Rhode Island Department of Transportation

Linear Stormwater Manual

February 2019

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Why this Manual?

PREFACE

This manual outlines a standardized process and provides tools to streamline stormwater treatment design for <u>RIDOT projects</u>. The contents of this manual provide guidance for complying with stormwater treatment requirements per the Consent Decree between RIDOT, the United States Department of Justice (DOJ) and the Environmental Protection Agency (EPA). The manual also aligns RIDEM and CRMC stormwater permitting requirements. This manual is not intended to replace state and federal permitting, but is intended to provide a consistent streamlined design process for RIDOT projects regardless of permitting.

Background

RIDOT has been required to develop and implement a Stormwater Management Program Plan (SWMPP) under their MS4 permit. The SWMPP included construction and maintenance of Stormwater Treatment Units (STUs) by RIDOT. In 2014, EPA audited and found RIDOT not compliant with its SWMPP. The resolution was for RIDOT to enter a Consent Decree with the EPA and DOJ. The Consent Decree requires RIDOT to mitigate their contribution to stormwater impaired waters of the State. This Linear Stormwater Manual was developed as part of the overall RIDOT program to improve water quality.

Objectives of the RIDOT Linear Stormwater Manual

Objective 1: Provide a clear, predictable and repeatable approach. The manual outlines a well-defined process for the scoping, planning, design, construction and maintenance of future RIDOT stormwater infrastructure. The purpose of this approach is to improve the consistency and efficiency across RIDOT projects.

Objective 2: Simplify the relationship between the RIDOT Work Breakdown Structure (WBS) and stormwater design. The manual references the WBS when presenting the processes and deliverables for stormwater planning, design and construction. It also indicates when to coordinate with the Office of Stormwater Management (OSM) and the documentation required by the OSM.

Objective 3: Standardize stormwater infrastructure & maintenance. The manual presents RIDOT preferred STUs and the design standards of these STUs. The manual also outlines the STU maintenance protocol, which incorporates RIDOT specific standards and requirements for streamlined maintenance activities.

Objective 4: Resolve differing requirements & present general information on stormwater permitting. The manual incorporates the differing requirements of the SWMPP and the Consent Decree and combines them into one process. The manual also provides general information on the various stormwater related permits that may be required on a RIDOT project.

Objective 5: Define project level stormwater treatment goals. The manual provides the steps and definitive end points to demonstrate that a stormwater management plan has diligently evaluated and identified an approach for treating stormwater.

Roles of the RIDOT Office of Stormwater Management (OSM)

The OSM will oversee the implementation of the RIDOT Linear Stormwater Manual for compliance with the requirements in the

Consent Decree. In this role, the OSM will conduct the following tasks for re-construction, maintenance and preservation activities, redevelopment, pavement management and other infrastructure development as defined in the Consent Decree and RI Stormwater Rules:

- Identify whether a project is exempt from the requirements of the manual;
- Identify opportunities to include watershed-level stormwater controls established in the Stormwater Control Plans (SCPs);
- Support progress toward achieving watershed-level stormwater treatment goals from the Consent Decree;
- Evaluate project deliverables for compliance with the RIDOT Linear Stormwater Manual; and
- Track progress toward achieving watershed-level stormwater treatment goals as stipulated by the Consent Decree.

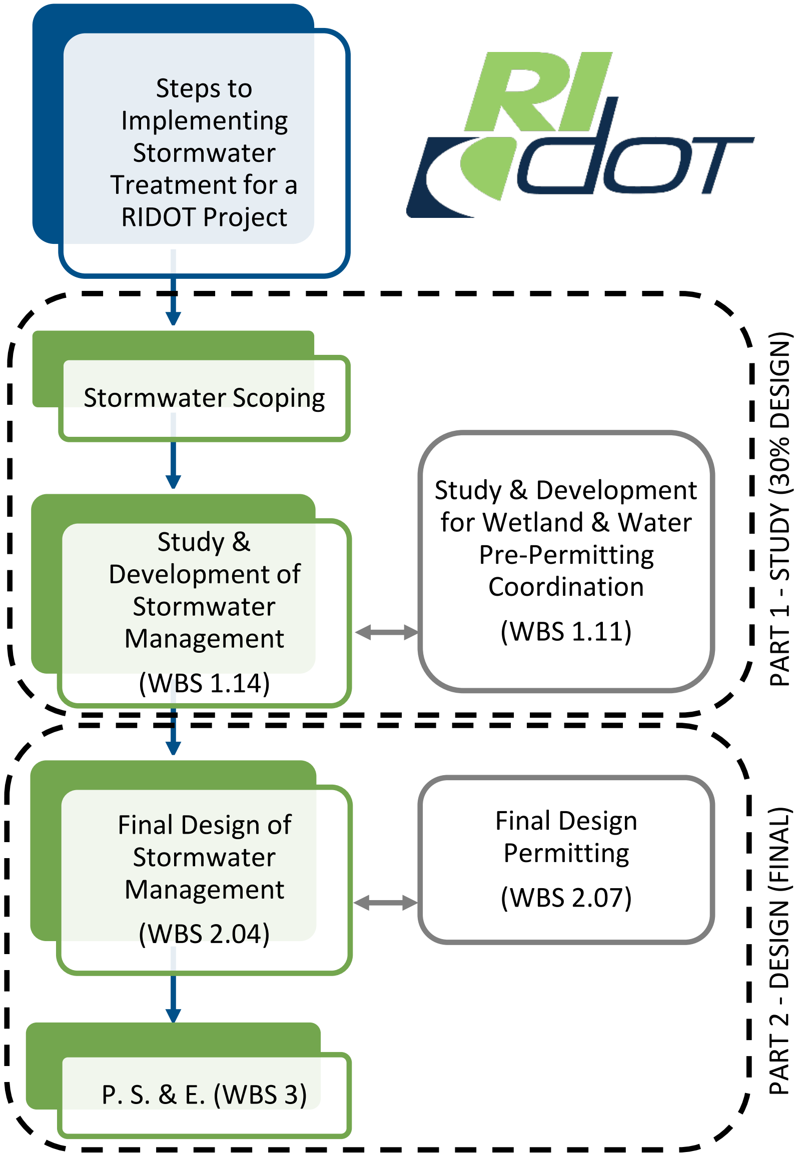


Figure P.1 – Organization of Linear Stormwater Manual

Organization of the Linear Stormwater Manual

This Linear Stormwater Manual comprises two main parts: Part 1 (Study) and Part 2 (Design). **Figure P-1** provides a graphical representation of the organization of the manual and its relation to the RIDOT Work Breakdown Structure (WBS).

Part 1 – Study. The front end of the manual outlines a process with templates and tools that are designed to help the design consultant efficiently achieve 30% design of stormwater measures. Part 1 begins with a section on the RIDOT process for scoping stormwater requirements and constraints. The next section guides the user through the Study & Development of Stormwater Management (WBS 1.14), which includes the selection of BMPs (herein referred to as Stormwater Treatment Units, or "STUs"). Part 1 also includes a section that informs the user of general permitting information to consider in Wetland & Water Pre-Permitting Coordination (WBS 1.11).

Part 2 – Design. The back end of the manual focuses on the Final Design tasks for Stormwater Management (WBS 2.04). This portion of the manual reflects RIDOT preferred STUs and incorporates RIDOT maintenance requirements. In accordance with Final Design Permitting (WBS 2.07), the design consultant must consider the requirements for stormwater permitting.

Part 1 – Study

Scoping of Stormwater

RIDOT personnel typically conduct stormwater scoping prior to selecting a design consultant. Stormwater related findings of the scoping exercise will be outlined in the “Environmental Considerations” portion of the RIDOT Project Definition Scoping Document (the Scoping Document). The design consultant receives the Scoping Document at the onset of a RIDOT project. Project Managers and design consultants shall start a design by reviewing the Scoping Document and referring to the guidance in the Scoping Section of this manual. This information will help provide answers to the following questions:

- Does this Linear Stormwater Manual apply to the project? And, does the project type trigger any programmatic goals or requirements?
- To what Waterbody ID (WBID) does the project contribute runoff? Does the project involve the watersheds of multiple WBIDs? Are any of these waterbodies impaired?
- Has a Stormwater Control Plan (SCP) been developed for the watershed, and does it identify stormwater opportunities near or within the project limits?
- Are there potential stormwater related constraints that may impact the budget?

Why is Scoping important? Scoping confirms whether this manual will be applicable to your project and stormwater related information that may impact your project.

Study & Development of Stormwater Management (WBS 1.14)

Study & Development of Stormwater Management (WBS 1.14) tasks will bring a design to 30% level, where the following questions have been answered:

- What are the project specific stormwater treatment goals?
- Are there opportunities to reduce the amount of impervious surface area within the project limits, and are there disconnected areas?
- Is there existing stormwater infrastructure that can be upgraded to satisfy the treatment goals?
- Do the SCPs, if available, identify water quality improvement opportunities near or within the project limits?
- What STUs are necessary to satisfy the treatment goals? What level of improvements will be required to satisfy the treatment goals?

Why is Study & Development of Stormwater important? Study & Development identifies the plan for a RIDOT project to treat stormwater in accordance with RIDOT stormwater requirements.

General Information on Permitting

The General Information on Permitting Section in this manual introduces regulatory coordination as it relates to stormwater considerations. It is not an exhaustive guide to the environmental review process under the Wetland & Water Pre-Permitting Coordination (WBS 1.11), but is presented to inform the design consultant of potential stormwater permitting requirements.

Part 2 – Design

Final Design of Stormwater Management (WBS 2.04) is conducted by the design consultant. Part 2 of this manual provides guidance for designing the STUs identified during Study & Development (WBS 1.14). The guidance considers RIDOT approved standards and requirements including those related to maintenance activities. The Design Sections in this manual include the following:

- Upgrading Existing Stormwater Infrastructure
- STU Pretreatment Practices
- STU Inlet & Outlet Options
- STUs (bioretention, infiltration, filter strips, etc.)
- Utility Management
- Vegetation

The Design Sections present a general description of the respective STU and their standards for design. The general description presents information such as siting and pollutant removal processes of the STU. The design standards primarily include sizing and materials information.

Construction details for STUs are available on the online RIDOT Stormwater Page. These details include a general configuration of each STU and outline construction specifications. The details also reference the correlating RIDOT Standard Specifications for the materials specified in the design.

Why are the Design Sections important? The Design Section presents standardized parameters for designing stormwater improvements for RIDOT projects. Standardization results in a cost-effective, consistent and predictable approach for designing stormwater features that simplifies and ultimately improves long-term operation and maintenance.

Combined Sewer System (CSS): Sewer system that conveys both sanitary sewage and stormwater. These systems are present within the City of Newport and the Narragansett Bay Commission (NBC) service areas.

Disconnected Area: Impervious surface area where the runoff is:

- Captured and infiltrated by a pervious surface, which is separated from a drainage system;
- Discharged to a drainage system, but the drainage system does not discharge to a waterbody per Section IV.6(cc) of the Consent Decree;
- Treated by a Qualified Pervious Areas (QPAs) per the RI Stormwater Rules; or
- Conveyed to a combined sewer system.

Filter Strip: Refer to the definition of the RI Stormwater Rules.

Impaired Water: Surface water that does not meet the water quality standards established for its designated use(s). States are required to update the list of impaired waters (i.e., the 303(d) List) every two years. Refer to the most recent Rhode Island Section 303(d) List.

Impervious Surface: Pavement, sidewalks, gravel travelways, and any other surface with a runoff coefficient equal to or greater than 0.85.

Project Limits: Area where construction is proposed (i.e., limit of disturbance). Note that the project study area (or area of interest) may extend beyond the project limits (e.g., to the drainage system outfall location).

Qualifying Pervious Area (QPA): Refer to the definition of the RI Stormwater Rules.

Redevelopment: Refer to the definition of the RI Stormwater Rules.

Rhode Island Stormwater Design and Installation Standards Manual (RISDISM): Manual that outlines the stormwater design standards in Rhode Island (*link*).

Seasonal High Groundwater Table (SHGT): Refer to the definition of the RI Stormwater Rules.

Stormwater Control Plan (SCP): Plan prepared by RIDOT that specifies structural and non-structural controls to address the causes of a specific impairment in a watershed.

Stormwater Treatment Unit (STU): Structural control specifically designed to treat stormwater pollutants. Commonly referred to as a structural Best Management Practice (BMP).

Total Maximum Daily Load (TMDL): The amount of a pollutant that may be discharged into a waterbody and still maintain water quality standards and its designated use. Current TMDLs established by RIDEM are in the TMDL & Water Quality Restoration Study Documents.

Waterbody ID (WBID): Numerical designation assigned by RIDEM for each waterbody or waterbody segment organized according to ten major drainage basins in Rhode Island. Waterbody ID (WBID) can be located by accessing the Stormwater Impacted Waters interactive map located at the online RIDEM GIS Map Room.

Water Quality Volume (WQV): The volume of the first inch of runoff from impervious surfaces (WQV = 1-inch X impervious area).

Water Quality Flow (WQF): The peak flow rate associated with the water quality design storm or WQV.

Abbreviations

CRMC	Rhode Island Coastal Resources Management Council
RIDEM	Rhode Island Department of Environmental Management
RIDOT	Rhode Island Department of Transpiration
RIPDES	Rhode Island Pollutant Discharge Elimination System
OSM	RIDOT Office of Stormwater Management
OWM	RIDEM Office of Waste Management
WBS	RIDOT Work Breakdown Structure
WVTS	Wet Vegetated Treatment System

Part 1 – Study

Section 1.1 – Scoping
Section 1.2 – Study & Development (WBS 1.14)
Section 1.3 – General Information for Permitting

1.1.1 Introduction

This section provides guidance for identifying the stormwater related information that is required by the RIDOT Scoping Document. Although RIDOT personnel typically develop the Scoping Document at the onset of a project, design consultants should familiarize themselves with this process. This process sets the framework for properly considering stormwater in subsequent phases of the project design in a manner that complies with the Consent Decree and the RI Stormwater Rules.

1.1.2 Steps for Stormwater Scoping

Step 1: Determine if the Project is Exempt from the Linear Manual

The requirements of this manual apply to all RIDOT projects unless the project has received an exemption from the RIDOT Office of Stormwater Management (OSM).

> Projects such as marking pavement, installing traffic loops, constructing wheel chair ramps, crack sealing, and bridge washing may receive exemptions from the RIDOT Office of Stormwater Management.

All non-exempt RIDOT projects, such as re-construction, maintenance and preservation activities, redevelopment, pavement management and other infrastructure development as defined in the Consent Decree and RI Stormwater Rules, are required to consider stormwater management as part of the project design for RIDOT compliance with the EPA Consent Decree. This requirement is not to be confused with stormwater permitting through RIDEM and CRMC. Stormwater must be treated to the level described in this manual even if no RIDEM or CRMC permitting is required.

Step 2: Assess Existing Stormwater Infrastructure

The purpose of this step is to collect data on existing stormwater infrastructure within the project limits. This step includes accessing data via the RIDOT VueWorks® Database and the RIDOT Plan Room to identify existing infrastructure and stormwater discharge locations. The following data should be compiled:

- Catch basins, manholes & diversion structures
- Pipes and other conveyance features
- Outfalls and their conveyances to the receiving waterbody
- Combined sewers
- Existing Stormwater Treatment Units (STUs)
- Open channel conveyances
- Repair status on infrastructure
- Maintenance status on infrastructure

The existing stormwater infrastructure identified in this step will need to be considered during subsequent design phases. Infrastructure that is damaged and/or not functioning as intended will need to be addressed.

Step 3: Identify Environmental Considerations that Impact Stormwater

The purpose of this step is to identify the Environmental Considerations on the RIDOT Scoping Document that have the potential to impact stormwater. It is important to identify these Environmental Considerations before finalizing the scope, budget, and schedule to avoid necessary rework during subsequent phases. Environmental Considerations such as waters of the State, wetlands, natural heritage areas, hazardous waste sites, etc. in the RIDOT defined project area shall be identified and included on the Scoping Document to provide Project Managers and design consultants with preliminary information regarding Environmental Considerations. Other considerations such as RIPTA bus routes, historical/cultural sites, Title IV, Stakeholders, etc. are also identified in Scoping, but are not the purview of this manual.

Step 3.1 – Input Relevant Information into Scoping Document

Refer to **Table 1.1.1** for a list of Environmental Considerations that impact stormwater and where to find more information relative to these considerations. This information will be necessary for the Scoping Document.

Step 3.2 – Identify Impairment & Stormwater Control Plan Status

In Study & Development of Stormwater Management (Section 1.2), a separate stormwater treatment goal will be established for each Waterbody ID as each will have its individual water quality needs. As a result, separate data is necessary for each Waterbody ID.

The waterbody impairment status and Stormwater Control Plan (SCP) status are important Environmental Considerations because they directly impact the level of stormwater treatment that is required by a project. The following steps outline the process to identify if a waterbody is impaired and if an SCP is available.

A. **Identify the planned project limits, Waterbody ID (WBID) and waterbody name where the project will be located.** This information can be found on the Stormwater Impacted Waters mapping in the online [RIDEM GIS Map Room](). Where prompted, enter the address of the project and click on the watershed where the project is located.

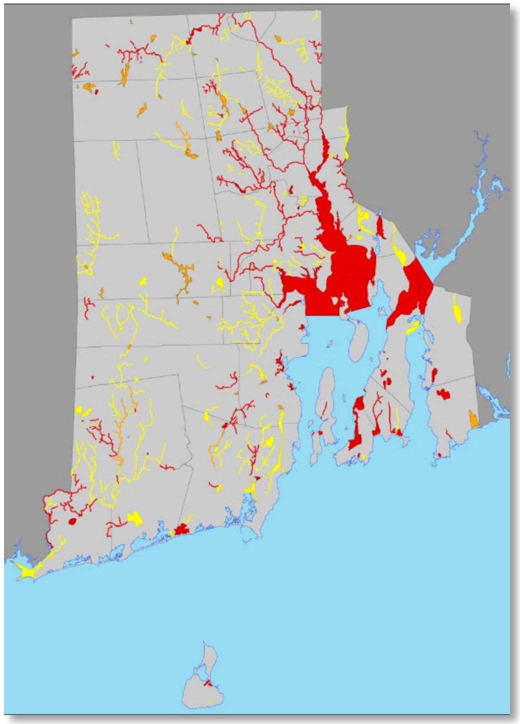


Figure 1.1.1: Rhode Island Impaired Waters - 2016 303(d)

B. **If the project is within a shaded watershed boundary:** click on the watershed. Clicking on the watershed will open a pop-up that indicates the WBID and waterbody name. If a project is located in more than one shaded watershed, follow this and the following steps for each shaded watershed. **If the project is outside a shaded watershed boundary:** click on the nearest waterbody not within a shaded watershed boundary. Clicking on the waterbody will open a pop-up that indicates the WBID and waterbody name. If a project is located near more than one waterbody, follow this step and the following steps for each waterbody. The design consultant will need to confirm the waterbody (or waterbodies) to which the project contributes runoff during subsequent phases.

C. **Determine whether the WBID is impaired.** Identify the impairment(s) using the most recent Rhode Island Section 303(d) List. This information will be used in future phases in your design. The 303(d) list outlines impairments by WBID and their pollutant(s)-of-concern. Impaired WBIDs will be under Category 4A and Category 5. **Figure 1.1.1** depicts the 2016 303(d) impaired waterbodies list.

D. **Determine whether RIDOT has developed an SCP for the WBID**. The SCP will be used as a guide for implementing project level and watershed level STUs in that WBID. Refer to the online RIDOT Stormwater Page to determine if an SCP is available for the WBID and/or any STUs have been identified in the WBID watershed.

STOP **Submit the stormwater related Environmental Considerations of the RIDOT Scoping Document to OSM for review and approval.**

Table 1.1.1 – Environmental Considerations

Environmental Considerations	Potential Impacts to Projects
Hazardous Waste Sites	The presence of contaminated soils may impact ability to infiltrate stormwater. The RIDEM Office of Waste Management (OWM) will need to be contacted.
Cold Water Fishery	Restrictions apply for stormwater management practices when working in a watershed that contributes runoff to a cold-water fishery. The Rhode Island Water Quality Regulations identify waterbodies that are designated as a cold-water fishery.
Wetlands	Work within or around wetland boundaries will require permitting through RIDEM Office of Water Resources – Freshwater Wetlands and/or Coastal Resources Management Council (CRMC). Refer to the online RIDEM GIS Map Room Environmental Resource Map for wetlands mapping.
Bodies of Water > 50 acres in Surface Area & 4th Order Streams	Stormwater attenuation requirements may be waived for sites that discharge to Bodies of Water > 50 acres in Surface Area or 4th Order Streams. Refer to Appendix I of the Rhode Island Stormwater Design & Installation Standards Manual (RISDISM) for stream order classifications.
Wellhead Protection Area	Work within a wellhead protection area may impact ability to infiltrate stormwater. Refer to the online RIDEM GIS Map Room Environmental Resource Map for groundwater resources mapping.
Drinking Water Supply Watershed	Work within a drinking water supply watershed may impact ability to infiltrate stormwater. Refer to the online RIDEM GIS Map Room Environmental Resource Map for drinking water supply watershed mapping.
Impaired Waterbody ID (WBID)	There are greater expectations to meet the stormwater treatment goal when discharging to an impaired WBID. Refer to Step 3.2 of *Section 1.1* to identify if a WBID is impaired.
RIDOT Stormwater Control Plan (SCP)	An SCP may already identify Stormwater Treatment Units (STUs) within the project limits. Contact the RIDOT Office of Stormwater Management (OSM) to determine if an SCP is available for the WBID.
Flood Zone/Floodplain	Work within a floodplain is regulated by RIDEM Office of Water Resources – Freshwater Wetlands and/or Coastal Resources Management Council (CRMC). Refer to the online RIDEM GIS Map Room Environmental Resource Map for floodplain mapping.

Section 1.2 – Study & Development (WBS 1.14)

PART 1 – STUDY

1.2.1 Introduction

This section presents the process for calculating stormwater treatment goals and selecting STUs.

This section defines the process for conducting the Study & Development of Stormwater Management (WBS 1.14) for a RIDOT project. In general, the design consultant will calculate the stormwater treatment goals and select the STUs necessary to comply reasonably with the RIDOT stormwater treatment goal.

The design consultant shall review *Section 1.3* (Permitting) prior to working through the steps in this section. *Section 1.3* outlines information related to permitting, including permitting requirements that will need to be considered during Study & Development of Stormwater Management.

1.2.2 Steps for Stormwater Study & Development

Step 1: Identify Pavement Reduction Opportunities & Disconnected Areas

This first step presents pavement reduction as it relates to stormwater treatment goals. Pavement reduction is often the most cost-effective approach to reduce the stormwater treatment goals of a RIDOT Project. Per the process in this manual, every square foot of impervious surface removed is equivalent to treating two square feet of impervious surface. Pavement reduction shall be completed concurrently with the Develop Alternatives tasks of WBS 1.08.04. The following list provides examples of pavement reduction opportunities. The design consultant needs to incorporate required roadway design and safety standards when identifying potential pavement reduction opportunities. These examples do not preclude roadway design and safety standards.

1. Eliminate unused pavement;
2. Reduce paved shoulder width;
3. Reduce lane widths (road diet with pavement removal); and
4. Replace pavement in islands and medians with vegetation.

In some instances, impervious surfaces do not directly contribute runoff to waters of the State. These impervious surfaces classify as disconnected areas (refer to the Key Definitions Section), and the design consultant shall evaluate the project site for these areas. If identified, delineate the disconnected area boundary (i.e., the impervious surface) and calculate its surface area.

Does any of the project contribute stormwater runoff to a combined sewer system?
YES: Meet with combined sewer authority; the authority may have requirements to treat runoff to the combined sewer.
NO: Continue to Step 2.1.

Step 2: Calculate Stormwater Treatment Goals

The second step outlines the steps for calculating the stormwater treatment goals for a RIDOT project. Disconnected areas are not factored into the stormwater treatment goals in this process.

Step 2.1: Complete Worksheet A

The design consultant shall complete Worksheet A, which is a form that documents stormwater treatment goals. Refer to the RIDOT Stormwater Page for this form and the associated instructions. Design consultants must complete a separate column of Worksheet A for each Waterbody ID (WBID) within the project limits; each WBID will have its individual stormwater treatment goals.

Steps 3, 4 and 5 (as follows) shall be conducted for each WBID. For example, if the treatment goal for one WBID has been satisfied at any step throughout the process, it is still necessary to continue the process for the remaining WBID(s) until the respective treatment goals have been satisfied.

Has Worksheet A calculated a treatment goal of zero or less for the WBID in the project limits?
YES: Continue to Step 5.
NO: Continue to Step 3.

Step 3: Identify Site Conditions

The goal of this step is to identify site conditions that will influence the location of STUs. Some STU siting conditions may not be readily apparent (e.g., soil investigations are necessary), but information can be obtained from many resources and through field observations.

Step 3.1: Collect Data

Step 3.1(a): Collect Data (including existing drainage conditions). Most of the data collection in this step is limited to the online RIDEM GIS Map Room, RIDOT VueWorks® Database, and/or from the RIDOT Plan Room. Please note: mapping the existing drainage structure beyond the project limits may be necessary to get an accurate picture of the existing drainage system, including the outfall. The existing drainage plans shall include the spatial considerations found in **Table 1.2.1**.

Table 1.2.1 – General STU Siting Considerations

Column A Spatial	Column B Capacity to Capture Stormwater	Column C Subsurface
• Structures • Aerial Utilities • Subsurface Utilities • Suitable Land Available • Drinking Water Supplies • Regulatory & Environmental Boundaries • ROW Space • Existing STUs	• Runoff Patterns • Low Points • Areas of Poor Drainage • Stormwater Ponding Areas • Topography	• Soil Types • Infiltration Rates • Depth to Bedrock or Limiting Layer • Depth to Groundwater • Contaminated Soils

Step 3.1(b) Considerations for Project Sites Regulated by RIDEM Office of Waste Management. RIDOT projects may occur within areas that are regulated by the RIDEM Office of Waste Management (OWM) due to contaminated soils. Accordingly, design consultants must pre-screen potential STU locations by conducting a review of RIGIS and RIDEM mapping. This information can be found through the online RIDEM GIS Map Room. These databases are not comprehensive; therefore, the design consultant also needs to be aware of adjacent land uses and their potential for contamination.

If the potential STU location is regulated by OWM, coordination with OWM is required to determine whether stormwater and/or soil management restrictions will apply to the RIDOT project. For instance, design consultants may be required to incorporate additional measures into the project, such as liners and water-tight joints, to minimize the potential for inadvertent migration of contaminants.

If OWM permits an infiltration STU in contaminated soil, the designer will have to test the infiltration rate of the material or remove the material to the water table and replace it with material with a known infiltration rate.

Refer to the RISDISM Subsurface Contamination Guidance.

Step 3.2: Identify Opportunities

Step 3.2(a): Identify Potential STU Locations. Identify potential STU locations within the project limits using the information collected in Step 3.1(a). As part of this step, design consultants shall identify all reasonable STU opportunities even if the opportunities do not initially appear ideal. Subsequent steps may reduce the number of feasible STUs, and identifying all reasonable STUs at this point will save time later in the process. Note: if the roadway contributes to an impaired WBID, STUs may be necessary outside the project limits (refer to Step 4.4 of *Section 1.2.2*).

Table 1.2.2 – RI Infiltration STU Setbacks

Feature Type	Minimum Horizontal Setback (ft.)
Public Drinking Water Supply Well – Drilled (rock), Driven or Dug	200
Public Drinking Water Supply Well – Gravel Packed, Gravel Developed	400
Private Drinking Water Wells	100
Surface Drinking Water Supply Impoundment with Water Intake	200
Tributaries that Discharge to the Surface Drinking Water Supply Impoundment*	100
Coastal Features	50+
All Other Surface Waters	50
Up-gradient from Natural slopes > 15%	50
Down-gradient from Building Structures**	25
Up-gradient from Building Structures**	50
Onsite Wastewater Treatment Systems (OWTS)	25

Note: This table is a compilation of minimum setback requirements from more than one permitting authority (e.g., Section 8.21(B)(10) of the RI Stormwater Rules). It is provided for convenience purposes only. If land availability permits, increase the horizontal setback distance. The design consultant shall verify setback requirements with the appropriate regulatory agency.

** Refer to RIDEM On-Site Wastewater Treatment System Rules Figures 14-16 for maps of the drinking water impoundments.*

*** Setback applies only where basement or slab is below the ponding elevation of the infiltration facility.*

The consideration for purchasing property or procuring an easement for constructing an STU shall be part of this step if the project already requires property acquisition or easement. Setbacks for infiltration STUs need to be considered in this step. These setbacks will influence the location and size of infiltration STUs. Refer to **Table 1.2.2**, which is provided for convenience purposes only. It is the responsibility of the design consultant to verify setback requirements with the appropriate regulatory agencies.

Safe access for RIDOT personnel and equipment is also necessary to maintain STUs. In addition to locating the STU, the design consultant shall also consider the space necessary to access and maintain the STUs in this step. Otherwise, the STU will not be feasible if it cannot be accessed in the future.

Step 3.2(b): Conduct Site Visit. Conduct a site visit to observe the conditions of the project limits and adjacent areas and compare them to the information from Steps 3.1(a) and 3.2(a). Document site conditions that differ from this information. Validate or modify the initial assumptions regarding potential STU locations, field verify outfalls and presence of any erosion, and identify other potential STU locations as necessary during and after the site visit.

Step 3.3: Identify Subsurface Soil Conditions

Step 3.3(a): Determine Soil Investigation Needs. Identify locations where subsurface soil investigations are necessary to support the functionality of potential STUs. It is necessary to adequately conduct the due diligence outlined in previous tasks before identifying these locations. This approach will help minimize unnecessary redesign costs resulting from site constraints and setbacks not previously identified. In general, critical soil criteria include the type(s) of soil, depth to the seasonal high groundwater table (SHGT), depth to bedrock and infiltration rates.

Step 3.3(b): Conduct Soil Investigations. It is recommended that soils are field evaluated by the end of the Study & Development of Stormwater Management tasks (WBS 1.14). Consider coordinating soil evaluations with the Borings in WBS 1.13.

A RIDEM-licensed Class IV soil evaluator or a licensed Rhode Island Professional Engineer shall perform soil testing in the location of proposed infiltration control(s). Refer to Section 8.21(E)(4)(b) of the RI Stormwater Rules and Appendix H of the Rhode Island Stormwater Design & Installation Standards Manual (RISDISM) for soil and field infiltration testing requirements. Test pits and infiltration testing must be performed in accordance with Table H-1 of the RISDISM.

Step 4: Select Stormwater Treatment Units (STUs)

The fourth step guides the user through a clear, predictable and repeatable process that develops the stormwater treatment approach for Final Design (WBS 2.04). It ensures that all reasonable efforts have been taken to comply with the stormwater treatment goal. Inherent to this process is recognizing that there are greater expectations to meet the Worksheet A stormwater treatment goal when discharging to an impaired WBID. **Figure 1.2.1** depicts the process for developing a stormwater treatment approach.

RIDOT has divided STUs into two broad categories that reflect their ability to construct and effectively maintain the STUs: Tier 1 and Tier 2. Tier 1 STUs are preferable by RIDOT due to their higher treatment-cost ratio and are generally simpler to construct and maintain. Tier 1 STUs also focus primarily on infiltration. Tier 2 STUs generally have a lower treatment-cost ratio and may require underdrains and liners. RIDOT reserves the use of Tier 2 STUs in impaired WBIDs when Tier 1 STUs have not achieved the treatment goal.

The following steps start with RIDOT preferred STU options that are most cost-effective and end with options that are effective but cost more to construct and maintain. Throughout the following steps, the design consultant shall reference **Figure 1.2.1** and complete Worksheet B. Worksheet B is available on the online RIDOT Stormwater Page.

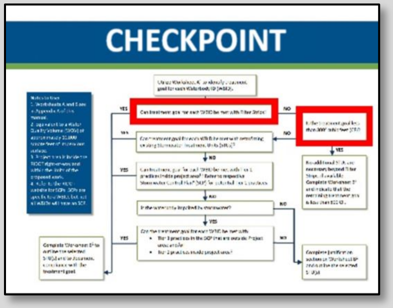
Step 4.1: Identify Filter Strip Opportunities

The design consultant shall first consider using filter strips. Utilizing filter strips is often a cost effective option to manage runoff. Identify areas that satisfy the criteria of filter strips as described in *Part 2 – Design*.

To receive stormwater treatment credit, filter strips require: an evaluation of soil compaction, soil type, and infiltration rate; a delineated boundary; and an operation and maintenance plan. Note that filter strips utilized for pretreatment purposes only do not qualify.

> **Filter Strip**
> Designated natural or landscaped vegetated area that filters and infiltrates runoff from adjacent impervious surfaces in accordance with the technical criteria provided in *Part 2 – Design.*

Can the treatment goal for each WBID be met with filter strips?

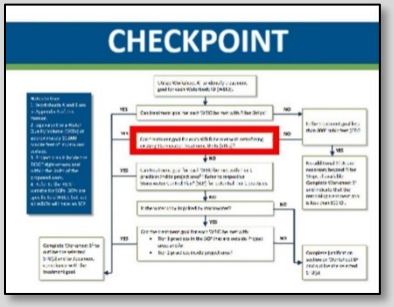


YES: Complete Part 1 of Worksheet B and continue to Step 5.
NO: Is the remaining treatment goal less than 800 cubic feet (CF)? If yes, complete Part 1 of Worksheet B and continue to Step 5. If no, continue to Step 4.2.

Step 4.2: Identify Existing Stormwater Control Upgrade Opportunities

Upgrading existing stormwater controls such as existing detention basins or swales can be a cost-effective option to increase stormwater treatment capacity and meet treatment goals. The benefits and process for identifying potential upgrade opportunities are discussed in *Part 2 – Design*. The portion of the WQV that is treated by an existing stormwater control that is upgraded is further discussed in this section.

Can the treatment goal for each WBID be met by upgrading existing STUs?



YES: Complete Part 1 of Worksheet B and continue to Step 5.
NO: Continue to Step 4.3.

Step 4.3: Identify Tier 1 STUs within the Project Limits

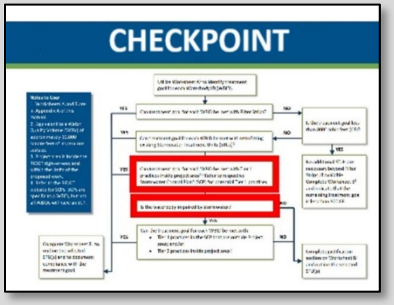
This manual provides a range of potential STUs that can be implemented in RIDOT Rights-of-Way (ROWs). This selection of STUs provides design consultants with a number of options to implement stormwater controls under a range of conditions.

Tier 1 STUs shall be considered in locations where they are feasible within the project limits. If an SCP has been prepared for this WBID as identified in the scoping phase, identify potential Tier 1 STUs recommended in the SCP that are within the project limits and have not yet been implemented.

Two tables are provided that summarize the capabilities of each STU. **Table 1.2.3** summarizes the potential of each of these alternative STUs to manage certain pollutants of concern and how they compare with respect to capital costs, maintenance efforts and land requirements. **Table 1.2.4** summarizes which STUs will best fit specific siting scenarios identified in Step 3 of *Section 1.2.2*.

A live, spreadsheet-driven, STU Selection Tool is available on the online [RIDOT Stormwater Page] to guide design consultants to which Tier 1 controls would best fit site conditions. While design consultants are required to confirm applicability of a potential STU based on actual field conditions, this tool provides a consistent screening approach. Design consultants shall work to locate feasible Tier 1 STU sites to adequately manage stormwater to meet the treatment goal.

Can the treatment goal for each WBID be met with Tier 1 STUs inside the Project Limits?



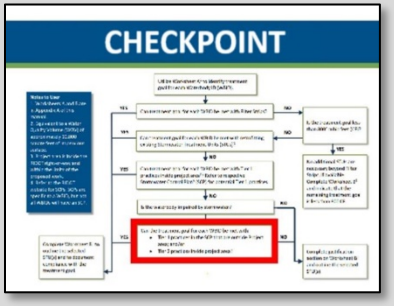
YES: Complete Part 1 of Worksheet B and continue to Step 5.

NO: Is the waterbody impaired by stormwater as listed on Worksheet A? If no, complete Part 1 of Worksheet B and continue to Step 5. If yes, continue to Step 4.4.

Step 4.4: Identify Tier 2 STUs in the Project Limits and/or Tier 1 STUs outside the Project Limits

Additional levels of controls will be required to meet stormwater treatment goals if the WBID is impaired. The process for filling out Worksheet A will identify if the WBID is impaired. The additional levels of controls will consist of either implementing Tier 2 controls within the project limits or implementing Tier 1 controls outside of the project limits but within the WBID watershed. Locating Tier 1 controls outside of the project limits could include placing those controls in other RIDOT ROWs (that could also be identified in an existing SCP), in other public ROWs or potentially on non-RIDOT owned property.

Can the treatment goal for each WBID be met with (1) Tier 1 STUs that are outside the project limits and/or (2) Tier 2 STUs inside the project limits?
YES: Complete Part 1 of Worksheet B and continue to Step 5.
NO: Complete Parts 1 and 2 of Worksheet B and continue to Step 5.



Step 5: Review & Summarize Findings

The design consultant shall revisit *Section 1.3* (Permitting) after working through the steps in this section and selecting STU(s) to reasonably comply with the stormwater treatment goal. This step is important to:

1. Confirm the selected STUs do not conflict with permitting requirements; and
2. Confirm the proper permits have been identified for the project.

If the selected STU(s) align with permitting, the design consultant shall develop the following deliverables to demonstrate compliance with the requirements of the Study & Development of Stormwater Management (WBS 1.14):

- Appendix A checklist Parts 1 & 2 and all supporting documentation;
- Worksheets A and B;
- Field checked existing drainage plans with preliminary siting considerations;
- Watershed map with potential STUs and watershed drainage boundaries; and
- Soils or boring information collected.

Submit the deliverables noted above to the RIDOT Project Manager, who will transmit the deliverables to the Office of Stormwater Management (OSM) for review. The OSM shall approve the deliverables prior to working with RIDEM and CRMC. Please provide at least three weeks for review.

Table 1.2.3 – General Comparison of Stormwater Treatment Units (STUs) for RIDOT Projects

Stormwater Treatment Unit (STU)	Infiltration Setbacks Apply[1]	Tier	Best for Infiltration Rate of <0.5-inch/hr. (at most restrictive layer)	Target Pollutants[2]			Implementation[3]		
				Sediment & Sediment- Bound Pollutants	Bacteria	Nitrogen & Dissolved Pollutants	Capital Cost	Maintenance Burden	Land Requirement
Bioretention Basin		1	X	💧	💧	💧	$ $	⛏⛏	🌱🌱🌱
Bioretention Curb Inlet Planter		1	X	💧	💧	💧	$ $ $	⛏⛏	🌱
Bioretention Swale		1	X	💧	💧	💧	$ $	⛏⛏	🌱🌱
Infiltration Basin	X	1		💧	💧		$	⛏⛏⛏	🌱🌱🌱
Infiltration Trench	X	1		💧	💧		$ $	⛏⛏	🌱🌱
Filter Strip		1	X	💧	💧	💧	$	⛏	🌱🌱🌱
Tree Filter		1		💧	💧	💧	$ $ $	⛏⛏	🌱
Tree Filter with Storage		1		💧	💧	💧	$ $ $	⛏⛏	🌱
Sand Filter		1	X	💧	💧		$ $	⛏⛏⛏	🌱🌱
Porous Pavement with Storage		1			💧		$ $ $	⛏⛏⛏	🌱
Bioretention Parking Lane Adjacent Planter		2	X	💧	💧	💧	$ $ $	⛏⛏	🌱
Bioretention Curb Extension Planter		2	X	💧	💧	💧	$ $ $	⛏⛏	🌱
Underground Infiltration System	X	2		💧	💧		$ $ $	⛏⛏	🌱🌱
Leaching Basin	X	2		💧	💧		$ $	⛏	🌱
Infiltration Gutter	X	2		💧	💧		$ $ $	⛏⛏⛏	🌱🌱
Gravel Wetland (WVTS)		2	X	💧	💧	💧	$ $	⛏⛏	🌱🌱🌱
Porous Pavement		2	X		💧		$ $ $	⛏⛏⛏	🌱

[1] *Refer to Table 1.2.2.*

[2] *Pollutant removal efficiencies vary across STUs; this information does not imply removal efficiency performance and shall be used for reference purposes only.*

[3] *One Symbol = Low, Two Symbols = Moderate, Three Symbols = High*

Table 1.2.4 – Stormwater Treatment Units (STUs) & Potential Site Locations for RIDOT Projects

Stormwater Treatment Unit (STU)	Description	Sidewalks, Pathways & Bikeways	Large Open Spaces	Roundabouts	Principal Arterial Shoulders & Medians	Minor Arterial Shoulders & Medians	Local Roadways
Bioretention Basin	Open surface bioretention basin that **filters** runoff	S	S	S	S	S	S
Bioretention Curb Inlet Planter	Bioretention planter adjacent to a roadway that **filters** runoff	S	-	-	-	S	S
Bioretention Parking Lane Adjacent Planter	Bioretention planter separated from the roadway by a sidewalk	S	-	-	-	S	S
Bioretention Curb Extension Planter	Bioretention planter that protrudes into roadway to create a ”bump-out”	S	-	-	-	S	S
Bioretention Swale	Open channel bioretention system that **filters** runoff	S	F	F	S	S	S
Infiltration Basin	Open surface basin that **infiltrates** runoff	S	S	S	S	S	S
Underground Infiltration System	Subsurface chambers that **infiltrate** runoff	S	F	F	S	S	S
Infiltration Trench	Crushed stone trench that **infiltrates** runoff	S	F	F	F	S	S
Leaching Basin	Subsurface vault that **infiltrates** runoff	S	F	F	F	S	S
Infiltration Gutter	Subsurface chambers along a roadway	S	-	-	-	S	S
Gravel Wetland (WVTS)	Subsurface gravel substrate with a dense surface of wetland plants	S	S	S	S	S	S
Filter Strip	Landscaped area that **filters** runoff draining across it	S	S	S	S	S	S
Tree Filter	Tree planter that **filters** runoff	S	-	-	-	S	S
Tree Filter with Storage	Same as above but with additional storage	S	-	-	-	S	S
Sand Filter	Surface basin that **filters** runoff through sand media	S	S	S	S	S	S
Porous Pavement	Pavement that captures and **infiltrates** runoff	S	-	-	-	-	-
Porous Pavement with Storage	Same as above but with additional storage	S	-	-	-	-	-

[1] *S = Suitable, F = Feasible but not Ideal*

[2] *Table provided for general reference purposes only.*

Figure 1.2.1 – RIDOT Process for Developing Stormwater Treatment Approach

Notes to User

1. Steps correlate to those in *Section 1.2.2* of the manual.
2. Worksheets A & B are available on the online RIDOT Stormwater Page.
3. Equivalent to a Water Quality Volume (WQV) of approximately 10,000 square feet of impervious surface.

Step 2: Utilize Worksheet A to identify the treatment goal for each Waterbody ID (WBID).

Step 4.1: Can the treatment goal for each WBID be met with Filter Strips?

YES

NO

Is the treatment goal less than 800 cubic feet (CF)? See Note #3.

NO

YES

No additional STUs are necessary beyond Filter Strips, if available. Complete Worksheet B and indicate that the remaining treatment goal is less than 800 CF.

Step 4.2: Can the treatment goal for each WBID be met with upgrading existing Stormwater Treatment Units (STUs)?

YES

NO

Step 4.3: Can the treatment goal for each WBID be met with Tier 1 STUs inside the project limits? Refer to respective Stormwater Control Plan (SCP) for potential Tier 1 STUs.

YES

NO

Is the waterbody impaired by stormwater?

NO

YES

Step 4.4: Can the treatment goal for each WBID be met with:

- Tier 1 STUs in the SCP that are outside the project limits; and/or
- Tier 2 STUs inside the project limits?

YES

NO

Complete Parts 1 & 2 of Worksheet B to outline the selected STU(s) and to justify that the treatment goal cannot be met.

Complete Part 1 of Worksheet B to outline the selected STU(s) and to document compliance with the treatment goal.

Section 1.3 – General Information for Permitting

1.3.1 Introduction

This section of the manual briefly presents the permitting programs that may regulate stormwater activity on a RIDOT project. The information in this section is neither all-inclusive regarding potential permits nor does it supersede the authority or permitting requirements of RIDEM, CRMC and other state or federal agencies having jurisdiction. It is the responsibility of the design consultant to identify and obtain the necessary permits for a project and to confirm that all regulatory requirements are satisfied.

Permitting is conducted as part of WBS Items 1.11 and 2.07 and needs to be performed concurrently with the stormwater management tasks in WBS Items 1.14 and 2.04, respectively. Permitting may influence the approach of a stormwater management plan (e.g., placement or extent of STUs), but the STU selection process may also trigger permitting (e.g., constructing an STU near a wetland).

1.3.2 Permitting Responsibilities

Pre-Application Meeting (30% Design or WBS 1.14)

A pre-application meeting with a permitting authority is commonly reserved for construction of new roads, bridges, etc. and larger/complex projects. The goal for a pre-application meeting is for the design consultant to work with the permitting authority at the onset of the project to conduct the following:

- Discuss project scope;
- Review permitting triggers and discuss potential regulatory issues;
- Discuss avoidance and minimization;
- Review treatment goals (Worksheet A);
- Discuss STUs and constraints identified during the Study & Development of Stormwater Management (WBS 1.14); and
- Identify additional application documents and details that will be helpful to the regulatory review.

Prior to the pre-application meeting, it is integral that the design consultant conduct the following tasks to ensure an informative and productive meeting:

- Complete the deliverables produced at the end of the Study & Development of Stormwater Management tasks (WBS 1.14) and request review and approval from the RIDOT Office of Stormwater Management (OSM);
- Review readily available documentation related to the permitting program; and
- Identify permit application requirements (forms, checklists reports, etc.).

The OSM is available to assist during a pre-application meeting with a permitting authority, upon request, but the design consultant is ultimately responsible to prepare for and attend the pre-application meeting.

Permit Applications (90% Design or WBS 2.04)

The design consultant is responsible for developing the permitting applications and the documentation that is required by this manual. The OSM shall review this documentation related to stormwater prior to the design consultant submitting it to the permitting authority. The purpose of the review is to ensure the project conforms to this manual and other stormwater policies.

1.3.3 General Guidance

- **RIDOT Contract Area vs. Permits Required**. Although one RIDOT contract can comprise more than one distinct site location, separate permits will be required for each location unless otherwise indicated by the permitting authority. The necessary permits and applicable permitting programs for each site location will vary based on site conditions (e.g., freshwater wetlands, impaired coastal waterbodies, etc.) and the proposed STUs.
- **Always prepare a Soil Erosion & Sedimentation Control Plan.** RIDOT projects that are subject to this Linear Stormwater Manual must develop a Soil Erosion and Sedimentation Control Plan (SESC Plan) using the RIDOT Stormwater Pollution Prevention Plan (SWPPP) template. Typically this requirement is a result of the RIPDES General Permit for Stormwater Discharge Associated with Construction Activity; however, RIDOT requires an SESC Plan regardless of permitting and land disturbance in order to comply with the RIDOT MS4 permit. Refer to the online RIDOT Stormwater Page for the RIDOT Construction SWPPP Template, which satisfies all SESC Plan requirements for permitting.
- **Pollutant Loading Analysis.** RIDOT has the responsibility for meeting pollutant loading goals specified by the Consent Decree. A Pollutant Loading Analysis for discharges to impaired waterbodies will be addressed in the RIDOT Stormwater Control Plans (SCPs). Each capital project that follows this manual is progress towards that goal.
- **Stormwater discharge to contaminated soils needs to be approved by the RIDEM Office of Waste Management (OWM).** The introduction of stormwater into contaminated soils must be reviewed by the OWM and should be conducted early in the process. Infiltration is not necessarily prohibited in contaminated soils, and early discussions with OWM may provide guidance to areas in the project limits where infiltration would be allowed or prohibited.
- **Erodible Soils.** Erodible soils are the non-engineered material below the roadway structure, bridge or sidewalk. Stormwater treatment is required by RIDOT in accordance with this manual regardless of soil disturbance and RIDEM/CRMC permitting.
- **RIDEM or CRMC Jurisdiction.** Refer to the RIDEM/CRMC Jurisdiction Map to determine if wetland activity is under the jurisdiction of RIDEM or CRMC. Note that even if the wetland activity is under CRMC jurisdiction, the project may also trigger a Water Quality Certification (WQC) from RIDEM. It is recommended to look at the RIDEM Stormwater Application Form to confirm.
- **Documentation from Study & Development.** The documentation developed during Study & Development (i.e., Worksheets A and B, Appendix A Checklist, etc.) shall be incorporated into the permit application. RIDOT created the templates for this documentation to help with the permitting process.
- **Guidance Documents.** Many guidance documents are on the RIDEM website to help with topics in the RI Stormwater Rules and RISDISM.

1.3.4 RIDEM Permitting Programs

RIDEM Stormwater Engineering & Water Quality Certification (WQC)

The RIDEM Application for Stormwater Construction Permit and Water Quality Certification Form has an embedded questionnaire that outlines the triggers for RIDEM Office of Water Resources (OWR) permitting. This application is a single form for the RIDEM Groundwater Discharge Program, the RIPDES Construction General Permit Program, the WQC Program, and the RIDEM Freshwater Wetlands Program. Note: the questionnaire will need to be completed for each distinct site location of a RIDOT contract.

RIDEM Groundwater Discharge (UIC): The RIDEM Groundwater Discharge Program (i.e., Underground Injection Control, or "UIC") is charged with protecting groundwater in Rhode Island. Stormwater infiltration systems that receive runoff from a roadway and parking area of any size will need a Stormwater Discharge System Registration. When applying for a RIDEM Application for Stormwater Construction Permit, if any of the UIC boxes are checked on the application form, you are essentially applying for a permit, verifying compliance under the RIDEM Groundwater Quality Rules and RIDEM Groundwater Discharge Rules. The horizontal setbacks and groundwater separation distances in this manual and in the RI Stormwater Rules exist to comply with the above rules and protect groundwater from potential pollutants in stormwater.

RIPDES General Permit for Stormwater Discharge Associated with Construction Activity: Stormwater runoff during construction is regulated under the RIPDES program. The environmental concern is primarily erosion and sediment control. When applying for a RIDEM Application for Stormwater Construction Permit, and any of the RIPDES boxes are checked on the application form, you are essentially applying for the RIPDES General Permit for Stormwater Discharge Associated with Construction Activity. RIPDES permits are automatically authorized upon RIDEM verification that a CRMC Assent has been issued.

RIDEM Water Quality Certification: The WQC Program encompasses a wide range of projects, but in the context of this manual, the most common permitting for those projects is fill for bridges and/or roadways in CRMC jurisdiction. Permits that trigger a WQC may need to be public noticed in accordance with the RIDEM Water Quality Regulations.

RIDEM Office of Water Resources – Freshwater Wetlands

If the RIDEM Application for Stormwater Construction Permit and Water Quality Certification Form previously discussed identifies that a RIDEM Freshwater Wetlands permit is required, then the RIDEM Freshwater Wetlands General Application Form must be submitted to the RIDEM Wetlands Office along with the Stormwater Application Form.

Any activity that may alter the character of a freshwater wetland, or its functions and values, is regulated under the RIDEM Freshwater Wetlands Program. Although some exemptions for limited project types are available under the program's rules, construction within regulated wetlands, activities that affect surface or groundwater flows, water quality, or otherwise may alter wetlands due to the size or nature of the project, must obtain a permit under this program.

When completing the Instructions for Submittal of Freshwater Wetlands Applications, also provide guidance on the United States Army Corps of Engineers (USACE) Programmatic General Permit (PGP). A USACE permit may be required for activity in a coastal and inland water and wetland.

RIDEM Office of Waste Management

If a stormwater infiltration system is proposed in contaminated soils, the RIDEM OWR will typically request a review by the OWM before approval. The OWM will be looking to protect existing contamination from leaching off the site, and if the contaminant is mobile, OWM will be looking to protect unwanted movement of any contaminants. Refer to the RISDISM Subsurface Contamination Guidance.

1.3.5 CRMC Permitting Programs

Activities within coastal resource areas are regulated by CRMC under the Rhode Island Coastal Resources Management Program (RICRMP). CRMC also retains jurisdictional authority for any activity that "has a reasonable probability of conflicting with the Council's goals and its management plans or programs, and/or has the potential to damage the environment of the coastal region." Under that authority, CRMC may restrict the sequence and duration of RIDOT construction activities to protect coastal resources. Refer to the CRMC Application for State Assent and the respective CRMC Assent Checklist.

Any activity that may alter the character of a freshwater wetland in the vicinity of the coast, or its functions and values, is also regulated by CRMC. Construction within regulated wetlands, activities that affect surface or groundwater flows, water quality, or otherwise may alter wetlands due to the size or nature of the project, must obtain a permit under this program. Refer to the CRMC Freshwater Wetlands in the Vicinity of the Coast Application Package.

CRMC has developed Special Area Management Plans (SAMPs) to address specific regional environmental concerns. In addition to those activities captured under other CRMC management programs, certain activities which occur throughout these SAMP watersheds are regulated.

1.3.6 Combined Sewer System Authorities

The Narragansett Bay Commission (NBC) and Newport Utilities regulate all stormwater discharges to their system of combined sewers and ultimately to their treatment facilities. Stormwater that discharges to combined sewer systems may originate from MS4s, direct connections from roadways or buildings, and through indirect connections, such as surface runoff. Design consultants must comply with the combined sewer authority and obtain permits as required by the authority. In general, stormwater disconnected from the combined sewer will require stormwater treatment and the appropriate RIDEM and CRMC permitting.

Part 2 – Design

Part 2 – Design

Introduction

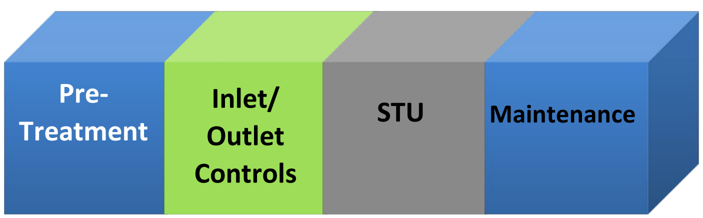
Part 2 provides design standards for Final Design of Stormwater Management (WBS 2.04) for RIDOT projects. The standards applicable to most, if not all, RIDOT stormwater treatment projects are as follows:

> Prior to final design of a RIDOT project, Section *1.2 – Study & Development (WBS 1.14)* of this manual shall be consulted to identify the STUs appropriate to meet the treatment goals for the project.

- Pretreatment
- Inlet & Outlet Controls
- STUs (see list)
- Maintenance

Part 2 also provides guidelines on the following topics:

- Upgrading STUs
- Vegetation
- Utility Management



Building Blocks to a Successful STU Design

Each STU section presents design parameters that are specific to that STU. It is also recommended that the design consultant also refer to the Pretreatment, Inlet/Outlet Controls and Maintenance Considerations sections for design parameters relative to these components, unless otherwise noted in the STU section. The intent of this approach is to apply standards from each section to design an STU. The remaining design sections are available if the design encompasses an upgrade to an existing stormwater feature, a utility crossing, and/or vegetation. Note that **Table 1.2.1** and **Table 1.2.4** in *Part 1 – Study* provide information relative to STU selection.

List of STU Design Sections
Bioretention Basin
Bioretention Curb Inlet Planter
Bioretention Parking Lane Adjacent Planter
Bioretention Curb Extension Planter
Bioretention Swale
Infiltration Basin
Underground Infiltration System
Infiltration Trench
Leaching Basin
Infiltration Gutter
Gravel Wetland (WVTS)
Filter Strip
Tree Filter
Tree Filter with Storage
Sand Filter
Porous Pavement (without storage)
Porous Pavement with Storage

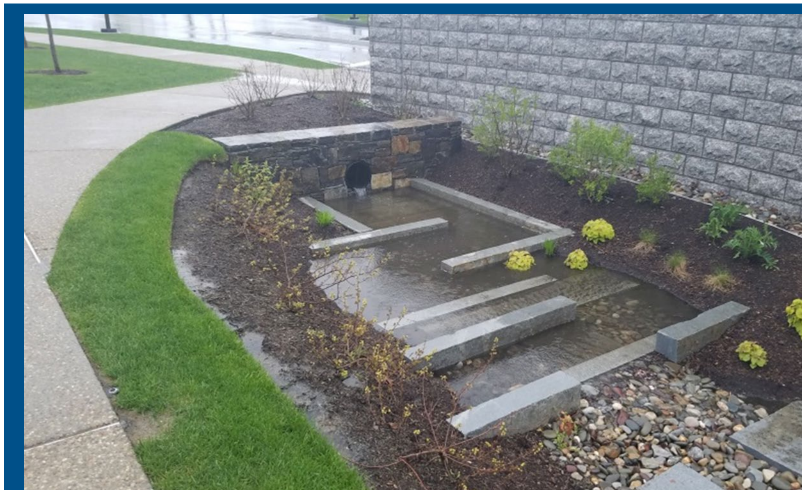


Figure 2.1.1 – Reused Granite Curb Pretreatment Basin; Providence College

Typical pretreatment practices include:

- Sediment Forebay
- Pretreatment Swale
- Pretreatment Vegetated Filter Strip
- Flow Through Devices:
  - Pretreatment Tank
  - Proprietary Structure
  - Deep-Sump, Hooded Catch Basin

2.1.1 General

Pretreatment practices are designed to capture and remove coarse sediment and debris (e.g., trash, leaves, oil and grease) upstream of a stormwater treatment unit (STU) while consolidating maintenance to a specific location. Properly designed pretreatment practices help maintain the pollutant removal efficiency of an STU, extend its service life and reduce maintenance costs. <u>All pretreatment practices require regular maintenance to function properly.</u>

Access Considerations

The performance of pretreatment practices is dependent on regular maintenance; therefore, maintenance access must be carefully considered and incorporated into a design. Refer to the Maintenance Considerations Section in this manual.

Selection

Pretreatment practices must be selected based on the following:

- The downstream STU;
- Site specific constraints (e.g., available space, topography, accessibility for maintenance);
- Flow type (e.g., sheet or concentrated flow); and
- Required pretreatment capacity.

Table 2.1.1 highlights the key differences between pretreatment practices and assists in pretreatment selection. Multiple pretreatment practices may be used when possible to increase pretreatment capacity.

Table 2.1.1 - Pretreatment Practices

Pretreatment Practice	Inlet Flow Type	Sizing Criteria (Capacity)	Maintenance Burden[1]	Land Requirement[1]	Capital Cost[1]	Pollutant Removal Process
Sediment Forebay	Diffuse/ Concentrated	25% WQV (small - large)		-	$ - $$	Settling
Pretreatment Swale	Diffuse/ Concentrated	WQF & 10-min. Residence Time (small/medium)			$	Filtration, Minor Infiltration & Vegetative Uptake
Vegetated Filter Strips	Diffuse	Length / Watershed Dependent (small)	-		$	Filtration, Minor Infiltration & Vegetative Uptake
Pretreatment Tank	Concentrated	25% WQV (small)		-	$$	Settling & Floatables Removal
Proprietary Structure	Concentrated	WQF (small/medium)			$$ - $$$	Settling & Floatables Removal
Deep-Sump Hooded Catch Basin	Concentrated	WQF (small)			$	Settling & Floatables Removal

[1] One symbol indicates low, two symbols indicate moderate, and three symbols indicate high.

[2] Table provided for general reference purposes only.

Typically Used as Pretreatment for:

- ☑ Bioretention Basin
- ☑ Curb Inlet Planter
- ☑ Parking Lane Adjacent Planter
- ☑ Curb Extension Planter
- ☑ Bioretention Swale
- ☑ Gravel Wetland (WVTS)
- ☑ Sand Filter
- ☑ Infiltration Basin
- ☑ Infiltration Trench

Figure 2.1.2 – Sediment Forebay with Concrete Berms

2.1.2 Sediment Forebay

Sediment forebays are separate depressed basins/cells located immediately upstream of a STU that capture, temporarily store, and settle coarse sediments and debris from runoff in an accessible area. Sediment forebays are highly flexible to meet site-specific constraints, are typically separated from downstream STUs with a berm or baffle, and provide a non-erosive outlet into the downstream STU. The outlet can be configured as a riser and pipe, overflow weir, or culvert but the invert of the outlet must be elevated such that the required WQV is stored below it.

Siting

Sediment forebays shall be located at each inflow point into the STU; there may be multiple conveyances into one forebay.

Dimensions

- Inflow Velocity
  - In accordance with Inlet/Outlet Section.
- Length/Width
  - Minimum: 1:1 ratio (2:1 or greater preferred)
- Freeboard
  - Minimum: 0.5-foot for off-line STUs; 1-foot for in-line STUs
- Bottom Surface Area
  - Size in accordance with Section 6.4.1 of the RISDISM.
- Volume
  - Size the sediment forebay to store 25% of the WQV below the outlet invert unless specified otherwise in the respective STU Design Section.
  - Do not account for infiltration in the analysis of the forebay.

- Ensure adequate depth to prevent resuspension of collected sediments during the design storm with flow-through velocities not exceeding 2 feet/second for all design storms.
- Side Slope
  - Maximum: 3(H):1(V)

Features

- Forebay Berm
  - Use gabion baskets, concrete or granite curbing, precast or cast-in-place concrete weirs.
- Bottom of Forebay
  - Line with a concrete or grouted stone pad to facilitate maintenance.
  - Provide at least two weep holes (2.5 inches in diameter) for every 25 square feet of surface area in bottom of forebay to facilitate low level drainage. Forebay must fully dewater within 48 hours after a storm event.
- Stage Indicator/Gage
  - Install a stage indicator/gage to monitor sediment levels. The gage shall indicate the level at which the forebay is considered full.

Materials

- Curbing
  - If used, granite or concrete curbing shall conform to Section 906 of the RIDOT Standards.
- Gabion Basket
  - If used, shall conform to ASTM A-974-97 and US Federal Specification QQ-W-461H and coated in accordance with ASTM A641, Finish 5, Class 3.
- Grouted Riprap
  - If used, placed stone riprap conforming to Section M.10.03.2 of the RIDOT Standards.
  - Grout shall be a non-shrink grout having a 4,000 psi 28-day compressive strength and a 2,400 psi 7-day compressive strength.
  - In accordance with Section 711.03.3 of the RIDOT Standards.
- Outlet or Riser Pipe
  - Refer to Inlet/Outlet Section
- Poured-in-Place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Precast Concrete
  - If used, shall be Class XX concrete conforming to Section 809 of the RIDOT Standards.
- Weep Holes
  - Shall be in accordance with Section 811 of the RIDOT Standards.

Typically Used as Pretreatment for:

- ☑ Bioretention Basin
- ☑ Bioretention Swale
- ☑ Gravel Wetland (WVTS)
- ☑ Sand Filter
- ☑ Infiltration Basin
- ☑ Infiltration Trench

Figure 2.1.3 – Vegetated Swale

2.1.3 Pretreatment Swale

Pretreatment swales are gradually sloped channels that increase travel time, reduce runoff velocity, and utilize vegetation to filter coarse sediments and debris from runoff. Pretreatment swales provide both conveyance and pretreatment for downstream STUs. Check dams may be utilized to increase pretreatment capacity by creating capacity to temporarily store runoff, further reducing the runoff velocity in the swale.

Siting

- As appropriate based on site design and constraints, pretreatment swales can be used as an alternative conveyance mechanism to traditional curb and gutter systems. Adequate length to ensure sufficient filtering of runoff.
- Do not use in areas with:
  - steep grades;
  - poorly drained soils;
  - in watersheds with high sediment loads; and/or
  - unstable upgradient areas.

Dimensions

- Cross Section Channel Shape
  - Minimum Bottom Width: 2 feet
  - Shape: Trapezoidal or parabolic; maximize wetted perimeter to the extent possible to increase vegetation contact and reduce velocities
- Side Slope
  - Maximum: 3(H):1(V)

- Length
  - Provide minimum residence time of 10-minutes from inlet to outlet for the WQV event. Where sheetflow enters the swale, residence time is measured from the mid-point between the upgradient most part of the swale to the outlet.
- Longitudinal Slope
  - Optimal Range: 1% to 2%.
  - Utilize check dams if necessary to ensure adequate residence time for steeper slopes.
- Velocity
  - Maximum velocity for WQV event: 1 foot per second.
  - Maximum velocity for 10-year design storm: 3 feet per second
  - If velocities are greater than the maximum velocities listed above, provide turf reinforcement matting (TRM).

Features

- Top Soil
  - Minimum Depth: 4 inches
- Check Dams
  - Can be installed to increase hydraulic residence time and promote additional infiltration.
  - Can be created using gabion basks, concrete or granite curbing or precast or cast-in-place concrete.
  - Maximum Height: 1/2 the height of swale bank
  - Spacing and height of check dams will depend on both the longitudinal slope of the swale and the runoff travel time.
  - Anchor check dams into swale side slopes to prevent washout. Each side of the dam must extend 2-3 feet into the swale side slopes.
  - Protect downstream side of check dam from scour with stabilized surface measure.
  - When check dams are used near the inlet to control the inlet flow velocity, protect the swale from scour with stabilized surface measure if inlet velocities are greater than 3 feet per second.

Materials

- Vegetation
  - Refer to the Vegetation Section of this manual.
- Turf Reinforcement Mat (TRM)
  - If used, shall be a woven material included on the RIDOT Approved Materials List, which exceeds the design velocity of the design storm and allows for the growth of the proposed vegetative species.
- Curbing
  - If used, granite or concrete curbing shall conform to Section 906 of the RIDOT Standards.
- Gabion Basket
  - If used, shall conform to ASTM A-974-97 and US Federal Specification QQ-W-461H and coated in accordance with ASTM A641, Finish 5, Class 3.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Precast Concrete
  - If used, shall be Class XX concrete conforming to Section 809 of the RIDOT Standards.
- Check Dams
  - If used, construct of gabions, granite or concrete curbing, or precast/cast-in-place concrete.

Other Considerations

- Culverts can be used to maintain swale connectivity where a driveway, walkway, or roadway crosses the swale. The culvert must be sized sufficiently to pass the 10-year design storm (at a minimum) without causing overtopping.

Typically Used as Pretreatment for:

- ☑ Bioretention Basin
- ☑ Bioretention Swale
- ☑ Gravel Wetland (WVTS)
- ☑ Sand Filter
- ☑ Infiltration Basin
- ☑ Infiltration Trench

Figure 2.1.4 – Filter Strip; Warren, RI

2.1.4 Pretreatment Vegetated Filter Strip

Vegetated filter Strips are uniformly graded, vegetated slopes that treat sheet flow from adjacent areas by reducing runoff velocity and utilizing vegetation to filter coarse sediments and debris. Vegetated Filter Strips are located between pollutant sources and downstream STUs and are required to run the entire width of the contributing upstream area. They are most effective if they receive uniformly distributed sheet flow and a level spreader is required if runoff will become concentrated.

Siting

- Vegetated filter Strips are best located in wide, uniformly sloped areas with ample space and mild slopes between the pollutant source and the downstream STU.
- Locate where:
  - Area is not subject to excessive fertilizer application or excessive irrigation.
  - Site conditions promote a dense vegetative growth.
  - Site use and aesthetic considerations allow for infrequent mowing (2-4 times a year).
  - Filter strip slopes between the pollutant source and downstream STU are between 2% and 4%.
  - Sheet flow shall be maintained across the length and width of the filter strip.
  - There is at least 18 inches of separation to groundwater.
  - Contributing watersheds have low sediment and floatable loads.

Inlet

- The vegetated filter strip shall receive evenly distributed sheet flow.
- If runoff directed to a vegetated filter strips could become concentrated, design to include a level spreader in accordance with the Inlet/Outlet Section of this manual.
- The velocity of the sheet flow shall not become erosive.
- Contributing upstream area shall not have a slope in the direction perpendicular to flow that exceeds 2%, and a slope in the direction parallel to flow that exceeds 5%.
- The top of the filter strip shall be set 2 inches below adjacent pavement so that sediment and debris accumulated at the edge of the strip does not prevent runoff from exiting the road surface.

Dimensions

- Length (direction of flow)
    - Refer to **Table 2.1.2.**
- Width (perpendicular to direction of flow)
    - Set width equal to or greater than the width of the upgradient impervious contributing surface.
- Slope
    - Minimum Slope: 2%; slopes less than 2% may result in ponding and other nuisances
    - Maximum Slope: 4%; slopes greater than 4% may results in concentrated flow and erosion.
        - Maximum velocity for WQV event: 1 foot per second
        - Maximum velocity for 10-year design storm: 3 feet per second
        - If velocities are greater than the maximum velocities listed above, provide turf reinforcement matting (TRM).
- Vegetation
    - Refer to the Vegetation Section of this manual.
    - Vegetation shall consist of 100% ground cover and shall consist of whatever composition is most likely to be successful based on project location and site specific conditions.
    - Use non-erosive, grass cover that can withstand relatively high velocity flows, and both wet and dry conditions.
    - Careful consideration should be taken when choosing vegetation. Some woody vegetation is acceptable; however, to maximize pretreatment, the majority of the area should be grassed.
    - Manage vegetation to maintain tall, vigorous growth.

Table 2.1.2 - Vegetated Filter Strip Width

Parameter	Impervious Area				Lawn Area			
Maximum Inflow Approach Width (feet)	35		75		75		150	
Slope (%)	<2	>2 <4	<2	>2 <4	<2	>2 <4	<2	>2 <4
Filter Strip Minimum Width (feet)	10	15	20	25	10	12	15	18

Typically Used as Pretreatment for:

☑ Curb Inlet Planter
☑ Curb Extension Planter
☑ Underground Infiltration System
☑ Leaching Basin
☑ Infiltration Gutter
☑ Tree Filter

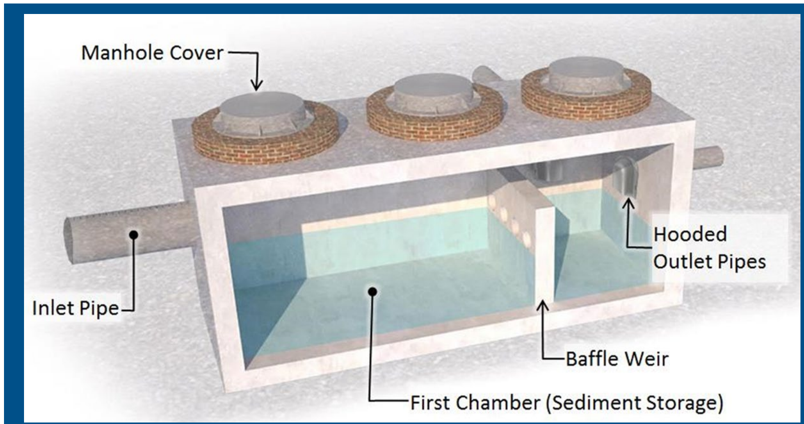


Figure 2.1.5 – Example of a Flow-Through Device

2.1.5 Flow-Through Devices

Flows through devices are underground, concrete vaults with one or more chambers that capture runoff through an inlet grate or receive flow from a piped system. Such devices include deep-sump, hooded catch basins, proprietary devices, such as hydrodynamic separators, and flow diversion structures, such as oil/particle separators. Where site configuration allows, they can also be used to divert the water quality volume to an off-line system.

Siting of Flow-Through Devices

- Locate where:
  - Land use requirements prohibit use of other pretreatment approaches.
  - Underground features are necessary due to site conditions.
  - Can accept runoff from watersheds with high trash, debris, oil and grease and other floatable loads.
- In areas with high groundwater, buoyancy and anchoring requirements must be considered.
- Siting limitations include:
  - Depth of bedrock
  - Presence of utilities
  - Unstable subsurface conditions that limit depth of excavation

Pretreatment Tank

Pretreatment tanks consist of multi-chambered systems with peak flow bypasses and baffles to improve retention of coarse sediments/debris and floatables. Multi-chamber systems typically include a sediment storage and a settling chamber, where the inlet pipes are connected, and a second chamber where the outflow baffle is fitted with a hooded orifice or an inverted elbow pipe to regulate the water level and remove floatables. The third chamber is where the outlet pipes are connected and serves as redundancy in the event the baffles become overtopped. A two chambered system, as shown in **Figure 2.1.5**, can be used to maximize sediment storage when the outlet pipes, in the second chamber, are fitted with hoods. Design guidance for pretreatment tanks is as follows:

- Size the pretreatment tank to store 25% of the WQV below the outlet invert unless specified otherwise in the respective STU Design Section.
- Make the permanent pool at least 4 feet deep from the outlet invert.
- Design the device to bypass storms greater than the WQF.
- Pretreatment tanks can be designed as flow diversion structures see Inlet/Outlet Section for more information.
- Shall be fitted with frame and cover to facilitate maintenance access to each chamber.
- Frame and cover must be in accordance with RIDOT Standard Details and RIDOT Specifications.
- Must be designed with enough internal vault space to allow access of vacuum truck suction nozzle without damaging hoods or access ladder steps.

Deep-Sump Hooded Catch Basin

Deep-sump hooded catch basins should be used in conjunction with other pretreatment measures. Where there is limited space in highly developed areas, deep-sump hooded catch basins may be used as the primary pretreatment practice with RIDOT approval. Design guidance for deep-sump hooded catch basins is as follows:

- Inlet grate shall not allow flow rates greater than 3 cubic feet per second (CFS) for the 10-year storm event.
- Contributing drainage area shall not exceed 0.25 acres of impervious cover.
- All proposed catch basins must have a minimum sump depth of 48 inches.
- All outlets in the catch basin that connect to STUs shall be equipped with hoods.

Proprietary Structure

There are several types of proprietary structures that can be used as pretreatment, including oil/grit separators, hydrodynamic devices and media filters. While these pretreatment practices must be designed in accordance with manufactures recommendations, they must also meet the design criteria outlined below. Selection guidance for proprietary structures is as follows:

- The proprietary structure shall have a minimum verified TSS removal efficiency of 50%.
    - Verified removal efficiency must comply with TARP (Technology Acceptance Reciprocity Partnership) and TAPE (Technology Assessment Protocol – Ecology) certification requirements.
- Proprietary Structures may be designed as online or office in accordance with recommendations of the manufacturer and TAPE/TARP certification requirements.
- All proprietary structures are subject to approval by the RIDOT Office of Stormwater Management (OSM).

2.2.1 Description

Inlet and outlet controls manage runoff into and out of Stormwater Treatment Units (STUs), respectively. This section presents inlet and outlet controls that can be used with the STUs in this manual and supplements information in the RISDISM. Refer to the specific STU sections for further information relative to inlet and outlet controls that are best suited for the respective STU.

2.2.2 Inlet Control Types

Level Spreader

Level spreaders collect and uniformly distribute runoff from an upgradient impervious surface to the downgradient STU. Level spreaders reduce the energy and velocity of runoff, which reduces the potential for erosion. Refer to the RI Erosion & Sediment Control Handbook for figures of a level spreader. The following must be considered when designing level spreaders:

- Concentrated flow may enter the level spreader at a single or multiple points and leaves as uniformly distributed sheet flow.
- The maximum drainage area for a level spreader shall be 2.5 acres for maximum efficiency.
- Flow shall be uniformly distributed and crest over the downgradient edge of the spreader along its entire length. The downgradient edge over which flow is distributed must be level. Small variations in height (of more than 0.25 inch) will result in concentrated flow and erosion.
- Stormwater flowing over the lip of a level spreader shall be limited to a depth of approximately 6 inches.
- The downslope side of the level spreader must be 10(H):1(V) or flatter and must be clear of obstacles that may result in concentrated flow.
- Level spreaders shall not be constructed in newly deposited fill locations as these areas will be most susceptible to erosion. Undisturbed earth is much more resistant to erosion than fill.
- Types of level spreaders include grouted riprap-lined channels/shallow trenches. Depths and widths typically range between 6 to 12 inches; the length depends on the flow rate.
- Refer to Appendix H of the RISDISM for additional level spreader design requirements.

Inlet Curb Cut Opening

Inlet curb cut openings are used for inlet control in locations where STUs are installed along curbed streets, parking lots, or landscaped islands. In certain situations, stormwater overflow discharges out of the STU via the same curb cut opening through which it entered. Once stormwater fills the STU, stormwater overflow will be directed back out through the curb opening to an existing drain structure that will then function as an overflow structure.

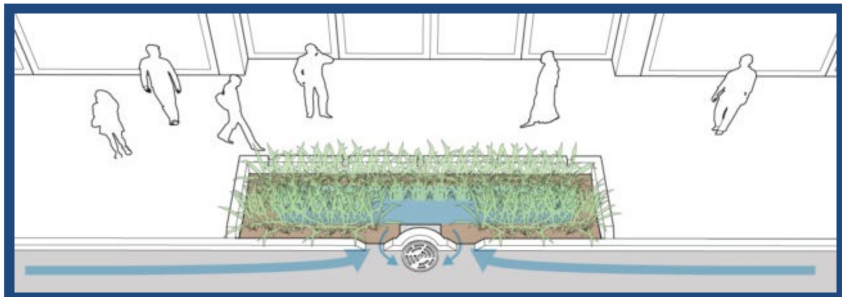


Figure 2.2.1 – Combined Inflow/Overflow Curb Cut Opening; NACTO

The following must be considered when designing curb cut openings:

- Curb cuts must be transition style and shall have a width not less than 18 inches to prevent clogging.
- Design the curb cut to resist blockage from garbage, debris and sediment in addition to ice and snow.
- Intermittently space curb cuts 3 to 15 feet apart.
- If designing the STU as an in-line structure, design the opening width to prevent flow from bypassing the opening.
- Slope the bottom of curb cut to drain toward the STU.
- Provide a minimum 2-inch drop in grade between the curb cut entry point and the downgradient finished surface/grade.
- Woody plants shall not be placed directly in the entrance flow path. Woody plants can restrict and concentrate flows and be damaged by erosion around the root ball.
- Stabilize area downstream of curb cut opening to prevent erosion. Concrete (e.g., a splash pad), paver blocks or grouted stone shall be used to armor the flow path to the base of the STU.

Figure 2.2.2 – Typical Curb Openings; Providence College & Cranston, RI

Inlet Structure

Inlet structures may be used to capture runoff, slow runoff velocities, settle solids and convey runoff to a downstream STU. A deep-sump catch basin is an example of an inlet structure. The following must be considered when designing inlet structures:

- Design the inlet to resist blockage from garbage, debris and sediment in addition to ice and snow.
- The recommended sump depth for deep-sump structures is 48 inches.

Figure 2.2.3 - Deep-Sump Catch Basin Inlet Structure; Barrington, RI

- To minimize the amount of floatable pollutants that are discharged to the STU, utilize hoods.

Piped Flow Entrance

Runoff may discharge to an STU via a pipe or culvert. The following must be considered when designing piped flow entrances:

- Include an energy dissipation device to dissipate energy and distribute runoff. The energy dissipating device must extend the entire width of the piped flow entrance and extend into the bottom of the STU. Acceptable energy dissipating devices include grouted stone riprap aprons, concrete splash pads and forebays/stilling areas created using concrete/granite curbing or gabion weir/baffles. When using concrete/granite curbing or gabion weir/baffles, consider potential tailwater impacts.
- Woody plants shall not be placed directly in the entrance flow path. Woody plants can restrict or concentrate flows and be damaged by erosion around the root ball.
- Design the flow entrance to resist blockage from garbage, debris and sediment in addition to ice and snow.

Flow Diversion Structure

STUs can be designed to receive all of the flow from a given area (in-line) or to receive only a portion of the flow (off-line), such as the WQV. Flow diversion structures, also called flow splitters, are designed to divert the Water Quality Flow (WQF) from a conveyance system to an off-line STU. Flows in excess of the WQF bypass the STU and continue through the conveyance system. The following must be considered when designing flow diversion structures:

- Flow diversion structures can comprise a diversion weir or multi-stage outlets or outflow pipes within a structure such as a manhole or vault.
- Size the low flow outlet to convey the WQF to the STU.
- Set the top elevation of the diversion weir or the overflow outlet at the maximum water surface elevation associated with WQF, or the water surface elevation in the STU when the entire WQV is being held, whichever elevation is higher. Consider tailwater conditions when modeling bypass flows.
- Provide sufficient freeboard in the diversion structure to accommodate the maximum water surface elevation in the diversion structure and in the STU. Avoid surcharging the STU under high flow conditions.
- Design diversion structures to minimize clogging potential and to allow for ease of inspection and maintenance.

Figure 2.2.4 – Curb Cut with Inlet Protection; Providence College

2.2.3 Inlet Control Design Criteria

In addition to the design criteria outlined in the respective inlet control sections, the following must be considered when designing inlets:

- Flow velocities shall not exceed 3 feet per second (ft/sec) for grassed surfaces and 1 ft/sec for mulched surfaces.
- Inlet areas must be stabilized to ensure that non-erosive conditions exist for at least the 1-year, 24-hour Type III design storm event.
- If designing the STU as an in-line system, inlet controls must be designed to accommodate flows in excess of the WQF. At minimum, inlet controls for in-line STUs must be designed to accommodate flows generated by the 10-year, 24-hour Type III design storm event.
- If designing the STU as an off-line system, the flow diversion structure must be designed to convey the WQF to the STU.

2.2.4 Outlet Control Types

Outlet Curb Cut Openings

Outlet curb cut openings can be used as a type of outlet control for STUs located along streets with a gradual but consistent slope. Excess volume above the designed ponding depth flows out of the outlet curb cut opening installed at the downstream end of the facility. The following must be considered when designing outlet curb cut openings:

- Set the crest of the outlet curb opening at or above the elevation of the shallow ponding depth; and at least 3 inches below the inlet elevation to prevent overtopping of the planter during the design storm.

Raised Overflow Structures or Risers

Raised overflow structures or risers can be designed as single-stage or multi-stage vertical structures consisting of orifices and/or weir openings set at different elevations to meet stormwater management requirements. The following must be considered when designing raised overflow structures and risers:

- Single-stage structures consist of a vertical (riser) overflow structure or riser pipe with an open top that is covered by a “beehive” grate, domed riser grate or trash rack. The crest of the overflow structure is set at or slightly above the elevation of the ponding depth associated with the WQV.

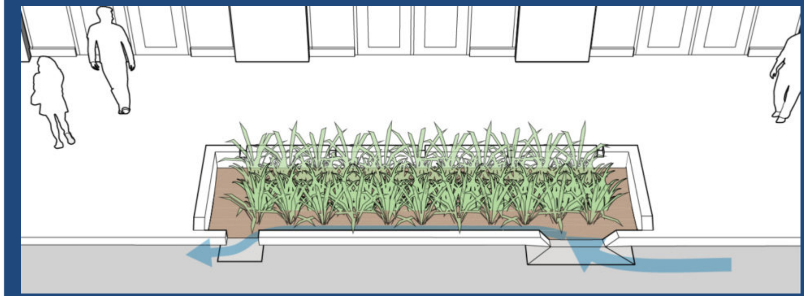


Figure 2.2.5 – Outlet Curb Cut Opening – Through-Flow Type; NACTO

- In certain cases, multiple orifices may be required to meet peak runoff attenuation performance requirements for in-line systems. As a result, the overflow structure must be designed as a multi-stage structure. Orifice sizes and elevations will vary to meet performance requirements.
- Locate the structure partially within the embankment of the STU to facilitate maintenance access during flooded conditions, promote safety and account for aesthetics.
- If the raised overflow structure or riser comprises a manhole or vault structure, access to outlet control structures should be provided by lockable manhole covers and manhole steps within easy reach of controls.

Outflow Weirs

Outflow weirs typically consist of stabilized overflow spillways or structural weirs constructed from gabions, concrete or curbing. Outflow weirs promote sedimentation by slowing flow velocities as water ponds behind the weir. They also provide a means of uniformly distributing runoff as it is discharged, helping to decrease concentrated flow and reduce velocities as the water travels downstream. In certain situations, these types of weirs may be designed with notches to limit or restrict overflow to desired locations or match pre-development peak flow rates for various storm events analyzed. The following must be considered when designing outflow weirs:

- Account for structural stability during extreme conditions in addition to flow velocities and upstream hydrostatic pressure from ponded water.
- Select materials that withstand design flow velocities and exposure to the elements.

Figure 2.2.6 - Typical Dome Grate Overflow/Outlet Structure; NACTO

Outlet Pipes/Culverts

An outlet pipe/culvert from an STU shall be designed to convey controlled flow in excess of the WQV to either a stormwater structure, drainage system or approved discharge point. It is necessary to confirm that the downstream infrastructure has adequate capacity to receive the proposed flow and that pre-development peak flow rates will not be increased for the analyzed storm events.

2.2.5 Outlet Control Design Criteria

Every in-line stormwater treatment facility must have a provision for outlet/overflow.

- An outlet control structure shall be provided for runoff in excess of the WQV. The outlet control structure shall be designed with openings to safely pass the 10-year, 24-hour Type III design storm, at minimum, with adequate freeboard.
  - For STUs without a perimeter constructed earthen berm (e.g., bioretention swale), design the outlet/overflow structure of an in-line STU to safely convey flows generated by the 10-year storm event (at minimum) with 6 inches of freeboard (unless noted otherwise in individual STU Design Sections).
  - For STUs with a perimeter constructed earthen berm, design the outlet/overflow structure of an in-line STU to safely convey flows generated by the 100-year storm event with 3 inches of freeboard (unless noted otherwise in individual STU Design Sections).
- For in-line STUs, the outlet control structure shall be designed as a multi-stage outlet structure positioned to meet each control requirement independently (e.g., treatment of WQV, conveyance of larger storms, compliance with other stormwater goals such as Natural Channel protection, Conveyance and Peak Runoff Attenuation, etc.).
  - For water quality purposes, the outlet elevation of the lowest outlet shall be set at, or slightly above, the elevation of the ponding depth associated with the WQV.
- Emergency spillways shall be a minimum of 8 feet wide, 1 foot deep, and have side slopes no steeper than 3(H):1(V).
- Discharge from an outlet shall be conveyed to either a stormwater structure (e.g., manhole), drainage system or approved discharge point.
  - Confirm that the conveyance system/storm drain network has adequate capacity to receive the proposed flow and that pre-development peak flow rates will not be increased for the analyzed storm events.

Protection from Clogging

Protection from clogging is required for any orifice size utilized as part of the outlet control structure. Small orifices, typically less than six inches in diameter, used for slow release applications can be susceptible to clogging. The following design measures shall be taken to prevent clogging.

- The low-flow orifice should be adequately protected from clogging by an acceptable trash rack. The orifice diameter shall always be greater than the thickness of trash rack openings. The trash rack area shall be at least ten times the area of the outlet opening being protected from clogging.
  - For external orifices, the minimum recommended orifice size is 3 inches.
  - For internal orifices, internal orifice protection may be utilized to allow for smaller orifice diameters down to a minimum recommended orifice size of 1 inch. However, orifice diameters smaller than 3 inches shall only be allowed on a case-by-case basis as demonstrated by the designer and/or upon approval from the permitting agency.
- Refer to Appendix H of the RISDISM for examples of low flow orifice protection and trash rack protection.

2.2.6 Inlet & Outlet Protection

Inlet and outlet protection must be installed to dissipate energy and limit erosion. Typical inlet and outlet protection devices include level spreaders, stone/riprap aprons, stone riprap basins or plunge pools, concrete pads or splash blocks and non-degradable turf reinforcement matting designed to reduce the velocity, energy and turbulence of the flow. Other options may be considered if allowable by RIDOT. These structures can be employed when highly erosive velocities are encountered at inlet and outlet locations, at the bottom of steep slopes, or where the discharge of sheet flow or non-erosive flow to down-gradient locations is required.

Provide stable and non-erosive energy dissipating devices at inflow and outlet locations where concentrated flow velocities are considered erosive. Flow velocities shall not exceed 3 feet per second (ft/sec) for grassed surfaces and 1 ft/sec for mulched surfaces.

Stone Riprap Apron

Stone riprap aprons are commonly used for energy dissipation due to their relatively low cost and ease of installation. A flat stone riprap apron can be used to prevent erosion at the transition from a pipe, culvert or spillway outlet to a natural channel. Riprap aprons will provide adequate protection if there is sufficient length and flare to dissipate energy by expanding the flow. To facilitate removal of sediment and minimize vandalism potential, stone riprap aprons may be grouted.

- The aprons shall be designed for the 10-year storm event at minimum.
- If the apron is installed at an inlet location within the STU that will be part of a sediment forebay, the stone riprap must be grouted to facilitate maintenance.
    - If grouted, provide at least two weep holes (2.5 inches in diameter) for every 25 square feet of surface area in bottom of forebay to facilitate low level drainage.
    - If grouted riprap is used, stone riprap shall conform to Section 920 of the RIDOT Standards. Grout shall be a non-shrink grout having a 4,000 psi 28-day compressive strength and a 2,400 psi 7-day compressive strength.

Stone Riprap Basin or Plunge Pool

A riprap outlet basin or plunge pool is a pre-shaped scour hole lined with riprap that functions as an energy dissipater. Like a riprap apron, a riprap basin can be used to prevent erosion at the transition from a pipe or box culvert outlet to an earthen channel. Proper setbacks from the roadway are necessary for plunge pools.

- The appropriate inlet and outlet protection type shall be based on site characteristics such as slope, available area and aesthetics.
- A key design issue is the interface between the end of the inlet/outlet protection structure and the adjacent downstream area, which is typically vegetated. Vegetation should be well established at this interface. A turf reinforcement mat may be used at this interface to provide additional structure for vegetation.
- Vegetation/plantings can be used to obscure views of inlet/outlet protection structures if aesthetics are a concern.

Figure 2.3.1.1 – Filter Strip; Warren, RI

Description

General Configuration

A filter strip is a natural or designed/landscaped area that filters and infiltrates runoff draining across it. A filter strip consists of a dense, stabilized stand of vegetation on gradually sloped land. Runoff directed to a filter strip must be evenly distributed sheet flow, which can be done naturally or through the use of a level spreader or other design modification. The vegetation within a filter strip must provide 100% ground cover, which can consist of grass, leaf litter and/or shrubs. Coastal features (wetlands, bluffs, beach, etc.) as defined by CRMC shall not be considered a filter strip.

Pollutant Removal Process

A filter strip provides the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration:** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake (only when ground cover consists of non-dormant plants):** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants commonly present within stormwater runoff.

Siting

- A filter strip is best located in wide right-of-ways or easements with ample space and mild natural slopes.
- Potential locations include adjacent to roadways, bike paths, sidewalks or other impervious surfaces.
- A filter strip can be applied as part of a strategy to reduce impervious area where excess pavement can be removed and subsurface soils can be amended to increase the infiltration capacity.
- Locate where:
    - Natural slopes are stable and meet filter strip slope requirements;
    - There is a minimum of 4 inches of topsoil or organic material, or such material can be added;
    - Area is not subject to excessive fertilizer application or excessive irrigation that could lead to nutrient export;
    - Site conditions promote vegetative growth;

- There are natural well-draining soils that will capture runoff and increase the potential for infiltration;
- RIDOT owns, controls or holds an easement on the land;
- Vehicles will not travel over the filter strip;
- Snow storage will not occur atop the filter strip; and
- There is a safe and readily available access for maintenance vehicles and workers, not within the filter strip.

Key Considerations

Feasibility

- The filter strip shall be designated as a treatment measure and cannot be used for other purposes.
- Onsite soils must be not be compacted and must be of HSG A, B or C.
- SHGT/bedrock shall be at least 18 inches below the surface of the filter strip.
- There shall be readily available maintenance access to all portions of the filter strip.

Treatment

- Filter strip must receive evenly distributed sheet flow to qualify as a treatment measure.

Vegetation

- Consider long-term maintenance capabilities and limitations.

Design Standards

Pretreatment

- Pretreatment is not required if a filter strip receives evenly distributed sheet flow directly.

Inlet

- The filter strip shall receive evenly distributed non-erosive sheet flow.
- If flow being directed to a filter strip is not evenly distributed sheet flow, use a concrete curb level spreader or earthen filter berm along the entire upstream length of the filter strip.
  - Level spreader or filter berm shall not cause ponding or spreading onto adjacent maintained surfaces for a 10-year design storm, at a minimum. Some roadways may be subject a stricter standard (e.g., 100-year).
- The velocity of the inflow shall not erode the filter strip.
  - Maximum velocity for WQV event: 1 foot per second
  - Maximum permissible velocity for 10-year design storm: 3 feet per second
- The top of the filter strip shall be set 2 inches below adjacent pavement so that sediment and debris accumulated at the edge of the strip does not prevent runoff from exiting the road surface.

Dimensions

- Width (perpendicular to direction of flow)
  - Set width equal to or greater than the width of the up gradient impervious contributing surface.

- Minimum width: 100 feet; treatment efficiency diminishes with lengths that are less than 100 feet.
- Maximum width: None.

- Length (direction of flow)
  - Set length of the filter strip equal to the length of the upgradient contributing impervious surface. Do not include the length of the level spreader as part of the length of the filter strip.
  - Length: Refer to Table 6-1 of RISDISM.
- Slope
  - Minimum slope: 2%; slopes less than 2% may result in ponding and other nuisances.
  - Maximum slope: 4%; slopes greater than 4% may result in flow channelization and erosion.
    - Maximum velocity for WQV event: 1 foot per second
    - Maximum velocity for 10-year design storm: 3 feet per second
    - If velocities are greater than the maximum velocities listed above, provide Turf Reinforcement Matting (TRM).
  - Slopes may be between 4% and 6% if TRM is provided.

Materials

- Vegetation
  - Refer to the Vegetation Section of this manual.
  - Vegetation shall consist of 100% ground cover and shall withstand design flow velocities through the filter strip.
  - Vegetation shall consist of the composition that is most likely to be successful based on project location and site specific conditions. In some cases, existing vegetation may be satisfactory.
- TRM
  - Stabilize the surface of the filter strip with a TRM to limit erosion in locations where flow velocities are greater than the maximum permissible velocities or to assist in the establishment of vegetation.
  - If used, shall be a woven material included on the RIDOT Approved Materials List with a permissible velocity that exceeds the design velocity while allowing vegetative growth. Conduct an engineering evaluation that calculates maximum flow velocity.

Underlying Soils Conditions & Design Infiltration Rate

- Complete in-situ soil testing in accordance with Section 1.2 – Study & Development of this manual to confirm the soil texture and Hydrologic Soil Group (HSG).
- In-situ soils shall be of HSG A, B or C.

Groundwater & Bedrock Separation

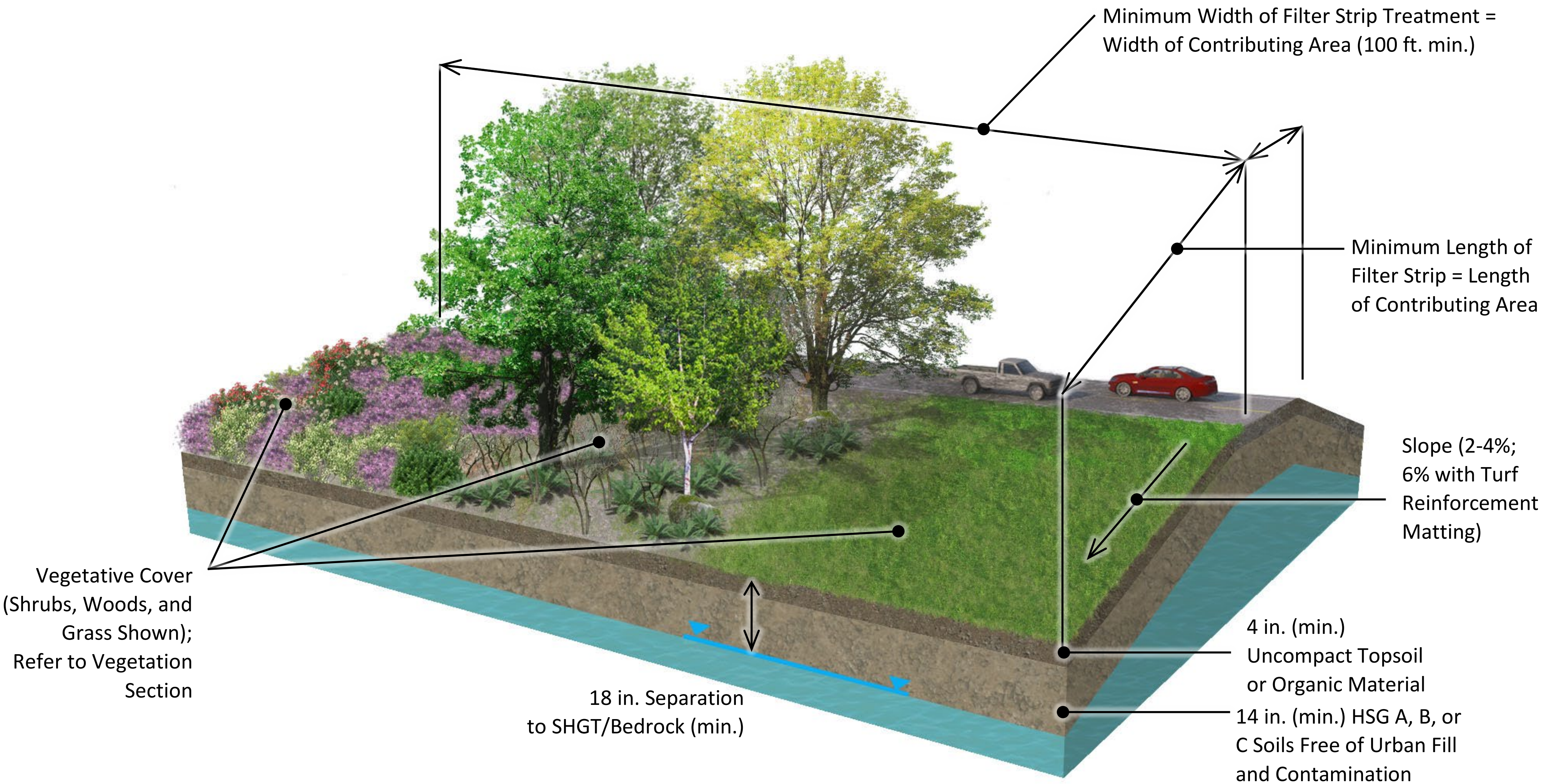
- SHGT/bedrock shall be at least 18 inches below the surface of the filter strip.

Outlet & Overflow

- Surface area at the bottom of the slope shall be as level as feasible to encourage continued sheet flow and to prevent concentrated flow and erosion.

Other Considerations

- Site shall be designed with readily available access to all STU features for maintenance.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.
- Provide delineator stakes along the perimeter of the filter strip; this approach will aide with maintenance.



Minimum Width of Filter Strip Treatment = Width of Contributing Area (100 ft. min.)
Minimum Length of Filter Strip = Length of Contributing Area
Slope (2-4%; 6% with Turf Reinforcement Matting)
Vegetative Cover (Shrubs, Woods, and Grass Shown); Refer to Vegetation Section
4 in. (min.) Uncompact Topsoil or Organic Material
18 in. Separation to SHGT/Bedrock (min.)
14 in. (min.) HSG A, B, or C Soils Free of Urban Fill and Contamination

Figure 2.3.2.1 – Gravel Wetland (WVTS); UNH Stormwater Center

Description

General Configuration

Gravel Wetlands (WVTS) are lined stormwater basins that filter stormwater runoff through a gravel substrate consisting of pea gravel, crushed gravel and organic soil that is covered with densely planted wetland vegetation. Gravel WVTS typically have multiple cells through which stormwater is hydraulically driven via a network of riser pipes and underdrains. The intent of this treatment practice is to maintain a saturated gravel substrate to promote water quality treatment conditions and support wetland vegetation.

Pollutant Removal Processes

Gravel WVTS provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants commonly present within stormwater runoff.

Siting

- Gravel WVTS are entirely visible and require their own designated surface space at the site.
- Gravel WVTS are generally non-linear and require open space.
- Best for rural applications.
- Well suited for upgrading existing stormwater detention and retention ponds.
- Potential locations include interstate medians and areas with excess right-of-way.
- Locate where:
  - The topography allows the bottom of the Gravel WVTS to be level;
  - Snow will not be stored on the Gravel WVTS, as sand from the road surface may result in failure of the system;
  - Separation from SHGT cannot be achieved, as Gravel WVTS may be located within the SHGT; and
  - Subsurface soil has a low infiltration rate.

Key Considerations

Feasibility
- Suitable in locations with high groundwater, high bedrock and/or poor draining soils.
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment
- Gravel WVTS must treat 100% of the WQV.

Vegetation
- Donor plant material cannot be from natural wetlands.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the gravel WVTS in accordance with the Pretreatment Section of this manual.
- Forebays are the preferred measure and should be a minimum of 3 feet in depth; however, other measures such as offline deep sump catch basins or hydrodynamic separators can be used.

Inlet

- Runoff can be introduced to the gravel WVTS via inlet structures, weirs/berms, swales/channels and/or pipes in accordance with the Inlet/Outlet Section of this manual.

Underdrain & Risers

- Underdrains and risers are critical in Gravel WVTS as they convey and distribute stormwater through the treatment cells as driven by the hydraulic head.
- Risers
  - Minimum central riser pipe diameter: 12 inches
  - Minimum end riser pipe diameter: 6 inches
  - Space perforated riser pipes across the width of the treatment cell with a maximum spacing of 15 feet.
  - Place inlet grates atop risers for an overflow when water levels exceed the WQV.
- Underdrains
  - Minimum diameter: 6 inches
  - Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, connects to a drainage structure and/or daylights.
  - Place the subsurface perforated distribution line at the upstream end of each treatment cell and the subsurface perforated collection drain at the downstream end. At a minimum, there shall be 15 feet between both.
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
- Include an observation well/cleanout at each end of the underdrains. The cleanout shall be highly visible.
  - Cleanouts shall be at least 6 inches in diameter, shall be perforated only within the gravel layer, and solid within the organic soil and storage area.
  - Cap cleanouts with a watertight removable cap.

Dimensions

- Ponding Depth/Height
  - Minimum: 1 foot of freeboard above WQV elevation (if designed to handle the WQV only).
  - Maximum: 4 feet above the WQV elevation or 6 inches of freeboard above 100-year storm elevation, whichever is less (if extended detention is provided).
- Volume
  - Size the entire facility (including pretreatment) to hold 100% of the WQV and to drain the WQV over a 24 to 30 hour period after a storm event.
  - Assume 33% void space when computing the amount of available storage within the gravel substrate.
  - WQV treatment shall be equally distributed in each treatment cell.
  - When used as an inline treatment practice the Gravel WVTS can be designed for extended detention for peak runoff control. In this case, the extended detention volume shall drain over a 24 to 48 hour period.
- Treatment Cells (gravel substrate layer)
  - Minimum length: 15 feet (in the direction of flow)
  - Maximum length: None; the length of the flow path should be maximized to maximize treatment.
  - Minimum width: 1:1 length to width ratio
  - Bottom slope: None; gravel WVTS shall be level
  - Maximum side slope: 3(H):1(V) slopes or flatter

Berms

- The top of the berms separating treatment cells shall be set at or above the height of the WQV elevation.
- Construct berms of low permeability soils (hydraulic conductivity less than 0.03 feet per day), to prevent water seepage between cells and to maintain the structural integrity of the berm.
- Use solid (non-perforated) pipe sections and watertight joints to connect pipes through the base of the berm to promote flow of the WQV between treatment cells.
- Extended detention (optional) when designed as an inline treatment practice:
  - If provided, extended detention occurs above the treatment cells. An overflow spillway or bypass pipe shall be provided in the berm at the height of the WQV elevation.
  - The surface of the berm shall be designed with materials to resist erosive velocities.
  - Provide stable and non-erosive energy dissipating devices between berms where overflow velocities are considered erosive. See the Inlet/Outlet Section under the Design Standards for additional information.

Materials

- Vegetation
  - Establish a dense vegetative cover or adequately stabilized landscaped surface across any upgradient areas disturbed by construction before runoff can be accepted into the facility.
  - The bottom of the Gravel WVTS shall be planted to achieve a rigorous root mat with grasses, forbs and shrubs with obligate and facultative wetland species.
  - Use New England Wetland Plants Wet Mix.

- Gravel Substrate
  - Do not use geotextiles between subsurface layers as they will clog and prevent root growth.
  - Organic Soil
    - Similar to a low permeability wetland soil made up of compost, sand and fine soils blended to have an organic matter content > 15%. Avoid using clay contents in excess of 15%, as the fines could migrate into the subsurface crushed stone (gravel) layer.
  - Pea Gravel
    - Provide a 4 inch layer of pea gravel to provide separation between the engineered soil layer and the crushed gravel layer.
    - Shall be washed and conform to Section M.01.06 Keystone and Section M.01.09, Table I, Column III of the RIDOT Standards.
    - D_{15} (of pea gravel) ≤ $5D_{85}$ (of organic soil) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of organic soil).
  - Crushed Gravel
    - Minimum Thickness: 24 inches
    - Shall conform to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards.
- Underdrain/Riser (perforated and non-perforated sections)
  - Polyethylene or polyvinyl pipe.
- Liner
  - 30 mil (minimum) HDPE or PVC liner;
  - 6 to 12 inches of Low Permeability Fill consisting of clay soil (minimum 15% passing the #200 sieve and a minimum hydraulic conductivity of 1 x 10^{-5} centimeter per second (cm/sec); or
  - Bentonite.
- Turf Reinforcement Matting (TRM)
  - Stabilize the side slopes of the infiltration basin with a TRM to limit erosion in locations where flow velocities exceed 3 to 5 feet per second (depending on soil and vegetation types) for the 1-year storm event.
  - If used, shall be a woven material included on the RIDOT Approved Materials List with a permissible velocity that exceeds the design velocity while allowing vegetative growth.

Groundwater & Bedrock Separation

- Bottom of Gravel WVTS shall be at or above bedrock.
- Gravel WVTS shall be lined.

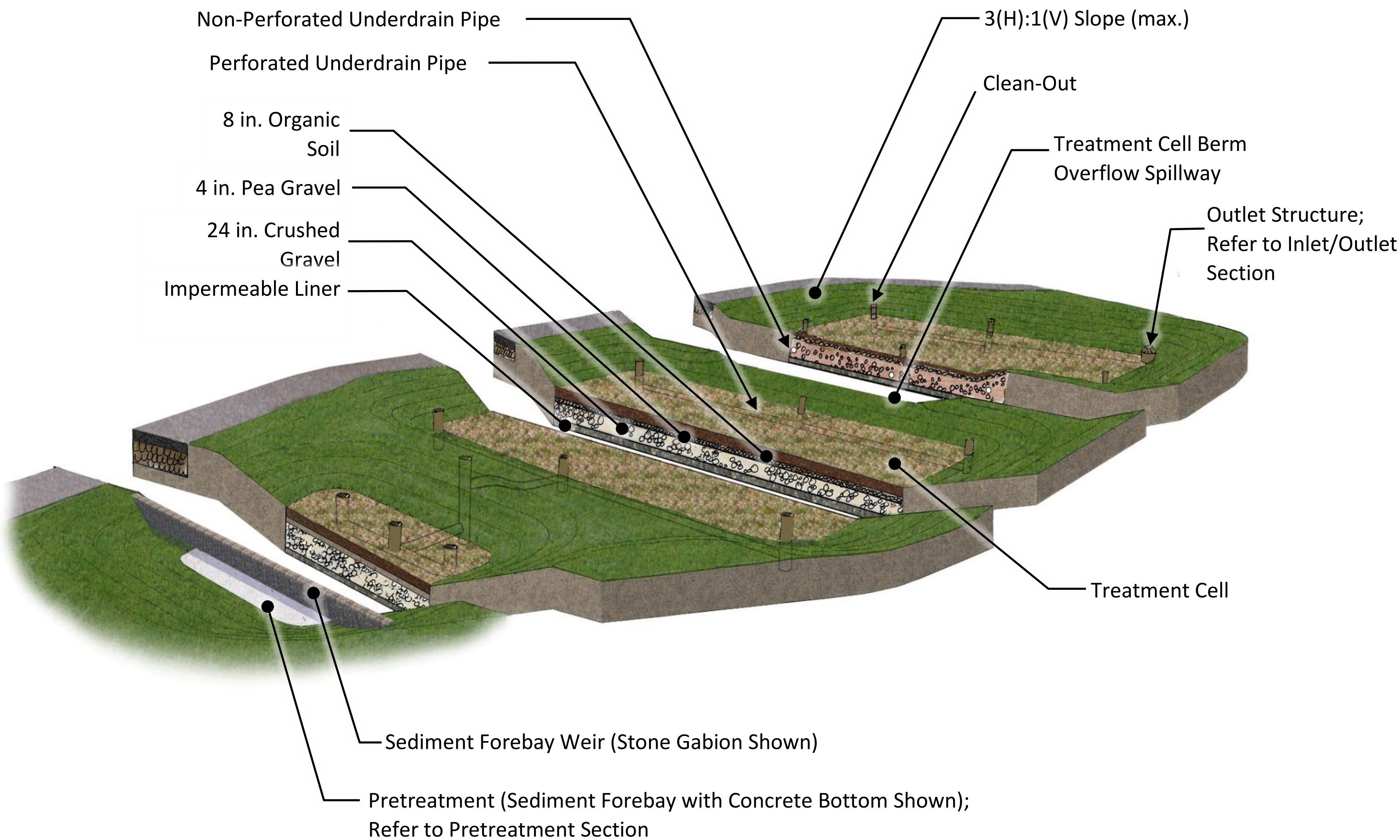
Outlet & Overflow

- All outlets shall be designed in accordance with the Inlet/Outlet Section of this manual.
- The primary outlet control structure shall be a riser with an orifice/outlet pipe for low flow. The WQV is conveyed into the outlet control structure through the underdrain.
- The WQV orifice/outlet shall be located 4-8 inches below the elevation of the organic soil surface.
- The top of the structure shall remain open with a grate for overflow. This configuration reduces the potential for creating siphoning.
- Extended detention (optional) when designed as an inline treatment practice:
  - A weir shall be provided in the center of the structure with a WQV orifice located in the weir. The elevation of the top of

the weir is set to provide control of lower frequency storm events, such as the 2 or 10 year event.
    - If the outlet controls multiple storm events, additional orifices may be added to the structure.
    - The top of the structure is set to allow the bypass of the 100-year event.
- Emergency Spillway:
    - If designed in-line with extended detention, an emergency spillway is required to convey the 100-year storm event (assuming the primary outlet control structure is not designed to pass the 100-year storm flow) and must be a minimum of 8 feet wide, 1 foot deep and have no steeper than 2(H):1(V) side slopes designed with TRM if determined necessary.

Other Considerations

- Site shall be designed with readily available access to all STU features for maintenance.
- Where SHGT is located at or above the bottom of the liner, complete a buoyancy analysis to verify buoyancy will not be an issue.



Non-Perforated Underdrain Pipe
Perforated Underdrain Pipe
8 in. Organic Soil
4 in. Pea Gravel
24 in. Crushed Gravel
Impermeable Liner
3(H):1(V) Slope (max.)
Clean-Out
Treatment Cell Berm Overflow Spillway
Outlet Structure; Refer to Inlet/Outlet Section
Treatment Cell
Sediment Forebay Weir (Stone Gabion Shown)
Pretreatment (Sediment Forebay with Concrete Bottom Shown); Refer to Pretreatment Section

Figure 2.3.3.1 – Infiltration Basin; Hanover, NH

Description

General Configuration

An infiltration basin is an open depression that captures, temporarily stores, and infiltrate stormwater runoff into the subsurface soils.

Pollutant Removal Processes

Infiltration basins provide the following pollutant removal mechanisms:

- **Infiltration:** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake (if vegetated):** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants commonly present within stormwater runoff.

Siting

- Infiltration basins are best located where there is adequate surface area to temporarily store stormwater.
- Potential locations include roundabouts, landscaping islands, highway medians, streetscapes, along shared-use paths, within parking lot islands, and within available commercial setbacks and open space/pervious areas.
- Infiltration basins are suitable in urban and rural settings, but require adequate surface space, which makes their use limited in urban areas.
- Locate where:
  - The topography allows the design of the infiltration basin bottom to be level;
  - The bottom of the infiltration basin is at least 3 feet above SHGT and bedrock;
  - The minimum horizontal setbacks in Table 1.2.2 of this manual can be met;
  - Snow storage will not occur atop the basin; and
  - There is a low likelihood that pedestrian traffic will cut across the basin.

Key Considerations

Feasibility

- Bottom of basin is at least 3 feet above SHGT and bedrock
- Minimum soil infiltration rate of 0.5 inches per hour
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Infiltration basin must treat 100% of the WQV.

Vegetation

- Consider long-term maintenance capabilities and limitations.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the infiltration basin in accordance with Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, grass channels, deep sump catch basins, and/or proprietary treatment devices.

Inlet

- Runoff is typically enters an infiltration basin through direct overland flow, curb cuts, inlet structures, swales/channels, and/or pipes.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.

Dimensions

- Size infiltration basin in accordance with Section 5.3.4 of the RISDISM.
- Volume
    - Size the basin to treat 100% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event.
- Bottom Width
    - Minimum: 2 feet
- Bottom Slope (i.e., surface)
    - Minimum: Level
    - Maximum: 0.5%
- Side Slope
    - Maximum: 3(H):1(V) slopes. If site topography does not allow for 3(H):1(V) slopes, vertical concrete walls with a maximum height of 30 inches can be used.

Materials

- Vegetation
    - Specify vegetation in accordance with the Vegetation Section in this manual.
- Mulch (if basin is not vegetated)
    - 2 to 4 inches of shredded hardwood bark mulch, aged for 6 months, minimum.
    - In some situations, designers may consider alternative surface covers such as pea gravel. Alternative covers will require approval from RIDOT.

- Poured-in-Place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Turf Reinforcement Matting (TRM)
  - Stabilize the side slopes of the infiltration basin with a TRM to limit erosion in locations where flow velocities exceed 3 to 5 feet per second (depending on soil and vegetation types) for the 1-year storm event.
  - If used, shall be a woven material included on the RIDOT Approved Materials List with a permissible velocity that exceeds the design velocity while allowing vegetative growth.

Groundwater & Bedrock Separation

- Bottom of infiltration basin shall be at least 3 feet above SHGT and bedrock.
- Reductions in the groundwater separation distance from the bottom of basin may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as “GB.”

Underlying Soil Conditions & Design Infiltration Rate

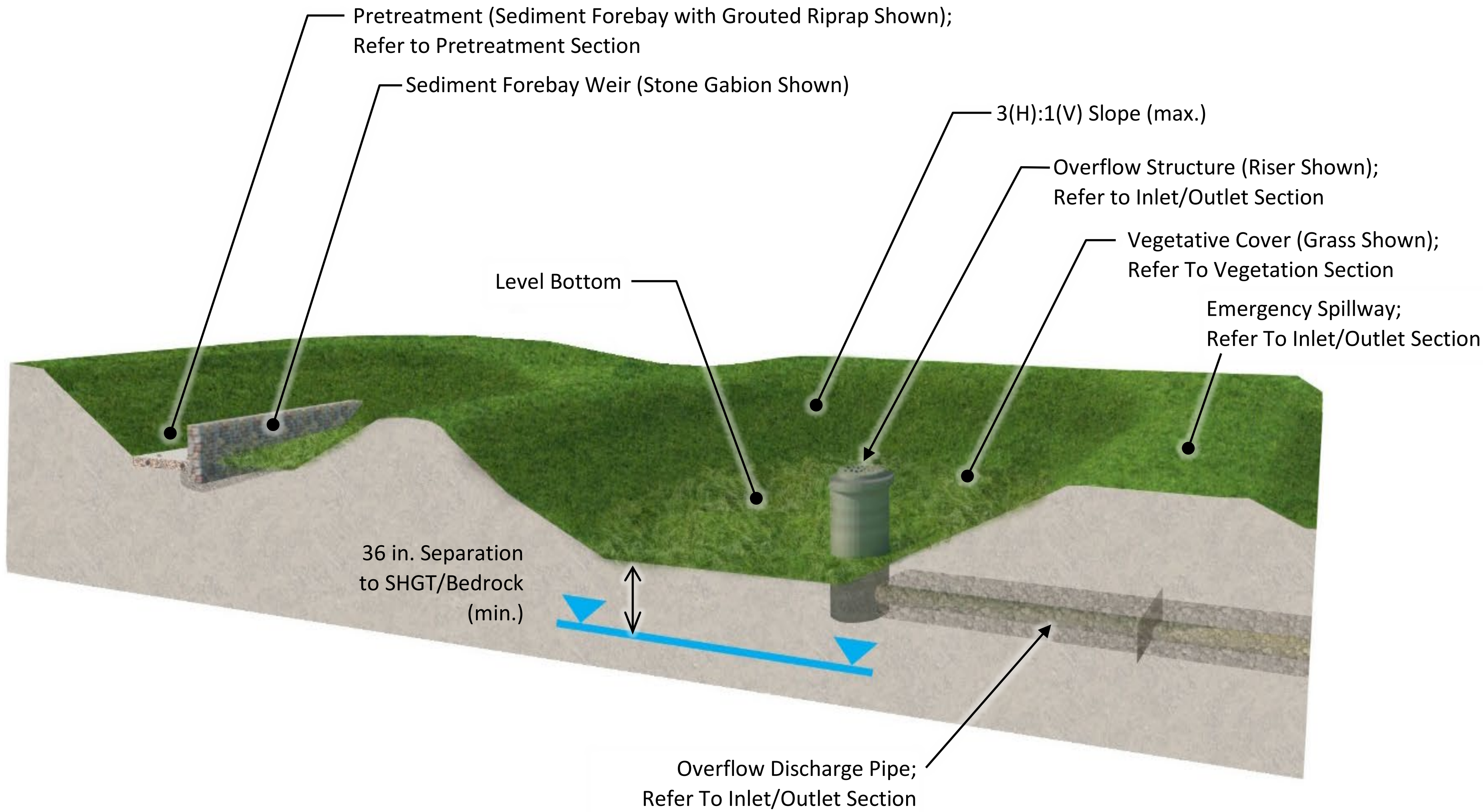
- Complete in-situ soil testing in accordance with Section 1.2 – Study & Development of this manual.
- The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use an infiltration rate of 0.52 inches per hour if a loam surface is used.
- Construct in locations where in-situ infiltration rates of underlying soils exceed 0.5 inches per hour.
- If the in-situ infiltration rate of underlying soils is greater than 8.3 inches per hour, do not use infiltration STUs.

Outlet & Overflow

- Infiltration basins must have a primary outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets are typically a stabilized spillway, gabion berm, concrete weir, precast concrete structure, or polyethylene/polyvinyl chloride riser structure.
- An emergency spillway is required to convey the 100-year storm event (assuming the primary outlet is not designed to pass the 100-year storm event).

Other Considerations

- Site shall be designed with readily available access to all STU features for maintenance.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.



Pretreatment (Sediment Forebay with Grouted Riprap Shown);
Refer to Pretreatment Section
Sediment Forebay Weir (Stone Gabion Shown)
3(H):1(V) Slope (max.)
Overflow Structure (Riser Shown);
Refer to Inlet/Outlet Section
Vegetative Cover (Grass Shown);
Refer To Vegetation Section
Level Bottom
Emergency Spillway;
Refer To Inlet/Outlet Section
36 in. Separation
to SHGT/Bedrock
(min.)
Overflow Discharge Pipe;
Refer To Inlet/Outlet Section

Figure 2.3.3.2 – Installation of an Underground Infiltration System; Narragansett, RI

Description

General Configuration

An underground infiltration system consists of open bottomed storage chambers in a crushed stone reservoir. The chamber and crushed stone reservoir provide temporary storage for stormwater before it infiltrates into subsurface soils.

Pollutant Removal Processes

Underground infiltration systems provide the following pollutant removal mechanisms:

- **Infiltration:** physical process where filtration also results in groundwater recharge.

Siting

- Underground infiltration systems can be located under pavement or vegetated areas where subsurface conditions allow.
- Potential locations include under roadways, parking lots, sidewalks, shoulders or medians.
- Underground infiltration systems are suitable in urban and rural settings.
- Locate where:
  - The topography allows the design of the arched chambers to be level; however, individual units can be stepped to accommodate grade changes;
  - The structural integrity of the roadbed material will not be compromised;
  - The underground infiltration system is outside the dripline of trees;
  - The bottom of crushed stone reservoir is at least 3 feet above SHGT and bedrock; and
  - The minimum horizontal setbacks in Table 1.2.2 of this manual can be met.

Key Considerations

Feasibility

- Bottom of crushed stone reservoir is at least 3 feet above SHGT and bedrock
- Minimum soil infiltration rate of 0.5 inches per hour
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Underground infiltration systems must treat 100% of the WQV.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the underground infiltration system in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include deep sump catch basins with hoods and proprietary treatment devices.

Inlet

- Runoff typically enters an underground infiltration system through a pipe from an existing or new upstream structure (e.g., deep sump catch basin, proprietary treatment device, flow diversion structure, etc.).
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.

Dimensions

- Size the underground infiltration system in accordance with Section 5.3.4 of the RISDISM.
- Volume
  - Size the underground infiltration system to treat 100% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event.
  - Assume 33% void space when computing the amount of available storage within the crushed stone reservoir.
  - Underground infiltration chambers are produced by several manufacturers and come in a variety of sizes and volumes.
  - Dimensions of crushed stone reservoir shall be per the manufacturer’s written direction; at minimum, there shall be 12 inches of crushed stone on each side of the chambers, 12 inches of crushed stone between adjacent chambers and 6 inches of crushed stone below and on top of the chambers.
- Bottom Slope
  - Design bottom of the underground infiltration system to be level

Materials

- Underground Infiltration Chambers
  - As available from the manufacturer. Appurtenant structures (e.g., end caps, cross connectors, observation wells, etc.) shall be from or approved for use by the chamber manufacturer.
  - Designer shall comply with manufacturer’s written specifications, details, installation instructions and other guidance documents.

- Crushed Stone
  - Shall be clean stone conforming to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards.
  - Install in locations and per specifications required and recommended by chamber manufacturer.
- Filter Fabric
  - Wrap around the exterior sides and top of the crushed stone only. Do not provide geotextile on the bottom of the crushed stone unless recommended by the manufacturer of the underground infiltration system.
    - Install fabric (including overlap) per specifications required and recommended by chamber manufacturer.
  - Shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for underdrain applications.

Groundwater & Bedrock Separation

- Bottom of crushed stone reservoir shall be at least 3 feet above SHGT and bedrock.
- Reductions in the groundwater separation distance from the bottom of crushed stone may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as “GB.”

Underlying Soils Conditions & Design Infiltration Rate

- Complete in-situ soil testing in accordance with Section 1.2 – Study & Development of this manual.
- The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative.
- Construct in locations where in-situ infiltration rates of underlying soils exceed 0.5 inches per hour.
- If the in-situ infiltration rate of underlying soils is greater than 8.3 inches per hour, do not use infiltration STUs.

Outlet & Overflow

- Underground infiltration systems designed as off-line systems are typically sized to handle only the WQV and typically do not require an outlet. Once the system has reached its capacity (i.e., once the STU is full), additional flow will bypass the system. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.
- Underground infiltration systems designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets are typically a closed conduit/pipe that discharges to a storm drainage system.

Other Considerations

- Site shall be designed with readily available access to all site features for maintenance.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.

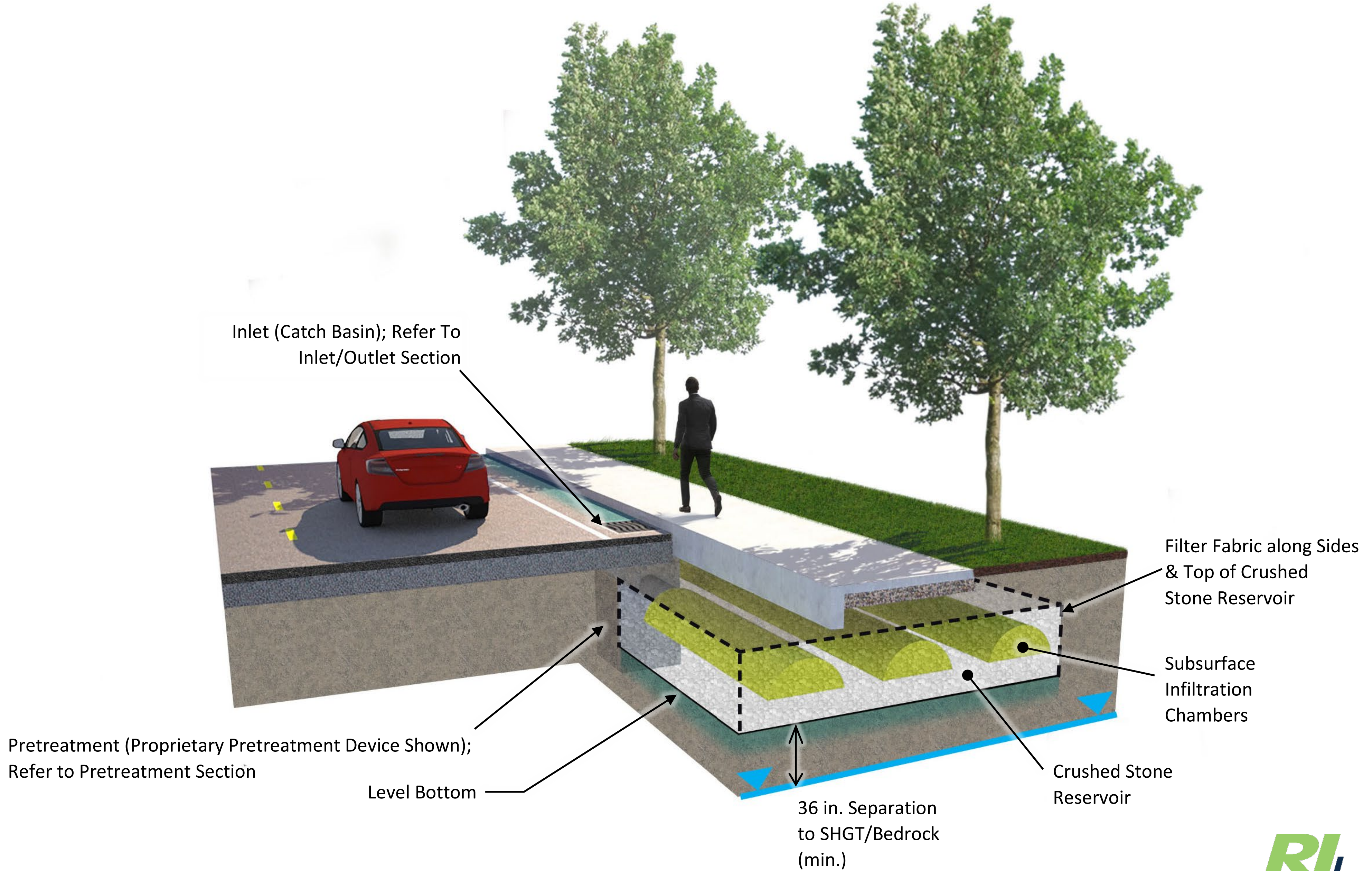

Inlet (Catch Basin); Refer To
Inlet/Outlet Section
Filter Fabric along Sides
& Top of Crushed
Stone Reservoir
Subsurface
Infiltration
Chambers
Pretreatment (Proprietary Pretreatment Device Shown);
Refer to Pretreatment Section
Level Bottom
Crushed Stone
Reservoir
36 in. Separation
to SHGT/Bedrock
(min.)

Figure 2.3.3.3 – Infiltration Trench; Providence, RI

Description

General Configuration

An infiltration trench is an excavated trench filled with crushed stone. The trench temporarily stores stormwater before it infiltrates into subsurface soils.

Pollutant Removal Process

Subsurface infiltration systems provide the following pollutant removal mechanisms:

- **Infiltration:** physical process where filtration also results in groundwater recharge.

Siting

- Potential locations include along roadways, bike paths and in medians.
- Infiltration gutters are suitable for urban and suburban settings.
- Locate where:
  - Snow storage will not occur atop the infiltration trench, as sand from the treatment of the road surface could result in the failure of the system;
  - The structural integrity of the roadbed material will not be compromised;
  - The infiltration trench is outside the dripline of trees;
  - The bottom of the infiltration trench is at least 3 feet above SHGT and bedrock; and
  - The minimum horizontal setbacks in Table 1.2.2 can be met.

Key Considerations

Feasibility

- Bottom of crushed stone reservoir is at least 3 feet above SHGT and bedrock
- Minimum soil infiltration rate of 0.5 inches per hour
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Infiltration trench must treat 100% of the WQV.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the trench in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales, deep sump catch basins, and/or proprietary treatment devices.

Inlet

- Runoff typically enters the infiltration trench at the surface via direct overland flow, curb cuts, piped flow entrances, and swales/channels.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.

Dimensions

- Size the infiltration trench in accordance with Section 5.3.4 of the RISDISM.
- Volume
  - Size the infiltration trench to treat 100% of the WQV below any outlet and fully dewater within 48 hours after a storm event.
  - Assume 33% void space when computing the amount of available storage within the crushed stone reservoir.
- Width
  - Minimum: 2 feet
- Bottom Slope
  - Design the infiltration trench bottom to be level
- Surface Slope
  - Minimum: Level
  - Maximum: 0.5%

Materials

- Vegetation (optional)
  - Specify vegetation in accordance with the Vegetation Section in this manual.
- Crushed Stone
  - Shall be clean, washed stone conforming to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards.
- Filter Fabric
  - Wrap around the exterior sides of the crushed stone.
  - When crushed stone is used at the surface, place filter fabric along the trench, 4 inches below the surface. Place 4 inches of crushed stone on top of fabric. This layer will capture sediment and facilitate maintenance/replacement of top layer. If using vegetation at the surface, provide filter fabric at the interface of the crushed stone and surface soil layer.
  - Do not provide geotextile on the bottom of the crushed stone.
  - Shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List.
- Observation Wells
  - Provide every 50 feet
  - Install a 4- to 6-inch diameter perforated PVC pipe with a lockable cap in each infiltration trench.

- Include a marker for observation wells that can easily be seen from the roadway.

Groundwater & Bedrock Separation

- Bottom of crushed stone reservoir shall be at least 3 feet above SHGT and bedrock
- Reductions in the groundwater separation distance from the bottom of crushed stone may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as "GB."

Underlying Soils Conditions & Infiltration Rate

- Complete in-situ soil testing in accordance with requirements Section 1.2 – Study & Development of this manual.
- The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use an infiltration rate of 0.52 inches per hour if a loam surface is used.
- Construct in locations where in-situ infiltration rates of underlying soils exceed 0.5 inches per hour.
- If the in-situ infiltration rate of underlying soils is greater than 8.3 inches per hour, do not use infiltration STUs.

Outlet & Overflow

- Infiltration trenches must have a primary outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets are typically an outflow weir (e.g., spillway), raised overflow riser, or pipe.

Other Considerations

- Site shall be designed with readily available access to all STU features for maintenance.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.

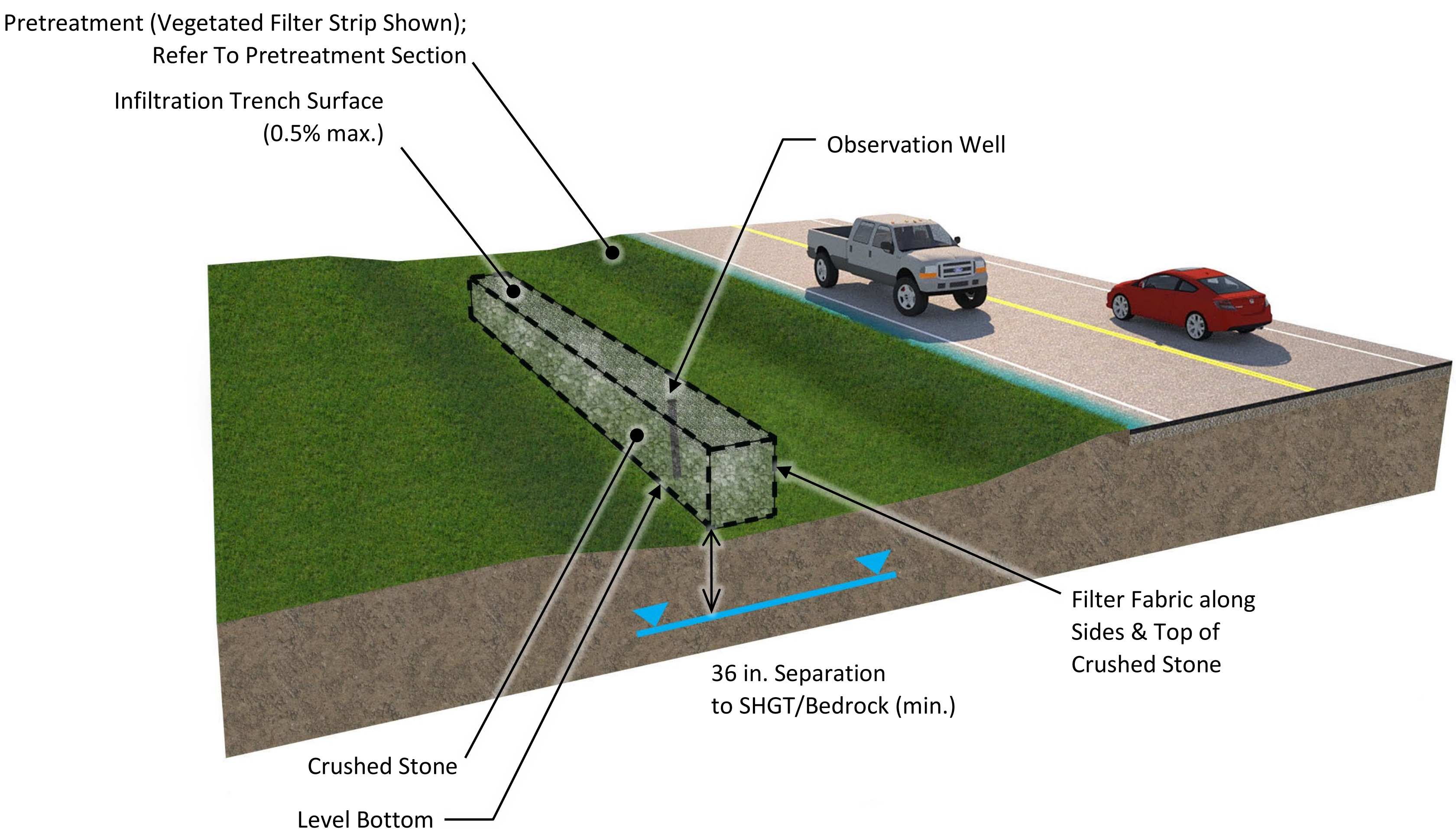

Pretreatment (Vegetated Filter Strip Shown);
Refer To Pretreatment Section
Infiltration Trench Surface
(0.5% max.)
Observation Well
Filter Fabric along
Sides & Top of
Crushed Stone
36 in. Separation
to SHGT/Bedrock (min.)
Crushed Stone
Level Bottom

Figure 2.3.3.4 Typical Leaching Basin

Description

General Configuration

A leaching basin is an open bottomed, perforated, subsurface, precast concrete structure surrounded by crushed stone and a layer of filter fabric. The basin temporarily stores stormwater before it infiltrates into subsurface soils.

Pollutant Removal Process

Leaching basins provide these pollutant removal mechanisms:

- **Infiltration:** physical process where filtration also results in groundwater recharge.

Siting

- Ideal for congested areas within roadways, sidewalks, bike paths and in medians where there is limited space.
- Leaching basins are suitable in urban and rural settings.
- Locate where:
    - The entire concrete vault of the leaching basin can be entirely within the roadway or entirely within the sidewalk;
    - The structural integrity of the roadbed material will not be compromised;
    - The leaching basin is outside the dripline of trees;
    - The bottom of the leaching basin is at least 3 feet above SHGT and bedrock; and
    - The minimum horizontal setbacks in Table 1.2.2 of this manual can be met.

Key Considerations

Feasibility

- Bottom of crushed stone reservoir is at least 3 feet above SHGT and bedrock
- Minimum soil infiltration rate of 0.5 inches per hour
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Leaching basins must treat 100% of the WQV.

Section 2.3.3 – Leaching Basin

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the leaching basin in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include deep sump catch basins with hoods and/or proprietary treatment devices.

Inlet

- Runoff typically enters a leaching basin through a pipe from an existing or new upstream structure (e.g., deep sump catch basin, proprietary treatment device, flow diversion structure, etc.).
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.

Dimensions

- Size leaching basins in accordance with Section 5.3.4 of the RISDISM.
- Volume
  - Size the leaching basin and crushed stone reservoir to treat 100% of the WQV below the elevation of any outlet and fully dewater within 48 hours after a storm event. Multiple leaching basins can be used to achieve the required treatment volume.
  - Assume 33% void space when computing the amount of available storage within the crushed stone reservoir.
  - Minimum dimensions for crushed stone:
    - 6 inches below bottom of precast basin
    - 1-foot surrounding precast basin
- Bottom Slope
  - Design the leaching basin to be level

Materials

- Precast Concrete Structures
  - As available from the manufacturer.
  - Open Bottom Perforated Precast Concrete Vault
- Crushed Stone
  - Shall be clean, washed stone conforming to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards.
- Filter Fabric
  - Wrapped around the exterior sides and top of the crushed stone only. Do not provide geotextile on the bottom of the crushed stone.
  - Shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List.

Groundwater & Bedrock Separation

- Bottom of crushed stone reservoir shall be at least 3 feet above SHGT and bedrock
- Reductions in the groundwater separation distance from the bottom of crushed stone may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC.

- Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
- Redevelopment areas where the groundwater is classified as “GB.”

Underlying Soils Conditions & Infiltration Rate

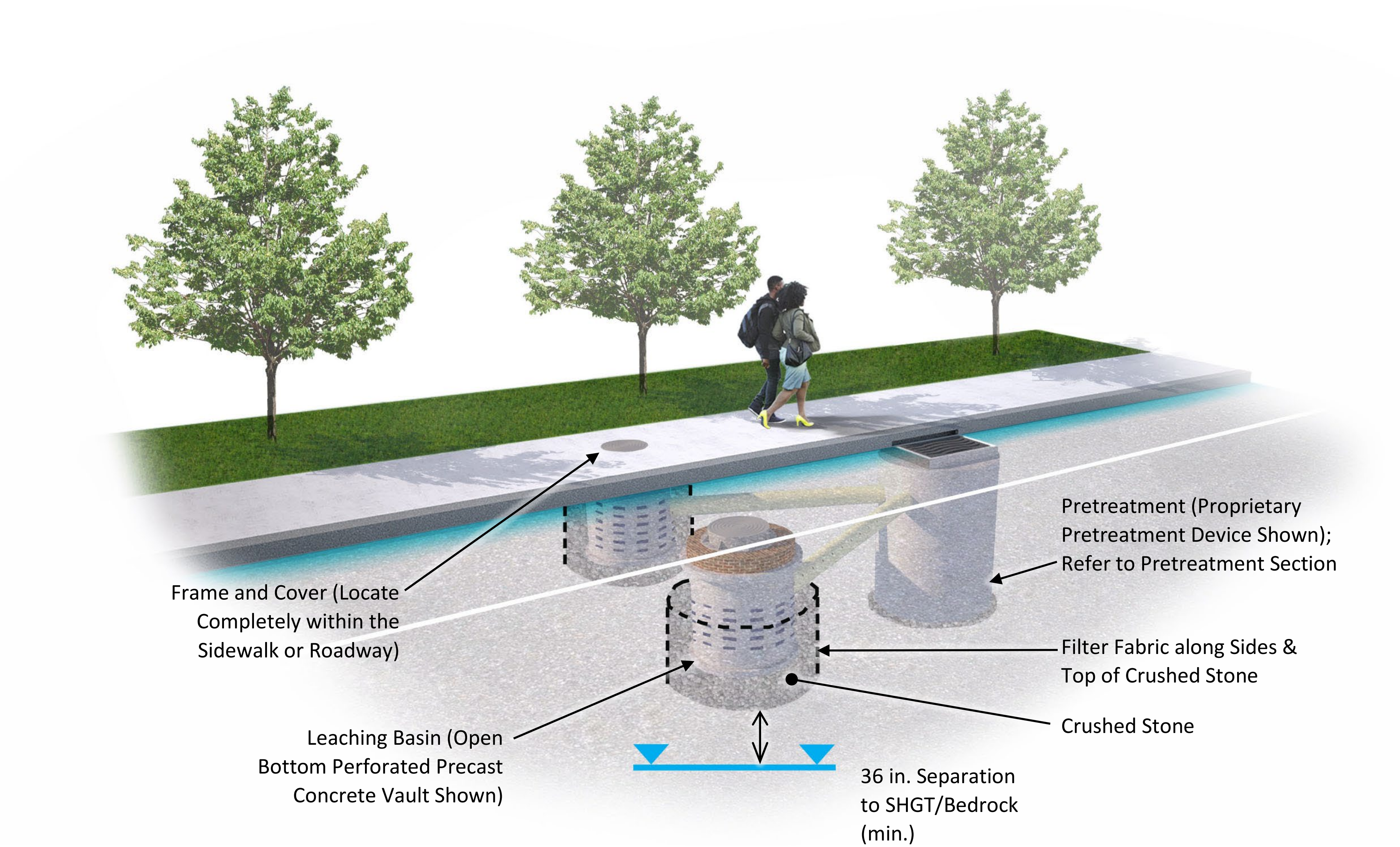
- Complete in-situ soil testing in accordance with requirements in the Section 1.2 – Study & Development of this manual.
- The design infiltration rate shall be half the field-derived value of the most restrictive layer below the bottom of the STU or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative.
- Construct in locations where in-situ infiltration rates of underlying soils exceed 0.5 inches per hour.
- If the in-situ infiltration rate of underlying soils is greater than 8.3 inches per hour, do not use infiltration STUs.

Outlet & Overflow

- Leaching basins designed as off-line are typically sized to handle only the WQV and typically do not require an outlet. Once the system has reached its capacity (i.e., once the STU is full), additional flow will bypass the system. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.
- Leaching basins designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets must be designed such that stormwater does not overflow from the leaching basin onto adjacent roadway surfaces.
  - Outlets are typically a closed conduit/pipe that discharges to a storm drainage system.

Other Considerations

- Site shall be designed with readily available access to all STU features for maintenance.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.



Pretreatment (Proprietary Pretreatment Device Shown); Refer to Pretreatment Section
Frame and Cover (Locate Completely within the Sidewalk or Roadway)
Filter Fabric along Sides & Top of Crushed Stone
Crushed Stone
Leaching Basin (Open Bottom Perforated Precast Concrete Vault Shown)
36 in. Separation to SHGT/Bedrock (min.)

Figure 2.3.3.5 – Installation of an Infiltration Gutter with Subsurface Chambers; West Warwick, RI

Description

General Configuration

An Infiltration gutter consists of a series of open bottomed subsurface chambers surrounded by a crushed stone reservoir. Stormwater entering the system is distributed to the chamber and surrounding crushed stone via a perforated distribution drain pipe, where it is then temporarily stored before it infiltrates into subsurface soils. Typically infiltration gutters are underneath sidewalks.

Pollutant Removal Processes

Infiltration gutters provide the following pollutant removal mechanism:

- **Infiltration:** physical process where filtration also results in groundwater recharge.

Siting

- Infiltration gutters are located adjacent to roadways with curbs, under sidewalks or paved roadway shoulders.
- Infiltration gutters are suitable for urban and suburban settings.
- Locate where:
  - The topography allows the design of the arched chambers to be level; however, individual units can be stepped to accommodate grade changes;
  - The structural integrity of the roadbed material will not be compromised;
  - The infiltration gutter is outside the dripline of trees;
  - The bottom of the infiltration gutter is at least 3 feet above SHGT and bedrock; and
- The minimum horizontal setbacks in Table 1.2.2 of this manual can be met.

Key Considerations

Feasibility

- Bottom of crushed stone reservoir is at least 3 feet above SHGT and bedrock
- Minimum soil infiltration rate of 0.5 inches per hour
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Infiltration gutter must treat 100% of the WQV.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the infiltration gutter in accordance with the Pretreatment Section of this manual.
- Pretreatment is typically provided by interior concrete sediment collection chambers, deep sump catch basins with hoods, and/or proprietary treatment devices.
- Interior Concrete Sediment Collection Chamber (if used)
    - Shall be equipped with a cover or grate.
    - Minimum sump depth: 4 feet from the perforated distribution drain pipe invert.
    - Minimum bottom surface area: 6 square feet with no individual dimension (length or width) less than 2 feet.
    - Shall be equipped with a hood.

Inlet

- Runoff typically enters an infiltration gutter via a curb cut, drop inlet, or a piped inlet in accordance with the Inlet/Outlet Section of this manual.
- Runoff discharges to infiltration gutter via perforated distribution drain pipe from the pretreatment measure.

Dimensions

- Size the infiltration gutter in accordance with Section 5.3.4 of the RISDISM.
- Volume
    - Size the infiltration gutter to treat 100% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event.
    - Assume 33% void space when computing the amount of available storage within the crushed stone reservoir.
    - Underground infiltration chambers are produced by several manufacturers and come in a variety of sizes and volumes.
    - Dimensions of crushed stone reservoir shall be per the manufacturer's written direction; at minimum, there shall be 12 inches of crushed stone on each side of the chambers, 12 inches of crushed stone between adjacent chambers and 6 inches of crushed stone below and on top of the chambers.
- Bottom Slope
    - Design bottom of the infiltration gutter to be level.

Materials

- Underground Infiltration Chambers
  - As available from the manufacturer. Appurtenant structures (e.g., end caps, cross connectors, observation wells, etc.) shall be from or approved for use by the chamber manufacturer.
  - Designer shall comply with manufacturer's written specifications, details, installation instructions and other guidance documents.
- Crushed Stone
  - Shall be clean, washed stone conforming to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards.
- Filter Fabric
  - Install fabric (including overlap) per specifications required and recommended by chamber manufacturer; do not provide geotextile on the bottom of the crushed stone unless recommended by the manufacturer.
  - If used, shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for underdrain applications.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Perforated Distribution Drain Pipe
  - Polyethylene or polyvinyl pipe.
  - Extend perforated distribution drain pipe across width of crushed stone reservoir at inlet (cap within a minimum of 6 inches of edge of crushed stone reservoir); connect to a perpendicular run of perforated distribution drain pipe that runs the length of the crushed stone reservoir with a Tee (cap within a minimum of 6 inches of the edge of the crushed stone reservoir).
  - Shall meet minimum cover requirements of pipe manufacturer, at minimum provide 12 inches cover over top of perforated distribution drain pipe.
  - Minimum Diameter: 4 inches (absolute minimum); 6 inch minimum preferred
  - Shall be equipped with clean-outs spaced (maximum) 25 feet apart.

Groundwater & Bedrock Separation

- Bottom of crushed stone reservoir shall be at least 3 feet above SHGT and bedrock
- Reductions in the groundwater separation distance from the bottom of crushed stone may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as "GB."

Underlying Soils Conditions & Design Infiltration Rate

- Complete in-situ soil testing in accordance with requirements in Section 1.2 – Study & Development of this manual.
- The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed

in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative.

- Construct in locations where in-situ infiltration rates of underlying soils exceed 0.5 inches per hour.
- If the in-situ infiltration rate of underlying soils is greater than 8.3 inches per hour, do not use infiltration STUs.

Outlet & Overflow

- Infiltration gutters designed off-line are typically sized to handle only the WQV and typically do not require an outlet. Once the system has reached its capacity (i.e., once the STU is full), additional flow will bypass the system. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.
- Infiltration gutters designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
    - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
    - Outlets must be designed such that stormwater does not overflow from the infiltration gutter onto adjacent roadway surfaces.
    - Outlets are typically a closed conduit/pipe that discharges to a storm drainage system.

Other Considerations

- Where existing sidewalks are modified to incorporate infiltration gutters, the sidewalk shall be ADA compliant.
- Site shall be designed with readily available access to all STU features for maintenance.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.

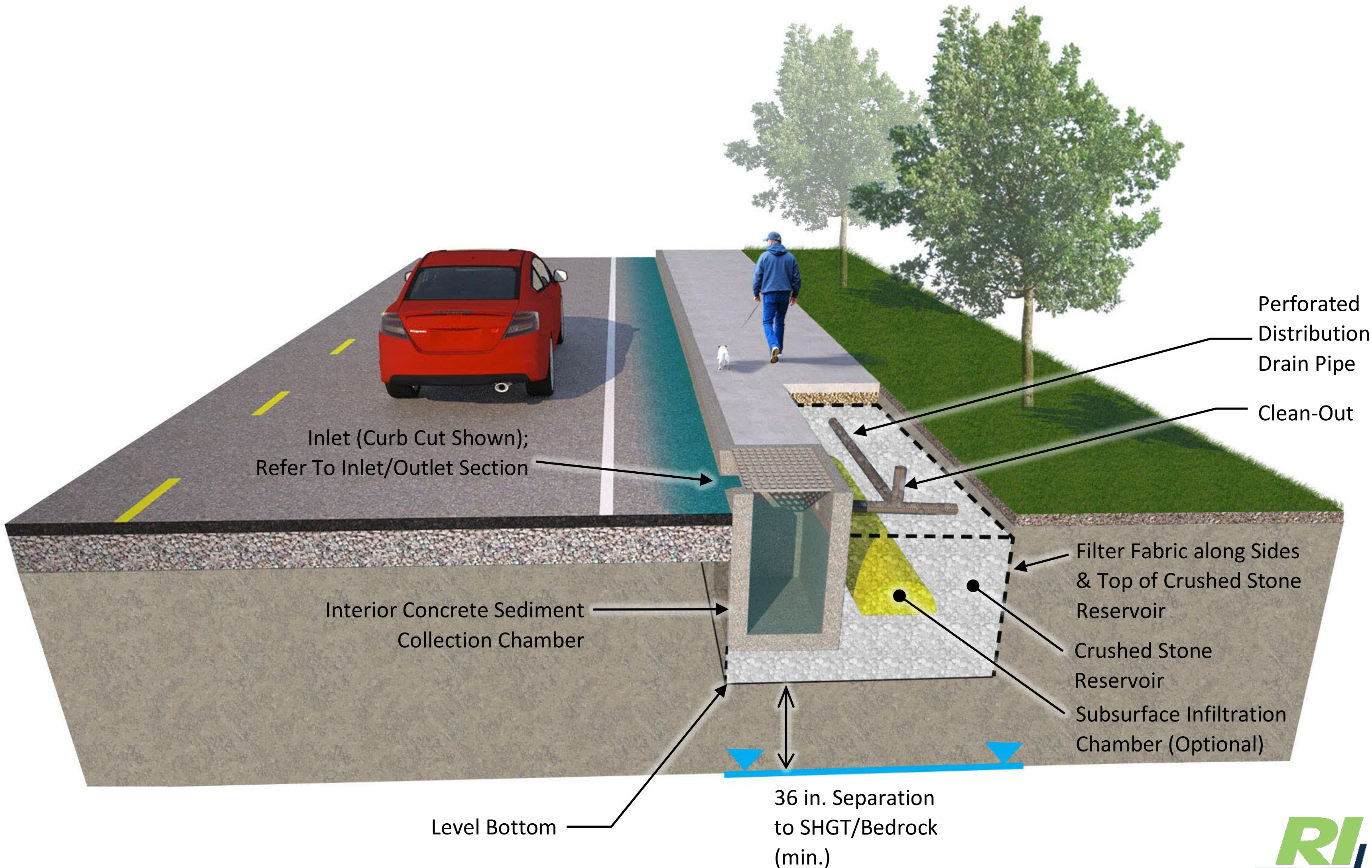

Perforated
Distribution
Drain Pipe
Clean-Out
Inlet (Curb Cut Shown);
Refer To Inlet/Outlet Section
Interior Concrete Sediment
Collection Chamber
Filter Fabric along Sides
& Top of Crushed Stone
Reservoir
Crushed Stone
Reservoir
Subsurface Infiltration
Chamber (Optional)
Level Bottom
36 in. Separation
to SHGT/Bedrock
(min.)

Figure 2.3.4.1 – Porous Pavement; Warren, RI

Description

General Configuration

Porous pavement is an alternative paving surface that captures stormwater runoff through voids in the pavement surface, where it is filtered and temporarily stored and/or infiltrated in an underlying stone reservoir. Many types of porous pavement are available, but the most common are porous asphalt, pervious concrete and permeable interlocking concrete pavers (PICP). Porous pavement has an additional filter course below the pavement and may be lined.

Pollutant Removal Processes

Porous pavement provides the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.

Siting

- Porous pavement is typically installed in locations where space for other STUs is limited.
- Porous pavement shall only be located in low speed and low traffic areas or outside main travel lanes. Avoid areas of frequent truck loading or excessive sediment loading.
- Potential locations include within the roadway outside of the travelway, adjacent to the curb line, parking stalls, along shared-use paths and along driveways or alleys.
- Porous pavement is suitable in urban and rural settings but requires careful consideration of potential sediment loading from adjacent areas.
- Porous pavement manages stormwater that falls on the actual porous pavement area, but it may also accept run-on from adjacent impervious areas such as travel lanes or parking lots.
- Locate where:
  - Roadway slopes do not exceed 5%;
  - The contributing drainage to the installation is as close to 100% impervious as possible;
  - The bottom of the reservoir course is at or above the seasonal high groundwater table (SHGT) and bedrock; the top of the filter course is at least 3 feet above SHGT;

- The minimum horizontal setbacks in Table 1.2.2 of this manual can be met if designed to infiltrate;
- Snow storage will not occur atop of the installation; and
- Street sanding will not occur within the contributing drainage area.

Key Considerations

Feasibility

- Unlined Pavement: Bottom of reservoir layer is at or above SHGT/bedrock; top of filter course is at least 3 feet above SHGT/bedrock.
- Lined Pavement: Use when separation to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as LUHHPLs or in locations where contaminated soils exist.
- Underdrain: Utilize an underdrain if infiltration rates of underlying soils are less than 0.5 inches per hour.
- Contributing drainage area to the porous pavement shall not exceed three times the surface area of the porous pavement and is as close to 100% impervious as possible.
- Site shall be designed with readily available access to all STU features for maintenance.
- Street sanding will not occur within the contributing drainage area.

Treatment

- Filter/reservoir layers must treat 100% of the WQV.

Design Standards

Pretreatment

- Pretreatment is not required for porous pavement, but may be appropriate if system receives stormwater runoff from pervious surfaces.

Inlet

- An inlet structure is not required if porous pavement receives evenly distributed sheet flow. Provide a level spreader or other feature to convert concentrated flow to sheet flow in accordance with the Inlet/Outlet Section of this manual.
- Conveyance to porous pavement is typically overland and must be sheet flow; avoid concentrating flows due to features such as raised islands. Porous pavement receiving concentrated flow is more likely to clog and require additional maintenance.

Underdrain

- Minimum diameter: 4 inches
- Minimum slope: 0.5%
- Install perforated underdrains within reservoir course with a minimum of 2 inches of crushed stone above and below the underdrain. The bottom of the underdrain shall not be less than 4 inches above SHGT.
- Lay underdrain such that perforations are on bottom of pipe.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure and/or daylights.

- Other considerations when designing/installing underdrains:
    - Provide a marking stake and an animal guard for underdrains that daylight at grade.
    - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain; one at the upstream end and one at the downstream end.
    - Cleanouts shall be at least 4 inches in diameter, be non-perforated, and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be highly visible.
    - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Size the porous pavement in accordance with Section 5.4.4 of the RISDISM.
- Surface Area
    - Size the porous pavement surface area such that the contributing drainage area to the porous pavement does not exceed three times the surface area of the porous pavement.
- Volume
    - Size the filter and reservoir courses to treat 100% of the WQV and fully dewater within 48 hours after a storm event.
    - Assume 33% void space when computing the amount of available storage within the courses.
- Surface Course
    - Porous Asphalt
        - Thickness: 4 to 6 inches
    - Pervious Concrete
        - Thickness: 4 inch (minimum)
    - PICP
        - Thickness: Per manufacturer
    - Design the surface course to support anticipated traffic and other design loads, including additional stresses that may be anticipated at the edges of the installation.
- Choker Course
    - Thickness: 4 to 8 inches
- Filter Course
    - Thickness: 8 to 12 inches; shall be increased to 18 inches if an underdrain is used or there is inadequate separation from SHGT/bedrock.
- Filter Blanket
    - Thickness: 3 inches
- Reservoir Course
    - Thickness: 4 inches; Increase thickness of reservoir course as needed to meet the design criteria in accordance with Appendix F.4, Section 2.1.A.4 of the RISDISM. Criteria include underlying soil infiltration rate, presence of an underdrain, storage of the WQV and frost depth for the project site.
    - Ensure the reservoir course depth is sufficient to prevent winter freeze-thaw and heaving in accordance with Appendix F.4, Section 2.1.A.4 of the RISDISM.

Materials

- Porous Asphalt
  - Shall conform to Appendix F.4 of the RISDISM.
- Pervious Concrete
  - Shall conform to Appendix F4.2 of the RISDISM.
- Flexible Porous Rubber Paving
  - Suitable for shared use paths only.
  - Shall follow manufacturer's requirements for construction.
- Pavers (PICP)
  - Shall conform to the requirements of Section 5.4 of the RISDISM.
- Choker Course
  - Shall consist of AASHTO No. 57 clean, washed stone.
- Filter Course
  - Shall consist of AASHTO M-6 or ASTM C-33 subbase material with a hydraulic conductivity of 10 to 60 feet per day at 95% Standard Proctor.
- Filter Blanket
  - Shall consist of ⅜" to ¾" size pea gravel conforming to gradation listed in Section M.01.06-Keystone and M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of filter blanket) ≤ $5D_{85}$ (of filter course) and D_{50} (of filter blanket) ≤ $25D_{50}$ (of filter course).
- Reservoir Course
  - Shall consist of washed crushed stone conforming to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards.
- Filter Fabric
  - Shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for underdrain applications.
  - Use along sides; filter fabric shall not be used between courses or beneath the reservoir course of the porous pavement.
- Underdrain
  - If used, polyethylene or polyvinyl pipe.
- Liner
  - If used, shall be 30 mil (minimum) HDPE or PVC liner.

Groundwater & Bedrock Separation

- Bottom of reservoir course is at or above SHGT/bedrock; top of filter is at least 3 feet above SHGT/bedrock.
- Install an impermeable liner (and underdrain) at the bottom of the reservoir course if adequate separation from the bottom of the filter course to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHPPLs or in locations where contaminated soils exist. Provide an underdrain.
- Reductions in the groundwater separation distance from the top of the filter course may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. Reservoir course shall not be placed below SHGT.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as "GB."

Underlying Soils Conditions & Design Infiltration Rate

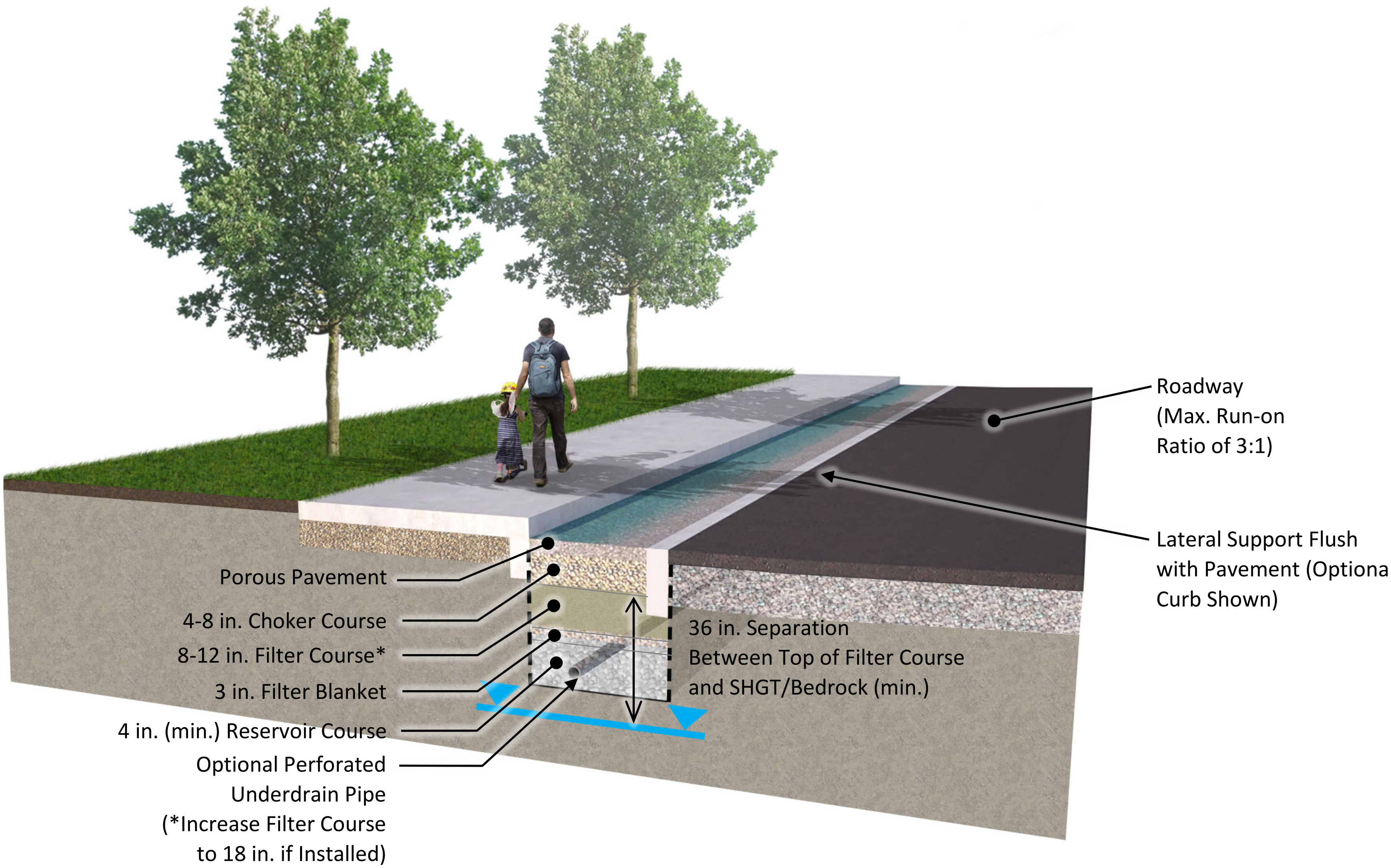
- If the porous pavement is designed to infiltrate:
  - Complete in-situ soil testing in accordance with requirements in Section 1.2 – Study & Development of this manual.
  - In-situ infiltration rate of underlying soils shall be 0.5 inches per hour or greater. Otherwise, provide an underdrain and increase filter course thickness to 18 inches.
  - The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative.

Outlet & Overflow

- Porous pavement shall be graded to convey runoff to a properly designed conveyance system for storms greater than the WQV event.
- Common outlets include curb cuts, catch basins or a perimeter stone trench.
- Design the outlet in accordance with the Inlet/Outlet Section of this manual.
- If used, underdrains can connect to a downstream drainage system or daylight at an approved discharge point.

Other Considerations

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.
- Site shall be designed with readily available access to all STU features for maintenance.
- The existing native subgrade material under porous pavement shall not be compacted or subject to excessive construction equipment traffic.
- The entire contributing drainage area must be completely stabilized prior to directing any flow to porous pavement.
  - Adequate vegetative cover must be established over any pervious area adjacent or contributing to the installation before runoff can be accepted.
- If designed to infiltrate, comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.
- Provide terraces and impermeable baffles or graded impermeable berms to maximize storage and prevent lateral reservoir course flow when subgrade slope exceeds 2%.


Roadway
(Max. Run-on
Ratio of 3:1)
Lateral Support Flush
with Pavement (Optional
Curb Shown)
Porous Pavement
4-8 in. Choker Course
8-12 in. Filter Course*
3 in. Filter Blanket
4 in. (min.) Reservoir Course
Optional Perforated
Underdrain Pipe
(*Increase Filter Course
to 18 in. if Installed)
36 in. Separation
Between Top of Filter Course
and SHGT/Bedrock (min.)

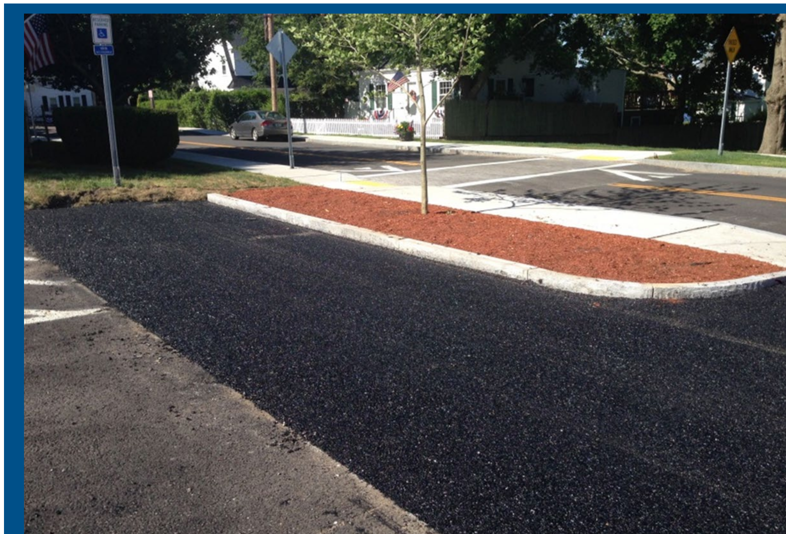


Figure 2.3.4.2 – Porous Pavement; Warren, RI

Description

General Configuration

Porous pavement is an alternative paving surface that captures runoff through voids in the pavement surface, where it is filtered and temporarily stored and infiltrated in an underlying stone reservoir. Many types of porous pavement are available, but the most common are porous asphalt, pervious concrete, and permeable interlocking concrete pavers (PICP). Porous pavement with storage has larger storage reservoirs below the pavement to increase infiltration and storage capacity.

Pollutant Removal Processes

Porous pavement provides the following pollutant removal mechanisms:

- **Infiltration:** physical process where filtration also results in groundwater recharge.

Siting

- Porous pavement is typically installed in locations where space for other STUs is limited.
- Porous pavement shall only be located in low speed and low traffic areas or outside main travel lanes. Avoid areas of frequent truck loading or excessive sediment loading.
- Potential locations include within the roadway outside of the travelway, adjacent to the curb line, parking stalls, along shared-use paths, and along driveways or alleys.
- Porous pavement is suitable in urban and rural settings but requires careful consideration of potential sediment loading from adjacent areas.
- Porous pavement manages stormwater that falls on the actual porous pavement area, but it may also accept run-on from adjacent impervious areas such as travel lanes or parking lots.
- Locate where:
    - Roadway slopes do not exceed 5%;
    - The contributing drainage to the installation is as close to 100% impervious as possible;
    - The bottom of the reservoir course is at least 3 feet above the seasonal high groundwater table (SHGT) and bedrock;

- The minimum horizontal setbacks in Table 1.2.2 of this manual can be met;
- Snow storage will not occur atop of the installation; and
- Street sanding will not occur within the contributing drainage area.

Design Standards

Pretreatment

- Pretreatment is not required for porous pavement, but may be appropriate if system receives stormwater runoff from pervious surfaces.

Inlet

- An inlet structure is not required if porous pavement receives evenly distributed sheet flow. Provide a level spreader or other feature to convert concentrated flow to sheet flow in accordance with the Inlet/Outlet Section of this manual.
- Conveyance to porous pavement is typically overland and must be sheet flow; avoid concentrating flows due to features such as raised islands. Porous pavement receiving concentrated flow is more likely to clog and require additional maintenance.

Dimensions

- Size the porous pavement in accordance with Section 5.4.4 of the RISDISM.
- Surface Area
  - Size the porous pavement surface area such that the contributing drainage area to the porous pavement does not exceed three times the surface area of the porous pavement.
- Volume
  - Size the reservoir course to treat 100% of the WQV and fully dewater within 48 hours after a storm event.
  - Assume 33% void space when computing the amount of available storage within the courses.
- Surface Course
  - Porous Asphalt
    - Thickness: 4 to 6 inches
  - Pervious Concrete
    - Thickness: 4 inch (minimum)
  - PICP
    - Thickness: Per manufacturer

Key Considerations

Feasibility

- Bottom of reservoir course is at least 3 feet above SHGT and bedrock
- Minimum soil infiltration rate of 0.5 inches per hour
- Contributing drainage area to the porous pavement does not exceed three times the surface area of the porous pavement and is as close to 100% impervious as possible.
- Street sanding will not occur within the contributing drainage area.
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Reservoir course must treat 100% of the WQV.

  - Design the surface course to support anticipated traffic and other design loads, including additional stresses that may be anticipated at the edges of the installation.
- Choker Course
  - Thickness: 4 to 8 inches
- Reservoir Course
  - Thickness: 4 inches; Increase thickness of reservoir course as needed to meet the design criteria in accordance with Appendix F.4, Section 2.1.A.4 of the RISDISM. Criteria include underlying soil infiltration rate, presence of an underdrain, storage of the WQV, and frost depth for the project site.
  - Ensure the reservoir course depth is sufficient to prevent winter freeze-thaw and heaving in accordance with Appendix F.4, Section 2.1.A.4 of the RISDISM.

Materials

- Porous Asphalt
  - Shall conform to Appendix F.4 of the RISDISM
- Pervious Concrete
  - Shall conform to Appendix F4.2 of the RISDISM
- Flexible Porous Rubber Paving
  - Suitable for shared use paths only
  - Shall follow manufacturer's requirements for construction.
- Pavers (PICP)
  - Shall conform to the requirements of Section 5.4 of the RISDISM
- Choker Course
  - Shall consist of AASHTO No. 57 clean, washed stone
- Reservoir Course
  - Shall consist of washed crushed stone conforming to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards
- Filter Fabric
  - Shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for underdrain applications
  - Use along sides; filter fabrics shall not be used between the choker and reservoir courses or beneath the reservoir course of the porous pavement
  - Where reservoir course extends beneath conventional pavement, use filter fabric at the top of the reservoir course.

Groundwater & Bedrock Separation

- Bottom of reservoir course is at least 3 feet above SHGT/bedrock.
- Do not install if adequate separation cannot be achieved, when cross-contamination is a concern such as at LUHPPLs, or in locations where contaminated soils exist.
- Reductions in the groundwater separation distance from the bottom of the reservoir course may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. Reservoir course shall not be placed below SHGT.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as "GB."

Underlying Soils Conditions & Design Infiltration Rate

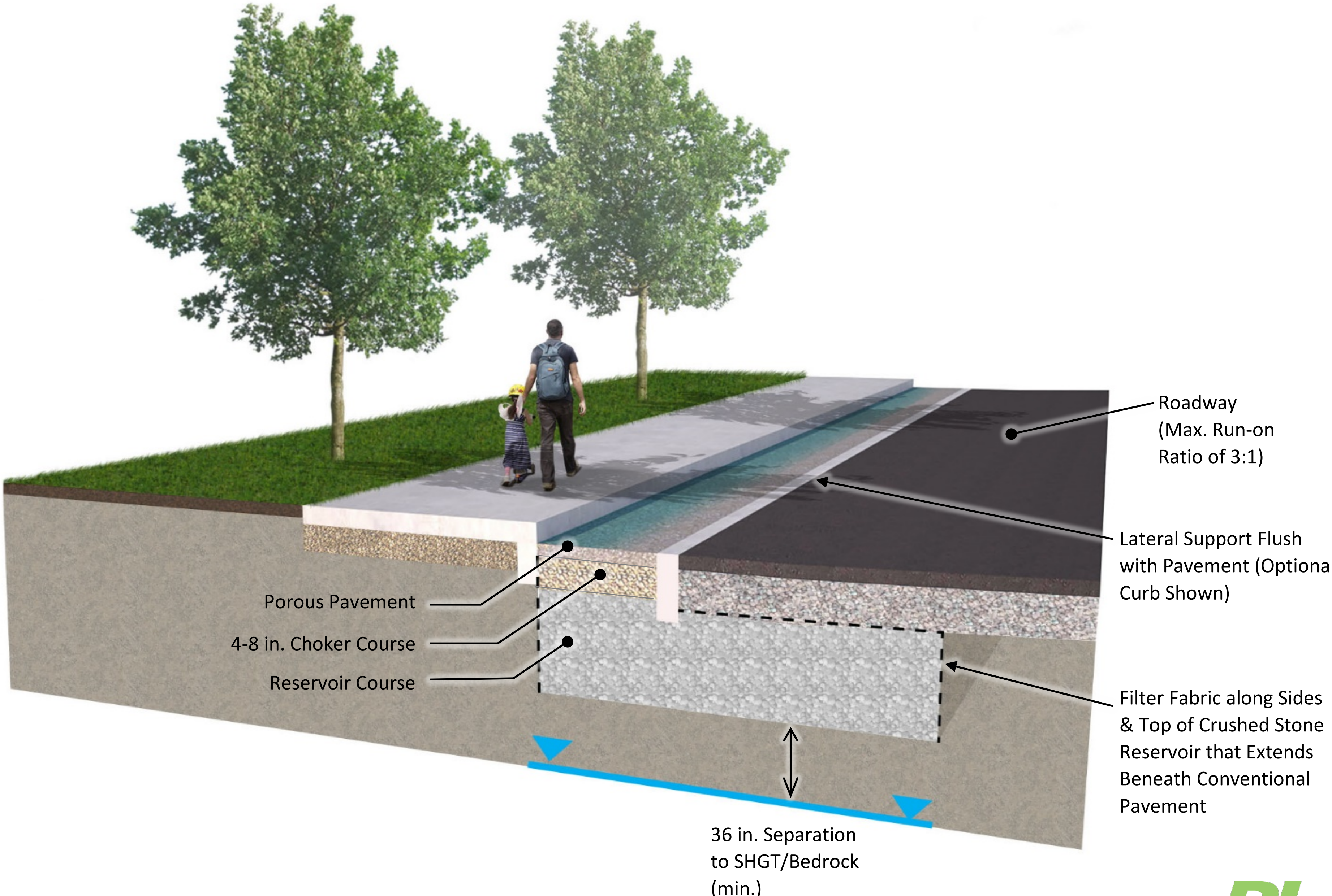
- Complete in-situ soil testing in accordance with requirements in Section 1.2 – Study & Development of this manual.
- The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative.
- Construct in locations where in-situ infiltration rates of underlying soils exceed 0.5 inches per hour.
- If the in-situ infiltration rate of underlying soils is greater than 8.3 inches per hour, do not use infiltration STUs.

Outlet & Overflow

- Porous pavement shall be graded to convey runoff to a properly designed conveyance system for storms greater than the WQV event.
- Common outlets include curb cuts, catch basins, or a perimeter stone trench.
- Design the outlet in accordance with the Inlet/Outlet Section of this manual.

Other Considerations

- Site shall be designed with readily available access to all STU features for maintenance.
- The existing native subgrade material under porous pavement shall not be compacted or subject to excessive construction equipment traffic.
- The entire contributing drainage area must be completely stabilized prior to directing any flow to porous pavement.
    - Adequate vegetative cover must be established over any pervious area adjacent or contributing to the installation before runoff can be accepted.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.
- Provide terraces and impermeable baffles or graded impermeable berms to maximize storage and prevent lateral reservoir course flow when subgrade slope exceeds 2%.



Roadway
(Max. Run-on
Ratio of 3:1)
Lateral Support Flush
with Pavement (Optional
Curb Shown)
Porous Pavement
4-8 in. Choker Course
Reservoir Course
Filter Fabric along Sides
& Top of Crushed Stone
Reservoir that Extends
Beneath Conventional
Pavement
36 in. Separation
to SHGT/Bedrock
(min.)

Figure 2.3.5.1 – Surface Sand Filter; Charlestown, RI

Description

General Configuration

Sand filters are sand filled basins or trenches that capture, temporarily store and filter stormwater runoff. Sand filters require less space than other filtering practices but must be in locations with adequate elevation to provide the necessary hydraulic head. Sand filters have higher longevity than other filtering practices and have a lower land requirement than bioretention. Sand filters are frequently designed to infiltrate, but are always equipped with an underdrain to capture filtered water and assist with drainage from the system. They can also be lined systems.

Pollutant Removal Processes

Sand filters provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Adsorption:** Designed additives in filter media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Sand filters are best located where there is adequate surface area to temporarily store stormwater and enough elevation to provide the required hydraulic head.
- Potential locations include medians, along shared-use paths, along borders of parking lots, within parking lot islands and within available open space/pervious areas.
- Sand filters are suitable in urban and rural settings.
- Locate where:
  - The topography allows the design of the sand filter bottom to be level;
  - The top of the sand is at least 3 feet above SHGT;
  - The minimum horizontal setbacks in Table 1.2.2 of this manual can be met when the sand filter is designed to infiltrate;
  - Snow storage will not occur atop the basin; and
  - There is a low likelihood that pedestrian traffic will cut across the system.

Key Considerations

Feasibility

- Unlined Sand Filter: Bottom of filter is at or above SHGT/bedrock; top of filter is at least 3 feet above SHGT/bedrock.
- Lined Sand Filter: Use when separation to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as LUHHPLs or in locations where contaminated soils exist.
- An underdrain shall be used.
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Sand filter must treat 75% of the WQV.

Vegetation (optional)

- Consider long-term maintenance capabilities and limitations.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the sand filter in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales, deep-sump catch basins and proprietary flow-through treatment devices.

Inlet

- Runoff can be introduced to the sand filter through direct overland flow, curb cuts, inlet structures, swales/channels and/or pipes.
- If flow is introduced through curb cuts, each surface sand filter cell must contain a minimum of two curb cut openings.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.

Underdrain

- Minimum diameter: 4 inches
- Minimum slope: 0.5%
- Install perforated underdrains in a bed of pea gravel with a minimum of 2 inches of pea gravel above and below the underdrain and within 2 feet (on both sides) of the underdrain (i.e., underdrain zone). Typical minimum pea gravel thickness outside of the underdrain zone is 4 inches. The pea gravel layer shall be underlain by a gravel sump with 12 inch (minimum) thickness.
    - In the underdrain zone the gravel sump will have a reduced thickness equal to the diameter of the underdrain.
- Lay underdrain such that perforations are on bottom of pipe.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure and/or daylights.
- Filter fabric shall be placed along sidewalls of excavation and above pea gravel for a distance of 2 feet on both sides of the underdrain.

- Other considerations when designing/installing underdrains:
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
  - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain; one at the upstream end and one at the downstream end.
  - Cleanouts shall be at least 4 inches in diameter, be non-perforated and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be easily visible.
  - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Size the sand filter in accordance with Section 5.5.4 of the RISDISM.
- Volume
  - Size the basin to treat 75% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event.
  - Sand Bed Thickness: 18 inches (minimum)
  - Assume 33% void space when computing the amount of available storage within the sand.
- Ponding Depth
  - Maximum: 6 feet
- Bottom Width
  - Minimum: 4 feet
- Bottom Slope
  - Design bottom of sand filter bed to be level.
- Side Slope
  - Maximum: 3(H):1(V) slopes. If site topography does not allow for 3(H):1(V) slopes, vertical concrete walls with a maximum height of 30 inches can be used.

Materials

- Vegetation (optional)
  - Specify vegetation in accordance with the Vegetation Section in this manual.
- Sand
  - Shall be concrete sand conforming to Section M.02.02 of the RIDOT Standards.
- Pea Gravel
  - Shall be washed and conform to Section M.01.06 Keystone and Section M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of pea gravel) ≤ $5D_{85}$ (of sand) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of sand).
- Gravel Sump
  - Shall be in accordance with Section M.01.07-Filter Stone and Section M.01.09, Table I, Column V of the RIDOT Standards.
- Filter Fabric
  - Shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for underdrain applications.
- Underdrain (perforated and non-perforated pipe sections)
  - Polyethylene or polyvinyl pipe.

- Liver
    - If used, shall be 30 mil (minimum) HDPE or PVC liner.
- TRM
    - Stabilize the side slopes of the infiltration basin with a TRM to limit erosion in locations where flow velocities exceed 3 to 5 feet per second (depending on soil and vegetation types) for the 1-year storm event.
    - If used, shall be a woven material included on the RIDOT Approved Materials List with a permissible velocity that exceeds the design velocity while allowing vegetative growth.

Groundwater & Bedrock Separation

- Bottom of filter is at or above SHGT/bedrock; top of filter is at least 3 feet above SHGT/bedrock.
- Install an impermeable liner at the bottom of the gravel sump if adequate separation from the top of the sand filter to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs or in locations where contaminated soils exist.
- Reductions in the groundwater separation distance from the top of the sand filter may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. The filter shall not extend below SHGT.
    - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
    - Redevelopment areas where the groundwater is classified as “GB.”

Underlying Soils Conditions & Design Infiltration Rate

- If the sand filter is designed to infiltrate:
    - Complete in-situ soil testing in accordance with requirements in Section 1.2 – Study & Development of this manual.
    - In-situ infiltration rate of underlying soils shall be 0.5 inches per hour or greater.
    - The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use an infiltration rate of 0.52 inches per hour if a loam surface is used.

Outlet & Overflow

- Sand filters must have a primary outlet sized to convey the 10-year storm event, at a minimum.
    - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
    - Outlets are typically a stabilized spillway, gabion berm, concrete weir, precast concrete structure or polyethylene/polyvinyl chloride riser structure.
- Ponding in the sand filter shall not extend onto adjacent roadways.
- An emergency spillway is required to convey the 100-year storm event (assuming the primary outlet is not designed to pass the 100-year storm event).
- The underdrains can connect to a drainage system or daylight at an approved discharge point.

Other Considerations

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner, complete a buoyancy analysis to verify buoyancy will not be an issue.
- Site shall be designed with readily available access to all STU features for maintenance.
- If designed to infiltrate, comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.

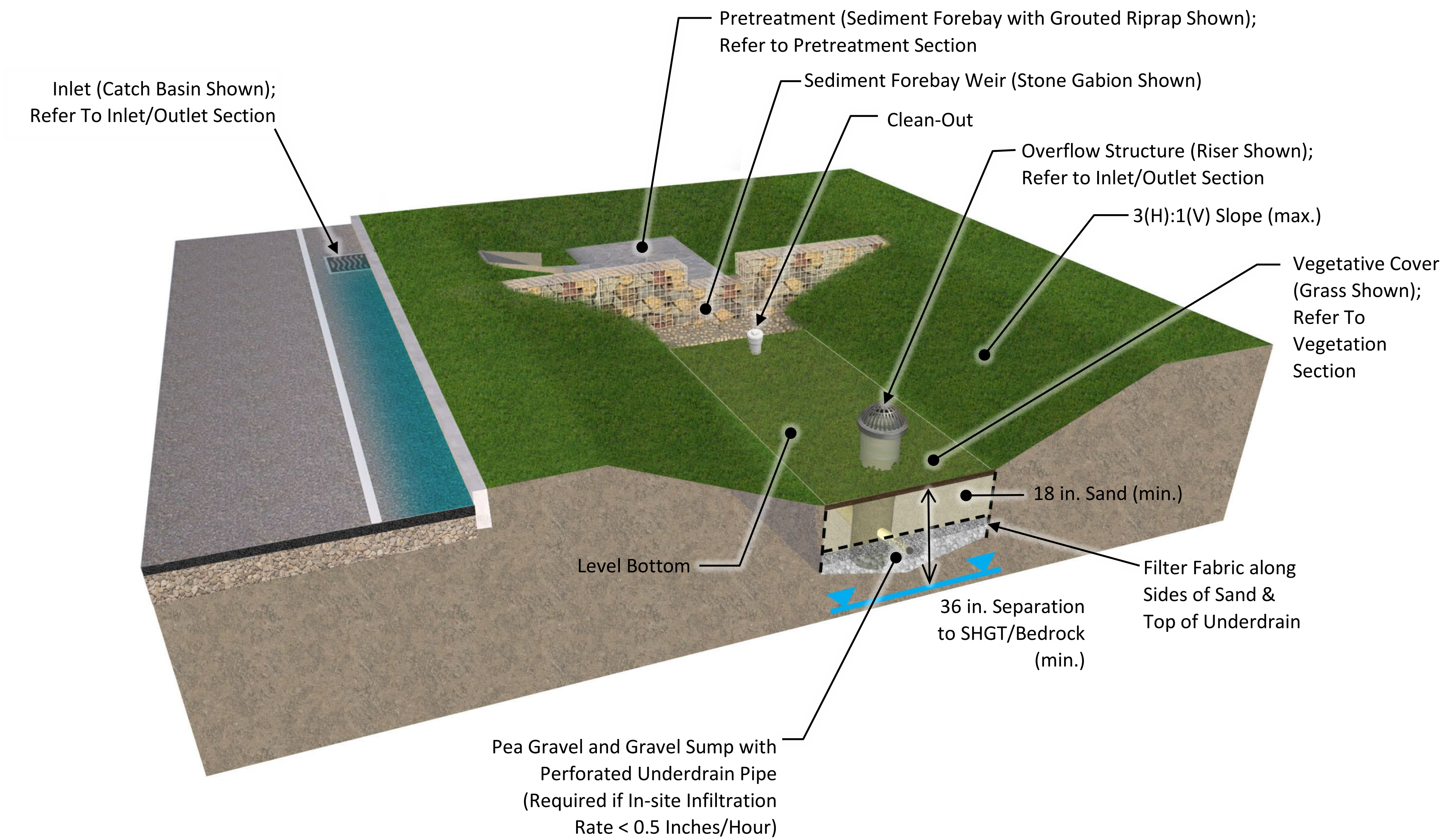

Pretreatment (Sediment Forebay with Grouted Riprap Shown);
Refer to Pretreatment Section
Inlet (Catch Basin Shown);
Refer To Inlet/Outlet Section
Sediment Forebay Weir (Stone Gabion Shown)
Clean-Out
Overflow Structure (Riser Shown);
Refer to Inlet/Outlet Section
3(H):1(V) Slope (max.)
Vegetative Cover
(Grass Shown);
Refer To
Vegetation
Section
18 in. Sand (min.)
Level Bottom
Filter Fabric along
Sides of Sand &
Top of Underdrain
36 in. Separation
to SHGT/Bedrock
(min.)
Pea Gravel and Gravel Sump with
Perforated Underdrain Pipe
(Required if In-site Infiltration
Rate < 0.5 Inches/Hour)

Figure 2.3.5.2 – Bioretention Basin; Providence, RI

Description

General Configuration

Bioretention basins are shallow, vegetated/landscaped depressions that capture, temporarily store and filter stormwater runoff. Bioretention basins have an engineered soil media below the surface of the basin that facilitates stormwater filtration and vegetative growth. Bioretention basins are frequently designed to infiltrate, typically referred to as infiltration bioretention basins, but can be designed with an underdrain to capture filtered water and assist with drainage from the system, typically referred to as flow-through bioretention basins. In certain situations, bioretention systems can also be designed with impermeable liners.

Pollutant Removal Processes

Bioretention basins provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration (if not designed with underdrain system or impermeable liner):** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants commonly present within stormwater runoff.
- **Adsorption:** Designed additives in filter media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Bioretention basins are best located in open areas where there is adequate surface area to temporarily store stormwater.
- Potential locations include roundabouts, landscaping islands, medians, streetscapes (e.g., between the curb and sidewalk), wide roadway shoulders, along shared-use paths, within parking lot islands, and along borders of parking lots. Bioretention basins are suitable in urban and rural settings, but require adequate surface space.

- Locate where:
  - The topography allows the design of the bioretention basin or basin cell bottoms to have a maximum slope of 0.5% or where terraced bottoms can be created or check dams used to reduce the effective slope of the cell bottom to 0.5% or less to minimize flow velocity and promote filtration.
  - For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
  - The minimum horizontal setbacks, as presented in Table 1.2.2 of this manual, can be met when designing bioretention basins to infiltrate.
    - Bioretention basins, however, can be constructed within setbacks if designed appropriately with an impermeable barrier to mitigate water migration.
  - Snow storage will not occur within the basin.
  - There is a low likelihood that pedestrian traffic will cut across the area.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the bioretention basin in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales (in locations where adequate space exists), deep-sump catch basins, and/or proprietary treatment devices.

Key Considerations

Feasibility

- Unlined systems: Bottom of filter is at or above SHGT/bedrock and the top of filter is at least 3 feet above SHGT/bedrock.
  - If in-situ infiltration rates of underlying soils exceed 0.5 inch per hour, bioretention basin does not require an underdrain system.
  - If in-situ infiltration rates of underlying soils are less than 0.5 inch per hour, bioretention basin requires an underdrain system.
- Lined systems: When bottom of filter is not at or above SHGT/bedrock, top of filter is not at least 3 feet above SHGT/bedrock, soils are contaminated, or horizontal separation from adjacent building foundations cannot be met; infiltration bioretention basin requires a liner and an underdrain system.

Pretreatment

- Pretreatment measure(s) shall have a volume of 25% of WQV, or equivalent by alternative approved pretreatment device.

Treatment

- Total system (including pretreatment) must hold 75% of the WQV.
- Engineered soil media shall be 2-4 feet deep planting soil with a mulch surface layer (when not planted with grasses), and the system shall allow 6-12 inches of ponding.

Vegetation

- Use Vegetation Section of this manual.
- Consider long-term maintenance capabilities and limitations.

Inlet

- Runoff can be introduced to the bioretention system through overland flow, curb cuts, inlet structures, swales/channels, and/or pipes.
- Provide stable and non-erosive energy dissipating devices at inflow locations where inflow velocities are considered erosive.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.
  - Design inlet to resist incursion by vehicles and bicycles.

Underdrain

- Install underdrains when the bioretention basin:
  - Is in native soil that has an infiltration rate less than 0.5 inch per hour;
  - Does not meet vertical separation distance to SHGT/bedrock and must be lined; and/or
  - Is within a horizontal setback zone per Table 1.2.2 of this manual and must be lined; and/ or
  - Is within a LUHPPL or area of contaminated soils and must be lined.
- Minimum underdrain pipe diameter: 4 inches.
- Minimum underdrain collector slope: 0.5%
- Install perforated underdrain in pea gravel layer with a minimum of 2 inches of pea gravel installed above and below the underdrain and within 2 feet (on both sides) of the underdrain (i.e., underdrain zone). The typical pea gravel thickness outside of the underdrain zone is 4 inches. The pea gravel layer shall be underlain by a gravel sump with a 12-inch typical thickness with exception to the section of gravel sump within underdrain zone. The thickness of the gravel sump in that location may be reduced to accommodate the increased thickness of the underdrain's pea gravel layer.
  - NOTE: If the bioretention basin is designed without an underdrain, pea gravel and gravel sump are optional.
- Lay underdrain such that perforations are on bottom of pipe.
- Bottom of underdrain shall be installed with not less than 4 inches above SHGT.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure, and/or daylights.
- Other considerations when designing/installing underdrains:
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
  - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain; one at the upstream end and one at the downstream end.
  - Cleanouts shall be at least 4 inches in diameter, be non-perforated, and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be highly visible.
  - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Bioretention Filter Bed (Bottom) Area
  - Size the filter bed (bottom) area to meet the minimum required area in accordance with Section 5.4.4 of the RISDISM.
- Volume
  - Size the entire facility (including pretreatment and void space in filter media) to hold 75% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event.
    - Assume 33% void space when computing the amount of available storage within the engineered soil media.
    - Underdrains can be added, as necessary, to accommodate drain time requirement.
  - Depth: Engineered soil media shall have a depth of 24 inches to 48 inches as necessary to accommodate the WQV and subsurface conditions.
- Ponding Depth
  - Maximum for WQV: 12 inches
  - Maximum for Overflow Events: 3 feet
- Bottom Width
  - Minimum: 2 feet
- Bottom Slope
  - Design bottom of infiltration bioretention basins to be level or have a maximum slope of 0.5% to promote infiltration and even distribution.
  - Flow-through bioretention basins with bottom slopes greater than 0.5% must be designed with check dams to limit.
- Side Slope
  - 3(H):1(V) slopes or flatter are preferred especially on grassed slopes where mowing is required. In ultra-urban locations or space constrained areas; side slopes of 2(H):1(V) may be utilized if properly designed to account for erosion and slope stability. Stabilize the slope with turf reinforcement matting or equivalent if the slope could potentially erode.
  - If site topography does not allow for 3(H):1(V) slopes or adequately stabilized 2(H):1(V) slopes, vertical concrete walls with a maximum height of 30 inches can be used. Drop curbs or similar precast structures can also be used to create stable, vertical bioretention side walls. For safety purposes, drop curb designs shall not exceed a vertical drop of more than 12 inches.

Materials

- Mulch (if basin is not grassed)
  - 2 to 4 inches of shredded hardwood bark mulch, aged for 6 months minimum.
  - In some situations, designers may consider alternative surface covers such as river stone. Alternative covers will require approval from RIDOT.
- Vegetation
  - Specify vegetation in accordance with the Vegetation Section in this manual.
  - Establish a dense vegetative cover or adequately stabilized landscaped surface throughout basin and any up-gradient areas disturbed by construction before runoff can be accepted into the facility.

- Plant vegetation and provide a planting plan in accordance with Section 5.5.5 and Appendix B of the RISDISM.
- Trees should be planted primarily along the perimeter of the facility and with 15 feet of separation from underdrain piping.
- Trees shall not be planted in lined STUs.
- Do not plant trees, shrubs, or grasses with a mature vegetation height exceeding 24-inches above the surrounding sidewalk or pavement surface in bioretention basins within medians, near intersections, or near pedestrian crossings to avoid obstruction of sight lines.
- Trees installed within bioretention basins located away from medians, intersections, or pedestrian crossings must allow for a mature tree height and branching clearance that provides approximately 14 feet of clearance if installed adjacent to bicycle facilities, pedestrian paths, and travel lanes.
- A native grass/wildflower seed mix can be used as an alternative to groundcover plantings.

- Engineered Soil Media
  - Select an engineered soil media mixture from Vegetation Section of this manual.
  - Do not excavate soils that comply with infiltration standards for treatment in order to install engineered soil media.
  - Compost shall not be used as organic matter. Acceptable organic soil amendments or matter shall include sphagnum peat, wood derivatives, or media amendments such as zero-valent iron and/or drinking water treatment residuals (alum) to enhance phosphorus sorption.
- Pea Gravel
  - Shall consist of ⅜" to ¾" size gravel conforming to gradation listed in Section M.01.06-Keystone and M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of pea gravel) ≤ $5D_{85}$ (of engineered soil media) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of engineered soil media).
- Gravel Sump
  - Shall be in accordance with Section M.01.07-Filter Stone and M.01.09, Table I, Column V of the RIDOT Standards.
- Filter Fabric
  - Shall be non-woven, comply with Section 703.02.2 of the RIDOT Standards, and shall be listed on the RIDOT Approved Materials List as a fabric suitable for subsurface drainage applications.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Underdrain (perforated and non-perforated pipe sections)
  - Polyethylene or polyvinyl pipe.
- Liner
  - If used, shall be a 30 mil (minimum) HDPE or PVC liner.
- Curbing (for Overflow Weirs or Check Dams)
  - If used for check dams, granite or concrete curbing shall conform to Section 906 of the RIDOT Standards.
- Turf Reinforcement Matting
  - If used, shall be a woven material included on the RIDOT Approved Materials List that exceeds the design velocity of the design storm and allows for the growth of the proposed vegetative species.

Groundwater & Bedrock Separation

- For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and

bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
  - Install an impermeable liner at the bottom of the gravel sump if adequate separation from the bottom of the engineered soil media to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs, or in locations where contaminated soils exist. Refer to RISDISM Section 5.5.1 and 5.5.4 guidance. Lined systems shall have underdrains.
- Reductions in the groundwater separation distance from the top of the engineered soil media may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. Engineered soil media shall not be placed below SHGT.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and with little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as “GB.”

Underlying Soils Conditions & Design Infiltration Rate

- Existing infiltration rates and in-situ conditions of underlying soils will determine if the basin can be designed to achieve infiltration, partial infiltration, or require an impermeable liner.
- Complete in-situ soil testing in accordance with requirements in the Planning Section of this manual.
- If in-situ infiltration rates exceed 0.5 inch per hour and adequate separation to SHGT/bedrock exists, the basin can be designed to infiltrate without the need of an underdrain system. These types of bioretention basins are referred to as infiltration bioretention basins.
- If in-situ infiltration rates are less than 0.5 inch per hour and adequate separation to SHGT/ bedrock exists, design basin with an underdrain system. If adequate separation to SHGT/bedrock does not exist or horizontal setbacks cannot be met, install with a liner. This types of bioretention basins are referred to as flow-through bioretention basins.
- The design infiltration rate shall be half the field-derived value of the most restrictive in-situ soil layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use a design infiltration rate of 0.52 inches per hour if a loam surface layer is used.

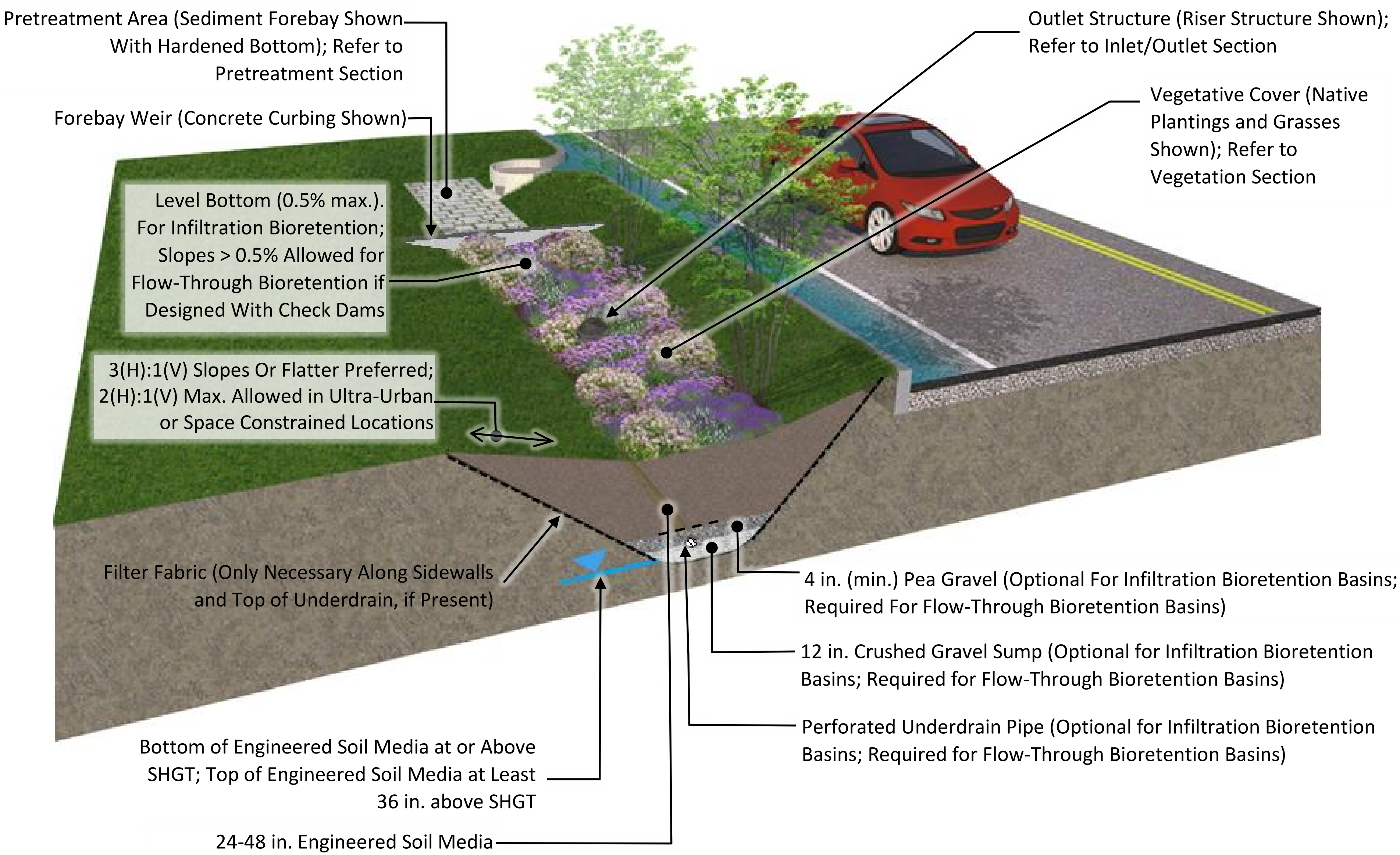
Outlet & Overflow

- Bioretention basins must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets are typically a stabilized spillway, gabion berm, concrete weir, curb cut opening, precast concrete structure, or polyethylene/polyvinyl chloride riser structure.

Other Considerations

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner or closed bottom of the system, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.

- If bottom of the bioretention basin has a slope greater than 0.5 percent, install check dams or consider designing as a terraced system with relatively flat bottoms in each cell.
  - Check dams must be evenly spaced and no more than six to 12 inches high.
  - Check dams that are designed for infiltration bioretention basins must not be constructed of porous materials like gabions, as water must sufficiently pond behind each check dam and be forced to infiltrate
  - Permeable weirs (e.g., gabion weirs) must be avoided in areas that receive high sediment loads. Utilize weirs constructed from concrete or granite curbing.
- Roadway stability can be a design issue when installing bioretention basins along roadways. It may be necessary to provide a vertical impermeable barrier to keep water from saturating the road's sub-base that is capable of supporting H-20 loads.
- Filter fabric shall be placed along the sidewalls of the STU to help direct the water flow downward, reduce lateral flows, and to reduce lateral soil migration. This is critical when installing STU in a median strip or adjacent to a roadway or parking lot.
- Site shall be designed with readily available access to all site features for maintenance.
- Surface slope downgradient from infiltrating STUs shall be less than 15% for a distance of 50 feet.



Pretreatment Area (Sediment Forebay Shown With Hardened Bottom); Refer to Pretreatment Section
Forebay Weir (Concrete Curbing Shown)
Level Bottom (0.5% max.). For Infiltration Bioretention; Slopes > 0.5% Allowed for Flow-Through Bioretention if Designed With Check Dams
3(H):1(V) Slopes Or Flatter Preferred; 2(H):1(V) Max. Allowed in Ultra-Urban or Space Constrained Locations
Filter Fabric (Only Necessary Along Sidewalls and Top of Underdrain, if Present)
Bottom of Engineered Soil Media at or Above SHGT; Top of Engineered Soil Media at Least 36 in. above SHGT
24-48 in. Engineered Soil Media
Outlet Structure (Riser Structure Shown); Refer to Inlet/Outlet Section
Vegetative Cover (Native Plantings and Grasses Shown); Refer to Vegetation Section
4 in. (min.) Pea Gravel (Optional For Infiltration Bioretention Basins; Required For Flow-Through Bioretention Basins)
12 in. Crushed Gravel Sump (Optional for Infiltration Bioretention Basins; Required for Flow-Through Bioretention Basins)
Perforated Underdrain Pipe (Optional for Infiltration Bioretention Basins; Required for Flow-Through Bioretention Basins)

Section 2.3.5 – Bioretention Curb Inlet Planter

PART 2 – DESIGN

Figure 2.3.5.3 – Stormwater Bioretention Curb Inlet Planter; New Haven, CT

Description

General Configuration

Curb Inlet Planters are a type of bioretention facility that is located within the roadway right-of-way immediately adjoining roadway curbing. Curb Inlet Planters have an engineered soil media below the surface of the planter that facilitates stormwater filtration and vegetative growth. These planters are frequently designed to infiltrate, typically referred to as infiltration planters, but can be designed with an underdrain to capture filtered water and assist with drainage from the system, typically referred to as flow-through planters. In certain situations, these planters can also be designed with impermeable liners.

Pollutant Removal Processes

Curb Inlet Planters provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration (if not designed with underdrain system or impermeable liner):** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants typically present in stormwater runoff.
- **Adsorption:** Designed additives in engineered soil media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Curb Inlet Planters are ideal for curbside areas within the right-of-way that immediately adjoin travel lanes, drive aisles, parking islands, or roadways where on-street parking is not allowed or does not exist.
    - These planters are also ideal for use within existing space-limited right-of-way areas as installation requires minimal site re-grading.

- Curb Inlet Planters are suitable for urban and ultra-urban areas and can be sized and modified easily to optimize infiltration rate in constrained spaces (e.g., flexible depth, edge construction, and vegetation).
- Locate where:
    - The topography allows the design of planter cell bottoms to have a maximum slope of 0.5% (or where terraced bottoms can be created or check dams used to reduce the effective slope of the cell bottoms to 0.5% or less to minimize flow velocity and promote filtration).
    - For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
    - The minimum horizontal setbacks, as presented in Table 1.2.2 of this manual, can be met when designing planters to infiltrate.
        - Planters, however, can be constructed within setbacks if designed appropriately with an impermeable barrier to mitigate water migration.
    - Snow storage will not occur within the planter.
    - Pedestrian access and capacity can be maintained. Planters must not encroach upon clear walking paths, and cannot impede designated accessible parking spaces or loading zones.
        - If pedestrian activity is moderate to high, maintain 8 feet (minimum) of clear width between the edge of the planter and the building or property line; if pedestrian activity is low, maintain 5-feet (minimum).

Key Considerations

Feasibility

- Unlined systems: Bottom of filter is at or above SHGT/bedrock and the top of filter is at least 3 feet above SHGT/bedrock.
    - If in-situ infiltration rates of underlying soils exceed 0.5 inch per hour, planter does not require an underdrain system.
    - If in-situ infiltration rates of underlying soils are less than 0.5 inch per hour, planter requires an underdrain system.
- Lined systems: When bottom of filter is not at or above SHGT/bedrock, top of filter is not at least 3 feet above SHGT/bedrock, soils are contaminated, or horizontal separation from adjacent building foundations cannot be met; planter requires a liner and an underdrain system.

Pretreatment

- Pretreatment measure(s) shall have a volume of 25% of WQV, or equivalent by alternative approved pretreatment device.

Treatment

- Total system (including pretreatment) must hold 75% of the WQV.
- Engineered soil media shall be 2-4 feet deep with a mulch surface layer (when not planted with grasses), and the system shall allow for 6-12 inches of ponding.

Vegetation

- Use Planting Palettes Section of this manual.
- Consider long-term maintenance capabilities and limitations.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the planter in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales (in locations where adequate space exists), deep-sump catch basins, and/or proprietary treatment devices.

Inlet

- Runoff can be introduced to the planter through overland flow, curb cuts, inlet structures, swales/channels, and/or pipes.
- Provide stable and non-erosive energy dissipating devices at inflow locations where inflow velocities are considered erosive.
- In locations adjacent to sidewalks or pedestrian use areas where raised curbing or edging is used along the edge of the planter to prevent incursion by pedestrians, install notches intermittently along the raised curbing or edging to allow runoff from adjacent sidewalk area to enter the planter. Notches shall be 4 inches in width to facilitate maintenance while also minimizing the risk that people get their feet caught in the openings.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.
    - Design inlet to resist incursion by vehicles and bicycles.

Underdrain

- Install underdrains when the planter:
    - Is in native soil that has an infiltration rate less than 0.5 inch per hour;
    - Does not meet vertical separation distance to SHGT/bedrock and must be lined; and/or
    - Is within a horizontal setback zone per Table 1.2.2 of this manual and must be lined; and/ or
    - Is within a LUHPPL or area of contaminated soils and must be lined.
- Minimum underdrain pipe diameter: 4 inches
- Minimum underdrain collector slope: 0.5%
- Install perforated underdrain in pea gravel layer with a minimum of 2 inches of pea gravel installed above and below the underdrain and within 2 feet (on both sides) of the underdrain (i.e., underdrain zone). The typical pea gravel thickness outside of the underdrain zone is 4 inches. The pea gravel layer shall be underlain by a gravel sump with a 12-inch typical thickness with exception to section of gravel sump within underdrain zone. The thickness of the gravel sump in that location may be reduced to accommodate the increased thickness of the underdrain's pea gravel layer.
    - *NOTE: If the planter is designed without an underdrain, pea gravel and gravel sump are optional.*
- Lay underdrain such that perforations are on bottom of pipe.
- Bottom of underdrain shall be installed with not less than 4 inches above SHGT.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure, and/or daylights.

- Other considerations when designing/installing underdrains:
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
  - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain collector pipe; one at the upstream end and one at the downstream end.
  - Cleanouts shall be at least 4 inches in diameter, be non-perforated, and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be highly visible.
  - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Planter Filter Bed (Bottom) Area
  - Size the filter bed (bottom) area to meet the minimum required area in accordance with Section 5.5.4 of the RISDISM.
- Maximum Loading Ratio
  - The maximum loading ratio of contributing impervious drainage area to planter bed area is 10:1.
- Volume
  - Size the entire facility (including pretreatment and void space in filter media) to hold 75% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event. Assume 33% void space when computing the amount of available storage within the engineered soil media.
  - Multiple planters may be linked or sequenced to prevent overloading a single planter.
  - Depth: Engineered soil media shall have a depth of 24 inches to 48 inches as necessary to accommodate the WQV and subsurface conditions.
- Ponding Depth
  - Maximum for WQV: 12 inches.
  - Maximum for Overflow Events: 2 feet.
    - Planters that exceed 12 inches in depth between adjacent sidewalk/ground surfaces must be designed with low-height barriers (e.g., raised 4-inch high curbing, edging, or low fencing less than 24-inches tall) to mitigate fall risks.
  - Ponded water shall drain within 48 hours or less. Underdrains can be added, as necessary, to accommodate drain time requirement.
- Bottom Width
  - Minimum: 4 feet (ideal); narrower planters may be allowed with widths no less than 2.5 feet; however, design must consider plant health, water quality performance, and implementation costs.
- Bottom Slope
  - Design bottom of infiltration planters to be flat or have a maximum slope of 0.5% to promote infiltration and even distribution.
  - Flow-through planters with bottom slopes greater than 0.5% must be designed with check dams or terraced/stepped planter cells.
- Side Slope
  - Drop curbs or similar precast structures should be used to create stable, vertical planter side walls. For safety purposes, drop curb designs without safety barriers should

not exceed a vertical drop of more than 12 inches. If vertical drops of greater than 12 inches are required, safety barriers are required.

  - When a vertical wall is located on the street side of the planter, the wall should be designed to support vehicular loads.

Materials

- Mulch (if planter is not grassed)
  - 2 to 4 inches of shredded hardwood bark mulch, aged for 6 months minimum.
  - In some situations, designers may consider alternative surface covers such as river stone. Alternative covers will require approval from RIDOT.
- Vegetation
  - Specify vegetation in accordance with the Vegetation Section in this manual.
  - Establish a dense vegetative cover or adequately stabilized landscaped surface throughout planter and any up-gradient areas disturbed by construction before runoff can be accepted into the facility.
  - Plant vegetation and provide a planting plan in accordance with Section 5.5.5 and Appendix B of the RISDISM.
  - Do not plant trees, shrubs, or grasses with a mature vegetation height exceeding 24-inches above the surrounding sidewalk or pavement surface in Curb Inlet Planters installed within medians, near intersections, or near pedestrian crossings to avoid obstruction of sight lines.
  - Trees shall not be planted in flow-through or lined planters. Comply with RIDOT Standard Detail 50.1.0 for tree installation as appropriate.
  - Trees installed within planters located away from medians, intersections, or pedestrian crossings must allow for a mature tree height and branching clearance that provides approximately 14 feet of clearance of adjacent bicycle facilities, pedestrian paths, and travel lanes.
  - A native grass/wildflower seed mix can be used as an alternative to groundcover plantings.
- Engineered Soil Media
  - Select an engineered soil media mixture from Vegetation Section of this manual.
  - Do not excavate soils that comply with infiltration standards for treatment in order to install engineered soil media.
  - Compost shall not be used as organic matter. Acceptable organic soil amendments or matter shall include sphagnum peat, wood derivatives, or media amendments such as zero-valent iron and/or drinking water treatment residuals (alum) to enhance phosphorus sorption.
- Pea Gravel
  - Shall consist of ⅜" to ¾" size gravel conforming to gradation listed in Section M.01.06-Keystone and M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of pea gravel) ≤ $5D_{85}$ (of engineered soil media) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of engineered soil media).
- Gravel Sump
  - Shall be in accordance with Section M.01.07-Filter Stone and M.01.09, Table I, Column V of the RIDOT Standards.
- Underdrain (perforated and non-perforated pipe sections)
  - Polyethylene or polyvinyl pipe.
- Filter Fabric
  - Shall be non-woven, comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for subsurface drainage

applications.

- Liner
  - If used, shall be a 30 mil (minimum) HDPE or PVC liner.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Curbing (for Overflow Weirs or Check Dams)
  - If used, granite or concrete curbing shall conform to Section 906 of the RIDOT Standards.

Underlying Soils Conditions & Design Infiltration Rate

- Existing infiltration rates and in-situ conditions of underlying soils will determine if the planter can be designed to achieve infiltration, partial infiltration, or require an impermeable liner.
- Complete in-situ soil testing in accordance with requirements in the Planning Section of this manual.
- If in-situ infiltration rates exceed 0.5 inch per hour and adequate separation to SHGT/bedrock exists, the planter can be designed to infiltrate without the need of an underdrain system. These types of planters are referred to as Infiltration Planters.
- If in-situ infiltration rates are less than 0.5 inch per hour but adequate separation to SHGT/ bedrock exists, design planter with an underdrain system. If adequate separation to SHGT/bedrock does not exist or horizontal setbacks cannot be met, install with a liner. These types of planters containing an underdrain system are referred to as Flow-Through Planters.
- The design infiltration rate used shall be half the field-derived value or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use a design infiltration rate of 0.52 inches per hour if a loam surface layer is used.

Groundwater & Bedrock Separation

- For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
  - Install an impermeable liner at the bottom of the gravel sump if adequate separation from the bottom of the engineered soil media to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs, or in locations where contaminated soils exist. Refer to RISDISM Section 5.5.1 and 5.5.4 guidance. Lined systems shall have under drains.
- Reductions in the groundwater separation distance from the top of the engineered soil media may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. Engineered soil media shall not be placed below SHGT.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as “GB.”

Outlet & Overflow

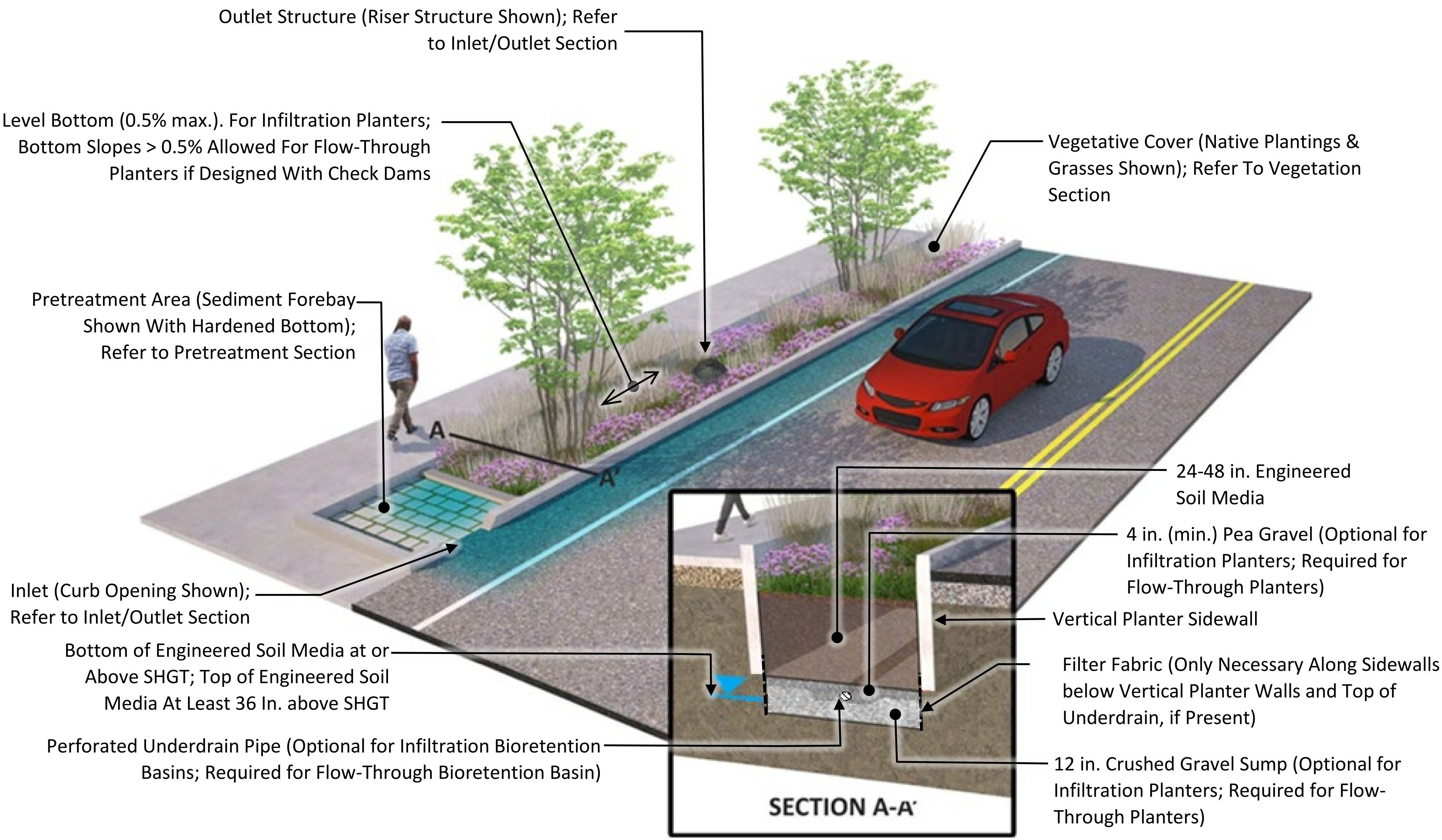
- Bioretention curb inlet planters designed off-line are typically sized to handle only the WQV.
  - If the planter is designed to infiltrate and meets the infiltration criteria, an outlet is not required. Once the system has reached its capacity (i.e., once the STU is full),

additional flow will bypass the planter. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.

- Bioretention curb inlet planters designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets are typically a stabilized spillway, gabion berm, concrete weir, curb cut opening, precast concrete structure, or polyethylene/polyvinyl chloride riser structure.
- If used, underdrains can connect to a downstream drainage system or daylight at an approved discharge point.

Other Considerations

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner or closed bottom of the system, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.
- If bottom of the planter has a slope greater than 0.5 percent, install check dams or consider designing as a terraced system with relatively flat bottoms in each cell.
  - Check dams must be evenly spaced and no more than six to 12 inches high.
  - Check dams that are designed for infiltration planters must not be constructed of porous materials like gabions, as water must sufficiently pond behind each check dam and be forced to infiltrate.
  - Permeable weirs (e.g., gabion weirs) must be avoided in areas that receive high sediment loads. Utilize weirs constructed from concrete or granite curbing.
- Roadway stability can be a design issue when installing bioretention planters along roadways. It may be necessary to provide a vertical impermeable barrier to keep water from saturating the road's sub-base that is capable of supporting H-20 loads.
- Filter fabric shall be placed along the sidewalls of the STU to help direct the water flow downward, reduce lateral flows, and to reduce lateral soil migration. This is critical when installing STU in a median strip or adjacent to a roadway or parking lot.
- Site shall be designed with readily available access to all site features for maintenance.
- Surface slope downgradient from infiltrating STUs shall be less than 15% for a distance of 50 feet.



Outlet Structure (Riser Structure Shown); Refer to Inlet/Outlet Section
Level Bottom (0.5% max.). For Infiltration Planters; Bottom Slopes > 0.5% Allowed For Flow-Through Planters if Designed With Check Dams
Vegetative Cover (Native Plantings & Grasses Shown); Refer To Vegetation Section
Pretreatment Area (Sediment Forebay Shown With Hardened Bottom); Refer to Pretreatment Section
A
A'
24-48 in. Engineered Soil Media
4 in. (min.) Pea Gravel (Optional for Infiltration Planters; Required for Flow-Through Planters)
Inlet (Curb Opening Shown); Refer to Inlet/Outlet Section
Vertical Planter Sidewall
Bottom of Engineered Soil Media at or Above SHGT; Top of Engineered Soil Media At Least 36 In. above SHGT
Filter Fabric (Only Necessary Along Sidewalls below Vertical Planter Walls and Top of Underdrain, if Present)
Perforated Underdrain Pipe (Optional for Infiltration Bioretention Basins; Required for Flow-Through Bioretention Basin)
12 in. Crushed Gravel Sump (Optional for Infiltration Planters; Required for Flow-Through Planters)
SECTION A-A'

Figure 2.3.5.4 – Bioretention Parking Lane Adjacent Planter; Philadelphia, PA (PWD)

Description

General Configuration

Parking Lane Adjacent Planters are a type of bioretention facility that is located along the edge of roadway but is separated from the roadway edge by a pedestrian access walkway or sidewalk. Parking Lane Adjacent Planters have an engineered soil media below the surface of the planter that facilitates stormwater filtration and vegetative growth. These planters are frequently designed to infiltrate, typically referred to as infiltration planters, but can be designed with an underdrain to capture filtered water and assist with drainage from the system, typically referred to as flow-through planters. In certain situations, these planters can also be designed with impermeable liners.

Pollutant Removal Processes

Parking Lane Adjacent Planters provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration (if not designed with underdrain system or impermeable liner):** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants typically present in stormwater runoff.
- **Adsorption:** Designed additives in engineered soil media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Parking Lane Adjacent Planters are ideal for curbside areas within the right-of-way where on-street parking or pedestrian access ways/sidewalks exist, or are required, immediately adjacent to the edge of roadway or parking lane.

    - These planters are also ideal for use within existing space-limited right-of-way areas as installation requires minimal site re-grading.
- Parking Lane Adjacent Planters are suitable for urban and ultra-urban areas and can be sized and modified easily to optimize infiltration rate in constrained spaces (e.g., flexible depth, edge construction, and vegetation).
- Locate where:
    - The topography allows the design of planter cell bottoms to have a maximum slope of 0.5% (or where terraced bottoms can be created or check dams used to reduce the effective slope of the cell bottoms to 0.5% or less to minimize flow velocity and promote filtration).
    - For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
    - The minimum horizontal setbacks, as presented in Table 1.2.2 of this manual, can be met when designing planters to infiltrate.
        - Planters, however, can be constructed within setbacks if designed appropriately with an impermeable barrier to mitigate water migration.
    - Snow storage will not occur within the planter.
    - Pedestrian access and capacity shall be maintained. Planters must be designed to maintain minimum widths for clear walking paths and designated accessible parking spaces or loading zones.
        - If pedestrian activity is moderate to high, maintain 8 feet (minimum) of clear width between the edge of the planter and building or property line; if pedestrian

Key Considerations

Feasibility

- Unlined systems: Bottom of filter is at or above SHGT/bedrock and the top of filter is at least 3 feet above SHGT/bedrock.
    - If in-situ infiltration rates of underlying soils exceed 0.5 inch per hour, planter does not require an underdrain system.
    - If in-situ infiltration rates of underlying soils are less than 0.5 inch per hour, planter requires an underdrain system.
- Lined systems: When bottom of filter is not at or above SHGT/bedrock, top of filter is not at least 3 feet above SHGT/bedrock, soils are contaminated, or horizontal separation from adjacent building foundations cannot be met; planter requires a liner and an underdrain system.

Pretreatment

- Pretreatment measure(s) shall have a volume of 25% of WQV, or equivalent by alternative approved pretreatment device.

Treatment

- Total system (including pretreatment) must hold 75% of the WQV.
- Engineered soil media shall be 2-4 feet deep with a mulch surface layer (when not planted with grasses), and the system shall allow for 6-12 inches of ponding.

Vegetation

- Use Vegetation Section of this manual.
- Consider long-term maintenance capabilities and limitations.

activity is low, maintain 5-feet (minimum).
    - Provide a level step-out zone along the curb to accommodate vehicle entry and exit where planters are configured adjacent to on-street parking.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the planter in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales (in locations where adequate space exists), deep-sump catch basins, and/or proprietary treatment devices.

Inlet

- Runoff can be introduced to the planter through overland flow, curb cuts, inlet structures, swales/channels, and/or pipes.
- Provide stable and non-erosive energy dissipating devices at inflow locations where inflow velocities are considered erosive.
- In locations adjacent to sidewalks or pedestrian use areas where raised curbing or edging is used along the edge of the planter to prevent incursion by pedestrians, install notches intermittently along the raised curbing or edging to allow runoff from adjacent sidewalk area to enter the planter. Notches shall be 4 inches in width to facilitate maintenance while also minimizing the risk that people get their feet caught in the openings.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.
    - Design inlet to resist incursion by vehicles and bicycles.

Underdrain

- Install underdrains when the planter:
    - Is in native soil that has an infiltration rate less than 0.5 inch per hour;
    - Does not meet vertical separation distance to SHGT/bedrock and must be lined;
    - Is within a horizontal setback zone per Table 1.2.2 of this manual and must be lined; and/ or
    - Is within a LUHPPL or area of contaminated soils and must be lined.
- Minimum underdrain pipe diameter: 4 inches
- Minimum underdrain collector slope: 0.5%
- Install perforated underdrain in pea gravel layer with a minimum of 2 inches of pea gravel installed above and below the underdrain and within 2 feet (on both sides) of the underdrain (i.e., underdrain zone). The typical pea gravel thickness outside of the underdrain zone is 4 inches. The pea gravel layer shall be underlain by a gravel sump with a 12-inch typical thickness with exception to section of gravel sump within underdrain zone. The thickness of the gravel sump in that location may be reduced to accommodate the increased thickness of the underdrain's pea gravel layer.
    - *NOTE: If the planter is designed without an underdrain, pea gravel and gravel sump are optional.*
- Lay underdrain such that perforations are on bottom of pipe.
- Bottom of underdrain shall be installed with not less than 4 inches above SHGT.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure, and/or daylights at the surface.

- Other considerations when designing/installing underdrains:
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
  - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain collector pipe; one at the upstream end and one at the downstream end.
  - Cleanouts shall be at least 4 inches in diameter, be non-perforated, and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be highly visible.
  - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Planter Filter Bed (Bottom) Area
  - Size the filter bed (bottom) area to meet the minimum required area in accordance with Section 5.5.4 of the RISDISM.
- Maximum Loading Ratio
  - The maximum loading ratio of contributing impervious drainage area to planter bed area is 10:1.
- Volume
  - Size the entire facility (including pretreatment and void space in filter media) to hold 75% of the WQV while safely conveying flows generated by overflow storm events. Assume 33% void space when computing the amount of available storage within the engineered soil media.
  - Multiple planters may be linked or sequenced to prevent overloading on a single planter.
  - Depth: Engineered soil media shall have a depth of 24 inches to 48 inches as necessary to accommodate the WQV and subsurface conditions.
- Ponding Depth
  - Maximum for WQV: 12 inches.
  - Maximum for Overflow Events: 2.0 feet.
    - Planters that exceed 12 inches in depth between adjacent sidewalk/ground surfaces must be designed with low-height barriers (e.g., raised 4-inch high curbing, edging, or low fencing less than 24-inches tall) to mitigate fall risks.
  - Ponded water shall drain within 48 hours or less. Underdrains can be added, as necessary, to accommodate drain time requirement.
- Bottom Width
  - Minimum: 4 feet (ideal); narrower planters may be allowed with widths no less than 2.5 feet; however, design must consider plant health, water quality performance, and implementation costs.
- Bottom Slope
  - Design bottom of infiltration planters to be flat or have a maximum slope of 0.5% to promote infiltration and even distribution.
  - Flow-through planters with bottom slopes greater than 0.5% must be designed with check dams or terraced/stepped planter cells.
- Side Slope
  - Drop curbs or similar precast structures should be used to create stable, vertical planter side walls. For safety purposes, drop curb designs without safety barriers should not exceed a vertical drop of more than 12 inches. If vertical

drops of greater than 12 inches are required, safety barriers are required.
    - When a vertical wall is located on the street side of the planter, the wall should be designed to support vehicular loads.
- Level Step-Out Zone
  - Planters configured adjacent to on-street parking should provide a 3-foot wide (minimum) level step-out zone along the curb to accommodate vehicle entry and exit. In cases where the planters are less than 20-feet long and regular 5-foot wide access paths are provided that connect the curb area to the sidewalk on the opposite side of the planter, the step-out zone may be reduced to 12-18 inches provided the step-out zone is not part of an ADA accessible route.

Materials

- Mulch (if planter is not grassed)
  - 2 to 4 inches of shredded hardwood bark mulch, aged for 6 months minimum.
  - In some situations, designers may consider alternative surface covers such as river stone. Alternative covers will require approval from RIDOT.
- Vegetation
  - Specify vegetation in accordance with the Vegetation Section in this manual.
  - Establish a dense vegetative cover or adequately stabilized landscaped surface throughout planter and any up-gradient areas disturbed by construction before runoff can be accepted into the facility.
  - Plant vegetation and provide a planting plan in accordance with Section 5.5.5 and Appendix B of the RISDISM.
  - Do not plant trees, shrubs, or grasses with a mature vegetation height exceeding 24-inches above the surrounding sidewalk or pavement surface in Parking Lane Adjacent Planters installed within medians, near intersections, or near pedestrian crossings to avoid obstruction of sight lines.
  - Trees shall not be planted in flow-through or lined planters. Comply with RIDOT Standard Detail 50.1.0 for tree installation as appropriate.
  - Trees installed within planters located away from medians, intersections, or pedestrian crossings must allow for a mature tree height and branching clearance that provides approximately 14 feet of clearance of adjacent bicycle facilities, pedestrian paths, and travel lanes.
  - A native grass/wildflower seed mix can be used as an alternative to groundcover plantings.
- Engineered Soil Media
  - Select an engineered soil media mixture from Vegetation Section of this manual.
  - Do not excavate soils that comply with infiltration standards for treatment in order to install engineered soil media.
  - Compost shall not be used as organic matter. Acceptable organic soil amendments or matter shall include sphagnum peat, wood derivatives, or media amendments such as zero-valent iron and/or drinking water treatment residuals (alum) to enhance phosphorus sorption.
- Pea Gravel
  - Shall consist of ⅜" to ¾" size gravel conforming to gradation listed in Section M.01.06-Keystone and M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of pea gravel) $\leq 5D_{85}$ (of engineered soil media) and D_{50} (of pea gravel) $\leq 25D_{50}$ (of engineered soil media).

- Gravel Sump
  - Shall be in accordance with Section M.01.07-Filter Stone and M.01.09, Table I, Column V of the RIDOT Standards.
- Underdrain (perforated and non-perforated pipe sections)
  - Polyethylene or polyvinyl pipe.
- Filter Fabric
  - Shall be non-woven, comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for subsurface drainage applications.
- Liner
  - If used, shall be a 30 mil (minimum) HDPE or PVC liner.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Curbing (for Overflow Weirs or Check Dams)
  - If used, granite or concrete curbing shall conform to Section 906 of the RIDOT Standards.
  - If used, shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List as a fabric suitable for underdrain applications.

Underlying Soils Conditions & Design Infiltration Rate

- Existing infiltration rates and in-situ conditions of underlying soils will determine if the planter can be designed to achieve infiltration, partial infiltration, or require an impermeable liner.
- Complete in-situ soil testing in accordance with requirements in the Planning Section of this manual.
- If in-situ infiltration rates exceed 0.5 inch per hour and adequate separation to SHGT/bedrock exists, the planter can be designed to infiltrate without the need of an underdrain system. These types of planters are referred to as Infiltration Planters.
- If in-situ infiltration rates are less than 0.5 inch per hour but adequate separation to SHGT/ bedrock exists, design planter with an underdrain system. If adequate separation to SHGT/bedrock does not exist or horizontal setbacks cannot be met, install with a liner. These types of planters containing an underdrain system are referred to as Flow-Through Planters.
- The design infiltration rate used shall be half the field-derived value or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use a design infiltration rate of 0.52 inches per hour if a loam surface layer is used.

Groundwater & Bedrock Separation

- For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
  - Install an impermeable liner at the bottom of the gravel sump if adequate separation from the bottom of the engineered soil media to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs, or in locations where contaminated soils exist. Refer to RISDISM Section 5.5.1 and 5.5.4 guidance. Lined systems shall have under drains.
- Reductions in the groundwater separation distance from the top of the engineered soil media may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and

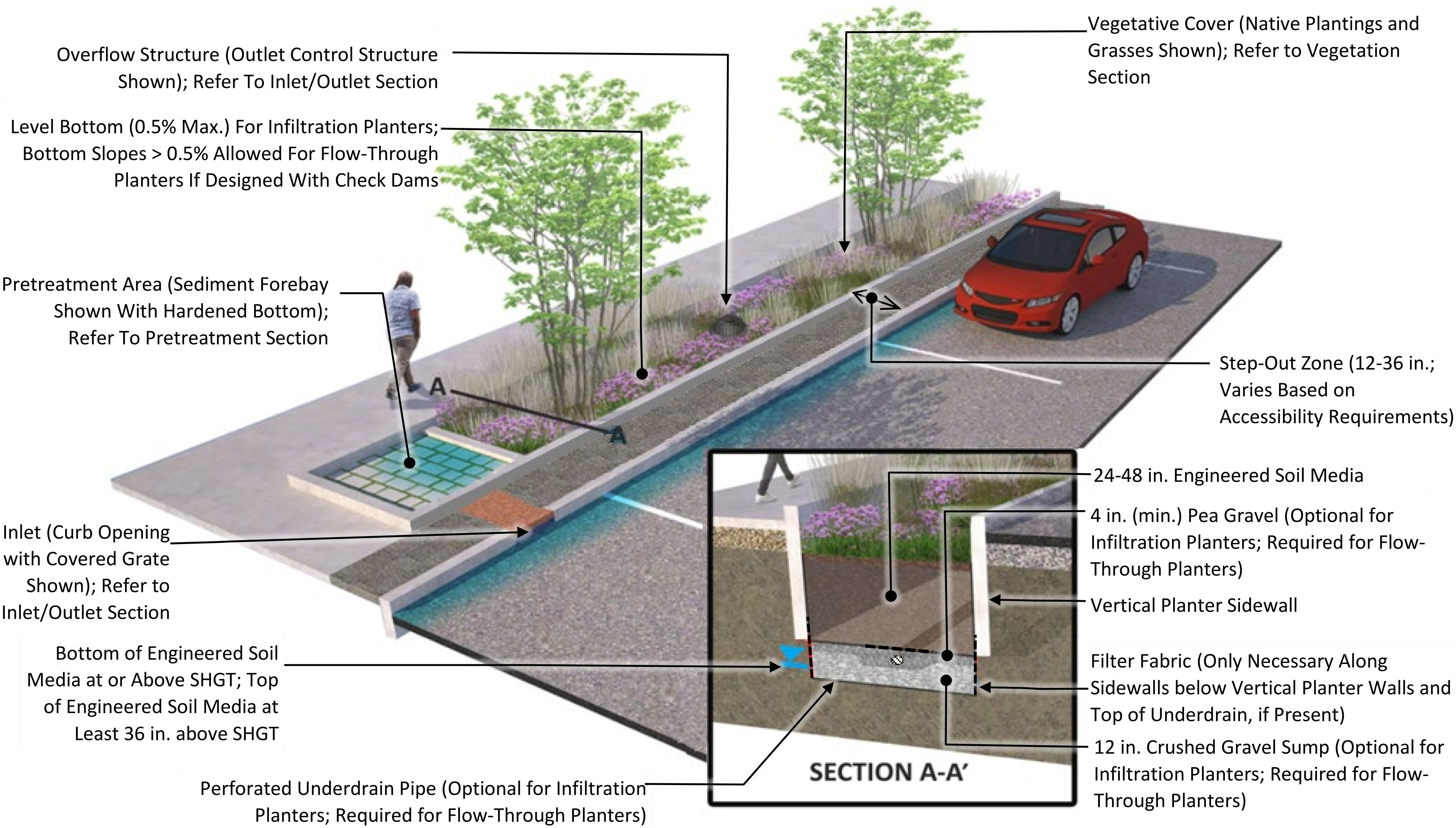
RIDEM/CRMC. Engineered soil media shall not be placed below SHGT.
    - Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
    - Redevelopment areas where the groundwater is classified as "GB."

Outlet & Overflow

- Bioretention parking lane adjacent planters designed off-line are typically sized to handle only the WQV.
    - If the planter is designed to infiltrate and meets the infiltration criteria, an outlet is not required. Once the system has reached its capacity (i.e., once the STU is full), additional flow will bypass the planter. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.
- Bioretention parking lane adjacent planters designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
    - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
    - Outlets are typically a stabilized spillway, gabion berm, concrete weir, curb cut opening, precast concrete structure, or polyethylene/polyvinyl chloride riser structure.
- If used, underdrains can connect to a downstream drainage system or daylight at an approved discharge point.

Other Considerations

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner or closed bottom of the system, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.
- If bottom of the planter has a slope greater than 0.5 percent, install check dams or consider designing as a terraced system with relatively flat bottoms in each cell.
    - Check dams must be evenly spaced and no more than six to 12 inches high.
    - Check dams that are designed for infiltration planters must not be constructed of porous materials like gabions, as water must sufficiently pond behind each check dam and be forced to infiltrate.
    - Permeable weirs (e.g., gabion weirs) must be avoided in areas that receive high sediment loads. Utilize weirs constructed from concrete or granite curbing.
- Roadway stability can be a design issue when installing bioretention planters along roadways. It may be necessary to provide a vertical impermeable barrier to keep water from saturating the road's sub-base that is capable of supporting H-20 loads.
- Filter fabric shall be placed along the sidewalls of the STU to help direct the water flow downward, reduce lateral flows, and to reduce lateral soil migration. This is critical when installing STU in a median strip or adjacent to a roadway or parking lot.
- Site shall be designed with readily available access to all site features for maintenance.
- Surface slope downgradient from infiltrating STUs shall be less than 15% for a distance of 50 feet.



Overflow Structure (Outlet Control Structure Shown); Refer To Inlet/Outlet Section
Level Bottom (0.5% Max.) For Infiltration Planters; Bottom Slopes > 0.5% Allowed For Flow-Through Planters If Designed With Check Dams
Vegetative Cover (Native Plantings and Grasses Shown); Refer to Vegetation Section
Pretreatment Area (Sediment Forebay Shown With Hardened Bottom); Refer To Pretreatment Section
Step-Out Zone (12-36 in.; Varies Based on Accessibility Requirements)
A
A
24-48 in. Engineered Soil Media
4 in. (min.) Pea Gravel (Optional for Infiltration Planters; Required for Flow-Through Planters)
Vertical Planter Sidewall
Inlet (Curb Opening with Covered Grate Shown); Refer to Inlet/Outlet Section
Bottom of Engineered Soil Media at or Above SHGT; Top of Engineered Soil Media at Least 36 in. above SHGT
Filter Fabric (Only Necessary Along Sidewalls below Vertical Planter Walls and Top of Underdrain, if Present)
12 in. Crushed Gravel Sump (Optional for Infiltration Planters; Required for Flow-Through Planters)
SECTION A-A'
Perforated Underdrain Pipe (Optional for Infiltration Planters; Required for Flow-Through Planters)

Figure 2.3.5.5 – Bioretention Curb Extension Planter; NACTO

Description

General Configuration

Curb Extension Planters are a type of bioretention facility that is located along the edge of roadway and protrudes from the existing curb line to form a vegetated "bump-out" area. These facilities are typically installed at street corners, mid-block locations, bus stops, and other curbside areas adjacent to on-street parking. These planters are frequently designed to infiltrate, typically referred to as infiltration planters, but can be designed with an underdrain to capture filtered water and assist with drainage from the system, typically referred to as flow-through planters. In certain situations, these planters can also be designed with impermeable liners.

Pollutant Removal Processes

Curb Extension Planters provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration (if not designed with underdrain system or impermeable liner):** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants typically present in stormwater runoff.
- **Adsorption:** Designed additives in engineered soil media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Curb Extension Planters are ideal within roadway right-of-way areas where parking lanes, travel lanes, or roadway shoulders can be reduced in width.
  - These curbside planters are also ideal for traffic calming purposes. When located at crosswalks, they provide a pedestrian safety benefit by reducing the street crossing distance.

- Curb Extension Planters are suitable for urban and ultra-urban areas and can be sized and modified easily to optimize infiltration rate in constrained spaces (e.g., flexible depth, edge construction, and vegetation).
- Locate where:
  - The topography allows the design of planter cell bottoms to have a maximum slope of 0.5% (or where terraced bottoms can be created or check dams used to reduce the effective slope of the cell bottoms to 0.5% or less to minimize flow velocity and promote filtration).
  - For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
  - The minimum horizontal setbacks, as presented in Table 1.2.2 of this manual, can be met when designing planters to infiltrate.
    - Planters, however, can be constructed within setbacks if designed appropriately with an impermeable barrier to mitigate water migration.
  - Snow storage will not occur within the planter.
  - Pedestrian access and capacity can be maintained. Planters must not encroach upon clear walking paths, and cannot impede designated accessible parking spaces or loading zones.
    - If pedestrian activity is moderate to high, maintain 8 feet (minimum) of clear width between the edge of the planter and the building or property line; if pedestrian activity is low, maintain 5-feet (minimum).

Key Considerations

Feasibility

- Unlined systems: Bottom of filter is at or above SHGT/bedrock and the top of filter is at least 3 feet above SHGT/bedrock.
  - If in-situ infiltration rates of underlying soils exceed 0.5 inch per hour, planter does not require an underdrain system.
  - If in-situ infiltration rates of underlying soils are less than 0.5 inch per hour, planter requires an underdrain system.
- Lined systems: When bottom of filter is not at or above SHGT/bedrock, top of filter is not at least 3 feet above SHGT/bedrock, soils are contaminated, or horizontal separation from adjacent building foundations cannot be met; planter requires a liner and an underdrain system.

Pretreatment

- Pretreatment measure(s) shall have a volume of 25% of WQV, or equivalent by alternative approved pretreatment device.

Treatment

- Total system (including pretreatment) must hold 75% of the WQV.
- Engineered soil media shall be 2-4 feet deep with a mulch surface layer (when not planted with grasses), and the system shall allow for 6-12 inches of ponding.

Vegetation

- Use Vegetation Section of this manual.
- Consider long-term maintenance capabilities and limitations.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the planter in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales (in locations where adequate space exists), deep-sump catch basins, and/or proprietary treatment devices.

Inlet

- Runoff can be introduced to the planter through overland flow, curb cuts, inlet structures, swales/channels, and/or pipes.
- Provide stable and non-erosive energy dissipating devices at inflow locations where inflow velocities are considered erosive.
- In locations adjacent to sidewalks or pedestrian use areas where raised curbing or edging is used along the edge of the planter to prevent incursion by pedestrians, install notches intermittently along the raised curbing or edging to allow runoff from adjacent sidewalk area to enter the planter. Notches shall be 4 inches in width to facilitate maintenance while also minimizing the risk that people get their feet caught in the openings.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.
  - Design inlet to resist incursion by vehicles and bicycles.

Underdrain

- Install underdrains when the planter:
  - Is in native soil that has an infiltration rate less than 0.5 inch per hour;
  - Does not meet vertical separation distance to SHGT/bedrock and must be lined; and/or
  - Is within a horizontal setback zone per Table 1.2.2 of this manual and must be lined; and/ or
  - Is within a LUHPPL or area of contaminated soils and must be lined.
- Minimum underdrain pipe diameter: 4 inches
- Minimum underdrain collector slope: 0.5%
- Install perforated underdrain in pea gravel layer with a minimum of 2 inches of pea gravel installed above and below the underdrain and within 2 feet (on both sides) of the underdrain (i.e., underdrain zone). The typical pea gravel thickness outside of the underdrain zone is 4 inches. The pea gravel layer shall be underlain by a gravel sump with a 12-inch typical thickness with exception to section of gravel sump within underdrain zone. The thickness of the gravel sump in that location may be reduced to accommodate the increased thickness of the underdrain's pea gravel layer.
  - *NOTE: If the planter is designed without an underdrain, pea gravel and gravel sump are optional.*
- Lay underdrain such that perforations are on bottom of pipe.
- Bottom of underdrain shall be installed with not less than 4 inches above SHGT.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure, and/or daylights.

- Other considerations when designing/installing underdrains:
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
  - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain collector pipe; one at the upstream end and one at the downstream end.
  - Cleanouts shall be at least 4 inches in diameter, be non-perforated, and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be highly visible.
  - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Planter Filter Bed (Bottom) Area
  - Size the filter bed (bottom) area to meet the minimum required area in accordance with Section 5.5.4 of the RISDISM.
- Maximum Loading Ratio
  - The maximum loading ratio of contributing impervious drainage area to planter bed area is 10:1.
- Volume
  - Size the entire facility (including pretreatment and void space in filter media) to hold 75% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event. Assume 33% void space when computing the amount of available storage within the engineered soil media.
  - Multiple planters may be linked or sequenced to prevent overloading on a single planter.
  - Depth: Engineered soil media shall have a depth of 24 inches to 48 inches as necessary to accommodate the WQV and subsurface conditions.
- Ponding Depth
  - Maximum for WQV: 12 inches.
  - Maximum for Overflow Events: 2 feet.
    - Planters exceeding 12 inches in depth between adjacent sidewalk/ground surfaces must be designed with low-height barriers (e.g., raised 4-inch high curbing, edging, or low fencing less than 24-inches tall) to mitigate fall risks.
  - Ponded water shall drain within 48 hours or less. Underdrains can be added, as necessary, to accommodate drain time requirement.
- Bottom Width
  - Minimum: 4 feet (ideal); narrower planters may be allowed with widths no less than 2.5 feet; however, design must consider plant health, water quality performance, and implementation costs.
- Bottom Slope
  - Design bottom of infiltration planters to be flat or have a maximum slope of 0.5% to promote infiltration and even distribution.
  - Flow-through planters with bottom slopes greater than 0.5% must be designed with check dams or terraced/stepped planter cells.
- Side Slope
  - Where adequate space exists to provide graded side slopes, 3(H):1(V) slopes or flatter are preferred especially on grassed slopes where mowing is required. Stabilize the

  - slope with turf reinforcement matting if the drainage area upstream of the slope could result in erosive conditions.
  - Where space is limited and side slopes are not practical, drop curbs or similar precast structures should be used to create stable, vertical planter side walls. For safety purposes, drop curb designs without safety barriers should not exceed a vertical drop of more than 12 inches. If vertical drops of greater than 12 inches are required, safety barriers are required.
    - When the vertical wall is located on the street side, the wall should be designed to support vehicular loads.

Materials

- Mulch (if planter is not grassed)
  - 2 to 4 inches of shredded hardwood bark mulch, aged for 6 months minimum.
  - In some situations, designers may consider alternative surface covers such as river stone. Alternative covers will require approval from RIDOT.
- Vegetation
  - Specify vegetation in accordance with the Vegetation Section in this manual.
  - Establish a dense vegetative cover or adequately stabilized landscaped surface throughout planter and any up-gradient areas disturbed by construction before runoff can be accepted into the facility.
  - Plant vegetation and provide a planting plan in accordance with Section 5.5.5 and Appendix B of the RISDISM.
  - Do not plant trees, shrubs, or grasses with a mature vegetation height exceeding 24-inches above the surrounding sidewalk or pavement surface in Curb Extension Planters installed within medians, near intersections, or near pedestrian crossings to avoid obstruction of sight lines.
  - Trees shall not be planted in flow-through or lined planters. Comply with RIDOT Standard Detail 50.1.0 for tree installation as appropriate.
  - Trees installed within planters located away from medians, intersections, or pedestrian crossings must allow for a mature tree height and branching clearance that provides approximately 14 feet of clearance of adjacent bicycle facilities, pedestrian paths, and travel lanes.
  - A native grass/wildflower seed mix can be used as an alternative to groundcover plantings.
- Engineered Soil Media
  - Select an engineered soil media mixture from Vegetation Section of this manual. Consider in-situ conditions, vegetation proposed, and/or target pollutants. Mixture composition shall have a pH of 5.2 to 7.0.
  - Do not excavate soils that comply with infiltration standards for treatment in order to install engineered soil media.
  - Compost shall not be used as organic matter. Acceptable organic soil amendments or matter shall include sphagnum peat, wood derivatives, or media amendments such as zero-valent iron and/or drinking water treatment residuals (alum) to enhance phosphorus sorption.
- Pea Gravel
  - Shall consist of ⅜” to ¾” size gravel conforming to gradation listed in Section M.01.06-Keystone and M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of pea gravel) ≤ $5D_{85}$ (of engineered soil media) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of engineered soil media).

- Gravel Sump
  - Shall be in accordance with Section M.01.07-Filter Stone and M.01.09, Table I, Column V of the RIDOT Standards.
- Underdrain (perforated and non-perforated pipe sections)
  - Polyethylene or polyvinyl pipe.
- Filter Fabric
  - Shall be non-woven, comply with Section 703.02.2 of the RIDOT Standards, and shall be listed on the RIDOT Approved Materials List as a fabric suitable for subsurface drainage applications.
- Liner
  - If used, shall be a 30 mil (minimum) HDPE or PVC liner.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Curbing (for Overflow Weirs or Check Dams)
  - If used, granite or concrete curbing shall conform to Section 906 of the RIDOT Standards.
- Turf Reinforcement Matting

  If used, shall be a woven material included on the RIDOT Approved Materials List that exceeds the design velocity of the design storm and allows for the growth of the proposed vegetative species.

Underlying Soils Conditions & Design Infiltration Rate

- Existing infiltration rates and in-situ conditions of underlying soils will determine if the planter can be designed to achieve infiltration, partial infiltration, or require an impermeable liner.
- Complete in-situ soil testing in accordance with requirements in the Planning Section of this manual.
- If in-situ infiltration rates exceed 0.5 inch per hour and adequate separation to SHGT/bedrock exists, the planter can be designed to infiltrate without the need of an underdrain system. These types of planters are referred to as Infiltration Planters.
- If in-situ infiltration rates are less than 0.5 inch per hour but adequate separation to SHGT/ bedrock exists, design planter with an underdrain system. If adequate separation to SHGT/bedrock does not exist or horizontal setbacks cannot be met, install with a liner. These types of planters containing an underdrain system are referred to as Flow-Through Planters.
- The design infiltration rate used shall be half the field-derived value or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use a design infiltration rate of 0.52 inches per hour if a loam surface layer is used.

Groundwater & Bedrock Separation

- For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
  - Install an impermeable liner at the bottom of the gravel sump if adequate separation from the bottom of the engineered soil media to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs, or in locations where contaminated soils exist. Refer to RISDISM Section 5.5.1 and 5.5.4 guidance. Lined systems shall have under drains.
- Reductions in the groundwater separation distance from the top of the engineered soil media may be permissible for the

following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. Engineered soil media shall not be placed below SHGT.

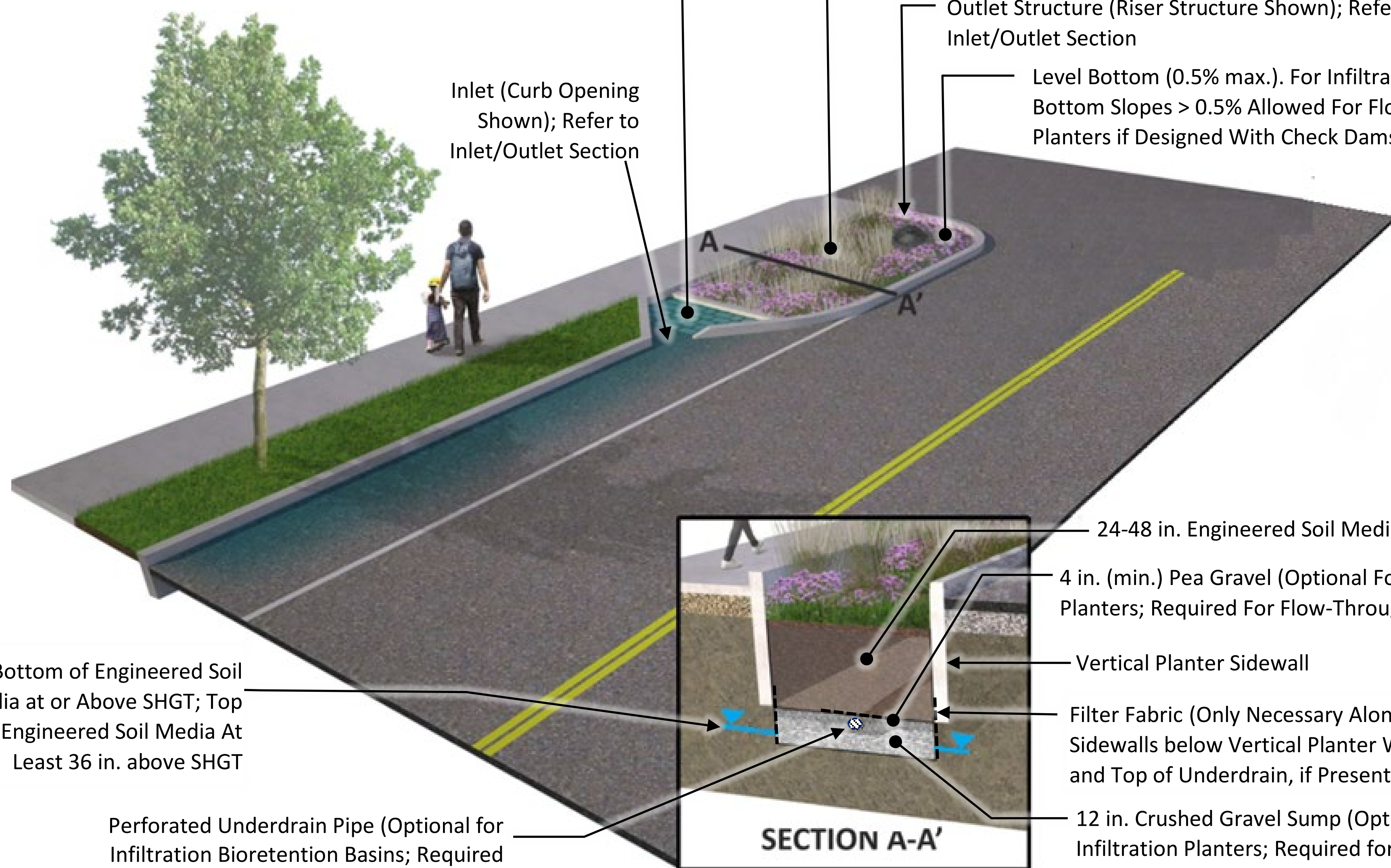
- Sites with existing constraints that prevent achievement of minimum separation requirements, and there is little risk to adversely impact groundwater quality.
- Redevelopment areas where the groundwater is classified as "GB."

Outlet & Overflow

- Bioretention curb extension planters designed off-line are typically sized to handle only the WQV.
  - If the planter is designed to infiltrate and meets the infiltration criteria, an outlet is not required. Once the system has reached its capacity (i.e., once the STU is full), additional flow will bypass the planter. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.
- Bioretention curb extension planters designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets are typically a stabilized spillway, gabion berm, concrete weir, curb cut opening, precast concrete structure, or polyethylene/polyvinyl chloride riser structure.
- If used, underdrains can connect to a downstream drainage system or daylight at an approved discharge point.

Other Considerations

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner or closed bottom of the system, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.
- If bottom of the planter has a slope greater than 0.5 percent, install check dams or consider designing as a terraced system with relatively flat bottoms in each cell.
  - Check dams must be evenly spaced and no more than six to 12 inches high.
  - Check dams that are designed for infiltration bioretention curb extension planters must not be constructed of porous materials like gabions, as water must sufficiently pond behind each check dam and be forced to infiltrate.
  - Permeable weirs (e.g., gabion weirs) must be avoided in areas that receive high sediment loads. Utilize weirs constructed from concrete or granite curbing.
- Roadway stability can be a design issue when installing bioretention planters along roadways. It may be necessary to provide a vertical impermeable barrier to keep water from saturating the road's sub-base that is capable of supporting H-20 loads.
- Filter fabric shall be placed along the sidewalls of the STU to help direct the water flow downward, reduce lateral flows, and to reduce lateral soil migration. This is critical when installing STU in a median strip or adjacent to a roadway or parking lot.
- Site shall be designed with readily available access to all site features for maintenance.
- Surface slope downgradient from infiltrating STUs shall be less than 15% for a distance of 50 feet.



Pretreatment Area (Sediment Forebay Shown with Hardened Bottom); Refer To Pretreatment Section
Vegetative Cover (Native Plantings & Grasses Shown); Refer To Vegetation Section
Outlet Structure (Riser Structure Shown); Refer to Inlet/Outlet Section
Level Bottom (0.5% max.). For Infiltration Planters; Bottom Slopes > 0.5% Allowed For Flow-Through Planters if Designed With Check Dams
Inlet (Curb Opening Shown); Refer to Inlet/Outlet Section
A
A'
24-48 in. Engineered Soil Media
4 in. (min.) Pea Gravel (Optional For Infiltration Planters; Required For Flow-Through Planters)
Vertical Planter Sidewall
Filter Fabric (Only Necessary Along Sidewalls below Vertical Planter Walls and Top of Underdrain, if Present)
12 in. Crushed Gravel Sump (Optional For Infiltration Planters; Required for Flow-Through Planters)
Bottom of Engineered Soil Media at or Above SHGT; Top of Engineered Soil Media At Least 36 in. above SHGT
Perforated Underdrain Pipe (Optional for Infiltration Bioretention Basins; Required for Flow-Through Bioretention Basins)
SECTION A-A'

Figure 2.3.5.6 – Grassed Bioretention Swale; Cranston, RI

Description

General Configuration

Bioretention swales are shallow, gently sloped, vegetated/landscaped open channel systems designed to convey and filter storm water. Bioretention swales have an engineered soil media below the surface of the basin that facilitates stormwater filtration and vegetative growth. Bioretention swales are frequently designed to infiltrate, but can be designed with an underdrain to capture filtered water and assist with drainage from the system. In certain situations, bioretention swales can also be designed with impermeable liners. Bioretention swales are planted with dense, native grasses or plants that function to slow the flow of runoff and encourage filtration.

Pollutant Removal Processes

Bioretention swales provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration (if not designed with underdrain system or impermeable liner):** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants commonly present within stormwater runoff.
- **Adsorption:** Designed additives in filter media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Bioretention swales are an alternative to bioretention basins where the site requires a sloped base or must convey runoff between points.
- Potential locations include unused right-of-way areas such as medians, along shared-use paths, and along borders or medians of parking lots. Consider RIDOT requirements when placing a bioretention swale along a roadway.
- Bioretention swales are suitable in urban and rural settings.
- Locate where:
  - The topography allows the design of the bioretention swale channel bottom to have a longitudinal slope of 2% or less.

Bioretention swales can be installed on slightly steeper slopes if designed appropriately with check dams to reduce the effective slope of the bioretention swale bottom to 2.0% or less to minimize flow velocity and promote filtration.

- The bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT)/ bedrock and the top of the soil media is at least 3 feet above SHGT.
- The minimum horizontal setbacks, as presented in Table 1.2.2 of this manual, are achieved when the bioretention swale is unlined.
- Snow storage will not occur within the bioretention swale.
- There is a low likelihood that pedestrian traffic will cut across the bioretention swale.
- The contributing drainage area is five acres or less, unless the flow enters the bioretention swale via sheet flow along a linear feature such as a road.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the bioretention swale in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include vegetative filter strips, sediment forebays, pretreatment swales, deep-sump catch basins, and/or proprietary treatment devices.

Inlet

- Runoff can be introduced to the bioretention swale through

Key Considerations

Feasibility

- Unlined Bioretention Swales: Bottom of filter is at or above SHGT/bedrock and the top of filter is at least 3 feet above SHGT/bedrock.
  - If in-situ infiltration rate of underlying soils: exceeds 0.5 inch per hour, an underdrain system is not required; is less than 0.5 inch per hour, an underdrain system is required.
- Lined Bioretention Swales: When bottom of filter is not at or above SHGT/bedrock, top of filter is not at least 3 feet above SHGT/bedrock, soils are contaminated, or horizontal separation from adjacent building foundations cannot be met; bioretention swale requires a liner and an underdrain.
- Maximum 2% longitudinal slope without check dams; 6% with check dams.

Conveyance

- Non-erosive (3.0 to 5.0 feet per second) peak velocity for the 1-year storm.
- Safe conveyance of the 10-year storm.
- Side slopes 3(H):1(V) preferred (2(H):1(V) allowed in space constrained areas).
- Maximum allowable temporary ponding time is 48 hours.

Pretreatment

- Pretreatment measure(s) shall have a volume of 10% of WQV, or equivalent by alternative approved pretreatment device.

Treatment

- Total system (including pretreatment) must hold 75% of the WQV.
- Bottom width no greater than 8 feet, but no less than 2 feet.
- Engineered soil media shall be 2-4 feet deep with a mulch surface layer (when not planted with grasses); 12 inches of ponding depth allowed.

Vegetation

- Use Vegetation Section of this manual.
- Consider long-term maintenance capabilities and limitations

overland flow, curb-cuts, inlet structures, swales/channels, and/or pipes.

- Provide stable and non-erosive energy dissipating devices at inflow locations where inflow velocities are considered erosive.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.
  - Design inlet to resist incursion by vehicles and bicycles.

Underdrain

- Install underdrains when the bioretention swale:
  - Is in native soil that has an infiltration rate less than 0.5 inch per hour;
  - Does not meet vertical separation distance to SHGT/bedrock and must be lined; and/or
  - Is within a horizontal setback zone per Table 1.2.2 of this manual and must be lined; and/ or
  - Is within a LUHPPL or area of contaminated soils and must be lined.
- Minimum underdrain pipe diameter: 4 inches
- Minimum underdrain collector slope: 0.5%
- Install perforated underdrain in pea gravel layer with a minimum of 2 inches of pea gravel installed above and below the underdrain and within 2 feet (on both sides) of the underdrain (i.e., underdrain zone). The typical pea gravel thickness outside of the underdrain zone is 4 inches. The pea gravel layer shall be underlain by a gravel sump with a 12-inch typical thickness with exception to section of gravel sump within underdrain zone. The thickness of the gravel sump in that location may be reduced to accommodate the increased thickness of the underdrain's pea gravel layer.
  - NOTE: If the bioretention basin is designed without an underdrain, pea gravel and gravel sump are optional.
- Lay underdrain such that perforations are on bottom of pipe.
- Bottom of underdrain shall be installed with not less than 4 inches above SHGT.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure, and/or daylights.
- Other considerations when designing/installing underdrains:
  - Provide a marking stake and an animal guard for underdrains that daylight at grade.
  - If designed with laterals, space collection laterals every 25 feet or less.
- Include a minimum of two observation wells/cleanouts for each underdrain; one at the upstream end and one at the downstream end.
  - Cleanouts shall be at least 4 inches in diameter, be non-perforated, and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be highly visible.
  - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Bioretention Swale Filter Bed (Bottom) Area
  - Size the filter bed (bottom) area to meet the minimum required area in accordance with Section 5.7.4 of the RISDISM.

- Volume
  - Size the entire facility (including pretreatment and void space in filter media) to hold 75% of the WQV below the elevation of any outlet and to fully dewater within 48 hours after a storm event.
    - Assume 33% void space when computing the amount of available storage within the engineered soil media.
    - Underdrains can be added, as necessary, to accommodate drain time requirement.
  - Depth: Engineered soil media shall have a depth of 24 inches to 48 inches as necessary to accommodate the WQV and subsurface conditions.
  - Install check dams as necessary to retain the water quality volume and to accommodate slopes greater than 2%. The volume of water retained behind check dams shall be included in the system volume calculation.
- Ponding Depth
  - Maximum for WQV: 12 inches at longitudinal mid-point of swale; 18 inches at downstream end of swale.
  - Minimum for Overflow Events: 6 inches above the 10-year storm water surface profile.
  - Maximum for Overflow Events: 3 feet
- Bottom Width
  - Minimum: 2 feet
  - Maximum: 8 feet
- Bottom Slope
  - Bioretention swales shall have a maximum longitudinal slope of 2% without check dams provided flow velocities are non-erosive (e.g., flow velocities should not exceed 3 feet per second (ft/sec) for grassed surfaces and 1 ft/sec for mulched surfaces).
  - Bioretention swales can have slightly steeper slopes (up to 6%) if designed with check dams.
  - Check dams must be designed to reduce the effective slope of the bottom of the bioretention swale to 2.0% or less for optimum water quality performance.
- Side Slope
  - 3(H):1(V) slopes or flatter are preferred especially on grassed slopes where mowing is required. In ultra-urban locations or space constrained areas; side slopes of 2(H):1(V) may be utilized if properly designed to account for erosion and slope stability. Stabilize the slope with turf reinforcement matting or equivalent if the slope could potentially erode.
- Water Velocity
  - For WQ Design Storm: 1.5 ft/sec (maximum)
  - Peak Flow Design Storm: 5.0 ft/sec (maximum)

Materials

- Alternative Surface Cover
  - In some situations when swale is not grassed, designers may consider alternative surface covers such as river stone. Do not use mulch surface for bioretention swales. Alternative covers require approval from RIDEM, RIDOT, or CRMC.
    - Use 3 to 4 inches of washed river stone, or smooth, crushed stone sized to resist movement for the 10-year storm.
- Vegetation
  - Specify vegetation in accordance with the Vegetation Section in this manual.
    - Vegetation must form a deep root system or form dense sod to resist scouring; have a high stem density

to help slow water and facilitate sedimentation; to be tolerant to flooding and be able to survive and continue to grow after the inundation period. If to be used near a road that is subject to winter salt operations, the plants must also be salt tolerant.
    - Establish a dense vegetative cover or adequately stabilized landscaped surface throughout swale and any up-gradient areas disturbed by construction before runoff can be accepted into the facility.
    - Plant vegetation and provide a planting plan in accordance with Section 5.5.5 and Appendix B of the RISDISM.
    - Trees should be planted primarily along the perimeter of the facility and with 15 feet of separation from underdrain piping.
    - Trees shall not be planted in lined STUs.
    - Do not plant trees, shrubs, or grasses with a mature vegetation height exceeding 24-inches above the surrounding sidewalk or pavement surface in bioretention swales within medians, near intersections, or near pedestrian crossings to avoid obstruction of sight lines.
    - Trees installed within bioretention swales located away from medians, intersections, or pedestrian crossings must allow for a mature tree height and branching clearance that provides approximately 14 feet of clearance if installed adjacent to bicycle facilities, pedestrian paths, and travel lanes.
- Engineered Soil Media
    - Select an engineered soil media mixture from Vegetation Section of this manual.
    - Do not excavate soils that comply with infiltration standards for treatment in order to install engineered soil media.
    - Compost shall not be used as organic matter. Acceptable organic soil amendments or matter shall include sphagnum peat, wood derivatives, or media amendments such as zero-valent iron and/or drinking water treatment residuals (alum) to enhance phosphorus sorption.
- Check Dams
    - If used, construct of gabions, granite or concrete curbing, or precast/poured-in-place concrete. If constructed of granite or concrete curbing, curbing shall conform to Section 906 of the RIDOT Standards.
- Pea Gravel
    - Shall consist of ⅜" to ¾" size gravel conforming to gradation listed in Section M.01.06-Keystone and M.01.09, Table I, Column III of the RIDOT Standards.
    - D_{15} (of pea gravel) ≤ $5D_{85}$ (of engineered soil media) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of engineered soil media).
- Gravel Sump
    - Shall be in accordance with Section M.01.07-Filter Stone and M.01.09, Table I, Column V of the RIDOT Standards.
- Filter Fabric
    - Shall be non-woven, comply with Section 703.02.2 of the RIDOT Standards, and shall be listed on the RIDOT Approved Materials List as a fabric suitable for subsurface drainage applications.
- Poured-in-place Concrete
    - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Underdrain (perforated and non-perforated pipe sections)
    - Polyethylene or polyvinyl pipe.
- Liner
    - If used, shall be a 30 mil (minimum) HDPE or PVC liner.

- Turf Reinforcement Matting
  - If used, shall be a woven material included on the RIDOT Approved Materials List that exceeds the design velocity of the design storm and allows for the growth of the proposed vegetative species.

Underlying Soils Conditions & Design Infiltration Rate

- Existing infiltration rates and in-situ conditions of underlying soils will determine if the bioretention swale can be designed to achieve infiltration, partial infiltration, or require an impermeable liner.
- Complete in-situ soil testing in accordance with requirements in the Planning Section of this manual.
- If in-situ infiltration rates exceed 0.5 inch per hour and adequate separation to SHGT/bedrock exists, the bioretention swale can be designed to infiltrate without the need of an underdrain system.
- If in-situ infiltration rates are less than 0.5 inch per hour and adequate separation to SHGT/ bedrock exists, design bioretention swale with an underdrain system. If adequate separation to SHGT/bedrock does not exist or horizontal setbacks cannot be met, install with a liner.
- The design infiltration rate shall be half the field-derived value of the most restrictive in-situ soil layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use a design infiltration rate of 0.52 inches per hour if a loam surface layer is used.

Groundwater & Bedrock Separation

- For unlined systems, the bottom of the engineered soil media is at or above the seasonal high groundwater table (SHGT) and bedrock and the top of the soil media is at least 3 feet above SHGT and bedrock.
  - Install an impermeable liner at the bottom of the gravel sump if adequate separation from the bottom of the engineered soil media to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs, or in locations where contaminated soils exist. Refer to RISDISM Section 5.5.1 and 5.5.4 guidance. Lined systems shall have underdrains.
- Reductions in the groundwater separation distance from the top of the engineered soil media may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. Engineered soil media shall not be placed below SHGT.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and with little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as “GB.”

Outlet & Overflow

- Bioretention swales must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets are typically a stabilized spillway, gabion berm, concrete weir, curb cut opening, precast concrete structure, or polyethylene/polyvinyl chloride riser structure.
- Culverts can be used to maintain bioretention swale

connectivity where a driveway, walkway, or roadway crosses the bioretention swale. The culvert must be sized sufficiently to pass the 10-year design storm (at a minimum) without causing overtopping.

Other Considerations

- If designing a lined system in a location where SHGT is located at or above the bottom of the liner or closed bottom of the system, complete a buoyancy analysis to ensure buoyancy of the system will not be an issue.
- If bottom of the bioretention swale has a longitudinal slope greater than 2 percent, install check dams or consider designing as a terraced system with relatively flat bottoms in each cell.
  - Check dams must be evenly spaced and shall be designed with a maximum height of 18 inches; height shall not exceed 1/2 the overall depth of swale.
  - Spacing of check dams shall be a function of both the longitudinal slope of the swale and the WQV that must be retained behind the dams. Space such that the upstream limit of ponding from one check dam is just below the downstream edge of the adjacent check dam.
  - Check dams that are designed to infiltrate (with no underdrain system) must not be constructed of permeable materials like gabions, as water must sufficiently pond behind each check dam and be forced to infiltrate.
  - Permeable weirs (e.g., gabion weirs) must be avoided in areas that receive high sediment loads. Utilize weirs constructed from concrete or granite curbing.
  - Anchor check dams into swale side slopes to prevent washout. Each side of the dam must extend 2-3 feet into the swale side slopes.
  - Protect downstream side of check dams from scour with stabilized surface protection measures.
- Roadway stability can be a design issue when installing bioretention swales along roadways. It may be necessary to provide a vertical impermeable barrier to keep water from saturating the road’s sub-base that is capable of supporting H-20 loads.
- Filter fabric shall be placed along the sidewalls of the STU to help direct the water flow downward, reduce lateral flows, and to reduce lateral soil migration. This is critical when installing STU in a median strip or adjacent to a roadway or parking lot.
- Site shall be designed with readily available access to all site features for maintenance.
- Surface slope downgradient from infiltrating STUs shall be less than 15% for a distance of 50 feet.

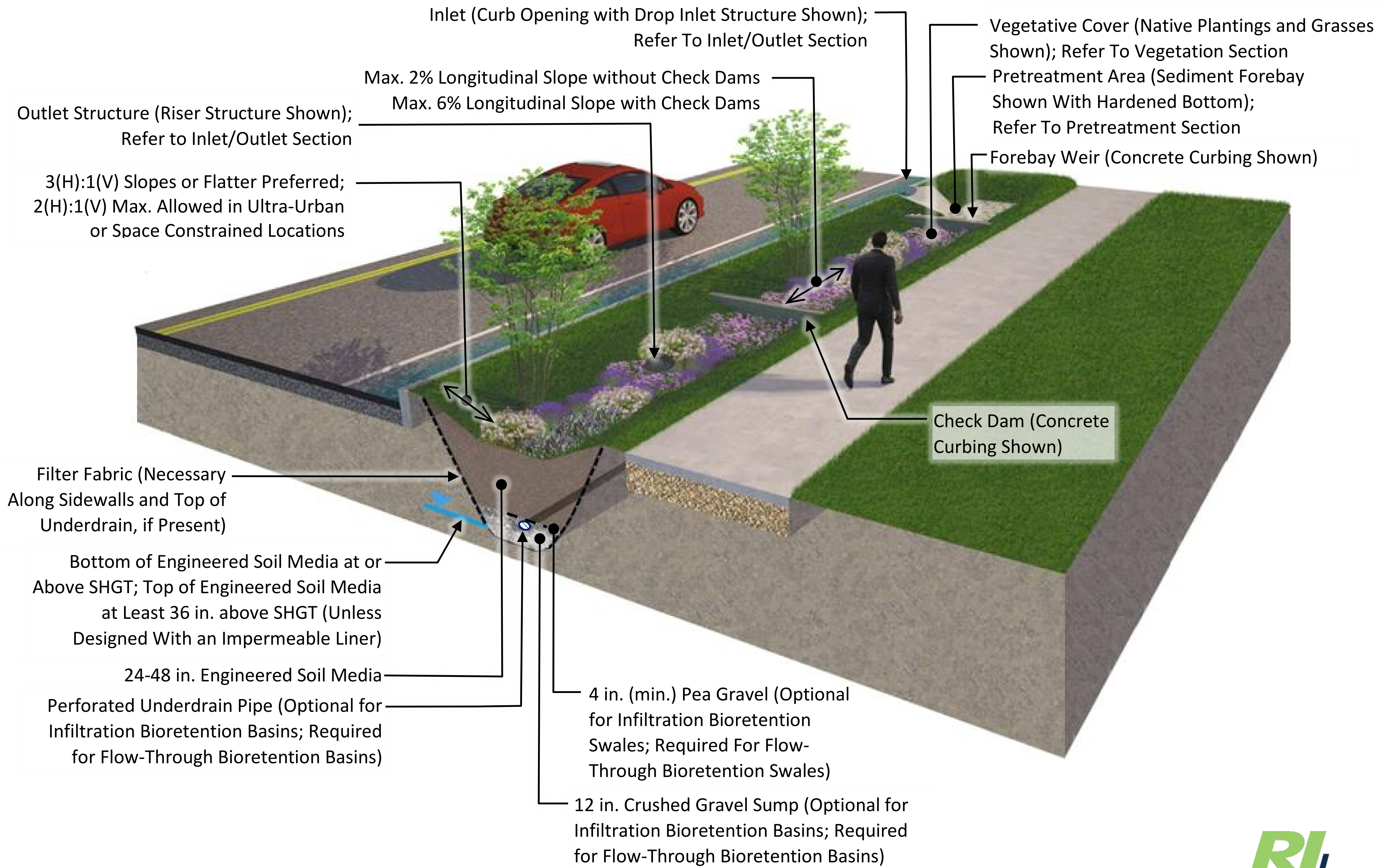

Inlet (Curb Opening with Drop Inlet Structure Shown); Refer To Inlet/Outlet Section
Vegetative Cover (Native Plantings and Grasses Shown); Refer To Vegetation Section
Max. 2% Longitudinal Slope without Check Dams
Max. 6% Longitudinal Slope with Check Dams
Pretreatment Area (Sediment Forebay Shown With Hardened Bottom); Refer To Pretreatment Section
Outlet Structure (Riser Structure Shown); Refer to Inlet/Outlet Section
Forebay Weir (Concrete Curbing Shown)
3(H):1(V) Slopes or Flatter Preferred; 2(H):1(V) Max. Allowed in Ultra-Urban or Space Constrained Locations
Check Dam (Concrete Curbing Shown)
Filter Fabric (Necessary Along Sidewalls and Top of Underdrain, if Present)
Bottom of Engineered Soil Media at or Above SHGT; Top of Engineered Soil Media at Least 36 in. above SHGT (Unless Designed With an Impermeable Liner)
24-48 in. Engineered Soil Media
Perforated Underdrain Pipe (Optional for Infiltration Bioretention Basins; Required for Flow-Through Bioretention Basins)
4 in. (min.) Pea Gravel (Optional for Infiltration Bioretention Swales; Required For Flow-Through Bioretention Swales)
12 in. Crushed Gravel Sump (Optional for Infiltration Bioretention Basins; Required for Flow-Through Bioretention Basins)

Figure 2.3.5.7 – Tree Filter

Description

General Configuration

Tree filters are open-bottomed systems that house one or more trees and are filled with engineered soil media atop an optional drainage layer. Tree filters collect, temporarily store and filter stormwater runoff through the soil and drainage layers, and the tree provides pollutant uptake.

Pollutant Removal Processes

Tree filters provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration:** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants commonly present within stormwater runoff.
- **Adsorption:** Designed additives in filter media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Tree filters are best located in narrow right-of-way areas where space is limited.
- Potential locations include medians, streetscapes (e.g., between the curb and sidewalk), shoulders and along shared-use paths.
- Tree filters are suitable in ultra-urban settings.
- Locate where:
    - The structural integrity of the roadbed material will not be compromised;
    - The bottom of the engineered soil media is at or above the SHGT and bedrock and the top of the engineered soil media is at least 3 feet above SHGT;

- The minimum horizontal setbacks in Table 1.2.2 of this manual can be met when the tree filter is designed to infiltrate; and
- Snow storage will not occur atop the tree filter.

Key Considerations

Feasibility

- Bottom of filter is at or above SHGT/bedrock; top is at least 3 feet above SHGT/bedrock.
- Underdrain: Utilize an underdrain if infiltration rates of underlying soils are less than 0.5 inches per hour.
- Site shall be designed with readily available access to all STU features for maintenance.

Treatment

- Tree filter shall treat 75% of the WQV.

Vegetation (optional)

- Consider long-term maintenance capabilities and limitations.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the tree filter in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include interior concrete sediment collection chambers and exterior deep sump catch basins.
- Interior Concrete Sediment Collection Chambers
    - Shall be designed to overflow directly into the tree filter via a level overflow weir wall.
        - Elevation of overflow weir wall shall be sufficiently lower than gutter line to at least pass the WQV below the elevation of the gutter line.
    - Shall be equipped with a cover or with an overall tree filter grate.
    - Minimum depth: 4 feet from top of overflow weir wall.
    - Minimum bottom surface area: 6 square feet with no individual dimension (length or width) less than 2 feet.
    - Provide two 2-inch diameter seep holes (the lowest being 2 feet above interior bottom of collection chamber) along the weir wall.
- Deep Sump Catch Basin
    - If constructing a new catch basin, use a square catch basin structure, which shall directly abut the tree filter. The width of the outlet shall extend the full inside width of the catch basin structure. Outlet opening height shall be sufficient to convey the WQV, but shall not be less than 4 inches.
    - If utilizing an existing round catch basin structure, runoff can be conveyed to the tree filter via a pipe.
    - Minimum sump depth: 4 feet

Inlet

- Runoff can be introduced via a curb cut, drop inlet or a pipe from an upstream structure.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.
- Depth between inlet and top of engineered soil media shall be 2 inches or less and shall be designed to minimize erosion within the tree filter.

Underdrain

- Minimum diameter: 4 inches
- Minimum slope: 0.5%
- Install perforated underdrains in a bed of pea gravel with a minimum of 2 inches of pea gravel above and below the underdrain and within 2 feet (on both sides) of the underdrain (i.e., underdrain zone). Typical minimum pea gravel thickness outside of the underdrain zone is 4 inches. The pea gravel layer shall be underlain by a gravel sump with 12 inch (minimum) thickness.
    - In the underdrain zone the gravel sump will have a reduced thickness equal to the diameter of the underdrain.
    - The bottom of the underdrain shall not be less than 4 inches above SHGT.
    - Filter fabric shall be placed at the top of the pea gravel layer and the sides of pea gravel layer and gravel sump.
- Lay underdrain such that perforations are on bottom of pipe.
- Use solid (non-perforated) pipe sections and watertight joints wherever the underdrain system passes below berms, extends down steep slopes, connects to a drainage structure and/or daylights.
- Other considerations when designing/installing underdrains:
    - Provide a marking stake and an animal guard for underdrains that daylight at grade.
- Include a minimum of two observation wells/cleanouts for each underdrain; one at the upstream end and one at the downstream end.
    - Cleanouts shall be at least 4 inches in diameter, be non-perforated and extend to the surface. Cap cleanouts with a watertight removable cap. The cleanout shall be easily visible.
    - Provide one cleanout for every 1,000 square feet of surface area (at a minimum) or for every 250 linear feet of total pipe length in larger systems.

Dimensions

- Size the tree filter in accordance with Section 5.5.4 of the RISDISM.
- Volume
    - Size the facility to hold 75% of the WQV below the elevation of any outlet and fully dewater within 48 hours after a storm event. Multiple tree filters can be combined to meet water quality goals.
    - Assume 33% void space when computing the amount of available storage within the engineered soil media.
    - Engineered soil media shall have a depth of 24 to 48 inches, as necessary to accommodate treatment and also subsurface conditions for the needs of the selected tree species.
- Concrete Tree Trench Vault
    - Shall be a minimum of 18 inches deep below top of curb/sidewalk and shall be designed to support adjacent structures.
- Ponding Depth
    - Maximum for WQV: 6 inches
    - Maximum for Overflow Events: 9 inches (preferred) to 12 inches (absolute maximum)
    - Ponded water shall drain from tree filter within 48 hours or less.
- Bottom Width
    - Minimum: 5 feet

- Bottom Slope
  - Design bottom of tree filter to be level.

Materials

- Engineered Soil Media
  - Select an engineered soil media mixture from the Vegetation Section of this manual. Consider in-situ conditions, vegetation proposed and/or target pollutants. Mixture composition shall have a pH of 5.2 to 7.0.
- Vegetation
  - Specify trees in accordance with the Tree Palette in this manual. Select the following tree species for tree filters adjacent to urban roadways:
    - Nyssa sylvatica (Tupelo Tree)
    - Quercus bicolor (White Oak)
    - Liquidambar styacifula (Sweet Gum Tree)
  - Refer to applicable RIDOT Standard Details and Appendix B in the RISDISM for additional guidance.
- Pea Gravel Layer
  - Shall be washed and conform to Section M.01.06 Keystone and Section M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of pea gravel) ≤ $5D_{85}$ (of engineered soil media) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of engineered soil media).
- Gravel Sump
  - Shall be washed and shall conform to Section M.01.07 Filter Stone and Section M.01.09, Table I, Column V of the RIDOT Standards.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Filter Fabric
  - If used, shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List.
- Underdrain
  - Polyethylene or polyvinyl pipe.

Groundwater & Bedrock Separation

- Bottom of engineered soil media is at or above SHGT/bedrock; top of engineered soil media is at least 3 feet above SHGT/bedrock.
- Do not install if adequate separation SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs or in locations where contaminated soils exist.
- Reductions in the groundwater separation distance from the top of the engineered soil media may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC.
  - Sites with existing constraints that prevent achievement of minimum separation requirements, and where there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as “GB.”

Underlying Soils Conditions & Design Infiltration Rate

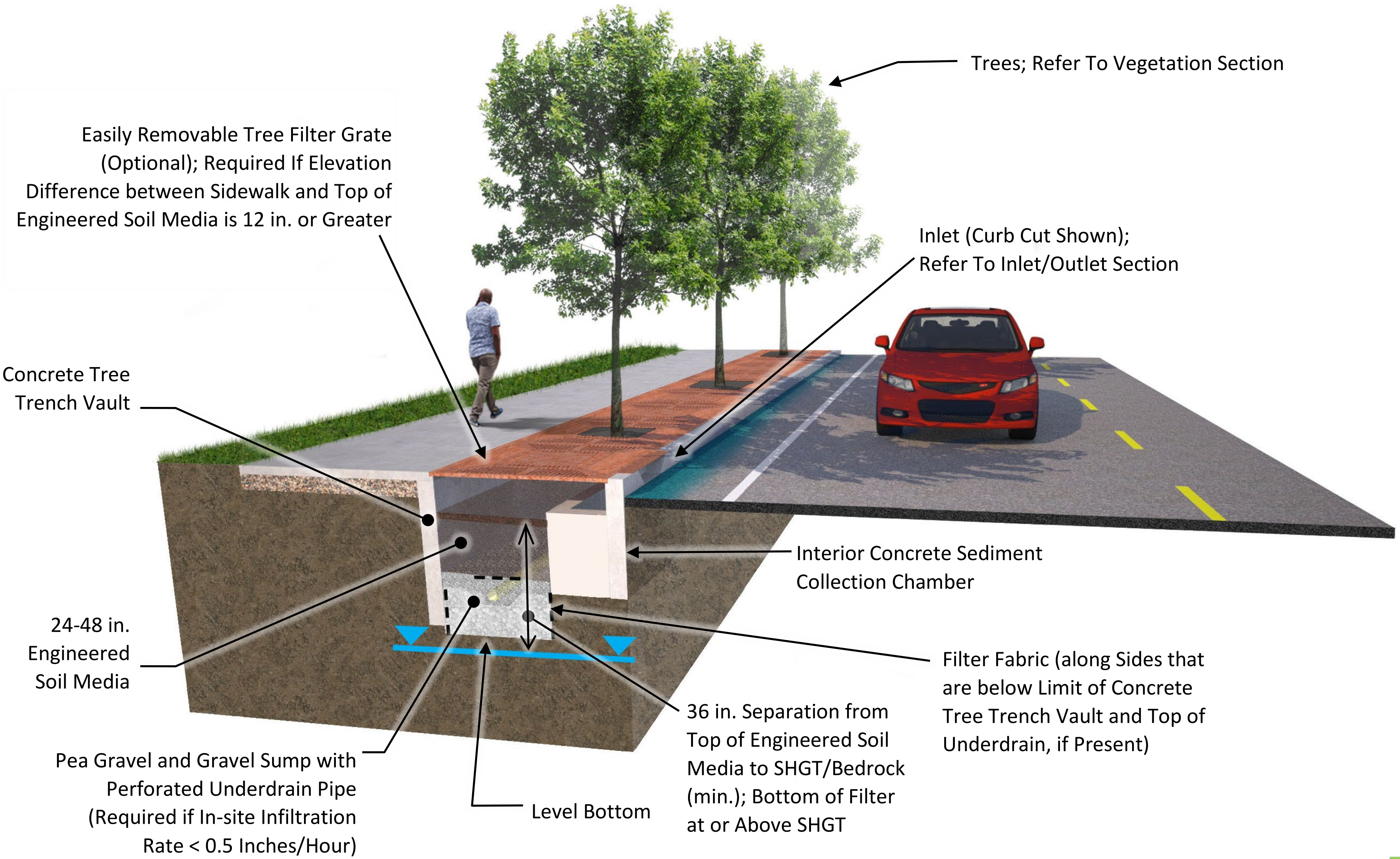
- If the tree filter is designed to infiltrate:
  - Complete in-situ soil testing in accordance with requirements in Section 1.2 – Study & Development of this manual.
  - In-situ infiltration rate of underlying soils shall be 0.5 inches per hour or greater. Otherwise, provide an underdrain.
  - The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use an infiltration rate of 0.52 inches per hour if a loam surface layer is used.

Outlet & Overflow

- Tree filters designed off-line are typically sized to handle only the WQV.
  - If the tree filter is designed to infiltrate and meets the infiltration criteria, an outlet is not required. Once the system has reached its capacity (i.e., once the STU is full), additional flow will bypass the tree filter. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.
- Tree filters designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets must be designed such that stormwater does not overflow from the tree filter onto adjacent roadway surfaces.
  - Outlets are typically an overflow riser that discharges to a storm drainage system.
- If used, underdrains can connect to a downstream drainage system or daylight at an approved discharge point.

Other Considerations

- If tree filter is located adjacent to a sidewalk or in an area subject to high pedestrian traffic, consider the use of curb around the perimeter of the tree filter, or the use of a grate over the tree filter to reduce trip hazard and prevent pet waste and trampling.
  - If height from top of tree filter media to sidewalk elevation is greater than 12 inches, use a grate.
- Where existing sidewalks are modified to incorporate tree filters, the sidewalk shall comply with ADA, as required.
  - Grates can be used over tree trenches to meet sidewalk width ADA requirements.
- Site shall be designed with readily available access to all site features for maintenance.
- If designed to infiltrate, comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.



Trees; Refer To Vegetation Section
Easily Removable Tree Filter Grate (Optional); Required If Elevation Difference between Sidewalk and Top of Engineered Soil Media is 12 in. or Greater
Inlet (Curb Cut Shown); Refer To Inlet/Outlet Section
Concrete Tree Trench Vault
Interior Concrete Sediment Collection Chamber
24-48 in. Engineered Soil Media
Filter Fabric (along Sides that are below Limit of Concrete Tree Trench Vault and Top of Underdrain, if Present)
36 in. Separation from Top of Engineered Soil Media to SHGT/Bedrock (min.); Bottom of Filter at or Above SHGT
Pea Gravel and Gravel Sump with Perforated Underdrain Pipe (Required if In-site Infiltration Rate < 0.5 Inches/Hour)
Level Bottom

Figure 2.3.5.8 – Tree Filter; NACTO

Description

General Configuration

Tree filters with storage are open-bottomed systems that house one or more trees and are filled with engineered soil media. Tree filters collect, temporarily store and filter stormwater runoff through the soil, and the tree provides pollutant uptake. These tree filters have additional subsurface storage reservoirs (crushed stone reservoirs with or without subsurface infiltration chambers) below the base of the engineered soil media layer to increase infiltration and storage capacity.

Pollutant Removal Processes

Tree filters provide the following pollutant removal mechanisms:

- **Filtration:** physical process where stormwater runoff passes through a porous subsurface media or through dense surface vegetation, which captures, removes and retains solid contaminants.
- **Infiltration:** physical process where filtration also results in groundwater recharge.
- **Pollutant Uptake:** biological process where vegetation extracts and utilizes readily available nitrogen, phosphorus and other pollutants commonly present within stormwater runoff.
- **Adsorption:** Designed additives in filter media act as an adsorbent, which chemically attract and accumulate dissolved pollutants in stormwater.

Siting

- Tree filters are best located in narrow right-of-way areas where space is limited.
- Potential locations include medians, streetscapes (e.g., between the curb and sidewalk), shoulders, and along shared-use paths.
- Tree filters are suitable in ultra-urban settings.
- Locate where:
  - The structural integrity of the roadbed material will not be compromised;
  - The minimum horizontal setbacks in Table 1.2.2 of this manual can be met;
  - The bottom of the crushed stone reservoir is at or above the SHGT and bedrock and the top of the engineered soil media is at least 3 feet above SHGT; and
  - Snow storage will not occur atop the tree filter.

Design Standards

Pretreatment

- Incorporate pretreatment measures at locations where runoff enters the tree filter in accordance with the Pretreatment Section of this manual.
- Acceptable pretreatment measures include interior concrete sediment collection chambers and exterior deep sump catch basins.
- Interior Concrete Sediment Collection Chambers
    - Shall be designed to overflow directly into the tree filter via a level overflow weir wall.
        - Elevation of overflow weir wall shall be sufficiently lower than gutter line to at least pass the WQV below the elevation of the gutter line.
    - Shall be equipped with a cover or with an overall tree filter grate.
    - Minimum depth: 4 feet from top of overflow weir wall.
    - Minimum bottom surface area: 6 square feet with no individual dimension (length or width) less than 2 feet
    - Provide two 2-inch diameter seep holes (the lowest being 2 feet above interior bottom of collection chamber) along the weir wall.
- Deep Sump Catch Basin
    - If constructing a new catch basin, use a square catch basin structure, which shall directly abut the tree filter. The width of the outlet shall extend the full inside width of the catch basin structure. Outlet opening height shall be sufficient to convey the WQV, but shall not be less than 4 inches.
    - If utilizing an existing round catch basin structure, runoff can be conveyed to the tree filter via a pipe.
    - Minimum sump depth: 4 feet

Key Considerations

Feasibility

- Bottom of crushed stone reservoir is at or above SHGT/bedrock; top of engineered soil media is at least 3 feet above SHGT/bedrock.
- Minimum soil infiltration rate of 0.5 inches per hour
- Site shall be designed with readily available access to all STU features for maintenance.
- Tree filters with storage are designed to infiltrate.

Treatment

- Total system shall hold 75% of the WQV.

Vegetation (optional)

- Consider long-term maintenance capabilities and limitations.

Inlet

- Runoff can be introduced via a curb cut, drop inlet or a pipe from an upstream structure.
- Design the inlet in accordance with the Inlet/Outlet Section of this manual.
- Depth between inlet and top of engineered soil media shall be 2 inches or less and shall be designed to minimize erosion within the tree filter.

Dimensions

- Size the tree filter in accordance with Section 5.5.4 of the RISDISM.

- Volume
  - Size the facility to hold 75% of the WQV below the elevation of any outlet and fully dewater within 48 hours after a storm event. Multiple tree filters can be combined to meet water quality goals.
  - Assume 33% void space when computing the amount of available storage within the engineered soil media and subsurface storage reservoir.
  - Engineered soil media shall have a depth of 24 to 48 inches, as necessary to accommodate treatment and also subsurface conditions and the needs of the selected tree species.
- Provide additional storage in subsurface storage reservoir below the bottom of the engineered soil media as space and separation to SHGT/bedrock allows. Subsurface storage reservoir shall consist of a crushed stone reservoir and filter fabric and may include subsurface infiltration chambers.
  - Dimensions of crushed stone reservoir shall be per the manufacturer's written direction; at minimum, there shall be 12 inches of crushed stone on each side of the chambers, 12 inches of crushed stone between adjacent chambers and 6 inches of crushed stone below and on top of the chambers.
  - Underground infiltration chambers are produced by several manufacturers and come in a variety of sizes and volumes. Do not install subsurface infiltration chambers within the dripline of trees or within 5 feet (minimum) of trees. Place between trees or to the side of tree filter under adjacent sidewalk, grassed surface or roadway.
  - Add a pea gravel layer between the engineered soil media and subsurface storage reservoir.
- Concrete Tree Trench Vault
  - Shall be a minimum of 18 inches deep below top of curb/sidewalk and shall be designed to support adjacent structures.
- Ponding Depth
  - Maximum for WQV: 6 inches
  - Maximum for Overflow Events: 9 inches (preferred) to 12 inches (absolute maximum)
  - Ponded water shall drain from tree filter within 48 hours or less.
  - Secondary inlet structures, which discharge and distribute water directly to the subsurface storage reservoir, may be installed. Crest elevations of these structures must be set at or above the WQV within the tree filter bed. Only runoff in excess of the WQV will be allowed to discharge directly to the subsurface storage reservoir.
    - Do not site any part of a secondary inlet structure within 5 feet (minimum) of trees.
- Bottom Width
  - Minimum: 5 feet
- Bottom Slope
  - Design bottom of tree filter to be level.

Materials

- Engineered Soil Media
  - Select an engineered soil media mixture from the Vegetation Section of this manual. Consider in-situ conditions, vegetation proposed and/or target pollutants. Mixture composition shall have a pH of 5.2 to 7.0.

- Vegetation
  - Specify trees in accordance with the Tree Palette in this manual. Select the following tree species for tree filters adjacent to urban roadways:
    - Nyssa sylvatica (Tupelo Tree)
    - Quercus bicolor (White Oak)
    - Liquidambar styacifula (Sweet Gum Tree)
  - Refer to applicable RIDOT Standard Details and Appendix B in the RISDISM for additional guidance.
- Pea Gravel Layer
  - Shall be washed and conform to Section M.01.06 Keystone and Section M.01.09, Table I, Column III of the RIDOT Standards.
  - D_{15} (of pea gravel) ≤ $5D_{85}$ (of engineered soil media) and D_{50} (of pea gravel) ≤ $25D_{50}$ (of engineered soil media).
- Crushed Stone Reservoir
  - Shall be clean, washed stone conforming to gradation listed in Section M.01.09, Table I, Column II of the RIDOT Standards.
- Poured-in-place Concrete
  - If used, shall be Class XX concrete conforming to Section 601 of the RIDOT Standards.
- Underground Infiltration Chambers
  - As available from the manufacturer. Appurtenant structures (e.g., end caps, cross connectors, observation wells, etc.) shall be from or approved for use by the chamber manufacturer.
  - Designer shall comply with manufacturer's written specifications, details, installation instructions and other guidance documents.
- Filter Fabric
  - Shall comply with Section 703.02.2 of the RIDOT Standards and shall be listed on the RIDOT Approved Materials List.
  - Install fabric (including overlap) per specifications required and recommended by chamber manufacturer; do not provide geotextile on the bottom of the crushed stone unless recommended by the manufacturer. Do not install along the interface of the crushed stone reservoir and the pea gravel layer.
- Secondary Inlet Structure
  - Vertical section above the subsurface storage reservoir shall consist of solid polyethylene or polyvinyl pipe with a 6 inch (minimum) diameter.
  - Vertical and horizontal sections within the subsurface storage reservoir shall consist of perforated polyethylene or polyvinyl pipe with a 6 inch (minimum) diameter.

Groundwater & Bedrock Separation

- Bottom of crushed stone reservoir is at or above SHGT/bedrock; top of engineered soil media is at least 3 feet above SHGT/bedrock.
- Do not install if adequate separation to SHGT/bedrock cannot be achieved, when cross-contamination is a concern such as at LUHHPLs or in locations where contaminated soils exist.
- Reductions in the groundwater separation distance from the top of the engineered soil media may be permissible for the following scenarios on a case-by-case basis after consultation with the RIDOT Office of Stormwater Management and RIDEM/CRMC. Crushed stone shall not be placed below SHGT.

  - Sites with existing constraints that prevent achievement of minimum separation requirements, and where there is little risk to adversely impact groundwater quality.
  - Redevelopment areas where the groundwater is classified as "GB."

Underlying Soils Conditions & Design Infiltration Rate

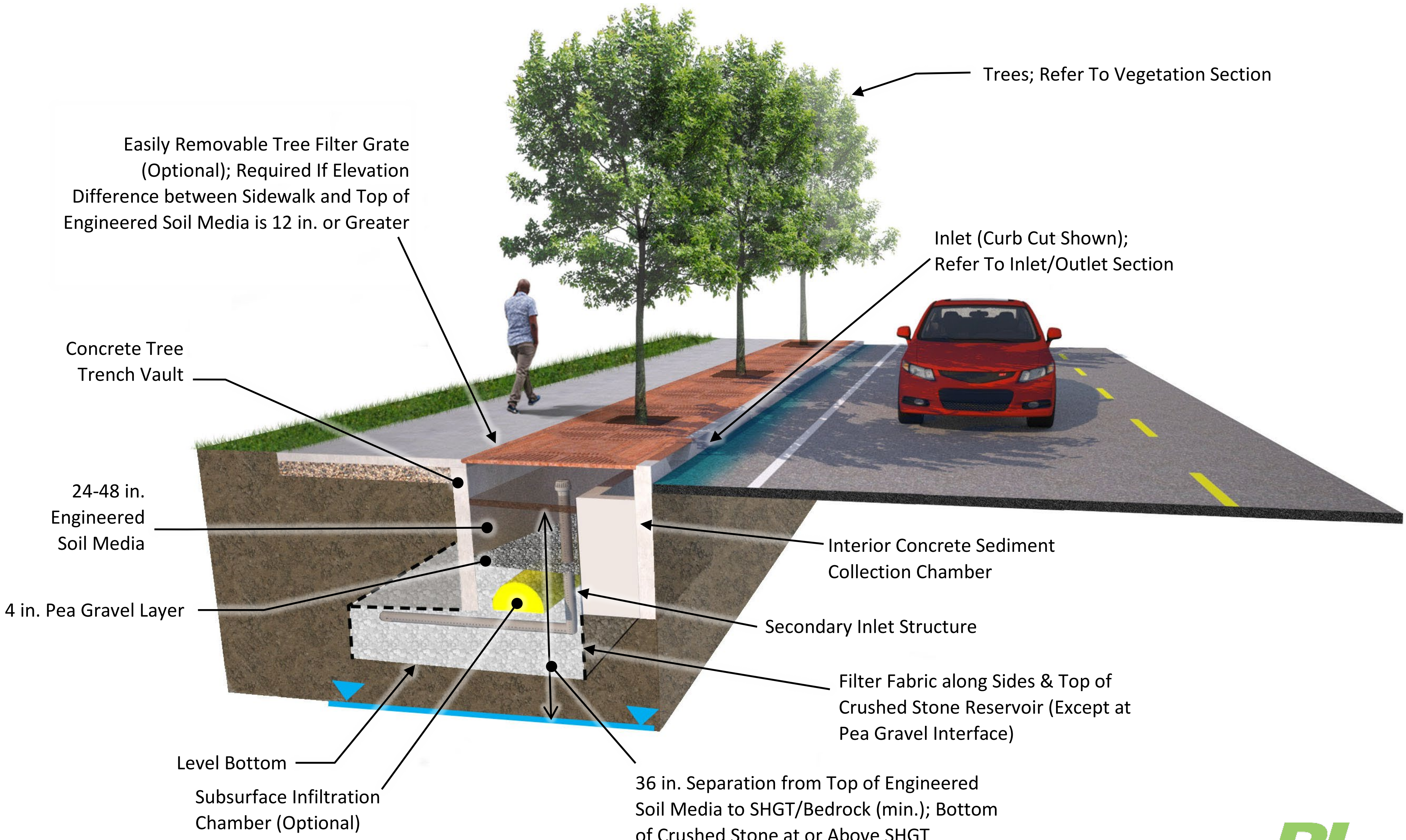
- Complete in-situ soil testing in accordance with requirements in Section 1.2 – Study & Development of this manual.
- In-situ infiltration rate of underlying soils shall be 0.5 inches per hour or greater.
- The design infiltration rate shall be half the field-derived value of the most restrictive layer or shall coincide with values listed in Section 8.21(E)(4)(a) of the RI Stormwater Rules; whichever is more conservative. Use an infiltration rate of 0.52 inches per hour if a loam surface layer is used.

Outlet & Overflow

- Tree filters designed off-line are typically sized to handle only the WQV, and an outlet is not required. Once the system has reached its capacity (i.e., once the STU is full), additional flow will bypass the tree filter. The designer shall confirm that the bypassed flow is managed downstream and does not worsen flooding.
- Tree filters designed in-line must have an outlet sized to convey the 10-year storm event, at a minimum.
  - Design the outlet in accordance with the Inlet/Outlet Section of this manual.
  - Outlets must be designed such that stormwater does not overflow from the tree filter onto adjacent roadway surfaces.
  - Outlets are typically an overflow riser that discharges to a storm drainage system.

Other Considerations

- If tree filter is located adjacent to a sidewalk or in an area subject to high pedestrian traffic, consider the use of curb around the perimeter of the tree filter, or the use of a grate over the tree filter to reduce trip hazard and to prevent pet waste and trampling.
  - If height from top of tree filter media to sidewalk elevation is greater than 12 inches, use a grate.
- Where existing sidewalks are modified to incorporate tree filters, the sidewalk shall comply with ADA, as required.
  - Grates can be used over tree trenches to meet sidewalk width ADA requirements.
- Site shall be designed with readily available access to all site features for maintenance.
- Comply with the minimum horizontal setbacks in Table 1.2.2 of this manual.


Trees; Refer To Vegetation Section
Easily Removable Tree Filter Grate (Optional); Required If Elevation Difference between Sidewalk and Top of Engineered Soil Media is 12 in. or Greater
Inlet (Curb Cut Shown); Refer To Inlet/Outlet Section
Concrete Tree Trench Vault
24-48 in. Engineered Soil Media
Interior Concrete Sediment Collection Chamber
4 in. Pea Gravel Layer
Secondary Inlet Structure
Filter Fabric along Sides & Top of Crushed Stone Reservoir (Except at Pea Gravel Interface)
Level Bottom
Subsurface Infiltration Chamber (Optional)
36 in. Separation from Top of Engineered Soil Media to SHGT/Bedrock (min.); Bottom of Crushed Stone at or Above SHGT

2.4.1 General Maintenance Requirements

> STUs that do not have appropriate access for inspection and maintenance are not considered feasible.

STUs that do not have appropriate access for inspection and maintenance are not considered feasible. In order for an STU to function as intended and receive treatment credit, periodic inspection and maintenance are required. **Appendix A** of this manual provides maintenance and inspection protocol for each STU type in this manual.

When designing an STU, conduct the following steps:

- Identify if non-RIDOT parties will be conducting the long-term inspections and maintenance, and coordinate with these parties to develop STU designs that align with their operation and maintenance capabilities.
- Evaluate if existing and/or upgraded stormwater infrastructure within the project limits comply with these guidelines. If deemed to be deficient, incorporate these guidelines to the extent feasible.
- Place inlet/outlet structures along the perimeter of the STU for easier access.
- Place a 4-foot high (minimum) flexible delineator post adjacent to infrastructure that may become hidden and can potentially become a safety hazard (e.g., trip and fall), may be damaged during maintenance, or may damage maintenance equipment. Examples include inlet structures, clean-outs, observation wells and raised outlet structures.
- Identify adequate space to stage maintenance activities and equipment. Consider on-street parking limitations when identifying this area. Access paths can also serve as a staging area for equipment during maintenance.
- Consider the weight of the equipment. Equipment shall not adversely impact the functionality of the STU (i.e., compacting the subsurface soil media). For instance, not relying on sediment removal equipment (e.g., excavator) accessing surfaces where water infiltrates as well as ensuring that surfaces that will be mowed will need to withstand 15 pounds per square foot (15 lb/SF) of pressure from typical RIDOT mowing tractors.

2.4.2 Maintenance Access Paths

- When identifying the locations of an access path to the STU:
  - Designate safe entry and exit points; design to allow for safe approach and exit speeds onto main road from access road.
  - Consider existing and proposed barriers (e.g., guardrail, fence, etc.) that may hinder access to the STU. Provide a gap, gate, etc. in the barrier accordingly.
  - Provide the appropriate level of access to the varying STU features. For instance, it is necessary to provide vehicular access to the STU, but it may only be necessary to provide access for mowing equipment to the vegetated portions within the STU.
  - Access shall include a ramp to the bottom of an STU basin where the embankment height is greater than 8 feet.
  - At a minimum, the access path shall abut pretreatment facilities and provide safe access to all points that require routine maintenance or sediment removal. Consider the

equipment type and any limitations. For instance, mini excavators have an 8- to 12-foot reach and vacuum trucks have 150 feet of hose. Also consider vegetation that may limit access, such as shrubs that would hinder the use of a hose.
  - Depict the access path on the figure that will be incorporated with the long-term operation and maintenance plan.
- Apply the following standards when designing the access path:
  - Minimum Width: 15 feet wide.
  - Provide a maximum longitudinal slope of 10% and a maximum 1% cross slope.
  - Provide a stable surface treatment of reinforced permeable material capable of supporting anticipated maintenance vehicle loads. Do not use any portion of the STU as an access path.
  - Provide for a 40-foot diameter maintenance vehicle turning radius.

2.4.3 Snow Management

- Evaluate the potential for snow storage on the STU, and consider the following:
  - Sediment/debris that accumulates within the plowed snow may impact the effectiveness of the STU after the snow melts and the sediment/debris remains.
  - STUs will need to withstand anticipated snow loads if plowed/shoveled snow is permitted to accumulate over the STU.
- Use transition curbs or steel plates where curb cuts are proposed. This approach will limit the potential for damage from approaching snow plows.
- Depict any snow storage areas on the figure that will be incorporated with the long-term operation and maintenance plan. In areas where snow storage is not permitted, identify these areas as well.

2.5.1 Planting Palettes

Four planting palettes suggested for vegetated RIDOT STUs are provided in this section. Designers should use these planting palettes as determined appropriate and applicable for each site. The planting palettes were designed to meet a variety of site needs and are intended to provide low-maintenance and salt-tolerant vegetation solutions. The palettes are mostly native plants, which are preferred wherever practicable. These palettes also include pollinators to support biodiversity and improve the ecosystem by cleaning air, purifying water and soil and preventing erosion. Note that these palettes are provided as a starting point; it is the ultimate responsibility of the designer to select vegetation that is suited for the project location and use with approval by the RIDOT landscape architect.

- Select vegetation that complements the surrounding environment and adjacent land uses. Do not interfere with surrounding surface and subsurface features such as hydrants.
- Locate vegetation in accordance with roadway and safety standards. Vegetation shall not impact traffic sight lines. Plantings selected within medians, near intersections or near pedestrian crossings shall reach a mature vegetation height of no greater than 24 inches above the surrounding sidewalk or pavement surface.
- Consider the entity that will maintain the vegetation. RIDOT may partner with other entities to maintain vegetation, and these entities have varying means to maintain vegetation. It is important to provide vegetation that is compatible with their existing maintenance practices.
- Establish a dense vegetative cover or adequately stabilized landscaped surface throughout the STU. Vegetation must form a deep root system or dense sod to resist erosion and help slow water to facilitate sedimentation.
- Refer to **Table 2.5.1** and **Table 2.5.2** to select the planting palette based on location and the STU, respectively.
- Refer to the RIDOT Standard Details 50.0 & 51.0, Sections L.01 and L.02 of the RIDOT Standards, and Appendix B of the RISDISM.

Table 2.5.1 – Planting Palettes by Location

Location	Planting Palette 1	Planting Palette 2	Planting Palette 3	Planting Palette 4
Sunny Areas	🍃	🍃		🍃
Partly Shaded Areas	🍃		🍃	🍃
Directly Adjacent to Roadways	🍃			🍃
Open & Wide Right-of-Way Areas	🍃	🍃	🍃	🍃

Table 2.5.2 – Planting Palettes by Location & Stormwater Treatment Units

Vegetated STUs	Palette 1 Table 2.5.3	Palette 2 Table 2.5.4	Palette 3 Table 2.5.5	Palette 4 Table 2.5.6
Bioretention Basin	🍃	🍃	🍃	🍃
Bioretention Curb Inlet Planter		🍃	🍃	
Bioretention Parking Lane Adjacent Planter		🍃	🍃	
Bioretention Curb Extension Planter		🍃	🍃	
Bioretention Swale	🍃	🍃	🍃	🍃
Sand Filter	🍃	🍃	🍃	🍃
Infiltration Basin	🍃	🍃	🍃	🍃
Infiltration Trench	🍃	🍃	🍃	🍃
Filter Strip	🍃	🍃	🍃	🍃

Planting Palette #1

Table 2.5.3 - Planting Palette #1

Type	Key	Botanical Name	Common Name	Notes
Ornamental Grasses	P1-1	Panicum virgatum	Switchgrass	Spacing: 2-3 feet on center
Grass Seed	P1-2	Festuca rubra	Red Fescue	Application Rate: 4-6 lbs./1,000SF
	P1-3	Lolium perenne	Perennial Ryegrass	Application Rate: 4-6 lbs./1,000SF
	P1-4	Poa Pratensis	Kentucky Bluegrass	Application Rate: 4-6 lbs./1,000SF

Planting Palette #2 (Sunny & Open Areas Only)

Table 2.5.4 – Planting Palette #2 (Sunny & Open Areas Only)

Type	Key	Botanical Name	Common Name	Notes
Perennials	P2-1	Achillea millefolium	Common Yarrow*	Spacing: 2-3 feet on center
	P2-2	Allium senescens	Ornamental Onion*	Spacing: 2-3 feet on center
	P2-3	Symphyotrichum novae-angliae	New England Aster*	Spacing: 18-24 inches on center
	P2-4	Echinacea purpurea	Coneflower*	Spacing: 18-24 inches on center
	P2-5	Rudbeckia hirta	Black-eyed Susan*	Spacing: 18-24 inches on center
Ornamental Grasses	P2-6	Andropogon gerardii	Big Blue Stem	Spacing: 18-24 inches on center
	P2-7	Chasmanthium latifolium	Northern Sea Oats	Spacing: 18-24 inches on center
	P2-8	Panicum virgatum	Switchgrass	Spacing: 2-3 feet on center
	P2-9	Pennisetum alopecuroides	Fountain Grass	Spacing: 2-3 feet on center
	P2-10	Schizachyrium scoparium	Little Bluestem	Spacing: 18-24 inches on center
Grass Seed	P2-11	Festuca arundinacea	Tall Fescue	Application Rate: 4-6 lbs./1,000SF
	P2-12	Festuca rubra	Red Fescue	Application Rate: 4-6 lbs./1,000SF
	P2-13	Lolium perenne	Perennial Ryegrass	Application Rate: 4-6 lbs./1,000SF
	P2-14	Poa Pratensis	Kentucky Bluegrass	Application Rate: 4-6 lbs./1,000SF

**Cross-pollinating species*

Planting Palette #3 (Partly Shaded & Open Areas Only)

Table 2.5.5 – Planting Palette #3 (Partly Shaded & Open Areas Only)

Type	Key	Botanical Name	Common Name	Notes
Perennials	P3-1	Arctostaphylos uva-ursi	Bearberry*	Spacing: 3-5 feet on center
	P3-2	Iris versicolor	Blue flag iris*	Spacing: 1-2 feet on center
	P3-3	Tiarella cordifolia	Foamflower*	Spacing: 12-24 inches on center
	P3-4	Lobelia cardinalis	Cardinal Flower*	Spacing: 12-24 inches on center
	P3-5	Liriope spicata	Lilyturf*	Spacing: 12-24 inches on center
Ornamental Grasses	P3-6	Chasmanthium latifolium	Northern Sea Oats	Spacing: 18-24 inches on center
	P3-7	Panicum virgatum	Switchgrass	Spacing: 2-3 feet on center
	P3-8	Schizachyrium scoparium	Little Bluestem	Spacing: 12-18 inches on center
Grass Seed	P3-9	Festuca rubra	Red Fescue	Application Rate: 4-6 lbs./1,000SF
	P3-10	Lolium perenne	Perennial Ryegrass	Application Rate: 4-6 lbs./1,000SF
	P3-11	Poa Pratensis	Kentucky Bluegrass	Application Rate: 4-6 lbs./1,000SF

**Cross-pollinating species*

Planting Palette #4

Table 2.5.6 – Planting Palette #4

Type	Key	Botanical Name	Common Name	
Ornamental Grasses	P4-1	Andropogon gerardii	Big Blue Stem	Spacing: 18-24 inches on center
	P4-2	Panicum virgatum	Switchgrass	Spacing: 2-3 feet on center
	P4-3	Schizachyrium scoparium	Little Bluestem	Spacing: 12-18 inches on center
Grass Seed	P4-4	Festuca arundinacea	Tall Fescue	Application Rate: 4-6 lbs./1,000SF
	P4-5	Festuca rubra	Red Fescue	Application Rate: 4-6 lbs./1,000SF
	P4-6	Lolium perenne	Perennial Ryegrass	Application Rate: 4-6 lbs./1,000SF
	P4-7	Poa Pratensis	Kentucky Bluegrass	Application Rate: 4-6 lbs./1,000SF

2.5.2 Shrub Palette

The Shrub Palette presents low-maintenance and salt-tolerant shrubs that can be used in vegetated RIDOT STUs. The shrubs in this palette are compatible with the vegetation in the four planting palettes and the tree palette of this manual. The palette also includes pollinators to support biodiversity and improve the ecosystem by cleaning air and purifying water and soil. Designers should use this palette as determined appropriate and applicable for each site. Shrubs require annual pruning of all dead limbs to help establish new growth.

- Locate shrubs in accordance with roadway and safety standards. Shrubs shall not impact traffic sight lines. Shrubs selected within medians, near intersections or near pedestrian crossings shall reach a mature vegetation height of no greater than 24 inches above the surrounding sidewalk or pavement surface.
- Select shrubs that complement the surrounding environment and adjacent land uses. Do not interfere with surrounding surface and subsurface features such as hydrants.
- Consider the entity that will maintain the vegetation. RIDOT may partner with other entities to maintain vegetation, and these entities have varying means to maintain vegetation. It is important to provide vegetation that is compatible with their existing maintenance practices.
- Refer to the RIDOT Standard Details 50.0 & 51.0 and Appendix B of the RISDISM.
- Refer to **Table 2.5.7** for a list of shrubs.

Table 2.5.7 – Shrub Palette

Key	Botanical Name	Common Name	Spacing (on center)
S-1	Clethra alnifolia	Summersweet Clethra[1]	3-5 feet
S-2	Ilex glabra	Inkberry	3-4 feet
S-3	Juniperus horizontalis	Creeping Juniper	3-4 feet
S-4	Lindera benzoin	Spicebush[1]	6-8 feet
S-5	Myrica pensylvanica	Northern bayberry[1]	6-8 feet
S-6	Itea virginica	Virginia sweetspire	3-5 feet
S-7	Rhus aromatic	Gro-low Sumac	5-9 feet
S-8	Ilex verticillata	Winterberry	See Note 2
S-9	Viburnum dentatum	Arrowwood[1]	5-7 feet

[1]*Cross-pollinating species*
[2]*Plant one male for up to 10 females*


S-1

S-2

S-3

S-4

S-5

S-6

S-7

S-8

S-9

2.5.3 Tree Palette

The Tree Palette has been developed to present low-maintenance and salt-tolerant solutions and presents options for trees that can be used in conjunction with any of the vegetation in the four planting palettes and the shrub palette of this manual. The palette also includes pollinators to support biodiversity and improve the ecosystem by cleaning air and purifying water and soil. Designers should use this palette as determined appropriate and applicable for each site. When selecting trees for an STU, note that these palettes are provided as a starting point; it is the ultimate responsibility of the designer to select vegetation that is suited for the project location and use with approval by the RIDOT landscape architect.

Selecting Trees

- Select trees that complement the surrounding environment and adjacent land uses.
- Compare the size of the fully developed tree canopy and root zone with the surrounding surface and subsurface features. Select trees that will not adversely interfere with these features. Example features include light poles, hydrants and overhead/underground utilities. The designer shall confirm the height and canopy spread with the supplier.
- Consider the entity that will maintain the trees. RIDOT may partner with other entities to maintain vegetation, and these entities have varying means to prune trees. It is important to provide vegetation that is compatible with their existing maintenance practices.
- Refer to **Table 2.5.8** for a list of deciduous and evergreen trees.

Locating Trees

- Plant trees with a minimum on-center spacing of 15 feet.
- Place trees in areas that get full to partial sunlight; trees require sunlight for proper growth.
- Locate trees in accordance with roadway and safety standards.
    - Provide a height and branching clearance that provides approximately 14 feet of clearance of adjacent bicycle facilities, pedestrian paths and travel lanes.
    - Incorporate required setbacks to features such as intersections and driveways; trees shall not impact traffic sight lines.
- Refer to the RIDOT Standard Details 50.0 & 51.0 and Appendix B of the RISDISM.

Table 2.5.8 –Tree Palette

Type	Key	Botanical Name	Common Name	Maintenance
Deciduous	T-1	Amelanchier canadensis	Shadblow Serviceberry[1]	Requires annual pruning of all dead limbs to help establish new growth.
	T-2	Betula populifolia	Grey Birch[1]	
	T-3	Cercis canadensis	Eastern Redbud	
	T-4	Gleditsia tricanthos var. inermis	Thornless Honeylocust	
	T-5	Liquidambar styraciflua	Sweet Gum Tree[1,2]	
	T-6	Nyssa sylvatica	Tupelo Tree[1]	
	T-7	Platanus occidentalis	American Sycamore[1]	
	T-8	Acer rubrum	Red Maple	
	T-9	Liriodendron tulipifera	Tulip Tree	
	T-10	Quercus bicolor	White Oak[1,3]	
Evergreen	T-11	Juniperus virginiana	Eastern Red Cedar[4]	
	T-12	Pinus strobus	White Pine[4]	

[1]*Cross-pollinating species*
[2]*Not recommended for pedestrian use areas due to fruit balls that drop*
[3]*Use oaks sparingly as the trees are difficult to establish*
[4]*Plant in smaller sizes for establishment*


T-1


T-2


T-3


T-4


T-5

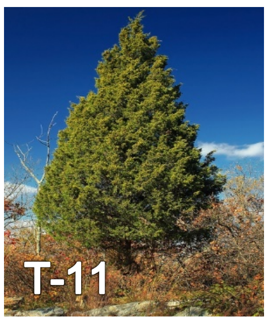

T-6


T-7


T-8


T-9


T-10


T-11


T-12

2.5.4 Engineered Soil Media Mixtures

Select an engineered soil media mixture as follows:

- Consider in-situ conditions, compatibility with proposed vegetation, and target pollutants.
  - Mixtures 1 & 2 are for STUs in locations with no specific targeted pollutants.
  - Mixtures 3 & 4 are for STUs in locations where nitrogen and/or phosphorous are concerns.
- Mixture composition shall have a pH of 5.2 to 7.0.

For STUs in locations with no specific targeted pollutants:

Mixture 1 (by Volume):

- 60 to 70 percent sand;
- 15 to 25 percent topsoil (sandy loam, loamy sand, or loam per USDA soil texture) or loam (RIDOT Standards Section M.18.01); and
- 15 to 25 percent organic matter.

Mixture 2 (by Volume):

- 70 to 85 percent sand; and
- 15 to 30 percent organic matter.

For STUs in locations where nitrogen or phosphorous are concerns:

Mixture 3 (by Volume):

- 75 to 85 percent medium to coarse washed sand;
- 8 to 15 percent fines (silt and clay) - use a higher percentage of fines (15%) when phosphorus is a concern and use a lower percentage of fines (8%) when nitrogen is a concern; and
- 5 to 10 percent organic matter.

Mixture 4 (by Volume):

- 50 to 65 percent sand;
- 25 to 35 percent topsoil (sandy loam, loamy sand, or loam per USDA soil texture) or loam (RIDOT Standards Section M.18.01); and
- 10 to 15 percent organic matter.

2.6.1 Introduction

There may be opportunities to upgrade existing stormwater management infrastructure to increase its treatment capacity. Depending on site conditions, upgrades may be a cost effective solution to stormwater management in comparison to construction of a new structural STU.

This section is intended to help designers identify upgrade opportunities and guide the design of upgrading measures. Every upgrade project/opportunity will be different; therefore, this section will not dictate specific design requirements, but will help consultants assess the feasibility of an upgrade. For specific design requirements for the STU being upgraded, the respective design sections of this manual should be referenced.

Key Considerations

1. **What are the potential treatment credits?**
2. **Do existing site conditions promote an upgrade?**
3. **Will upgrades be cost effective as compared to other alternatives?**

Upgraded stormwater management systems must be designed to improve water quality treatment capacity of existing system.

Upgrading should be evaluated through a cost benefit assessment in comparison to other available alternatives, including construction of new STUs.

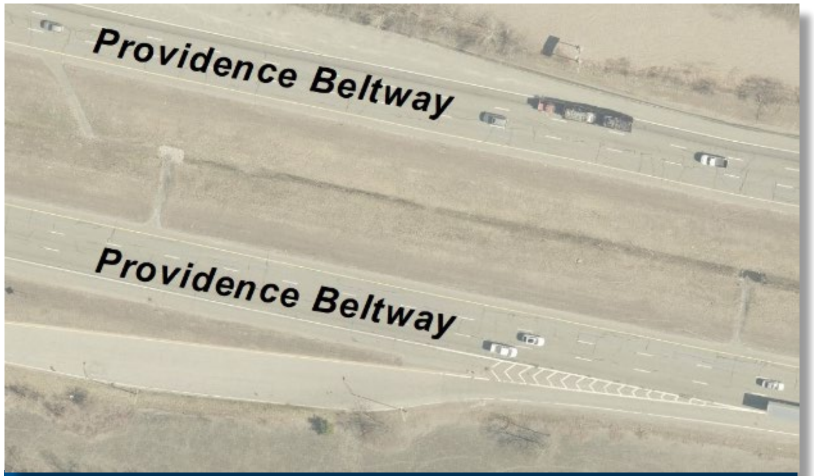


Figure 2.6.1 – Example of an opportunity to replace impervious drainage swales with bioretention swales along a highway median.

What Are the Potential Treatment Credits?

Treatment credit for an upgraded STU may be claimed if the STU meets the design requirements of this manual. These requirements include assuring that safe access for maintenance is provided to the STU and that maintenance of the structure is feasible. Sections 8.32 and 8.33 of the RI Stormwater Rules also provide treatment related information for storage basins.

Do Existing Site Conditions Promote Feasible Upgrading?

Upgrade projects can be limiting due to the configuration of the existing stormwater management infrastructure. The design consultant will need to evaluate existing site conditions and stormwater infrastructure systems to determine if upgrades/modifications to conveyance systems are necessary, if the system should be designed online or offline, and how these decisions may impact project feasibility and cost.

Typically, a hydrologic and hydraulic analysis of the existing system and proposed modifications will be required to ensure that modifications will not cause flooding or other undesirable conditions for adjacent infrastructure or site uses. Review of any available design and permitting documentation on the existing system will also be necessary to complete this evaluation.

Some stormwater basin upgrades will result in a partial loss of flood storage and peak discharge control. It is the designer's responsibility to understand the function of existing infrastructure and gather information on the previous design to identify potential concerns with modifying the design. Where changes in peak discharge control are proposed, such changes must be explicitly stated on permitting documentation (if permitting is required) and a memorandum documenting proposed changes sent to the RIDOT Stormwater Management Program. This may also require RIDEM and CRMC permitting.

Will Upgrading be Cost Effective as Compared to Other Alternatives?

While many upgrade projects may be less expensive to construct due to reduced earthwork or infrastructure needs onsite, there are several other factors that could contribute to upgrade costs beyond those directly associated with upgrading the existing STU itself. Designers shall weigh the costs for an upgrade in order to determine whether it is cost effective.

2.6.2 Example Upgrade Opportunities

There are several types of existing stormwater management infrastructure that can be upgraded to improve treatment capacity. **Table 2.6.1** and **Table 2.6.2** present some options for upgrading existing sites and existing STUs to maximize treatment capacity and storage.

Figure 2.6.2 – Example of a potential opportunity to use an existing depression that receives stormwater to implement a wet vegetated treatment system (Intersection of Rt. 238 & 138).

Table 2.6.1 - Upgrade Opportunities for Detention Ponds

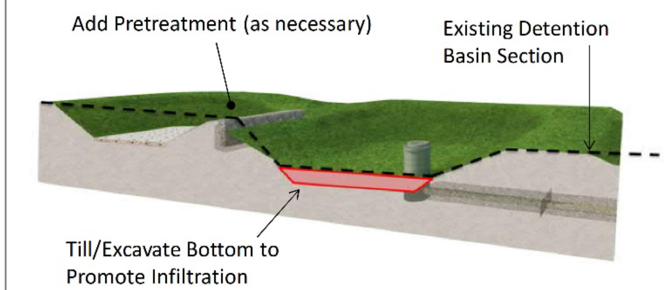
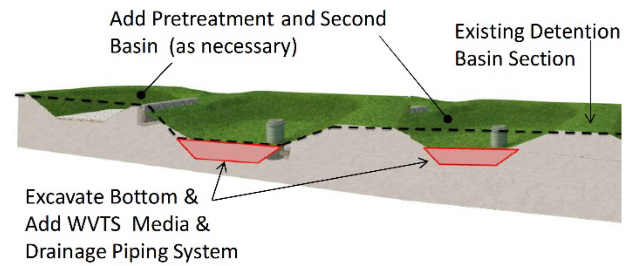
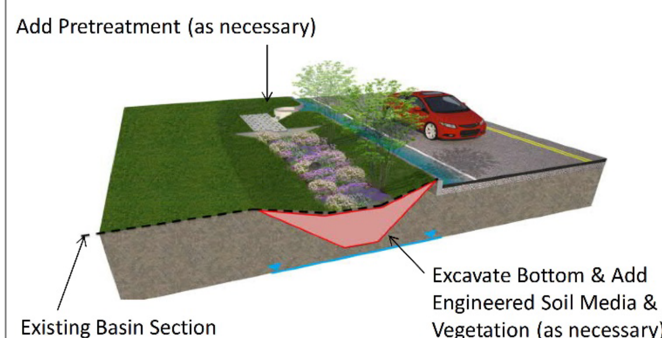
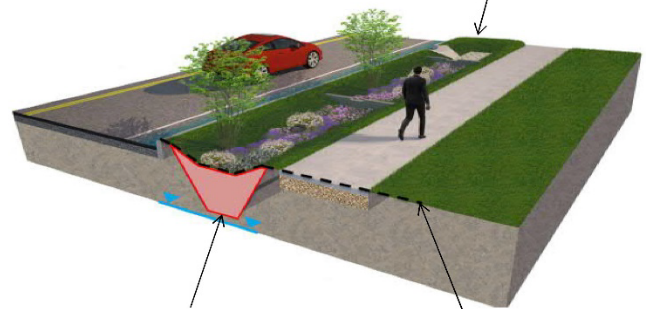
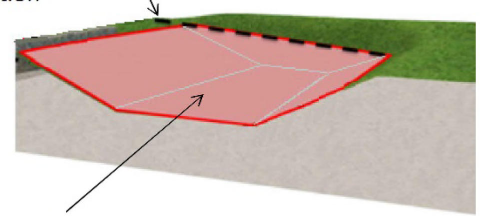
Existing Feature = Detention Ponds	Upgrade Option A Convert to Infiltration Basin	Design in Accordance with Infiltration Basin Design Section May Require: - Infiltration testing - Grading, tilling and/or excavating/dredging - Addition of pretreatment - Revegetation - Modifications to outlet control structure Consider: - Any fill material will create loss of peak flood control and flood storage, which may impact adjacent structures/site features/ site uses - Infiltration capacity of most restrictive layer and depth to bedrock and groundwater - Embankment/slope stability	
	Upgrade Option B Convert to Gravel WVTS	Design in Accordance with Gravel Wet Vegetated Treatment System Design Section May Require: - Grading - Addition of pretreatment, liner, media layers and/or underdrains - Revegetation Consider: - Any fill material will create loss of peak flood control and flood storage, which may impact adjacent structures/site features/ site uses - Embankment/slope stability	
	Upgrade Option C Convert to Bioretention Basin	Design in Accordance with Bioretention Basin Design Section May Require: - Infiltration testing - Grading - Addition of pretreatment, engineered soil media, check dams and/or underdrain - Revegetation - Modifications to outlet control structure Consider: - Any fill material will create loss of peak flood control and flood storage, which may impact adjacent structures/site features/ site uses - Infiltration capacity of most restrictive layer and depth to bedrock and groundwater - Embankment/slope stability	

Table 2.6.2 – Upgrade Opportunities for Conveyance Swales

Existing Feature = Conveyance Swale	Upgrade Option A Convert to Bioretention Swale	Design in Accordance with Bioretention Swale Design Section May Require: - Infiltration testing - Grading - Addition of pretreatment - Addition of engineered soil media - Addition of check dams/weirs - Addition of underdrain - Revegetation Consider: - Any fill material will create loss of peak flood control and flood storage, which may impact adjacent structures/site features/ site uses - Infiltration capacity of most restrictive layer - Depth to bedrock and depth to groundwater - Weir design and stabilization - Impact to adjacent structures/site features/ site uses	
	Upgrade Option B Convert Riprap/Impervious Swales to Infiltration Swales	May Require: - Infiltration testing - Addition of pretreatment - Addition of check dams/weirs - Revegetation Consider: - Infiltration capacity of most restrictive layer - Depth to groundwater	

2.7.1 Introduction

Surface and subsurface utilities can pose significant challenges to the design, construction and maintenance of STUs; especially in urban areas. Effective planning and design of STUs shall incorporate the following steps:

> Utility management should be considered at the beginning stages of the design . Otherwise, the project runs the risk of unnecessary rework.

- Coordinate with public and private utilities to determine the presence of existing utilities within the project limits as well as design and construction requirements for utility related construction. RIDOT maintains a list of utility companies and contact information on the Project Management Portal (PMP).
- Locate existing utilities during the design phase in accordance with the RIDOT Highway Design Manual (2008).
- Verify separation requirements between proposed STU features and existing onsite utilities with the utility owner.
- Where sidewalk STUs are being proposed, utility poles should be at the back of sidewalk. Where possible, locate utilities outside the sidewalk limits. Sidewalks shall meet ADA requirements.
- If fire hydrants are present near the proposed STU or must be relocated, coordinate with the local fire department/district and water utility owner for design and construction requirements.
- Consider the potential for conflict with overhead utilities. These conflicts include both permanent fixed objects and constructability issues. Consult the utility pole owner, and NESC & OSHA guidelines.
- Determine potential conflicts with federally or privately owned mailboxes or collection boxes. If relocation of mailbox or collection box is necessary, follow guidance from the mailbox owner.

2.7.2 Relocation of Utilities

Relocating utilities should be carefully considered during the selection of a STU. Relocation can be costly and requires early coordination with the utility owner. The proposed relocation design must be reviewed and approved by the utility owner.

2.7.3 Configuration of STUs & Utilities

The vertical and horizontal separation requirement between STUs and existing utilities varies between utility owners. Separation and orientation must be approved during design by the utility owner. The configuration of a STU must allow utility owner access to all mains and service laterals for maintenance.

Designers should minimize siting infiltrating STUs adjacent to or above existing utility trenches even when approved by the utility owner. Utility trenches that are adjacent to infiltrating STUs can “short circuit” the STUs drainage mechanisms if preferential flow is through the bedding material of the utility trench. To avoid this occurrence, the STUs can be lined in the area near the utility trench. Impermeable liner should extend 5 feet beyond the limit of the utility trench or beyond where short circuiting is anticipated to occur.

Example Option A: Sleeve Utility

If a STU must be placed over an existing underground utility or separation requirements cannot be met, the use of an encasement sleeve or saddle is preferred to relocation. Encasement sleeves and saddles ease utility maintenance and reduce the risk of maintenance activities disrupting STU function. These options must be approved by the utility owner during the design phase.

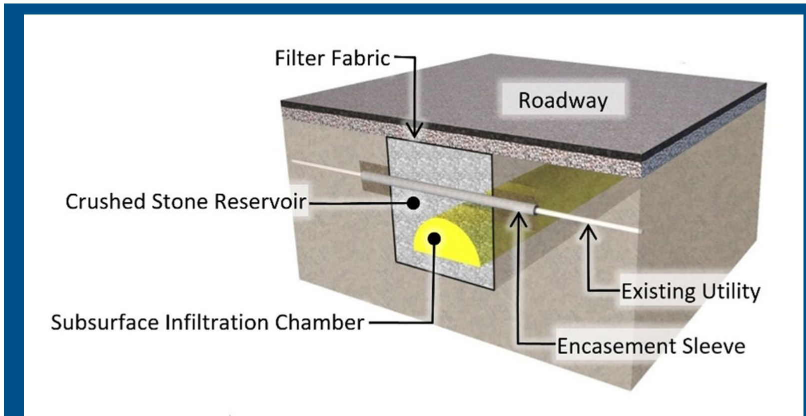


Figure 2.7.1 – Encasement Sleeve through Underground Infiltration STU

Example Option B: Accommodate Utility

Breaks in underground STUs can also be made to accommodate utilities while still keeping the system hydraulically connected. For example, where a utility crosses over an underground infiltration system, a pipe or crushed stone can be used to convey water under the utility. A filter fabric liner can be used to separate the utility trench backfill and the subsurface infiltration system. In locations where sleeves or breaks are proposed, marking tape should be used 6-8 inches above the STU.

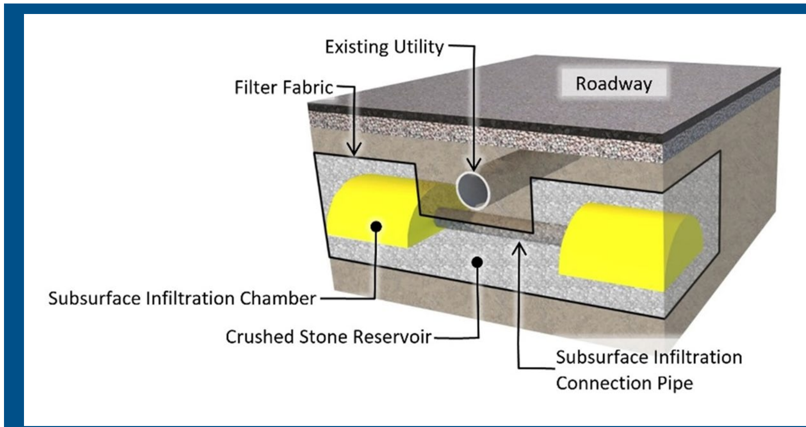


Figure 2.7.2 – Stormwater Conveyance under Utility for Underground Infiltration STU

2.7.4 Existing Drainage Systems

If permitted, work to an existing drainage system may include the following:

1. Rerouting or diverting stormwater from an existing system into a proposed STU; and
2. Connecting overflows/outlets from the STU back into the same drainage system.

Precast "doghouse" style manholes can ease the connection of proposed manholes or catch basins into existing drainage pipes. The "doghouse" fits over the existing pipe or pipes. The bottom and sides of the manhole or catch basin shall be sealed to avoid groundwater infiltration.

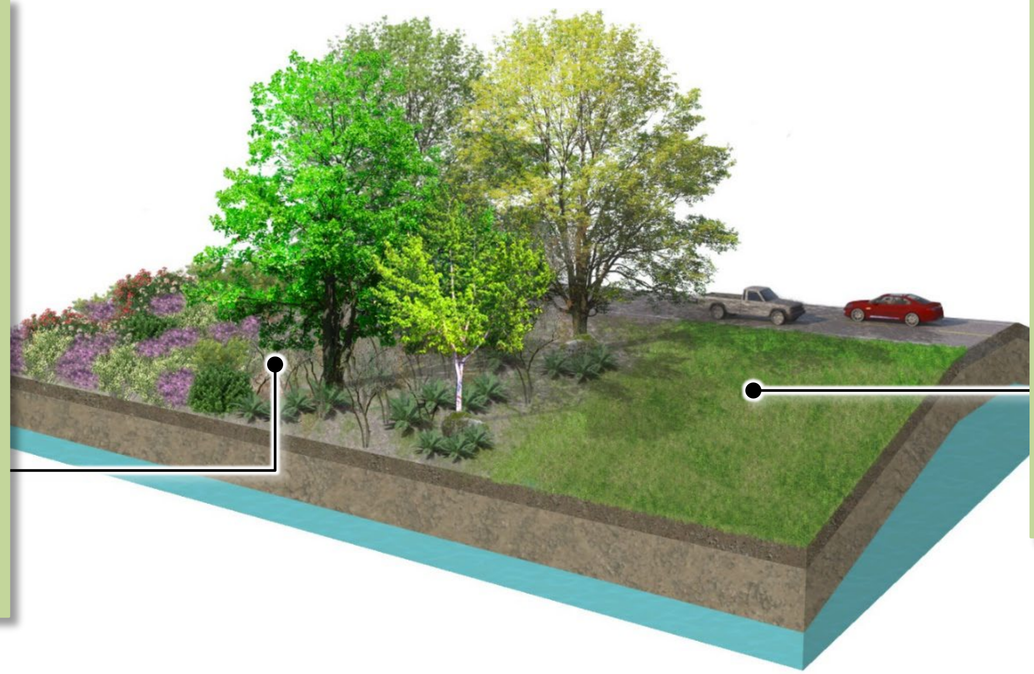
Any work to an existing drainage system will require coordination with the drainage system owner (e.g., municipality, RIDOT, etc.) and conformance with applicable regulations and requirements.

Appendix A – Maintenance Sheets

Filter Strip

MAINTENANCE

#1



#1

*Image numbers refer to those in table.

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Filter Strip	• Inspect for accumulated debris/sediment within the filter strip area. • Inspect for damage such as erosion, rutting and patches of soil.	• Remove and properly dispose of debris/sediment. • Restore areas of erosion, rutting, etc. to a condition similar to that of the overall filter strip.

Gravel Wetland (WVTS)

MAINTENANCE

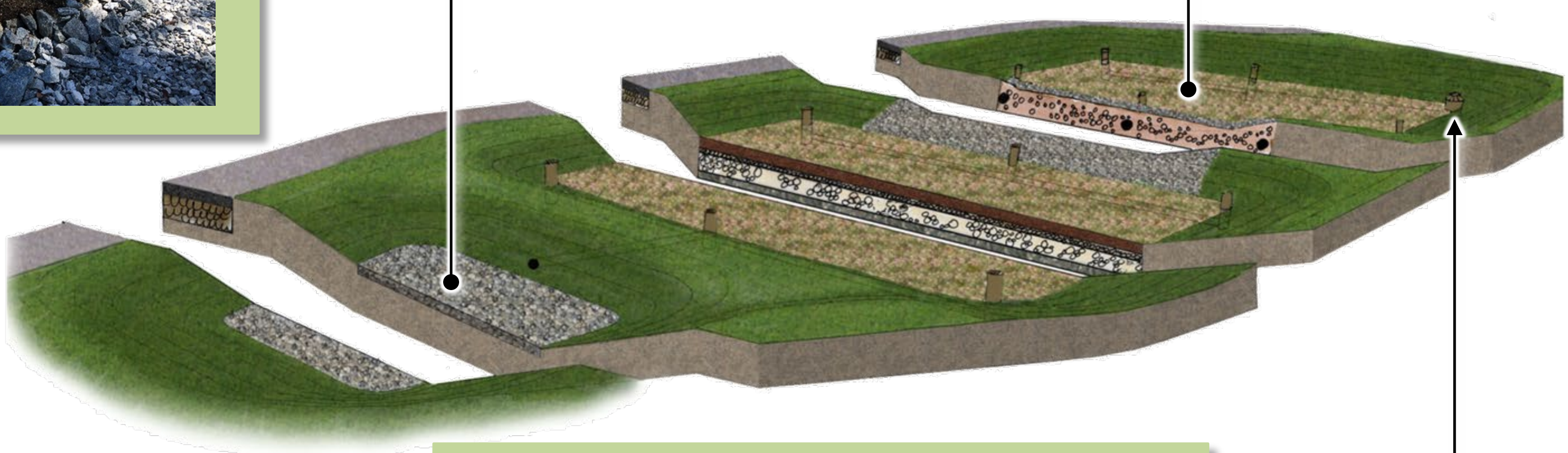


*Image numbers refer to those in table.

Gravel Wetland (WVTS)

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance
#1	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#2	Berms	• Inspect for debris/sediment buildup. • Inspect for damage (e.g., erosion, weeps, failure, animal burrows).	• Remove debris/sediment buildup behind berms. • Restore damaged areas to their original condition.
#3	WVTS Cell	• Inspect for condition and percentage of cover of wetland vegetation within WVTS. • Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil, lack of vegetation and animal burrows. • Inspect for standing water in the basin and inspection ports (if underdrains are present).	• Cut back vegetation where overgrown and replace vegetation where necessary. • Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin and vegetation. • Restore areas of erosion, rutting, etc. with vegetation similar to that in the overall basin. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Infiltration Basin

MAINTENANCE

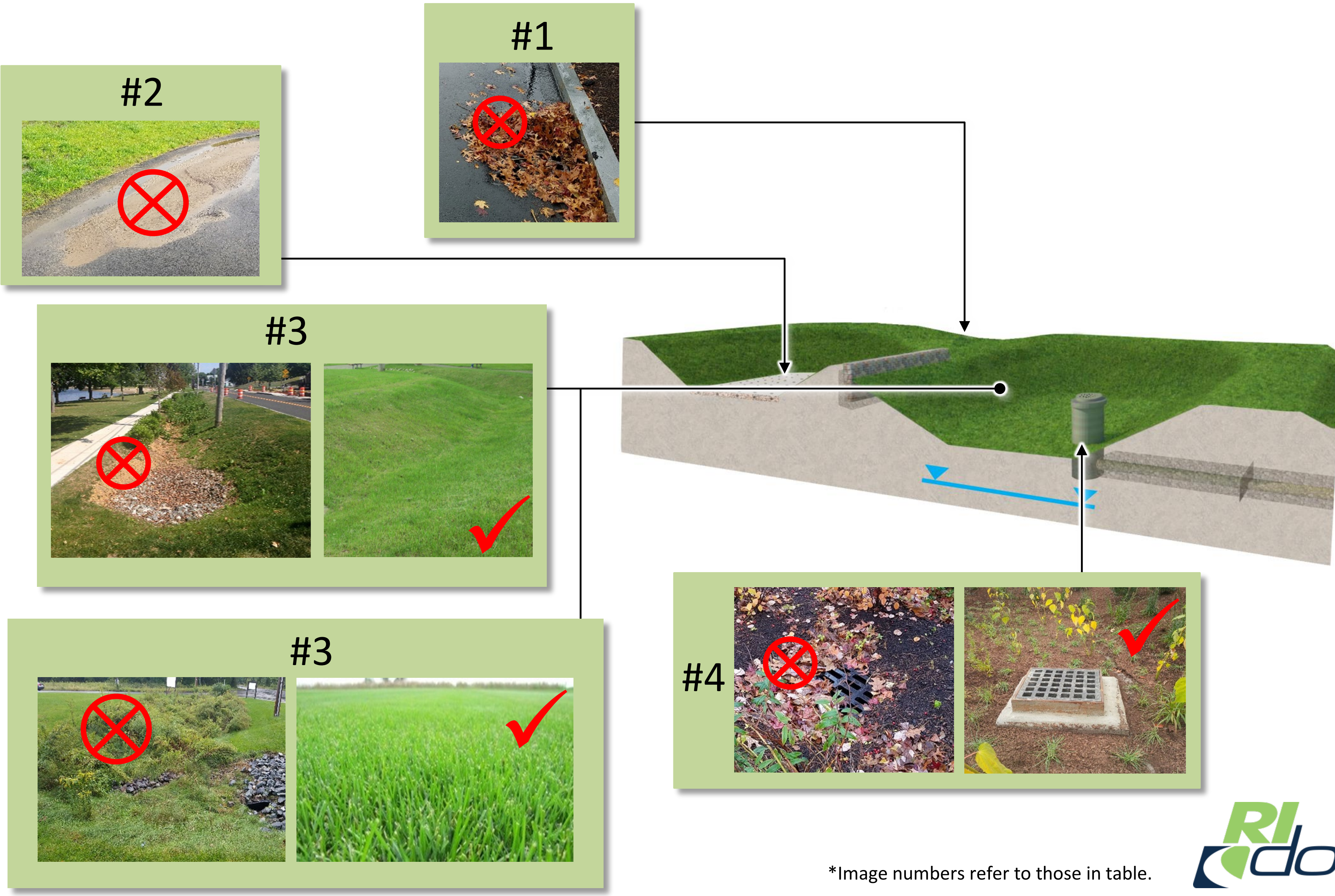


*Image numbers refer to those in table.

Infiltration Basin

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the inlet (e.g., grate, curb cut, etc.) and within the structure (if applicable). • Inspect inlet for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Basin Cell	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows in the basin and in surrounding upgradient areas. • Inspect for overgrown grass and weeds. • Inspect for standing water in the basin.	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin. • Restore areas of erosion, rutting, etc. to a condition similar to that in the overall basin. • Mow grass and remove weeds. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Underground Infiltration

MAINTENANCE

#1

#1

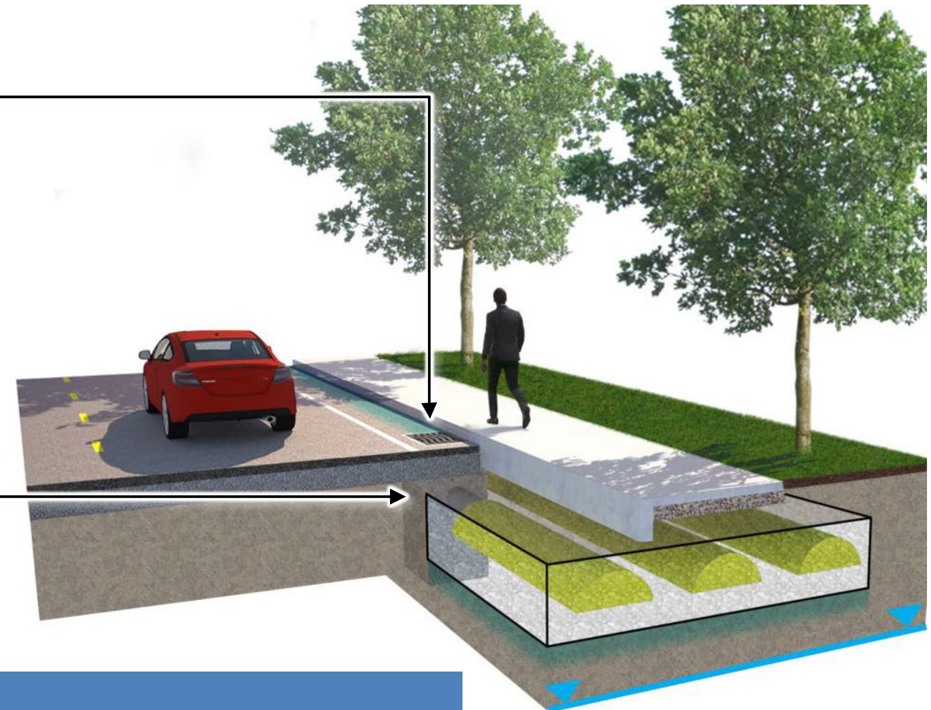


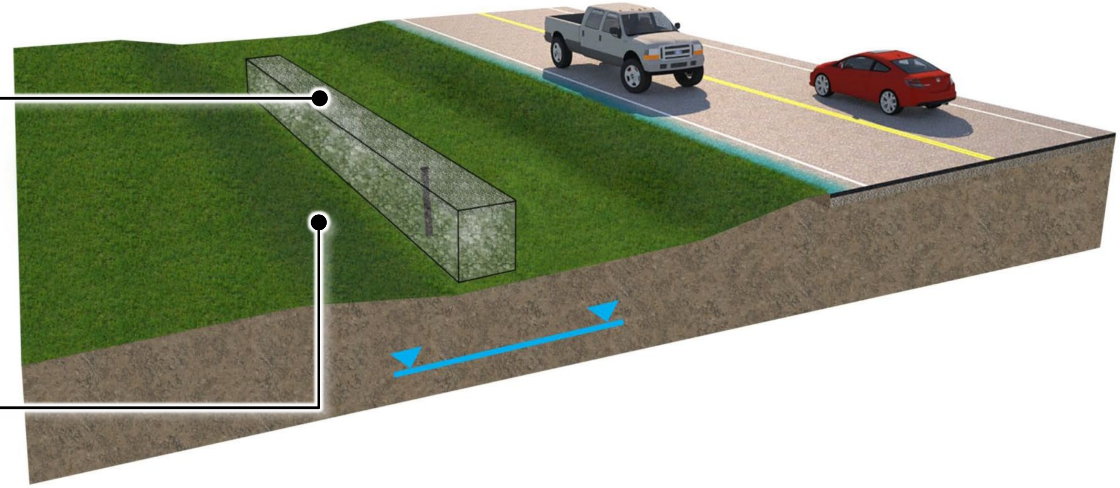
*Image numbers refer to those in table.

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet / Pretreatment Structure	• Inspect for accumulated debris/sediment at the surface (e.g., grate) and surrounding the inlet. • Inspect for accumulated debris/ sediment within the pretreatment structure. • Remove grate and inspect for damage.	• Remove debris/sediment around the outside of the inlet. • Remove debris/sediment within the pretreatment structure. • Restore damaged areas to their original condition.
#2	Subsurface Reservoir	• Inspect for standing water in inspection ports.	• Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.

Infiltration Trench

MAINTENANCE

#3



#3

#4

*Image numbers refer to those in table.

Infiltration Trench

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the inlet (e.g., grate, curb cut, etc.) and within the structure (if applicable). • Inspect inlet for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Basin Cell	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows in the basin and in surrounding upgradient areas. • Inspect for overgrown grass and weeds. • Inspect for standing water in the basin.	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin. • Restore areas of erosion, rutting, etc. to a condition similar to that in the overall basin. • Mow grass and remove weeds. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Leaching Basin

MAINTENANCE

#1

#1 & #2

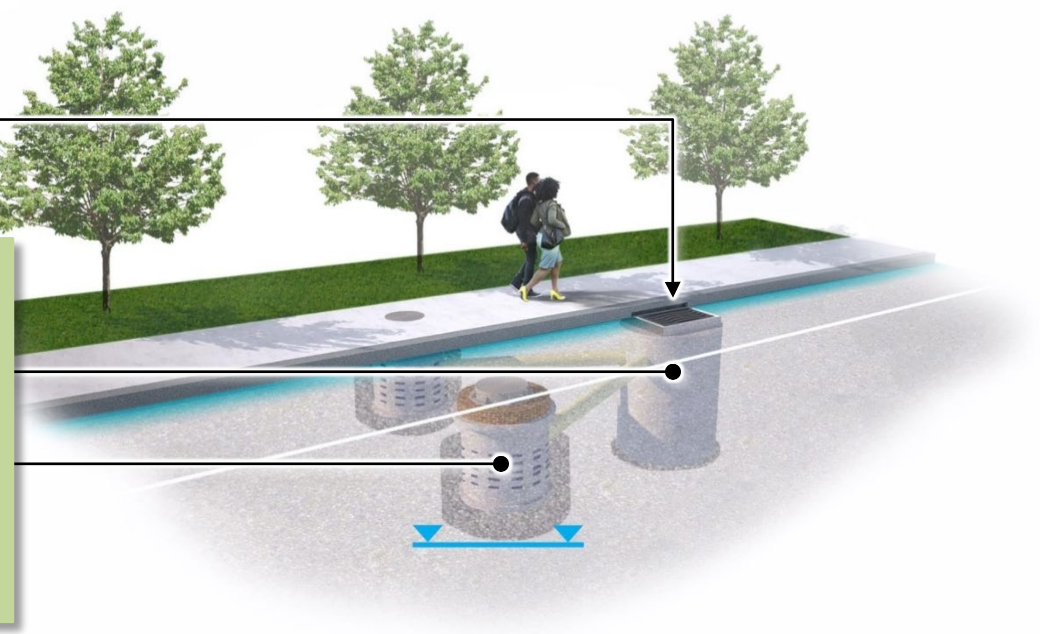


*Image numbers refer to those in table.

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet / Pretreatment Structure	• Inspect for accumulated debris/sediment at the surface (e.g., grate) and surrounding the inlet. • Inspect for accumulated debris/sediment within the pretreatment structure. • Remove grate and inspect for damage.	• Remove debris/sediment around the outside of the inlet. • Remove debris/sediment within the pretreatment structure. • Restore damaged areas to their original condition.
#2	Leaching Basin	• Inspect for accumulated debris/sediment within structure. • Inspect for standing water in inspection ports.	• Remove accumulated debris/sediment from structure. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.

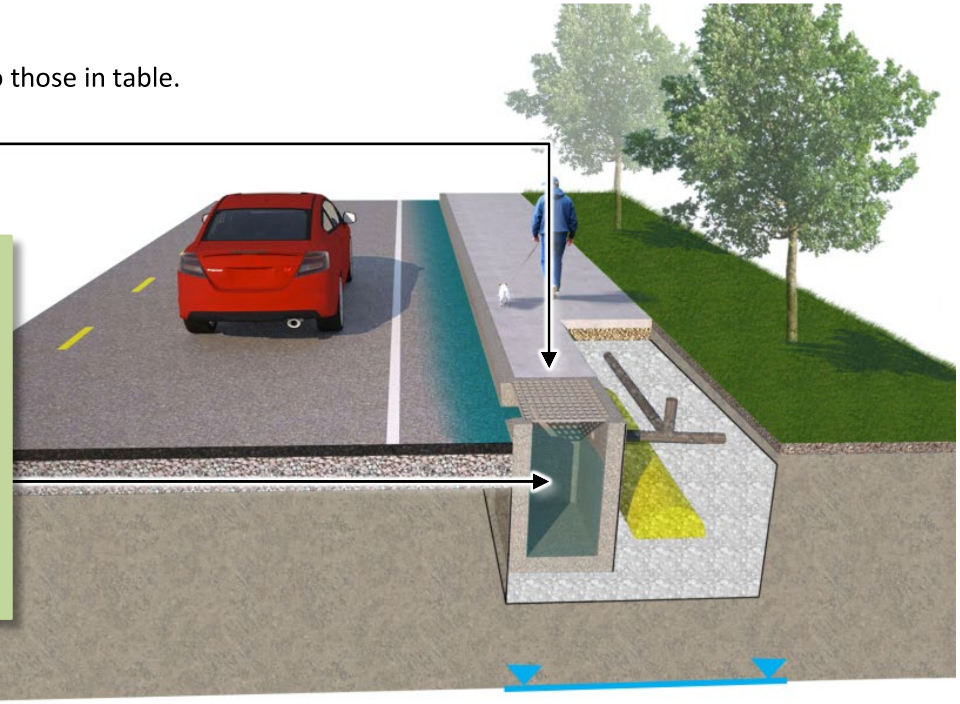
Infiltration Gutter

MAINTENANCE

#1

#1

*Image numbers refer to those in table.



O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet / Pretreatment Structure	• Inspect for accumulated debris/sediment at the surface (e.g., grate) and surrounding the inlet. • Inspect for accumulated debris/ sediment within the pretreatment structure. • Remove grate and inspect for damage.	• Remove debris/sediment around the outside of the inlet. • Remove debris/sediment within the pretreatment structure. • Restore damaged areas to their original condition.
#2	Subsurface Reservoir	• Inspect for standing water in inspection ports.	• Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.

Porous Pavement

MAINTENANCE

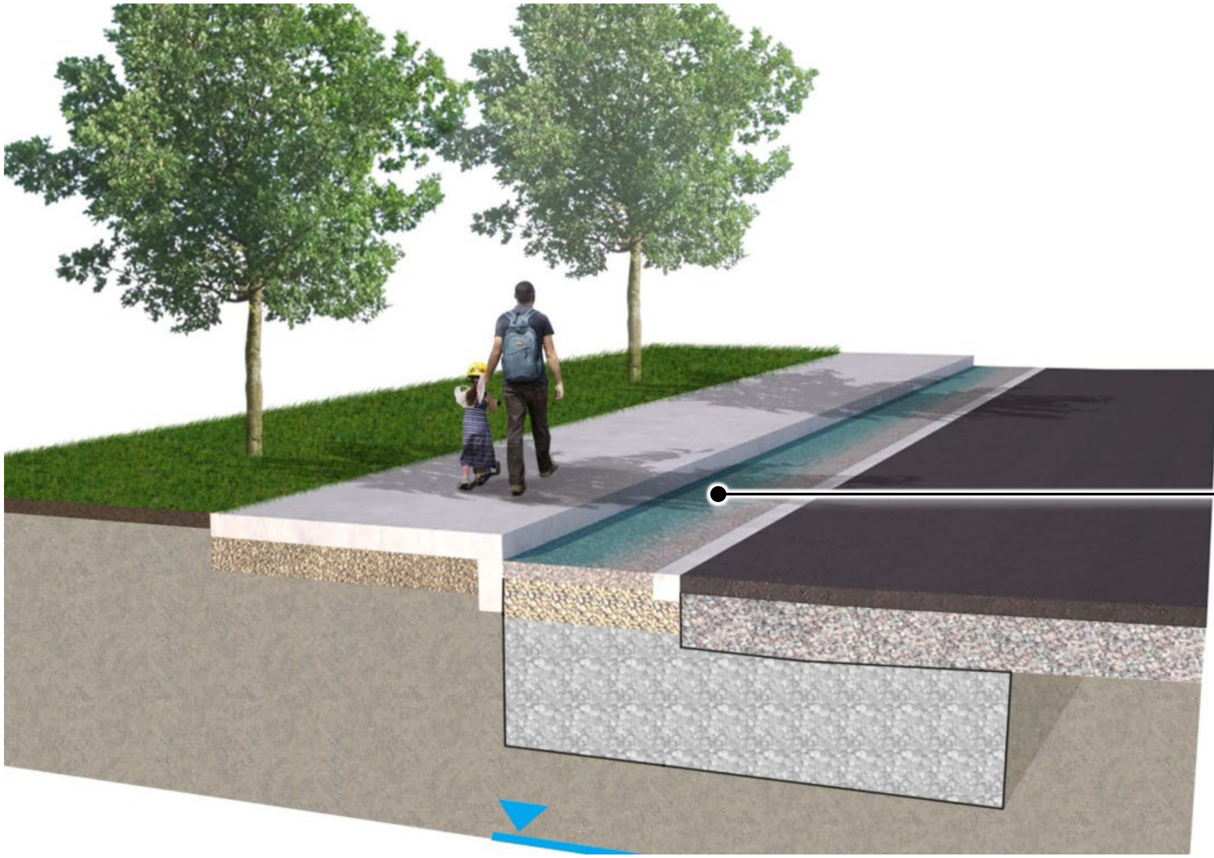


*Image numbers refer to those in table.

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Porous Pavement Surface	• Inspect for accumulated sediment, possible clogs and standing water. • Inspect for erosion/rutting in upgradient areas. • Inspect for cracks or damage to porous pavement.	• Remove accumulated debris/sediment with vacuum/sweeper truck. • Restore eroded areas to original condition. • Restore damaged areas to their original condition (potholes will require a specialized mix).
#2	Gutter Line	• Inspect for erosion, cracks, damage and accumulated debris/sediment.	• Remove debris/sediment on surface and along gutter line.

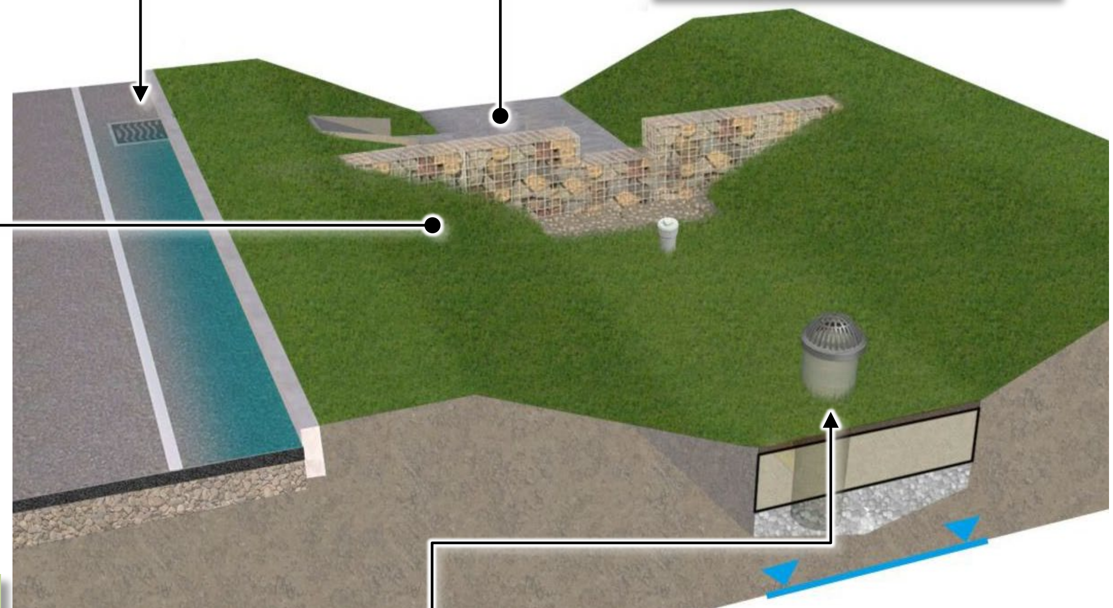
Sand Filter

MAINTENANCE

*Image numbers refer to those in table.

#1

#2



#3

#3

#4

Sand Filter

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the inlet (e.g., grate, curb cut, etc.) and within the structure (if applicable). • Inspect inlet for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Basin Cell	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows in the basin and in surrounding upgradient areas. • Inspect for overgrown grass and weeds. • Inspect for standing water in the basin and inspection ports (if underdrains are present).	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin. • Restore areas of erosion, rutting, etc. to a condition similar to that in the overall basin. • Mow grass and remove weeds. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

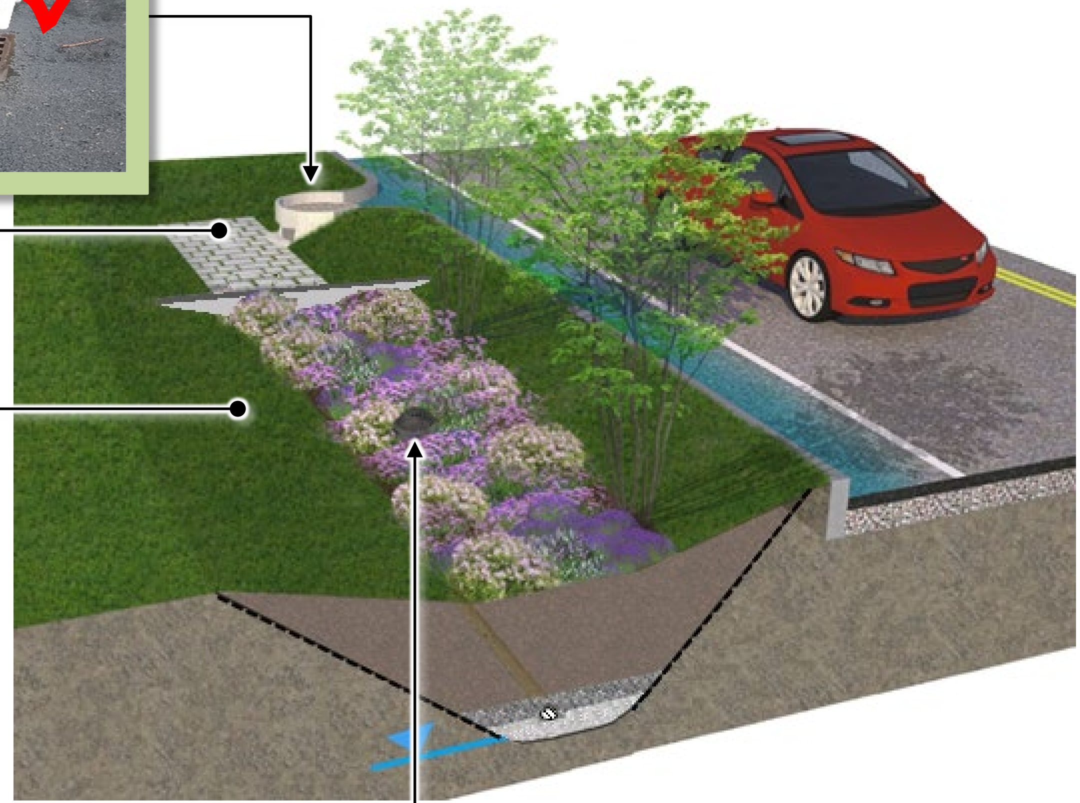
Bioretention Basin

MAINTENANCE

*Image numbers refer to those in table.

#1

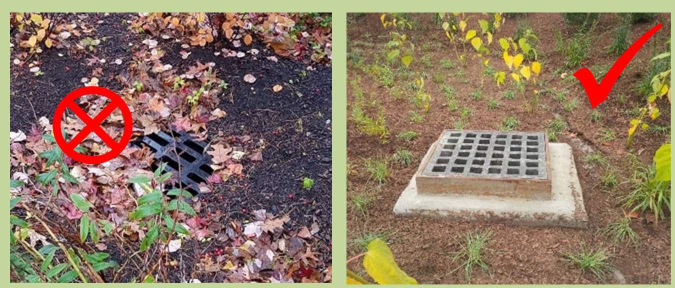
#2



#3

#3

#4



Bioretention Basin

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the inlet (e.g., grate, curb cut, etc.) and within the structure (if applicable). • Inspect inlet for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Basin Cell	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows in the basin and in surrounding upgradient areas. • Inspect for overgrown/dead vegetation and weeds. • Inspect for standing water in the basin and inspection ports (if underdrains are present).	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin and vegetation. • Restore areas of erosion, rutting, etc. with vegetation similar to that in the overall basin. • Mow, cut back and replace vegetation where overgrown/dead and remove weeds. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Bioretention Curb Inlet Planter

MAINTENANCE

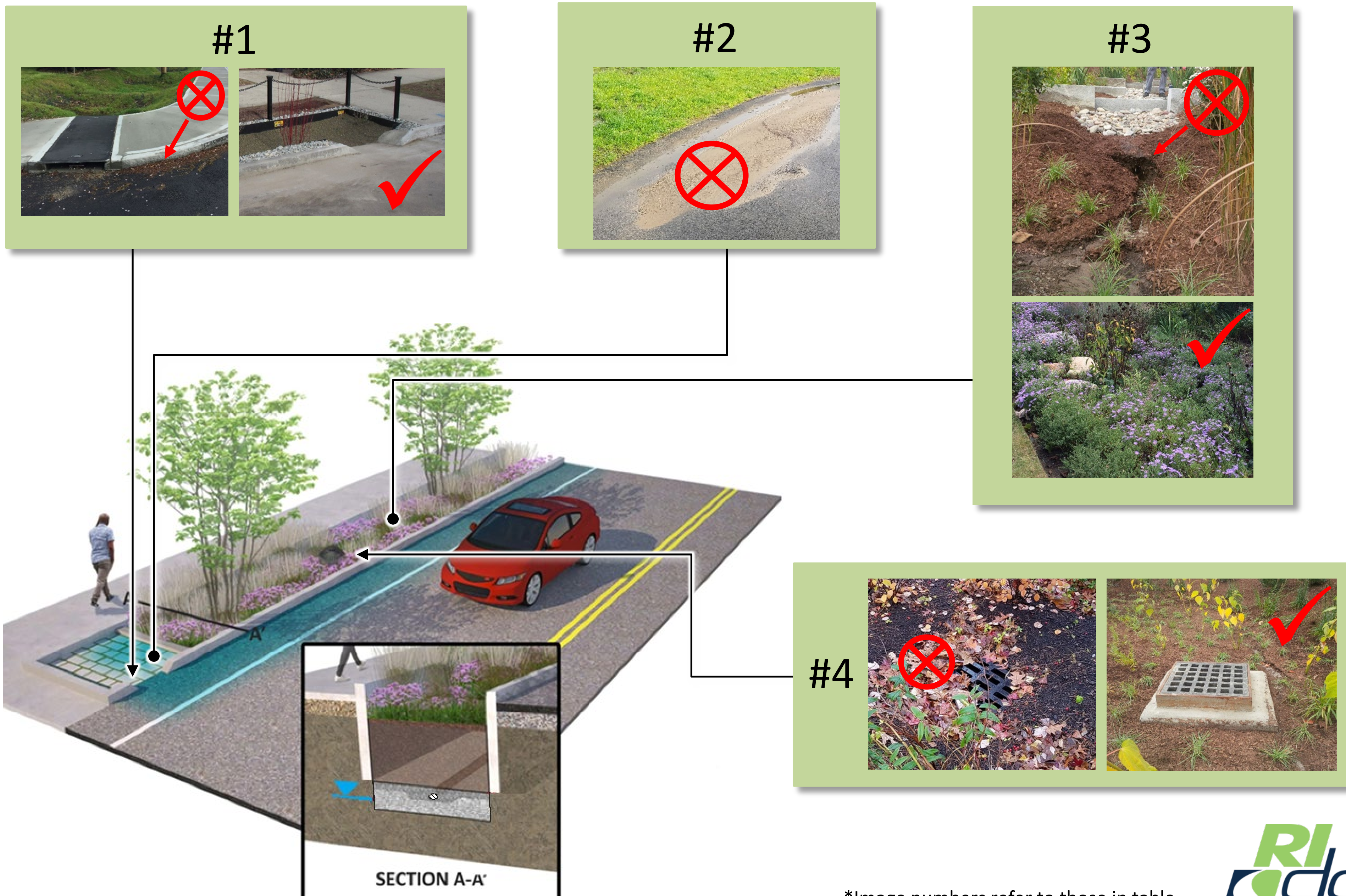


*Image numbers refer to those in table.

Bioretention Curb Inlet Planter

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the inlet (e.g., grate, curb cut, etc.) and within the structure (if applicable). • Inspect inlet for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Planter Cell	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows. • Inspect for overgrown/dead vegetation and weeds. • Inspect for standing water in the basin and inspection ports (if underdrains are present).	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin and vegetation. • Restore areas of erosion, rutting, etc. with vegetation similar to that in the overall basin. • Mow, cut back and replace vegetation where overgrown/dead and remove weeds. Trim tree branches (if applicable). • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Bioretention Parking Lane Adjacent Planter

MAINTENANCE

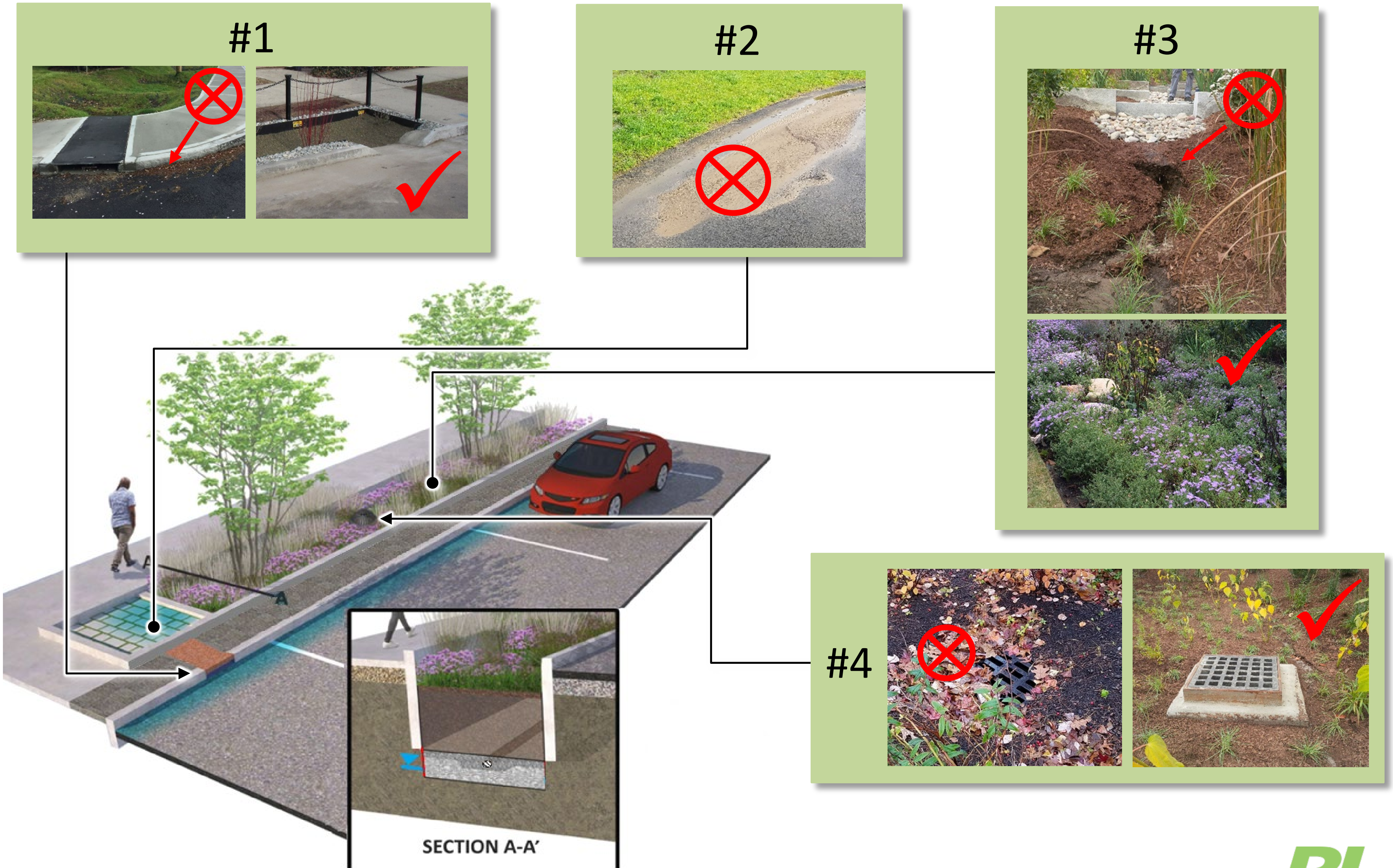


*Image numbers refer to those in table.

Bioretention Parking Lane Adjacent Planter

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the inlet (e.g., grate, curb cut, etc.) and within the structure (if applicable). • Inspect inlet for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Planter Cell	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows. • Inspect for overgrown/dead vegetation and weeds. • Inspect for standing water in the basin and inspection ports (if underdrains are present).	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin and vegetation. • Restore areas of erosion, rutting, etc. with vegetation similar to that in the overall basin. • Mow, cut back and replace vegetation where overgrown/dead and remove weeds. Trim tree branches (if applicable). • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Bioretention Curb Extension Planter

MAINTENANCE

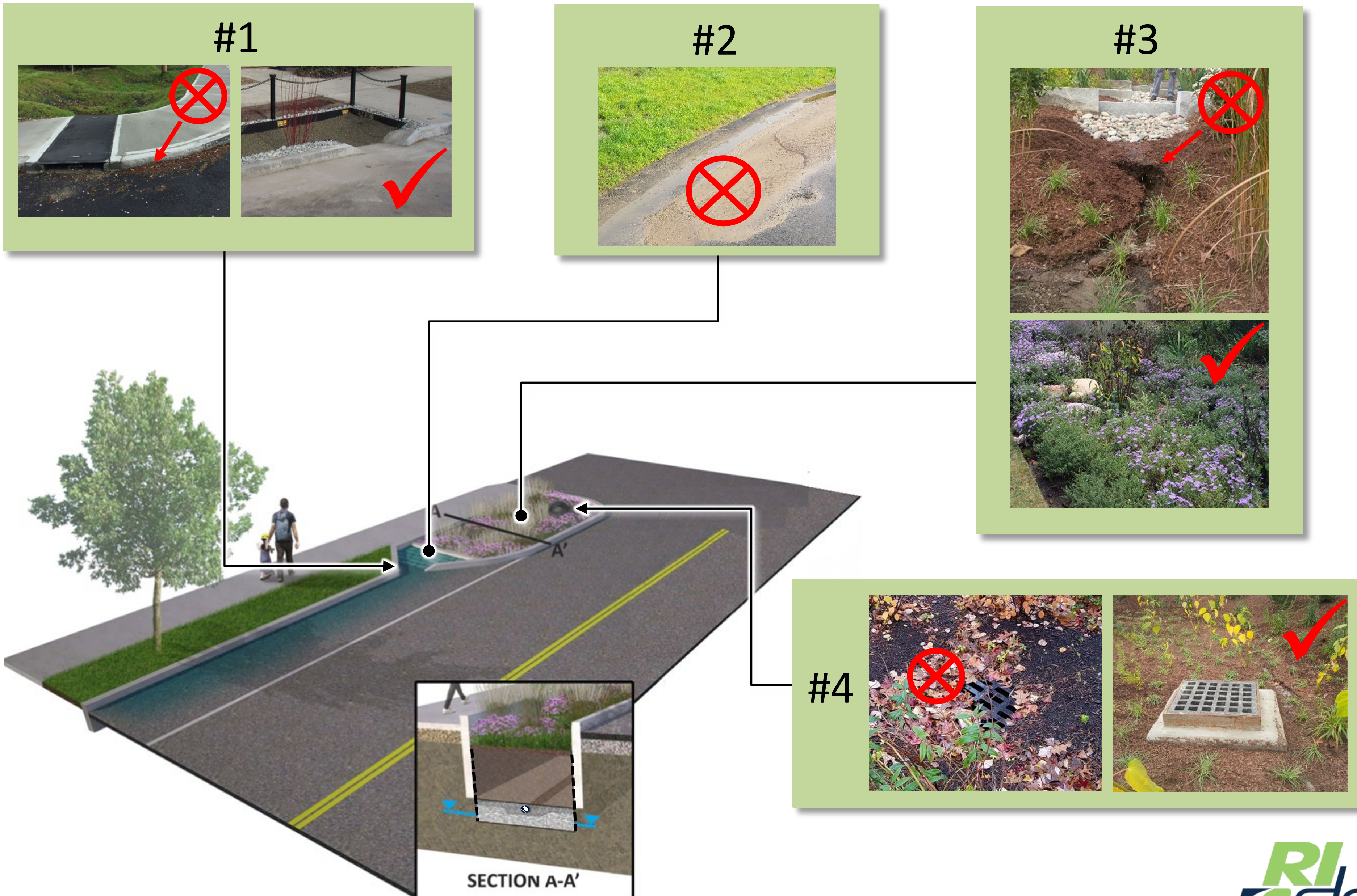


*Image numbers refer to those in table.

Bioretention Curb Extension Planter

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the inlet (e.g., grate, curb cut, etc.) and within the structure (if applicable). • Inspect inlet for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Planter Cell	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows. • Inspect for overgrown/dead vegetation and weeds. • Inspect for standing water in the basin and inspection ports (if underdrains are present).	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin and vegetation. • Restore areas of erosion, rutting, etc. with vegetation similar to that in the overall basin. • Mow, cut back and replace vegetation where overgrown/dead and remove weeds. Trim tree branches (if applicable). • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#4	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Bioretention Swale

MAINTENANCE

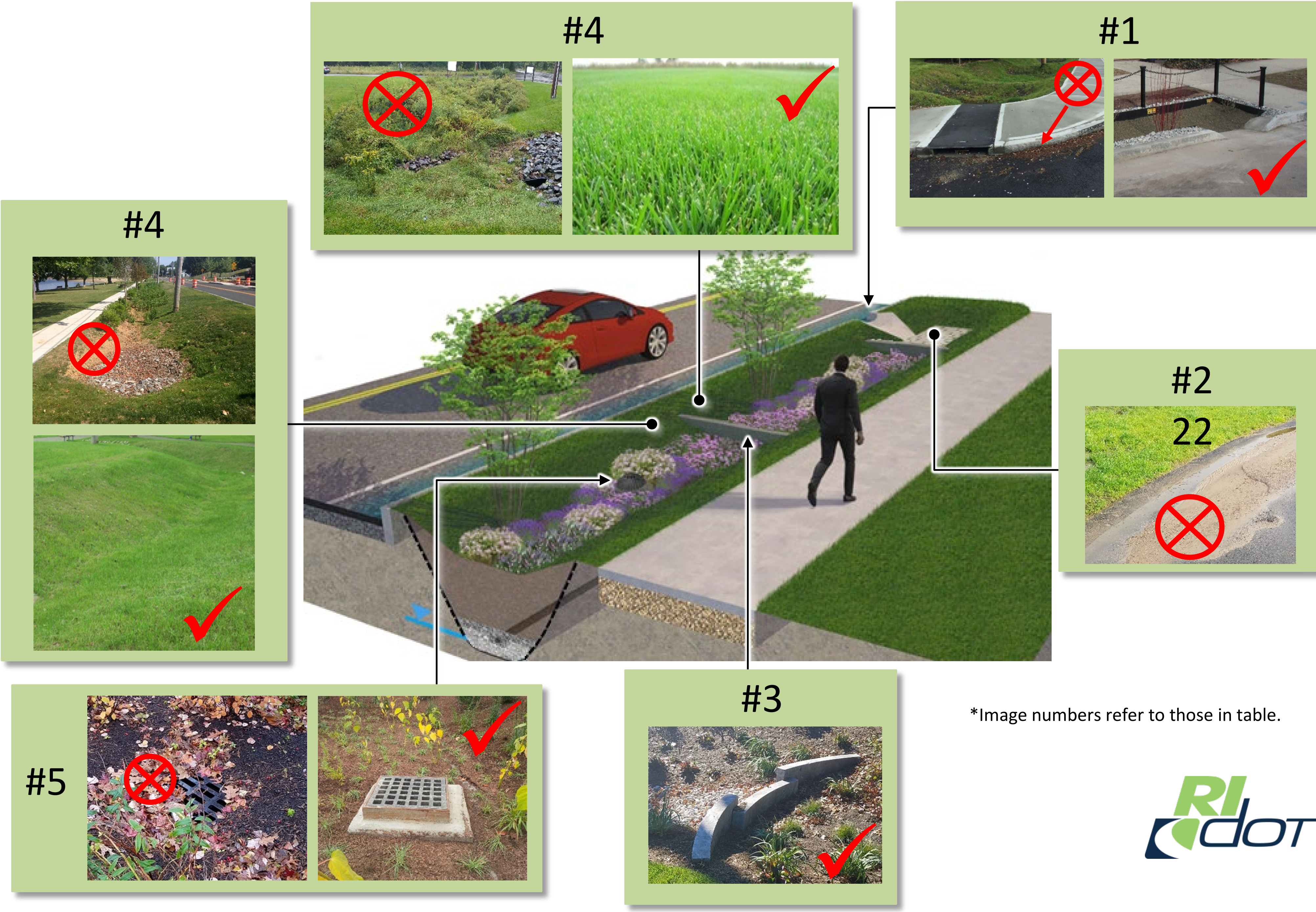


*Image numbers refer to those in table.

Bioretention Swale

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet Structure	• Inspect for accumulated debris/sediment at the surface (e.g., grate) and within the structure. • Remove grate and inspect for damage.	• Remove debris, sediment and floatables in and around the structure. • Restore damaged areas to their original condition.
#2	Pretreatment Structure	• Inspect for accumulated debris/sediment. • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. Avoid damage to the structure. • Restore damaged areas to their original condition.
#3	Berms/Weirs	• Inspect for accumulated debris/sediment • Inspect for damage (e.g., erosion, cracks, spalling, weeps, failure, animal burrows).	• Remove debris/sediment buildup behind berms/weirs. • Restore damaged areas to their original condition.
#4	Swale	• Inspect for accumulated debris/sediment and leaf litter. • Inspect for damage such as erosion, rutting, patches of soil and animal burrows. • Inspect for overgrown/dead vegetation and weeds. • Inspect for standing water in the basin and inspection ports (if underdrains are present).	• Remove and properly dispose of debris/sediment, leaf litter, etc. Avoid damage to the basin and vegetation. • Restore areas of erosion, rutting, etc. with vegetation similar to that in the overall basin. • Mow, cut back and replace vegetation where overgrown/dead and remove weeds. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.
#5	Outlet Structure	• Inspect for accumulated debris/sediment at the outlet and within the structure (if applicable). • Inspect for structural damage.	• Remove and properly dispose of debris/sediment. • Restore damaged areas to their original condition.

*O&M numbers refer to images in diagram.

Tree Filter

MAINTENANCE

#1

#2

*Image numbers refer to those in table.

Tree Filter

MAINTENANCE

O&M Number*	System Component	Inspection Measure	Maintenance Activity
#1	Inlet / Pretreatment Structure	• Inspect for accumulated debris, sediment and floatables at the surface (e.g., grate) and surrounding the inlet. • Inspect for accumulated debris/ sediment within the pretreatment structure. • Remove grate and inspect for damage.	• Remove debris, sediment and floatables around the outside of the inlet. • Remove debris/sediment within the pretreatment structure. • Restore damaged areas to their original condition.
#2	Tree Filter	• Inspect for accumulated debris/sediment around tree bed. • Inspect for overgrown tree branches and weeds. • Inspect for standing water in the basin.	• Remove accumulated debris/sediment from structure. • Trim tree branches as necessary and remove weeds. • Record depth of water and notify the RIDOT Office of Stormwater Management if standing water is observed beyond 2-3 days since the last rainfall event.

*O&M numbers refer to images in diagram.