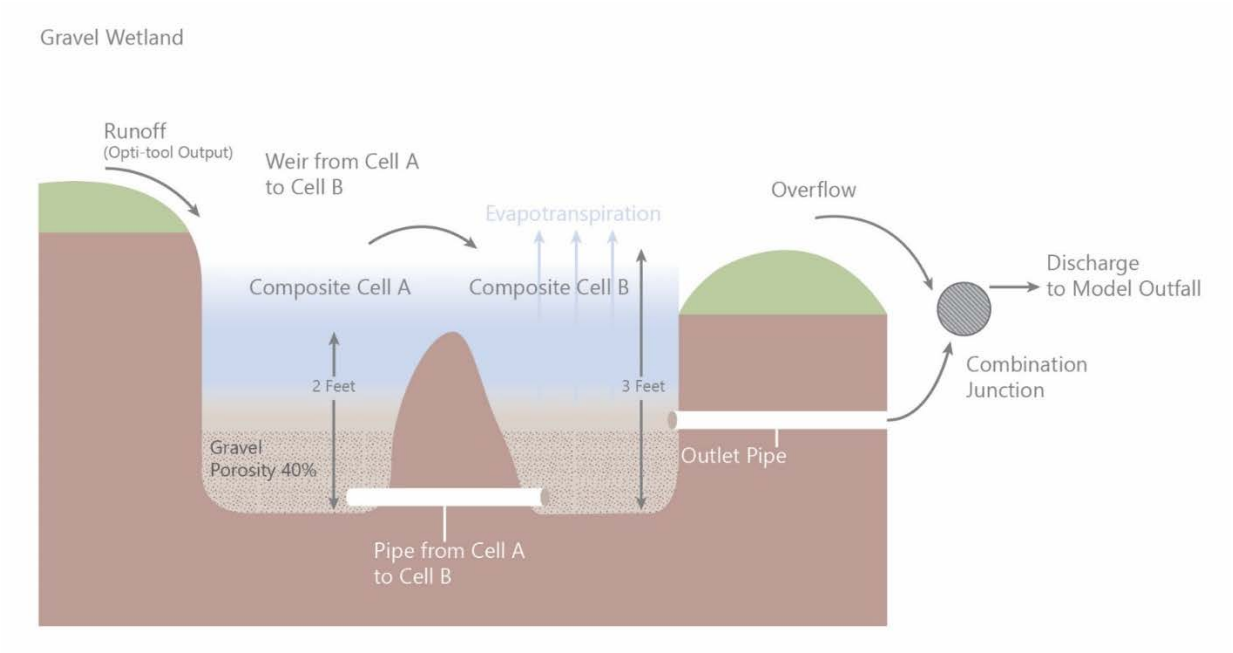
Appendix E – Simplified Model Node-Link Diagrams

For all model STUs, "Overflow" links are modeled as 10-foot wide weirs to represent free discharge.

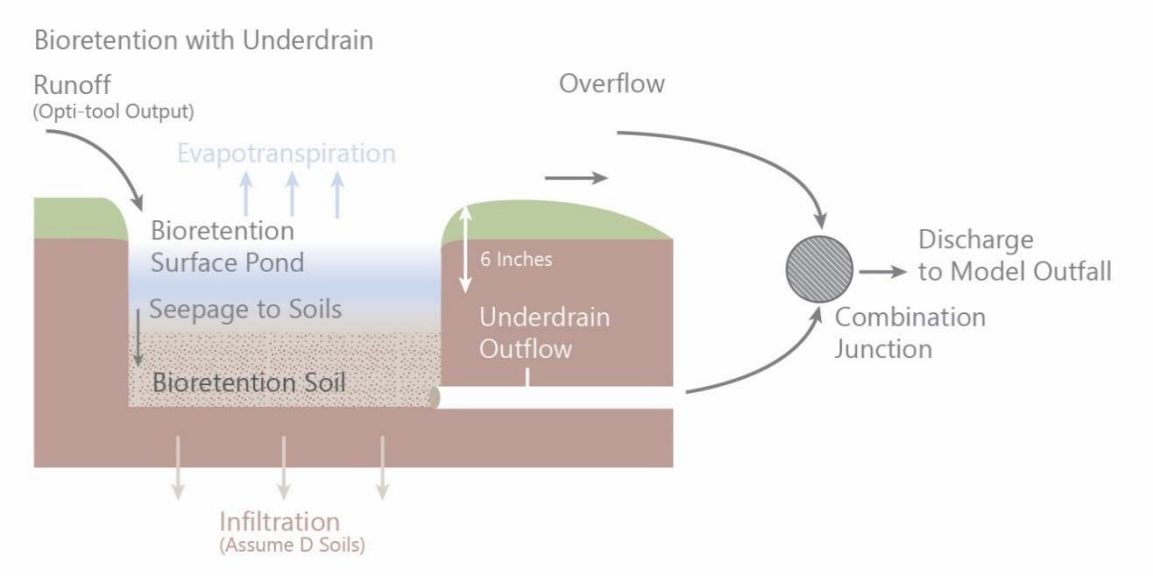




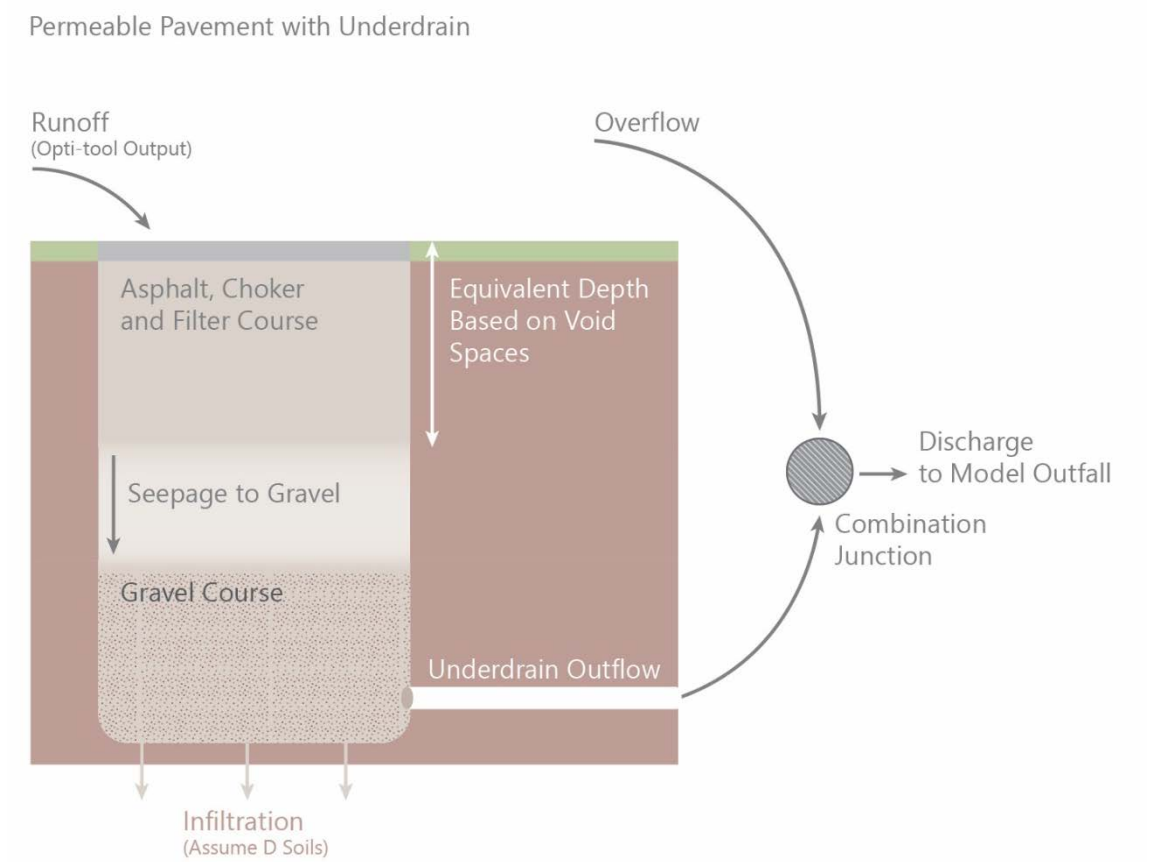




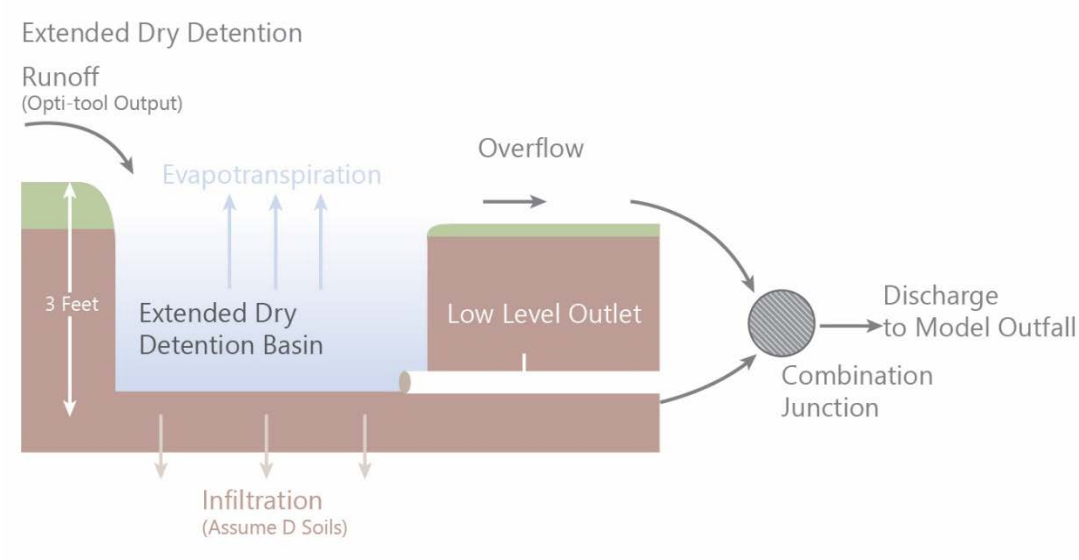
*Outlet pipe is assumed to be 4 inches, discharge to outfall assumed 24 inches to represent free discharge.



*Underdrain is assumed to be 4 inches



*Underdrain is assumed to be 4 inches



*Low level outlet is assumed to be a 2-ich orifice at the bottom of the basin

Appendix F – Credit for Partially Pervious Catchments

In highway settings, the contributing catchment area to a control may potentially contain a significant amount of pervious area due to a grassed right-of-way or other contributions. This differs from the 100% impervious area contributing catchment area assumptions used to generate EPA's pollutant crediting results. VHB performed a sensitivity analysis for a range of catchments with fixed impervious cover and varying amounts of additional pervious cover, over different types of structural controls. The results showed that the additional pervious cover had little effect on total infiltration or peak flow reduction, and only significant effect on pollutant removal when the impervious cover was less than 50% of the catchment area.

Therefore, in cases where the contributing catchment area is 50% IC or greater, the calculations are simplified and the pervious area is not taken into account: the effective treatment depth for the control is calculated using the control's volume and the area of the impervious cover only, and IC credit is based on the impervious cover area only. This method uses the pollutant, runoff reduction, and flow factors for a 100% IC watershed for cases where the contributing watershed is 50% IC or greater.

The following sections present the approach to crediting when the contributing catchment area is less than 50% IC.

TMDL Method Pollutant Removal Credits

An analysis was done of pollutant removal in mostly pervious catchments using EPA's iteration method[36] in the original Consent Decree. VHB estimated pollutant crediting results for contributing catchment areas of less than 50% IC assuming a representative 35% IC with pervious area of HSG B soils (required for estimates of pervious area runoff). A review of the hydrology soil groups within the vicinity of RIDOT roadways showed a range of hydrology soil groups including almost half as not-characterized, with HSG B representing the approximate "average" between the A, B and C primarily represented groups.

Due to higher flows to the control, the pollutant removal rates were lower than for a completely impervious catchment, but were all fairly close to the model catchment with 35% IC. Therefore, this model catchment with 35% impervious cover was used to calculate a new set of pollutant removal percentages, applicable for catchments with less than 50% IC. In general, pollutant reductions decreased by approximately 0%-5% when using these inputs showing a minimal impact on pollutant reduction performances.

To calculate pollutant removal for catchments with less than 50% IC, the pervious cover is not taken into account, except to determine which set of pollutant removal tables to use. The treatment depth for the structural control is calculated using the volume of the control and the area of impervious cover in the catchment, and the pollutant removal percentage taken from the appropriate table (>50% IC or <50% IC), based on the type of control and the treatment depth.

[36] Massachusetts MS4 General Permit. Appendix F. Attachment 1. Available online at: https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/appendix-f-2016-ma-sms4-gp.pdf

For this methodology, the EPA's "Developed Land Pervious (HSG B)" runoff depths based on precipitation depth are used for pervious areas representing the "average" pervious land that may be contributing runoff to the STU.

IC Method Pollutant Removal Credits

For IC crediting, this methodology uses the pollutant treatment as described in the Section 4.3 to develop Pollutant Factors.

The sensitivity analysis showed that annual runoff reduction input (as total volume) of a given control and the results indicated that the reduction value is minimally affected by the addition of pervious catchment area. Therefore, when comparing a control's runoff reduction volume to runoff from a 1-acre impervious watershed, the percent reduction remains unchanged. The Runoff Reduction Factor for catchment areas with less than 50% IC is assumed the same as the 100% IC condition.

The flow response of a stormwater control will be influenced by having pervious areas as part of the contributing catchment area. The level of attenuation of the IC's runoff is difficult to parse out given the dynamic nature of runoff response and flow routing through the various controls. After much review and discussion with EPA, we have concluded that using the flow attenuation performance of a control treating 100% IC is satisfactory to represent performance when the contributing catchment area is <100% IC.

To calculate runoff factor and flow factor, the pervious area is not taken into account: the treatment depth is calculated using the volume of the control and the area of impervious cover only; and the IC credit is based on the impervious cover area only. The Equivalent Area credit for catchment areas with <50% IC are therefore a combination of the Pollutant Factors calculated using the adjusted pollutant credits and the base Runoff and Flow Factors.

Appendix G - Structural Control Pollutant Removal Results

Notes:

- Values are listed as fractional reductions.
- The results assume zero credit for zero storage and maximum credit is the credit received for the 2-inch depth of runoff treated.
- Credits are not fully developed for select structural controls presented in Appendix D and therefore not included here.
- Percent IC is for CATCHMENT to STU, not watershed % IC.

Total Phosphorus >50% IC

	Depth of Runoff Treated from Impervious Area (inches) (>50% IC)									
Treatment Category:	**0.00**	**0.10**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.35	0.52	0.72	0.82	0.88	0.92	0.97	0.99	0.99
Shallow Infiltration (silt loam)	0.00	0.37	0.54	0.74	0.85	0.90	0.93	0.98	0.99	0.99
Shallow Infiltration (loam)	0.00	0.38	0.56	0.77	0.87	0.92	0.95	0.98	0.99	0.99
Shallow Infiltration (sandy loam)	0.00	0.41	0.60	0.81	0.90	0.94	0.97	0.99	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.46	0.67	0.87	0.94	0.97	0.98	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.59	0.81	0.96	0.99	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.18	0.33	0.57	0.73	0.83	0.90	0.97	0.99	0.99
Deep Infiltration (silt loam)	0.00	0.20	0.37	0.63	0.78	0.86	0.92	0.97	0.99	0.99
Deep Infiltration (loam)	0.00	0.23	0.42	0.68	0.82	0.89	0.94	0.98	0.99	0.99
Deep Infiltration (sandy loam)	0.00	0.27	0.47	0.73	0.86	0.92	0.96	0.99	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.33	0.55	0.81	0.91	0.96	0.98	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.50	0.75	0.94	0.98	0.99	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.03	0.06	0.08	0.09	0.11	0.12	0.13	0.14	0.14
Bioretention	0.00	0.14	0.25	0.37	0.44	0.48	0.53	0.58	0.63	0.63
Sand Filter	0.00	0.14	0.25	0.37	0.44	0.48	0.53	0.58	0.63	0.63
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Gravel Wetland	0.00	0.19	0.26	0.41	0.51	0.57	0.61	0.65	0.66	0.66
Wet Pond	0.00	0.14	0.25	0.37	0.44	0.48	0.53	0.58	0.63	0.63
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Total Phosphorus <50% IC

	Depth of Runoff Treated from Impervious Area (inches) (<50% IC)									
Treatment Category:	**0.00**	**0.10**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.35	0.52	0.72	0.80	0.86	0.91	0.95	0.98	0.98
Shallow Infiltration (silt loam)	0.00	0.37	0.54	0.74	0.83	0.89	0.92	0.96	0.98	0.98
Shallow Infiltration (loam)	0.00	0.38	0.56	0.77	0.85	0.91	0.94	0.97	0.98	0.98
Shallow Infiltration (sandy loam)	0.00	0.41	0.60	0.81	0.89	0.93	0.96	0.98	0.99	0.99
Shallow Infiltration (loamy sand)	0.00	0.46	0.67	0.87	0.93	0.96	0.98	0.99	1.00	1.00
Shallow Infiltration (sand)	0.00	0.59	0.81	0.96	0.99	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.18	0.33	0.57	0.71	0.80	0.88	0.95	0.98	0.98
Deep Infiltration (silt loam)	0.00	0.20	0.37	0.63	0.76	0.84	0.90	0.95	0.98	0.98
Deep Infiltration (loam)	0.00	0.23	0.42	0.68	0.80	0.87	0.92	0.97	0.98	0.98
Deep Infiltration (sandy loam)	0.00	0.27	0.47	0.73	0.84	0.90	0.95	0.98	0.99	0.99
Deep Infiltration (loamy sand)	0.00	0.33	0.55	0.81	0.89	0.95	0.97	0.99	1.00	1.00
Deep Infiltration (sand)	0.00	0.50	0.75	0.94	0.97	0.99	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.03	0.06	0.08	0.09	0.10	0.12	0.13	0.13	0.13
Bioretention	0.00	0.14	0.25	0.37	0.43	0.47	0.51	0.56	0.60	0.60
Sand Filter	0.00	0.14	0.25	0.37	0.43	0.47	0.51	0.56	0.60	0.60
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Gravel Wetland	0.00	0.19	0.26	0.41	0.49	0.55	0.60	0.64	0.65	0.65
Wet Pond	0.00	0.14	0.25	0.37	0.43	0.47	0.51	0.56	0.60	0.60
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Total Suspended Solids >50% IC

	Depth of Runoff Treated from Impervious Area (inches) (>50% IC)									
Treatment Category:	**0.0**	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**	**1.5**	**2.0**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.64	0.80	0.93	0.98	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.65	0.81	0.94	0.98	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (loam)	0.00	0.65	0.83	0.95	0.99	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.67	0.94	0.96	0.99	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.70	0.88	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.79	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.32	0.56	0.84	0.95	0.98	0.99	1.00	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.36	0.51	0.88	0.97	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (loam)	0.00	0.40	0.66	0.91	0.98	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.44	0.70	0.93	0.99	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.50	0.77	0.97	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.18	0.31	0.38	0.40	0.44	0.46	0.47	0.49	0.49
Bioretention	0.00	0.44	0.69	0.91	0.97	0.98	0.99	1.00	1.00	1.00
Sand Filter	0.00	0.44	0.69	0.91	0.97	0.98	0.99	1.00	1.00	1.00
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Gravel Wetland	0.00	0.48	0.61	0.82	0.91	0.95	0.97	0.99	0.99	0.99
Wet Pond	0.00	0.30	0.44	0.60	0.68	0.74	0.77	0.83	0.86	0.86
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Total Suspended Solids <50% IC

	Depth of Runoff Treated from Impervious Area (inches) (<50% IC)									
Treatment Category:	**0.0**	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**	**1.5**	**2.0**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.64	0.80	0.93	0.97	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.65	0.81	0.94	0.97	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (loam)	0.00	0.65	0.83	0.95	0.98	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.67	0.94	0.96	0.99	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.70	0.88	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.79	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.32	0.56	0.84	0.93	0.97	0.99	1.00	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.36	0.51	0.88	0.96	0.98	1.00	1.00	1.00	1.00
Deep Infiltration (loam)	0.00	0.40	0.66	0.91	0.97	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.44	0.70	0.93	0.98	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.50	0.77	0.97	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.18	0.31	0.38	0.40	0.43	0.45	0.47	0.48	0.48
Bioretention	0.00	0.44	0.69	0.91	0.96	0.98	0.99	1.00	1.00	1.00
Sand Filter	0.00	0.44	0.69	0.91	0.96	0.98	0.99	1.00	1.00	1.00
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Gravel Wetland	0.00	0.48	0.61	0.82	0.90	0.94	0.96	0.98	0.99	0.99
Wet Pond	0.00	0.30	0.44	0.60	0.67	0.72	0.76	0.81	0.84	0.84
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Nitrogen >50% IC

	Depth of Runoff Treated from Impervious Area (inches) (>50% IC)									
Treatment Category:	**0.00**	**0.10**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.52	0.69	0.85	0.92	0.96	0.98	0.99	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.54	0.71	0.87	0.93	0.97	0.98	0.99	1.00	1.00
Shallow Infiltration (loam)	0.00	0.56	0.74	0.89	0.94	0.98	0.99	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.59	0.77	0.92	0.96	0.98	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.64	0.82	0.95	0.98	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.75	0.92	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.56	0.72	0.87	0.93	0.96	0.98	0.99	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.57	0.74	0.88	0.94	0.97	0.98	0.99	1.00	1.00
Deep Infiltration (loam)	0.00	0.59	0.76	0.90	0.95	0.98	0.99	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.61	0.78	0.92	0.97	0.98	0.99	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.65	0.83	0.95	0.98	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.76	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.01	0.03	0.06	0.09	0.11	0.13	0.19	0.23	0.23
Bioretention	0.00	0.09	0.16	0.23	0.28	0.31	0.32	0.37	0.40	0.40
Sand Filter	0.00	0.09	0.16	0.23	0.28	0.31	0.32	0.37	0.40	0.40
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gravel Wetland	0.00	0.22	0.33	0.48	0.57	0.64	0.68	0.74	0.79	0.79
Wet Pond	0.00	0.09	0.16	0.23	0.28	0.31	0.32	0.37	0.40	0.40
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Nitrogen <50% IC

	Depth of Runoff Treated from Impervious Area (inches) (<50% IC)									
Treatment Category:	**0.00**	**0.10**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.52	0.69	0.85	0.91	0.95	0.97	0.99	0.99	0.99
Shallow Infiltration (silt loam)	0.00	0.54	0.71	0.87	0.92	0.96	0.98	0.99	0.99	0.99
Shallow Infiltration (loam)	0.00	0.56	0.74	0.89	0.93	0.97	0.99	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.59	0.77	0.92	0.95	0.97	0.99	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.64	0.82	0.95	0.98	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.75	0.92	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.56	0.72	0.87	0.92	0.95	0.97	0.99	0.99	0.99
Deep Infiltration (silt loam)	0.00	0.57	0.74	0.88	0.93	0.96	0.98	0.99	0.99	0.99
Deep Infiltration (loam)	0.00	0.59	0.76	0.90	0.94	0.97	0.99	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.61	0.78	0.92	0.96	0.98	0.99	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.65	0.83	0.95	0.98	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.76	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.01	0.03	0.06	0.08	0.11	0.12	0.17	0.20	0.20
Bioretention	0.00	0.09	0.16	0.23	0.27	0.30	0.32	0.35	0.38	0.38
Sand Filter	0.00	0.09	0.16	0.23	0.27	0.30	0.32	0.35	0.38	0.38
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gravel Wetland	0.00	0.22	0.33	0.48	0.56	0.62	0.67	0.72	0.76	0.76
Wet Pond	0.00	0.09	0.16	0.23	0.27	0.30	0.32	0.35	0.38	0.38
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Zinc >50% IC

	Depth of Runoff Treated from Impervious Area (inches) (>50% IC)									
Treatment Category:	**0.00**	**0.10**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.71	0.86	0.96	0.98	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.73	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loam)	0.00	0.75	0.90	0.98	0.99	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.78	0.92	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.82	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.91	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.51	0.77	0.94	0.98	0.99	0.99	1.00	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.57	0.84	0.97	0.99	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (loam)	0.00	0.65	0.90	0.98	0.99	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.72	0.94	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.81	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.53	0.67	0.68	0.69	0.72	0.73	0.74	0.76	0.76
Bioretention	0.00	0.68	0.88	0.95	0.96	0.96	0.97	0.98	0.99	0.99
Sand Filter	0.00	0.68	0.88	0.95	0.96	0.96	0.97	0.98	0.99	0.99
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gravel Wetland	0.00	0.57	0.68	0.83	0.88	0.90	0.90	0.91	0.92	0.92
Wet Pond	0.00	0.59	0.71	0.80	0.85	0.87	0.89	0.92	0.93	0.93
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Zinc <50% IC

	Depth of Runoff Treated from Impervious Area (inches) (<50% IC)									
Treatment Category:	**0.00**	**0.10**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.71	0.86	0.96	0.98	0.99	1.00	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.73	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loam)	0.00	0.75	0.90	0.98	0.99	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.78	0.92	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.82	0.95	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.91	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.51	0.77	0.94	0.97	0.99	0.99	1.00	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.57	0.84	0.97	0.99	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (loam)	0.00	0.65	0.90	0.98	0.99	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.72	0.94	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.81	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.53	0.67	0.68	0.69	0.71	0.73	0.74	0.75	0.75
Bioretention	0.00	0.68	0.88	0.95	0.96	0.96	0.97	0.98	0.98	0.98
Sand Filter	0.00	0.68	0.88	0.95	0.96	0.96	0.97	0.98	0.98	0.98
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gravel Wetland	0.00	0.57	0.68	0.83	0.87	0.89	0.90	0.91	0.91	0.91
Wet Pond	0.00	0.59	0.71	0.80	0.84	0.86	0.88	0.91	0.92	0.92
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Porous Pavement with Underdrain

Porous Pavement	Filter Course Depth (inches) (>50% IC)			
	12.0	**18.0**	**24.0**	**32.0**
Total Phosphorus Removal	0.62	0.70	0.75	0.78
TSS Removal	0.92	0.94	0.96	0.97
Nitrogen Removal	0.76	0.77	0.77	0.79
Zinc Removal	0.85	0.97	0.97	0.98

Currently there are no credits developed for the rare scenario of porous pavement with a <50% IC watershed.

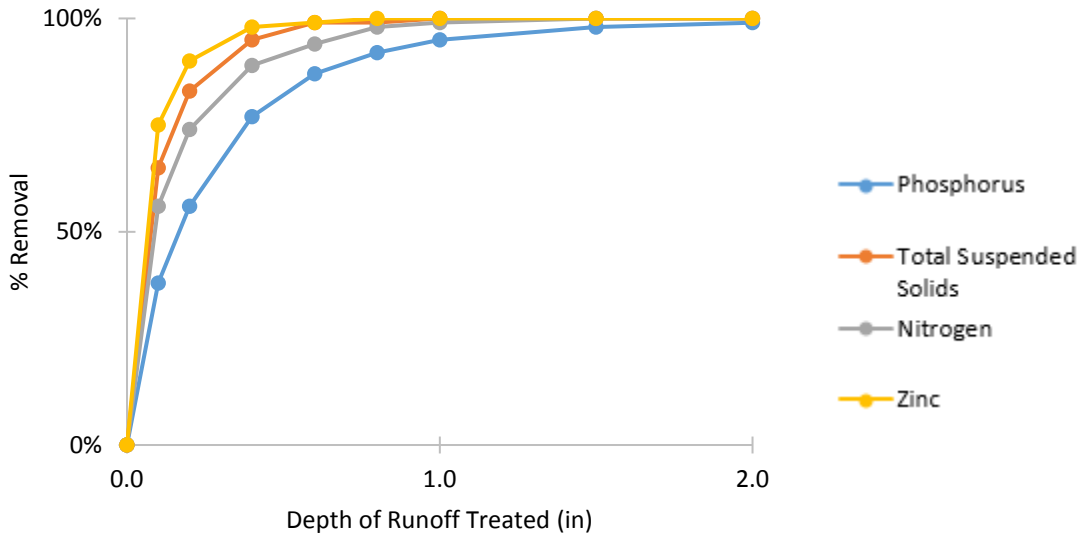
Qualifying Pervious Areas

This methodology assumes 100% reduction for all stormwater related impairments when meeting qualifying pervious area criteria in the Rhode Island Stormwater Design and Installation Standards Manual.

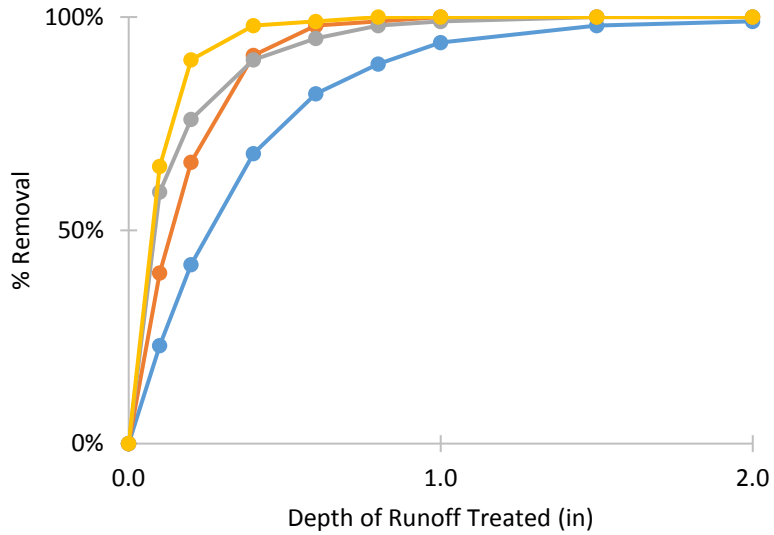
Structural Controls Pollutant Performance Curves

Note: Performance curves are based on EPA's values and represent the >50% IC watershed scenario. For shallow and deep infiltration, the loam soil type is shown.

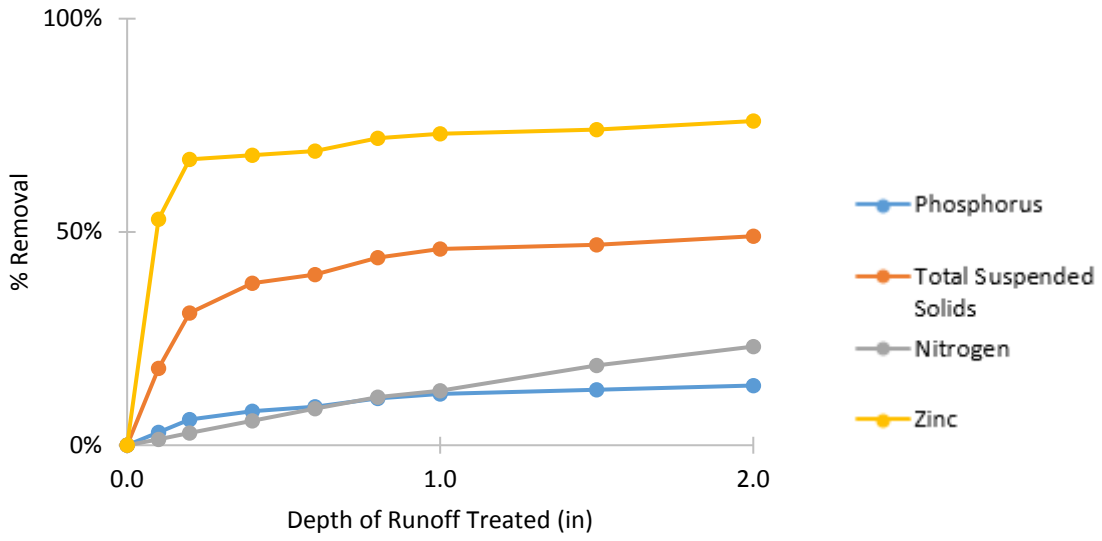
Shallow Infiltration (Loam soil type shown)



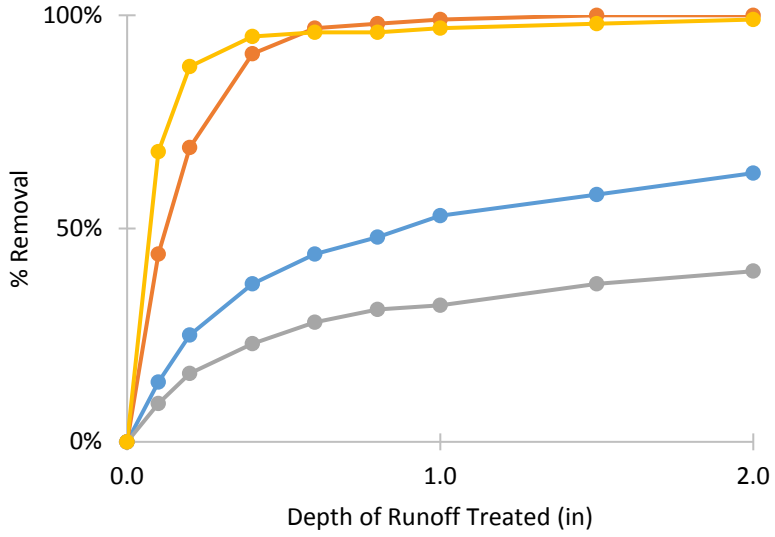
Deep Infiltration (Loam soil type shown)



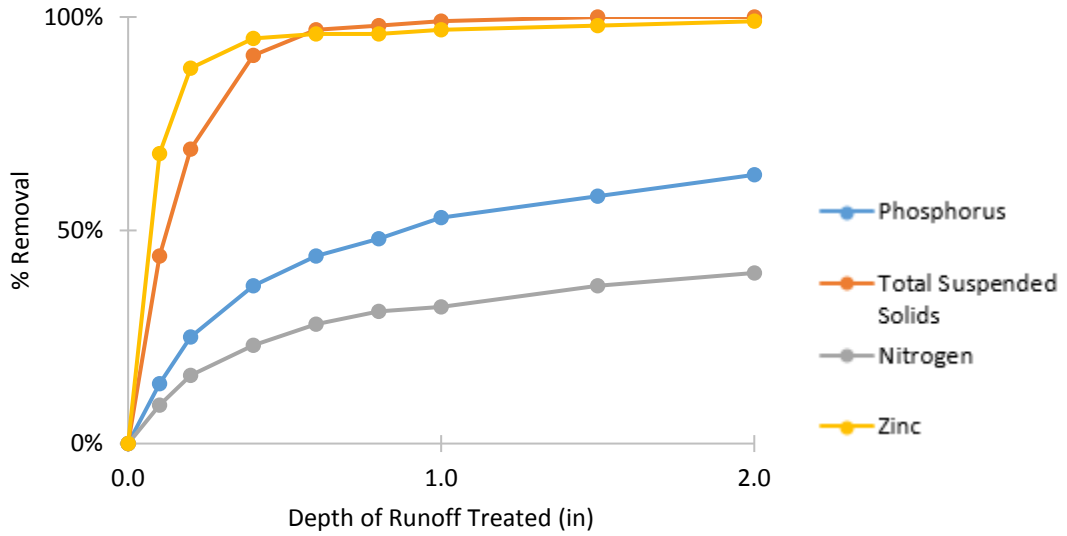
Extended Dry Detention



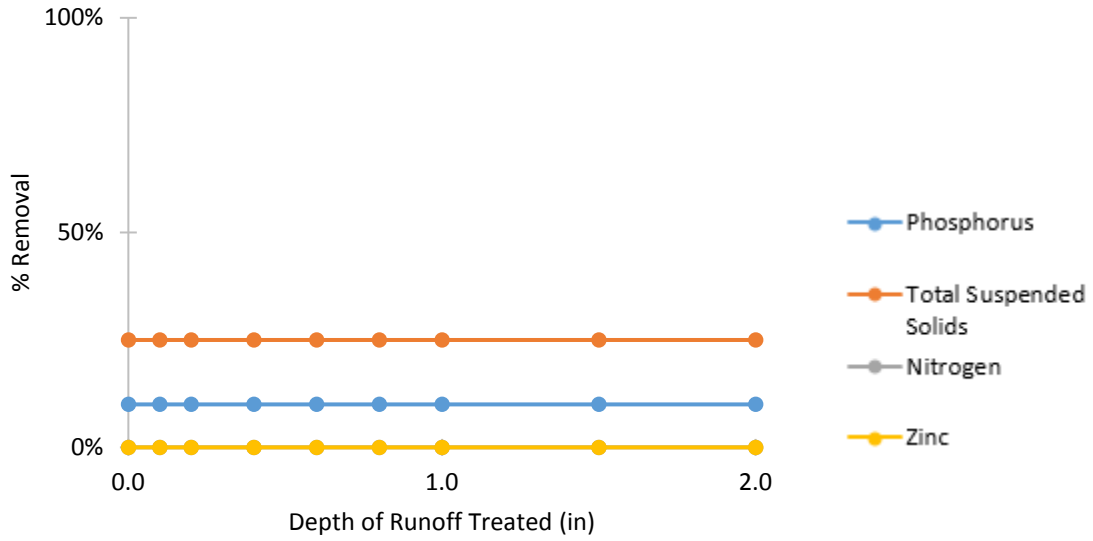
Bioretention



Sand Filter

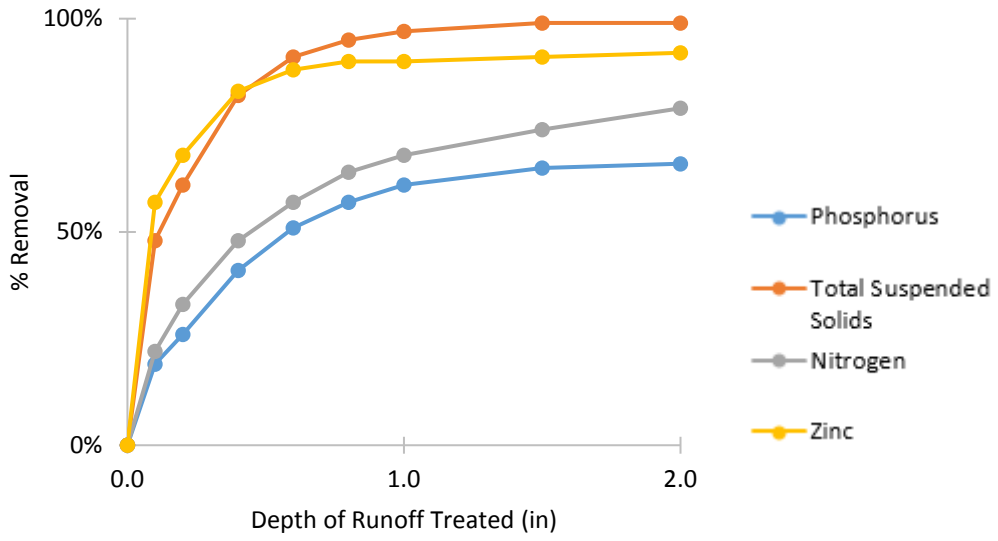


Hydrodynamic Separator

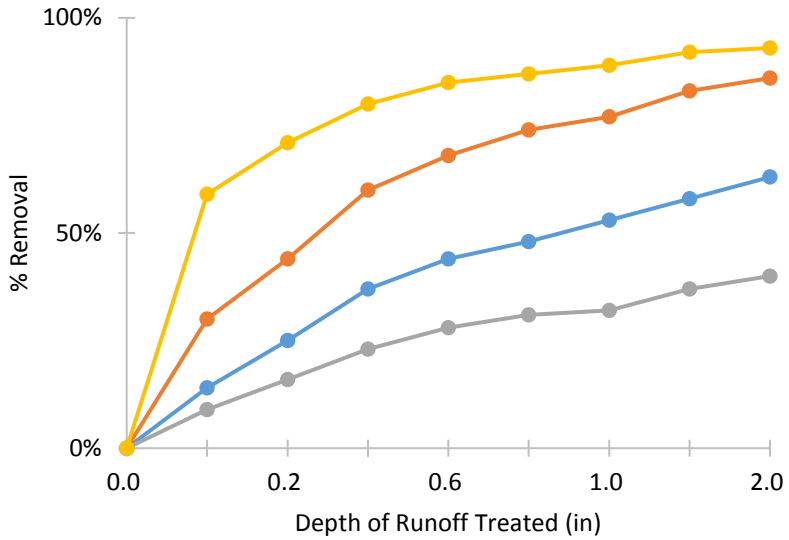


Note: Zinc and Nitrogen removal are currently 0% for all treatment depths.

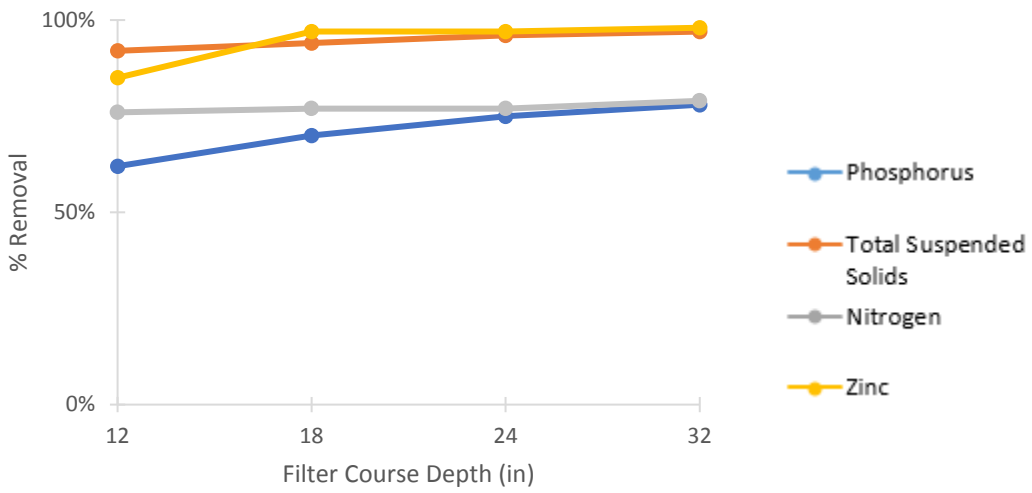
Gravel Wetland



Wet Pond



Porous Pavement with Underdrain



Appendix H – Structural Control IC Crediting Results

Credits are not fully developed for select structural controls presented in Appendix D and therefore not included here.

Pollutant Factor: Total Phosphorus

Phosphorus Factor	Depth of Runoff Treated from Impervious Area (inches)									
Treatment Category:	**0.00**	**0.10**	**0.20**	**0.40**	**0.60**	**0.80**	**1.00**	**1.50**	**2.00**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.39	0.58	0.80	0.91	0.98	1.00	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.41	0.60	0.82	0.94	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loam)	0.00	0.42	0.62	0.86	0.97	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.46	0.67	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.51	0.74	0.97	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.66	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.20	0.37	0.63	0.81	0.92	1.00	1.00	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.22	0.41	0.70	0.87	0.96	1.00	1.00	1.00	1.00
Deep Infiltration (loam)	0.00	0.26	0.47	0.76	0.91	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.30	0.52	0.81	0.96	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.37	0.61	0.90	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.56	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.03	0.07	0.09	0.10	0.12	0.13	0.14	0.16	0.16
Bioretention	0.00	0.16	0.28	0.41	0.49	0.53	0.59	0.64	0.70	0.70
Sand Filter	0.00	0.16	0.28	0.41	0.49	0.53	0.59	0.64	0.70	0.70
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Gravel Wetland	0.00	0.21	0.29	0.46	0.57	0.63	0.68	0.72	0.73	0.73
Wet Pond	0.00	0.16	0.28	0.41	0.49	0.53	0.59	0.64	0.70	0.70
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

FYI: Pollutant Factor is equivalent to Appendix G - STU Pollutant Removal % values divided by 0.9.
Note: values may not exceed a value of 1.0

Pollutant Factor: TSS

TSS Factor	Depth of Runoff Treated from Impervious Area (inches)									
Treatment Category:	**0.0**	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**	**1.5**	**2.0**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.71	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.72	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loam)	0.00	0.72	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.74	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.78	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.36	0.62	0.93	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.40	0.57	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (loam)	0.00	0.44	0.73	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.49	0.78	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.56	0.86	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.20	0.34	0.42	0.44	0.49	0.51	0.52	0.54	0.54
Bioretention	0.00	0.49	0.77	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sand Filter	0.00	0.49	0.77	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28
Gravel Wetland	0.00	0.53	0.68	0.91	1.00	1.00	1.00	1.00	1.00	1.00
Wet Pond	0.00	0.33	0.49	0.67	0.76	0.82	0.86	0.92	0.96	0.96
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

FYI: Pollutant Factor is equivalent to Appendix F - STU Pollutant Removal % values divided by 0.9.

Runoff Factor

Runoff Factor	Depth of Runoff Treated from Impervious Area (inches)									
Treatment Category:	**0.0**	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**	**1.5**	**2.0**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.14	0.28	0.50	0.68	0.83	0.95	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.17	0.34	0.58	0.76	0.87	0.94	1.00	1.00	1.00
Shallow Infiltration (loam)	0.00	0.22	0.41	0.67	0.84	0.94	1.00	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.28	0.50	0.78	0.92	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.40	0.66	0.92	1.00	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.68	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.10	0.21	0.41	0.58	0.71	0.82	0.97	1.00	1.00
Deep Infiltration (silt loam)	0.00	0.14	0.28	0.51	0.68	0.80	0.89	1.00	1.00	1.00
Deep Infiltration (loam)	0.00	0.18	0.35	0.60	0.78	0.88	0.96	1.00	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.23	0.43	0.69	0.86	0.95	1.00	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.32	0.55	0.84	0.96	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.54	0.82	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.12	0.21	0.34	0.41	0.43	0.44	0.41	0.39	0.39
Bioretention	0.00	0.00	0.03	0.06	0.09	0.11	0.14	0.24	0.31	0.31
Sand Filter	0.00	0.00	0.03	0.06	0.09	0.11	0.14	0.24	0.31	0.31
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gravel Wetland	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.06	0.06
Wet Pond	0.00	0.04	0.10	0.21	0.32	0.43	0.53	0.75	0.90	0.90
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Flow Factor

Flow Factor	Depth of Runoff Treated from Impervious Area (inches)									
Treatment Category:	**0.0**	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**	**1.5**	**2.0**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.08	0.15	0.31	0.46	0.62	0.79	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.09	0.19	0.36	0.54	0.66	0.79	0.97	1.00	1.00
Shallow Infiltration (loam)	0.00	0.12	0.24	0.44	0.61	0.76	0.88	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.15	0.30	0.53	0.71	0.89	0.98	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.24	0.41	0.71	0.92	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.42	0.68	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.06	0.11	0.24	0.40	0.51	0.62	0.84	0.98	0.98
Deep Infiltration (silt loam)	0.00	0.07	0.15	0.31	0.48	0.57	0.70	0.90	1.00	1.00
Deep Infiltration (loam)	0.00	0.10	0.20	0.37	0.55	0.65	0.80	0.97	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.12	0.25	0.44	0.63	0.78	0.91	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.18	0.33	0.57	0.78	0.96	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.33	0.53	0.92	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.08	0.17	0.31	0.46	0.52	0.64	0.79	0.84	0.84
Bioretention	0.00	0.09	0.15	0.24	0.34	0.39	0.46	0.73	0.73	0.73
Sand Filter	0.00	0.09	0.15	0.24	0.34	0.39	0.46	0.73	0.73	0.73
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gravel Wetland	0.00	0.06	0.13	0.18	0.21	0.23	0.26	0.32	0.36	0.36
Wet Pond	0.00	0.04	0.06	0.12	0.20	0.30	0.40	0.61	0.78	0.78
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Pervious Cover Factor

Pervious Cover Factor	Depth of Runoff Treated from Impervious Area (inches)									
Treatment Category:	**0.0**	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1.0**	**1.5**	**2.0**	**>2.00**
Shallow Infiltration (sandy clay loam)	0.00	0.33	0.48	0.65	0.76	0.86	0.93	1.00	1.00	1.00
Shallow Infiltration (silt loam)	0.00	0.35	0.51	0.69	0.81	0.88	0.93	0.99	1.00	1.00
Shallow Infiltration (loam)	0.00	0.37	0.55	0.74	0.85	0.92	0.97	1.00	1.00	1.00
Shallow Infiltration (sandy loam)	0.00	0.41	0.62	0.80	0.91	0.97	0.99	1.00	1.00	1.00
Shallow Infiltration (loamy sand)	0.00	0.48	0.70	0.90	0.98	1.00	1.00	1.00	1.00	1.00
Shallow Infiltration (sand)	0.00	0.66	0.88	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Deep Infiltration (sandy clay loam)	0.00	0.18	0.33	0.55	0.70	0.78	0.86	0.95	0.99	0.99
Deep Infiltration (silt loam)	0.00	0.21	0.35	0.62	0.76	0.83	0.90	0.98	1.00	1.00
Deep Infiltration (loam)	0.00	0.24	0.44	0.68	0.81	0.88	0.94	0.99	1.00	1.00
Deep Infiltration (sandy loam)	0.00	0.29	0.49	0.73	0.86	0.93	0.98	1.00	1.00	1.00
Deep Infiltration (loamy sand)	0.00	0.36	0.59	0.83	0.93	0.99	1.00	1.00	1.00	1.00
Deep Infiltration (sand)	0.00	0.61	0.80	0.98	1.00	1.00	1.00	1.00	1.00	1.00
Extended Dry Detention	0.00	0.11	0.20	0.29	0.35	0.39	0.43	0.47	0.48	0.48
Bioretention	0.00	0.18	0.31	0.43	0.48	0.51	0.55	0.65	0.69	0.69
Sand Filter	0.00	0.18	0.31	0.43	0.48	0.51	0.55	0.65	0.69	0.69
Oil/Grit Separator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrodynamic Separator	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Gravel Wetland	0.00	0.20	0.27	0.39	0.45	0.47	0.49	0.52	0.54	0.54
Wet Pond	0.00	0.14	0.23	0.35	0.44	0.52	0.59	0.73	0.83	0.83
Vegetated Filter Strip/Qualifying Pervious Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Porous Pavement with Underdrain

Porous Pavement	Filter Course Depth (inches)			
	12.0	**18.0**	**24.0**	**32.0**
Phosphorus Factor	0.69	0.78	0.83	0.87
TSS Factor	1.00	1.00	1.00	1.00
Flow Factor	1.00	1.00	1.00	1.00
Runoff Factor	1.00	1.00	1.00	1.00
Pervious Cover Factor	0.92	0.94	0.96	0.97

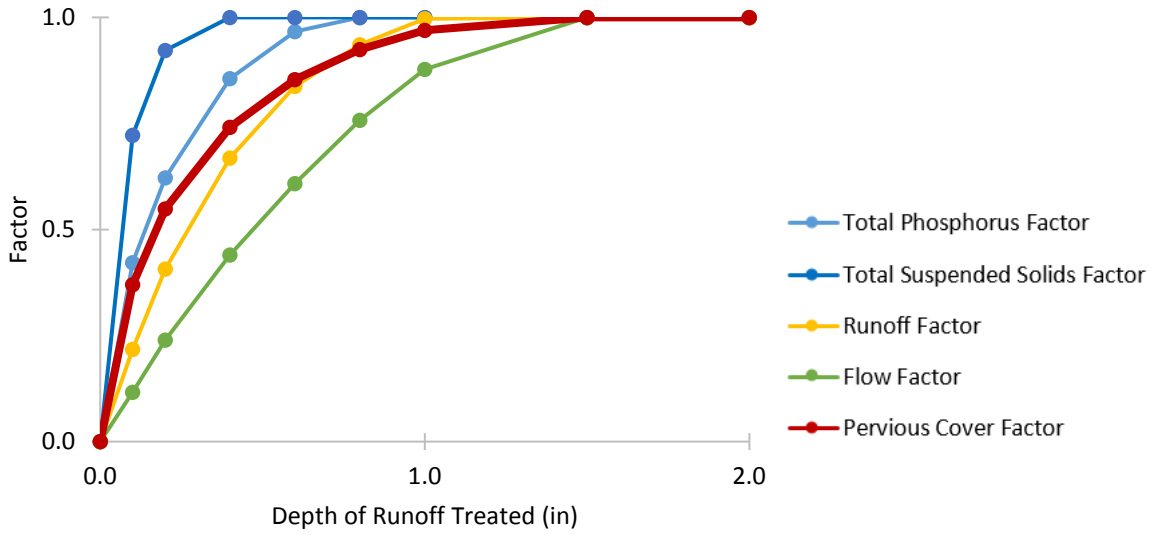
Qualifying Pervious Areas

This methodology assumes a Pervious Cover Factor of 1.0 when meeting the criteria for a qualifying pervious area in the RISDISM Manual.

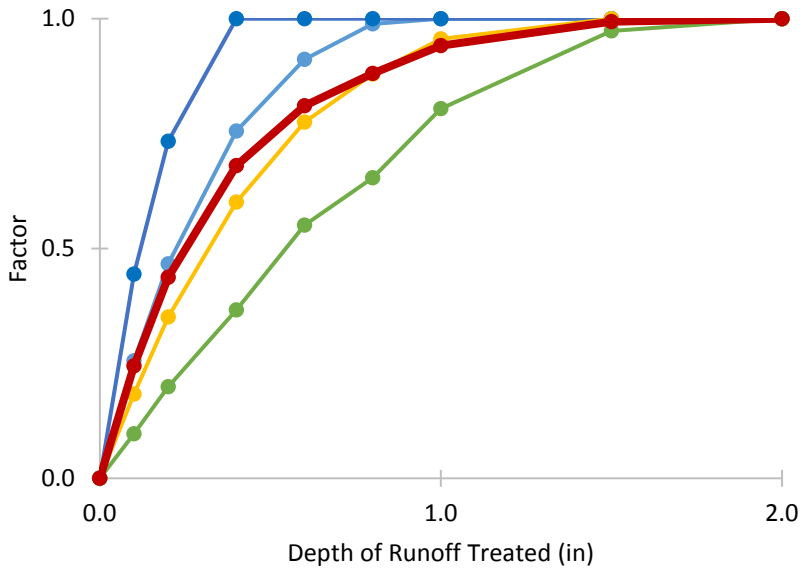
Pervious Cover Factor Curves

Note: For shallow and deep infiltration, the loam soil type is shown.

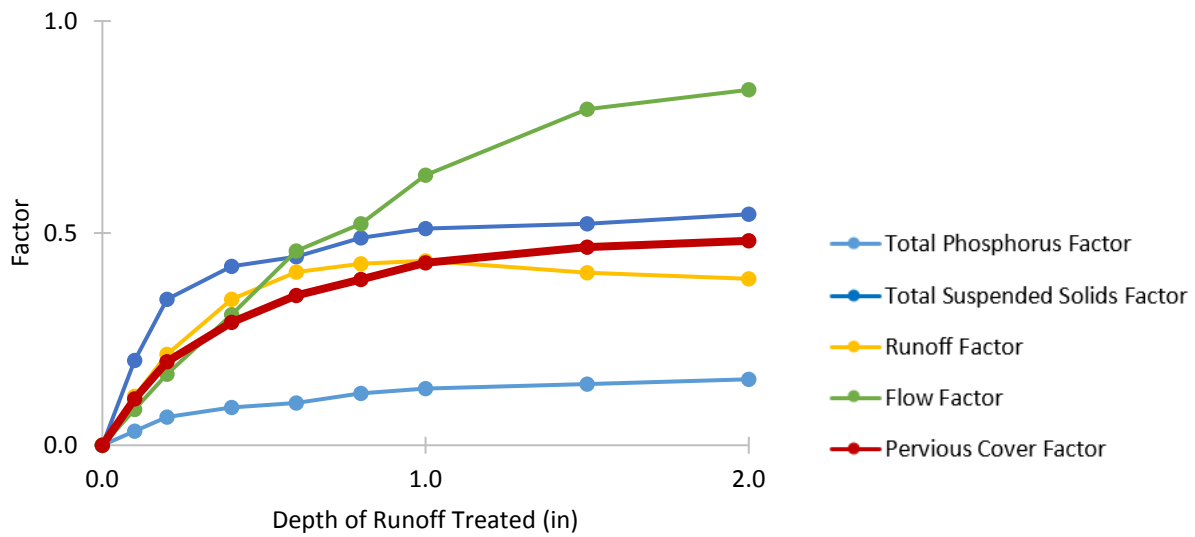
Shallow Infiltration (Loam soil type shown)



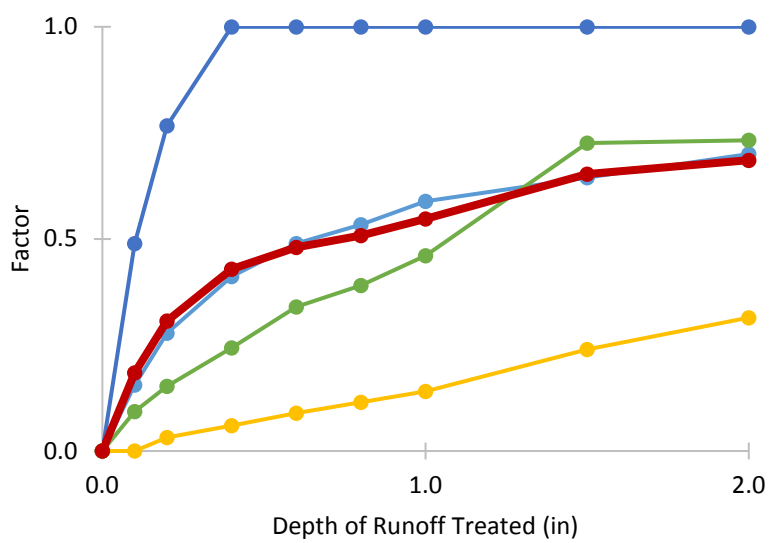
Deep Infiltration (Loam soil type shown)



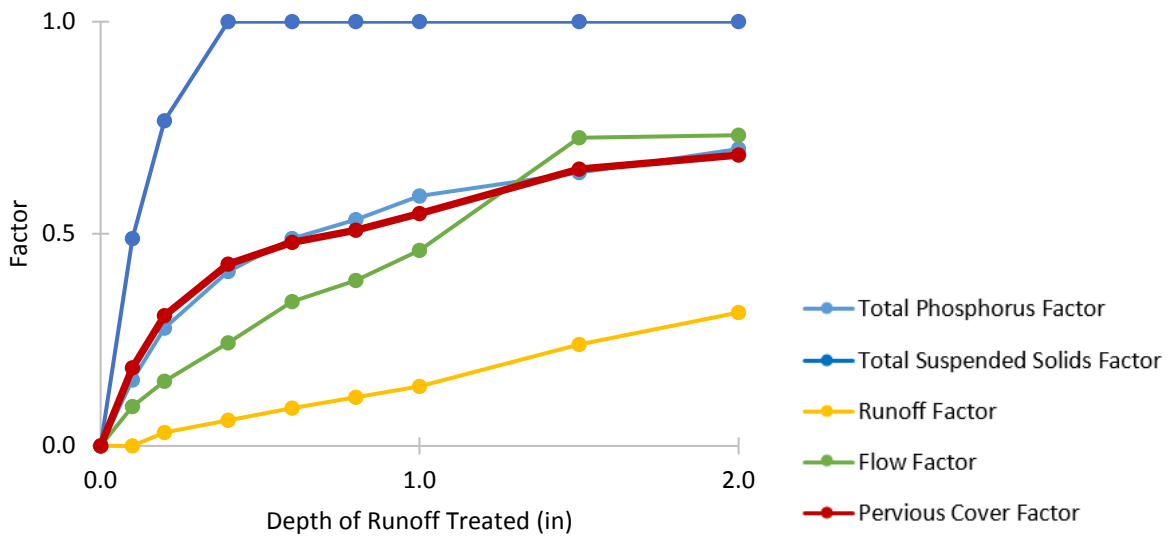
Extended Dry Detention



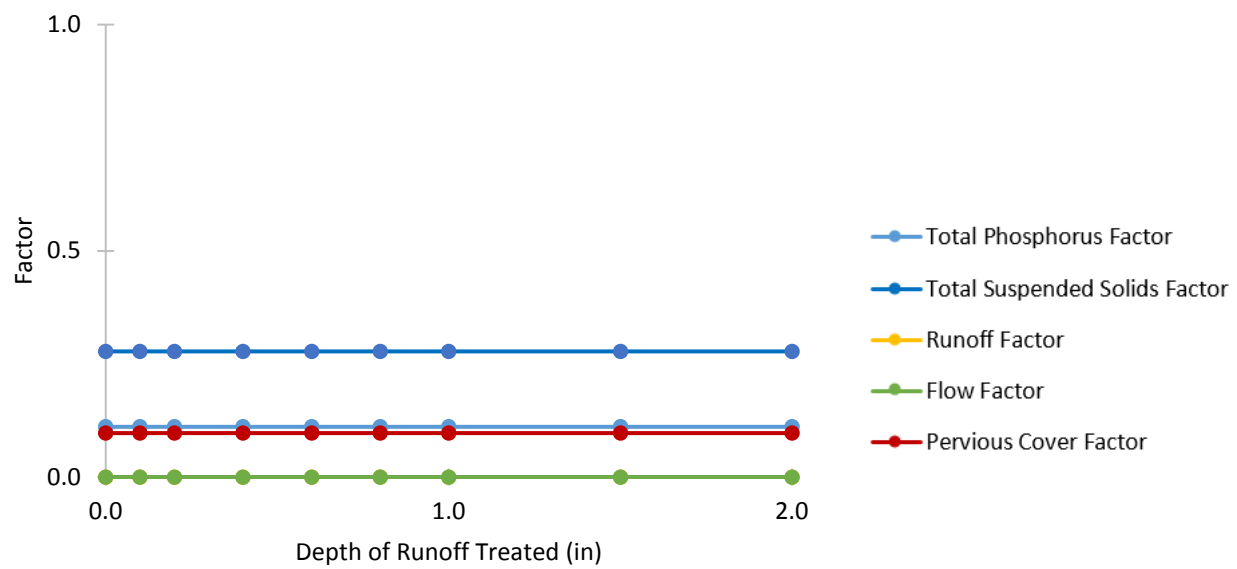
Bioretention



Sand Filter

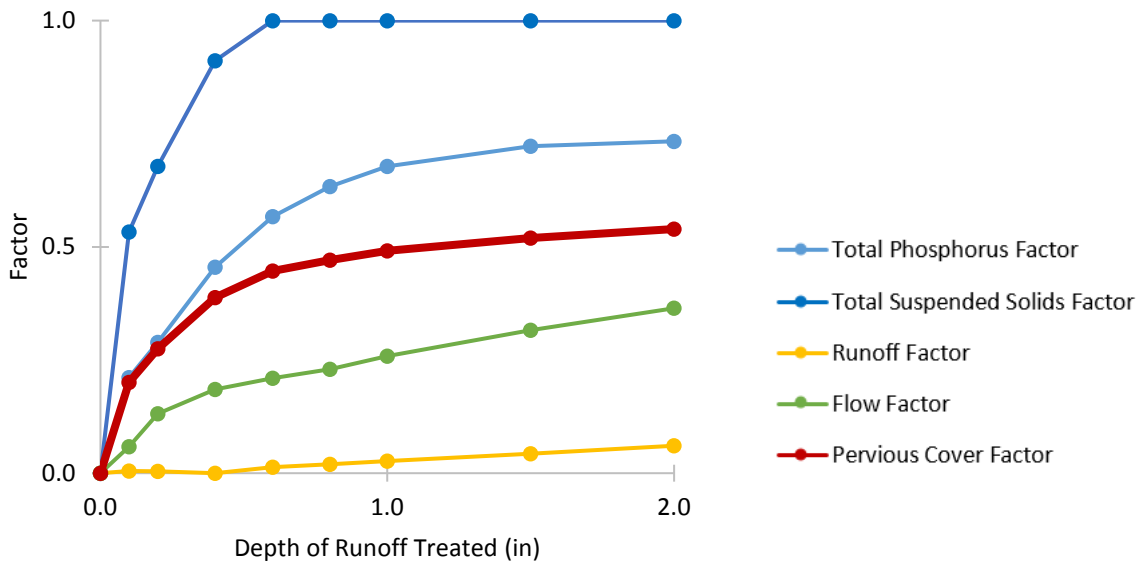


Hydrodynamic Separator

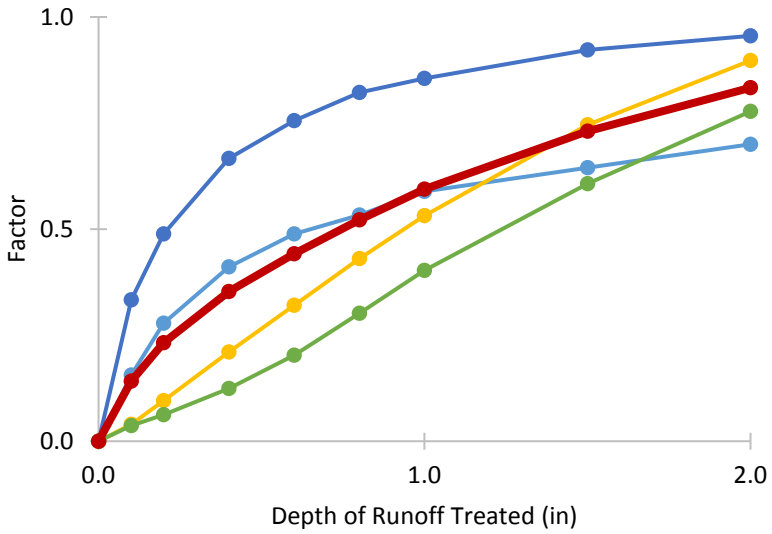


Note: Runoff and Flow Factors are 0.0 for all treatment depths.

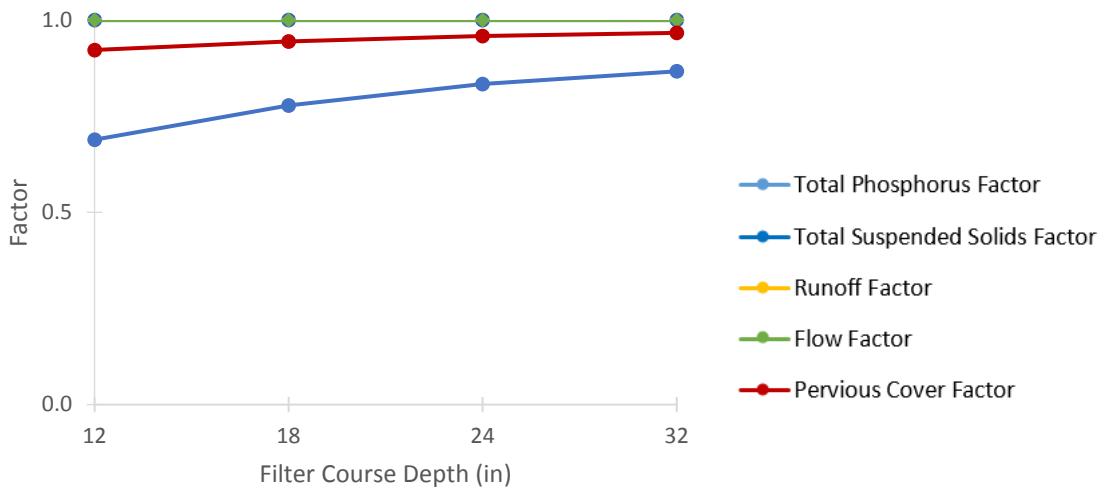
Gravel Wetland



Wet Pond



Porous Pavement with Underdrain



Note: TSS, Runoff, and Flow Factors are 1.0 for all filter course depths.

Appendix I – Framework to be utilized by EPA and RIDEM for Determining Credit for Stormwater Treatment

Framework to be utilized by U.S. EPA and RIDEM for Determining Credit

for Stormwater Treatment Outside a MS4 Operator's Area of Responsibility

January 31, 2018

The Rhode Island Department of Transportation (RIDOT) municipal separate storm sewer system (MS4) Consent Decree and municipal MS4 Operator Consent Agreements require that the MS4 operators implement stormwater treatment practices within their area of responsibility to satisfy pollutant load reduction requirements. This framework clarifies the U.S. Environmental Protection Agency's (EPA's) and Rhode Island Department of Environmental Management's (RIDEM's) approach for granting credit under these agreements for stormwater controls that treat stormwater from areas outside the MS4 operator's area of responsibility. The purpose of this framework is to encourage cost-effective controls to meet the goals of the agreements while ensuring accurate accounting of credits for actual pollution reductions.

Under the Consent Decree and Consent Agreements, MS4 operators are required to select a combination of structural stormwater controls and enhanced non-structural best management practices (BMPs) that to the maximum extent practicable (MEP) collectively achieve the required pollutant load reductions (based on TMDL requirements or an Impervious Cover Standard). The Stormwater Control Plans (SCPs) (or TMDL Implementation Plans) required by these agreements will document the analyses performed to calculate the required pollutant load reductions or impervious acres to be treated (referred to as Equivalent Area Requirement), and identify the structural and enhanced non-structural BMPs that will be implemented to meet the requirements. Prior to completion of these analyses, if one MS4 operator is given credit for reductions that occur within another MS4 operator's area of responsibility, there is a risk that the sub-watershed stormwater treatment requirements will not be achieved.

For RIDOT, projects outside its area of responsibility include:

1) privately-owned impervious surfaces and other MS4s that discharge to the RIDOT MS4,
2) privately-owned impervious surfaces that discharge to another MS4 or to the impaired water body segment without going through a permitted MS4 system, and
3) other MS4s that discharge to the impaired water body segment.

For municipal MS4 operators, projects outside their area of responsibility include:

1) other MS4s that discharge to the municipal MS4,
2) privately-owned impervious surfaces that discharge to another MS4 or to the impaired water body segment without going through a permitted MS4 system, and
3) other MS4s that discharge to the impaired water body segment.

Parameters for granting stormwater credits:

1. Credit Cap. The maximum amount of credit for impervious surface or pollutant load reduction outside an MS4 operator's area of responsibility shall not exceed 25% of the MS4 operator's required reduction for a water body segment. Once the MS4 operator's SCP (or TMDL Implementation Plan) analysis has been completed and it is determined that the required pollutant load reductions cannot be achieved within the MS4 operator's area of responsibility, EPA or RIDEM may revise the credit cap. If an MS4 operator determines, while preparing an SCP or a TMDL Implementation Plan, that less than 75% of its required pollutant reduction goals can be practicably met within its area of responsibility, it may propose additional controls outside of its area of responsibility, subject to EPA or RIDEM approval.

2. Credit for structural stormwater controls, green infrastructure and enhanced non-structural BMPs (collectively referred to herein as "stormwater controls") implemented to achieve compliance with pollutant load reduction requirements and the Impervious Cover Standard shall be calculated as set forth in the relevant Consent Decree/Agreement.

3. Credit for stormwater controls shall only be given for the water body segment to which the stormwater drains. In exceptional circumstances and with prior approval, EPA and RIDEM may grant credit for controls treating stormwater draining to a different but hydraulically connected water body segment.

4. No credit shall be given for any stormwater control treating impervious area that drains to a combined sewer system.

5. As laid out in the Consent Agreements, municipal MS4 operators may receive credit for stormwater controls unrelated to development projects or associated with new development or redevelopment on private property that discharge to its MS4 system (i.e., within its area of responsibility) regardless of whether the MS4 operator has funded the project.

6. RIDOT may receive full credit for stormwater controls that it has funded unrelated to development projects on private properties.

7. Credit for stormwater controls associated with new development or redevelopment on private property (outside of an MS4 operator's area of responsibility) shall only be granted for pollutant

removal/impervious surface reduction that exceeds that required by the RI Stormwater Design and Installation Standards Manual and other state and federal environmental requirements.

8. If one MS4 operator proposes to receive credit for a stormwater control treating stormwater from another MS4 operator's area of responsibility, a written statement of concurrence from the operator of the second MS4 must be submitted.

9. No more than 100% credit shall be awarded for any given stormwater control. If more than one MS4 is seeking credit for a stormwater control, credit for eligible projects shall be prorated based on the proportion of the costs funded by the MS4 operator(s) seeking credit. Alternative written credit agreements between MS4 operators may be submitted to EPA and RIDEM for consideration. If more than one MS4 operator is seeking credit for a stormwater control, the agreement shall specify the operator responsible for maintenance of the control.

10. The MS4 operator seeking credit for a stormwater control outside its area of responsibility shall be responsible for maintenance of the control. Appropriate easements shall be secured to ensure proper maintenance of the control. For stormwater controls on private property, a written statement of agreement from the property owner shall be submitted (for RIDOT the statement may be included in the SCP or with the Operation and Maintenance plan submitted with the annual compliance report under paragraph 60.f of the Consent Decree). An MS4 operator may enter into agreements with other parties to maintain the stormwater control, but the MS4 operator remains responsible for ensuring maintenance is performed in accordance with the approved maintenance schedule. If an MS4 operator is seeking credit for a stormwater control outside its area of responsibility, the control must be included in the maintenance management system required by the Consent Decree/Agreement, and the MS4 operator must include a summary of operation and maintenance activities performed for the control in its annual compliance reports.

11. Compliance with this framework must be supported by field verified documentation or as-built site plans of the drainage systems subject to the credits being sought. This and other documentation required by this framework must be made available for review by EPA/RIDEM upon request, and submitted by the MS4 operator claiming the credit as part of their MS4 Annual Report/Consent Agreement or Consent Decree Compliance Report.

12. MS4 operators must maintain a spreadsheet of approved credits claimed for stormwater treatment outside their area of responsibility detailing the impaired Waterbody Identification (WBID) sub-watershed, stormwater controls installed or implemented, the location of the control, name of property owner, whether property is privately owned or another MS4, the discharge point of the stormwater control (e.g., another MS4 or a receiving water body), impervious acres treated, and pollutant load reduction.