City of Philomath

Low Impact Development Manual

DESIGN GUIDANCE FOR STORMWATER TREATMENT AND CONTROL PROJECTS IN THE CITY OF PHILOMATH

AUGUST 2017

ACKNOWLEDGEMENTS

This manual is an adaptation of the “Low Impact Development in Western Oregon: A Practical Guide for Watershed Health” template provided by the Oregon Department of Environmental Quality. Portions of this guidance were adapted from the City of Eugene’s Stormwater Management Manual.

DISCLAIMERS

This manual provides information for educational and outreach purposes only, to enhance the sustainability of sites. Unless adopted or approved by the appropriate registered professional under contract, information provided is not for construction. The recommendations contained in this guidance should not be construed as a requirement of rule or statute, but rather as best available information on current practices as of 2017. The following material is provided for informational purposes only. Before taking any action that could have legal or other important consequences, speak with qualified professionals who can provide guidance that considers your own unique circumstances.

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1.1 INTRODUCTION

Sustainable and long-term solutions to stormwater management is a key element in the City of Philomath's progress. As Philomath grows to accomadate an increasing population, development will introduce additional impervious surface area. The presence of hardscape prevents groundwater recharge, increases runoff and introduces pollutants to waterways. In a community that values fish and wildlife along with outdoor recreation and clean drinking water, the aforementioned effects are troubling. Low impact development (LID) offers practical and aesthetically pleasing methods that address water quality and water flow issues. Intelligent implementation of LID in Philomath would imitate the natural hydrology found in the Mary's River Watershed; therefore properly managing stormwater runoff and protecting water resources.

The Municipal Separate Storm Sewer System (MS4) permit requirements of the National Pollution Discharge Elimination System (NPDES) most recently reissued in 2010 requires the introduction of a LID manual. This guidance was created in compliance with the MS4 program and associated Total Maximum Daily Loads (TMDL) planning.

1.2 MANUAL OBJECTIVE

The purpose of this document is to provide detailed implementation guidance to stakeholders in Philomath, Oregon. Although this is a technical document, every effort has been made to write in accessible language so that involved parties in both the public and private sectors may develop more environmentally sound and cost-effective sites. This document is not meant to take the place of additional measures that may be needed to completely address stormwater and regulatory requirements.

The presented information seeks to instruct contractors about the differences between low impact development and conventional stormwater approaches. Implementing a Low Impact Development (LID) site is similar to conventional development in many ways; however, the main difference is that the site's natural and built conditions drive decisions. Site design should lead with stormwater considerations as the primary programmatic element. This document has been adapted by the City of Philomath to account for the natural variations in rainfall and soils, along with current requirements specific to the local environment.

1.3 MANUAL ORGANIZATION

Chapter 1: An Overview of Low Impact Development outlines the use of the manual, introduces the concept of low impact development, defines relevant terms, documents benefits of the practice, introduces best management practices (BMPs) and discusses the costs of LID.

Chapter 2: Recommended Best Management Practices provides detailed guidance for each BMP through the planning, design, and construction project phases, as well as BMP-specific cost considerations.

Chapter 3: Sizing and Implementing LID Facilities defines a hierarchy of BMPs and provides two methods for sizing BMP footprints.

Chapter 4: Operations and Maintenance includes operations and maintenance agreement submittals forms, which document who will be responsible for BMP maintenance. The chapter also addresses required maintenance activities.

Appendix A: Site Planning Checklists is a checklist of site planning reports and specific information for what should be included in each report, so that the proper scope of work to implement LID sites is known.

Appendix B: Infiltration Testing provides detailed information on infiltration testing, which is needed to implement many of the BMPs.

Appendix C: Facility Planting Design describes important considerations when choosing plants.

Appendix D: Material Specifications clarifies the materials specifications for a variety of components specified in BMPs such as gravel, compost, and impermeable liners. It also includes detailed specifications for constructing porous asphalt pavements.

Appendix E: **Details** includes standard details for almost every BMP included in this guidance, as well as supporting infrastructure.

1.4 GLOSSARY

Approved discharge point: A location where overflow from a BMP may be directed, which includes a surface infiltration facility; storm drain or other conveyance system; a waterway (as approved by the Oregon Department of State Lands), or an underground injection control facility (as approved by the Oregon Department of Environmental Quality).

Bedrock: A hard, solid rock surface that may underlie fragmented/decomposed rock and soil. Considered an impervious surface.

Best management practice (BMP): "A device, practice, or method for removing, reducing, retarding, or preventing targeted stormwater runoff constituents, pollutants, and contaminants from reaching receiving waters."

Cation exchange capacity (CEC): "The amount of exchangeable cations that a soil can adsorb at pH 7.0 expressed in terms of millequivalents per 100 grams of soil." An adequate CEC in soil contributes to pollutant treatment.

Contaminated soils: Soils at sites where contaminants have accumulated as a result of historic activities, not necessarily limited to industrial sites. Contaminated sites have a highly regulated development path with additional permitting. Coordination with the local DEQ Cleanup program is advised.

Detention basin: A large depression in the ground where runoff is stored and released slowly. Detention basins were used to reduce flooding, but have been found to be inadequate at protecting downstream water quality.

Downspout disconnection: A form of dispersion that directs a building's roof drains to a lawn or garden instead of into storm sewer pipes.

Evaporation: The process of water changing from a liquid to a gas. Evaporation is a significant portion of the annual water cycle that reduces runoff in undeveloped and/or forested areas of Western Oregon.

Evapotranspiration: The collective term for the process of water returning to the atmosphere via interception and evaporation from plant surfaces and transpiration through plant leaves.

Invasive plants: Aggressive plants that outcompete native plants for water, sunlight and nutrients and therefore harm the environment, economy and human health.

Impervious surface: A surface that prohibits water from soaking into the ground. Examples include roofs, concrete, asphalt, pavers, compacted gravel, compacted clay, plastic liners, and clogged landscape fabric.

Landslide/ landslide area: The downslope movement of rock, soil, or related debris. This term includes areas that already experienced a landslide and landscapes that have the potential to slide in the future.

Limit disturbance BMP: Any BMP that protects a site or portion of a site in its current, natural vegetated state and/or protects soil permeability.

Low impact development (LID): A pattern of land development that preserves natural resources and promotes opportunities to manage stormwater where it falls. LID relies on a collection of carefully selected techniques to reduce, receive, and clean stormwater runoff to protect and improve water availability and quality.

Minimal excavation foundation BMP: A foundation type that allows groundwater to move freely through soil (not pipes) underneath the building (e.g. pier foundations and buildings with crawl spaces).

Minimize impervious area BMP: Any BMP that reduces land area not able to infiltrate or evaporate rainfall or runoff as a result of being covered by buildings, roofs, and roads, parking lots and sidewalks.

Mulch: Material such as compost, bark or wood chips spread on soil to retain moisture, discourage weeds and protect against wind and rain erosion.

Native plants: Plants that occur historically in an area. If planted in conditions they naturally occur, these plants need little or no fertilizer or care once established and provide wildlife habitat.

Non-native (ornamental) plant: Plants that do not occur historically in an area, which may not be invasive, but also may not provide wildlife habitat.

Mycorrhizae: The mycelium (roots) of a fungus.

New development: Any project where the land cover is changed from a natural, pre-developed state into another land cover.

Predevelopment or predeveloped condition: The naturally vegetated land cover and contour that would historically have been on a site.

Porous/Pervious/Permeable: A material that allows water to pass through it.

Post-development or post-developed condition: The land cover on a site as a result of development activities, which may include but is not limited to buildings, roads, sidewalks, ornamental, and working and protected landscapes.

Rainfall management: Use of BMPs to treat and reduce the volumes of stormwater leaving a site by infiltrating or evaporating rain that falls directly on the surface of the BMP. When rainfall management BMPs are used, they are referred to as "Runoff Prevention BMPs".

Redevelopment: Any project where existing land cover, which was previously developed, is changed to another land cover.

Retrofit: Any project that improves water quality from an existing developed area.

Runoff: Rainfall and snowmelt that flows off of a land surface instead of seeping into the ground or evaporating in the air. Runoff carries pollutants to waterways.

Runoff management: Using BMPs to treat and reduce the volumes of stormwater leaving a site by infiltrating or evaporating runoff collected and/or channeled from other areas to the BMP. Examples of runoff management facilities include rain gardens, stormwater planters, and LID swales. When runoff management BMPs are used, they are referred to as "Runoff Reduction BMPs".

Runoff treatment: Use of BMP(s) to treat runoff.

Total Maximum Daily Load (TMDL): An analysis and written quantitative plan for attaining and maintaining water quality standards in a stream. It includes a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet state water quality standards, allocations of portions of that amount to the pollutant sources or sectors, and a Water Quality Management Plan to achieve water quality standards.

Treatment soil: A naturally occurring or engineered mix which may include clay, silt, sand, gravel, compost, microorganisms, and mycorrhizae that has the desired physical and chemical properties needed to clean stormwater as it passes through it.

Watershed: An area of land delineated by a ridge that causes water to drain to different rivers, ponds, lakes, seas, or oceans.

Wetland: An area that has surface water or saturated soils often enough to create unique soil characteristics that support vegetation that is adapted to inundation and saturation and lacks vegetation that is intolerant of inundation or saturation.

Urbanized: Any watershed where publicly or privately owned land surfaces in a city, town, or rural area have been developed and cause that watershed to be 5% or more impervious.

Underground Injection Control (UIC): A manmade structure that places fluid underground.

Vegetated stormwater facilities: This is a general term that applies to rain gardens, stormwater planters, and LID swales, which are configured differently, but achieve a similar, high level treatment and runoff reduction through intentional temporary ponding of water.

1.6 LOW IMPACT DEVELOPMENT

1.6.1 WHAT IS LOW IMPACT DEVELOPMENT?

Low impact development is a pattern of land development that preserves natural resources and promotes opportunities to manage stormwater where it falls. LID relies on a collection of carefully selected techniques to reduce, receive, and clean stormwater runoff to protect and improve water availability and quality. LID is a stormwater and land use management strategy that strives to mimic pre-disturbance hydrologic processes of infiltration, filtration, storage, evaporation and transpiration by emphasizing conservation, use of on-site natural features, site planning, and distributed stormwater management practices that are integrated into a project design.[1]

1.6.2 SIGNIFICANCE OF LOW IMPACT DEVELOPMENT

There are a number of reasons to begin using low impact development. LID reduces water pollution, which supports the health and welfare of our communities with improved drinking water quality[2], reduced water treatment costs[3], and cleaner waterways that provide recreational and economic opportunities. It also reduces localized flooding during storms by mimicking predevelopment hydrology patterns. Additionally, LID is more cost-effective to build and maintain than conventional stormwater facilities such as detention basins and pipes (see "1.6.5 The Cost of Low Impact Development"). Low impact development also creates more livable cities, which incorporate distributed patches of nature that reduce crime, calm traffic, improve the value of the land, increase sales in commercial areas, and improve cognitive function.[4]

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[1] University of Washington, College of Environment. Urban Forestry/Urban Greening Research. Green Cities: Good Health. Retrieved from : http://depts.washington.edu/hhwb/Thm_Livable.html

[2] U.S. Environmental Protection Agency. Water: Green Infrastructure. Retrieved from: http://water.epa.gov/infrastructure/greeninfrastructure/gi_why.cfm

[3] Ernst, C. (2004). Protecting the Source. Retrieved from: http://syracusecoe.org/EFC/images/allmedia/LIBRARYProtectingtheSource_TPLAWWA2004.pdf

[4] University of Washington, College of Environment. Urban Forestry/Urban Greening Research. Green Cities: Good Health. Retrieved from: http://depts.washington.edu/hhwb/Thm_Livable.html

1.6.3 BEST MANAGEMENT PRACTICES

The EPA defines a best management practice (BMP) as "a device, practice, or method for removing, reducing, or preventing targeted stormwater runoff constituents, pollutants, and contaminants from reaching receiving waters." Despite widespread use of the word "best" to describe these practices, these practices can be ineffective if improperly applied. LID, by definition, uses a number of BMPs together. BMPs must be selected appropriately based on site opportunities and constraints and project objectives. They must also be applied during the appropriate phase of the project.

Figure 1- An example of BMPs being used on a university campus. A series of stormwater planters treat runoff from roofs and sidewalks.

BMPs may be incorporated into existing as well as newly built developments and redevelopments. Since LID includes an array of BMPs, LID is generally applicable on all sites and for all land use classification.

BMPs are classified depending on their fundamental function. Perhaps the most significant distinction is whether a BMP prevents runoff in the first place (*i.e.* runoff prevention BMP) or manages runoff from existing, new, or redeveloped surfaces (*i.e.* runoff reduction BMP).

Runoff prevention BMPs may be either informed decisions that protect a site or reduce the volume of runoff leaving a site by evaporating and/or infiltrating rainfall that falls directly on it. These restoration and protection practices are often employed during the early planning phase.

Runoff reduction BMPs decrease the volume of runoff leaving a site by evaporating and/or infiltrating runoff directed to the BMP from another area. They tend to be engineered or highly designed facilities that mitigate the damage created by changing the land cover from more porous to more impervious. Runoff reduction strategies can be used in retrofit, redevelopment and new construction projects and should be considered only after all potential runoff prevention BMPs have been considered and applied.

1.6.4 WHY SOME BMPS ARE NOT ADDRESSED

The stormwater management practices described below are recognized methods for addressing runoff in certain situations. They will not be further heeded in this manual, but may be an appropriate option for particular projects. If interested in implementing one of the following practices, contact the City of Philomath Public Works Department.

Contained Planters & Vegetated Roofs

Contained planters placed over hard surfaces intercept rainfall and reduce runoff through evaporation. Vegetated roofs are an assembly of materials that intercept rainfall and reduce runoff through evaporation. Both of these BMPs have the tendency to contribute nutrients (i.e. nitrogen and phosphorus) to the water that flows through them. An excess of nutrients in the water allows algae to grow faster than the ecosystem can handle, therefore leading to algal blooms that negatively impact water quality, food resources and aquatic life. At present, the City of Philomath is a nutrient "problem area", so implementing contained planters and vegetated roofs is considered a high risk BMP choice.

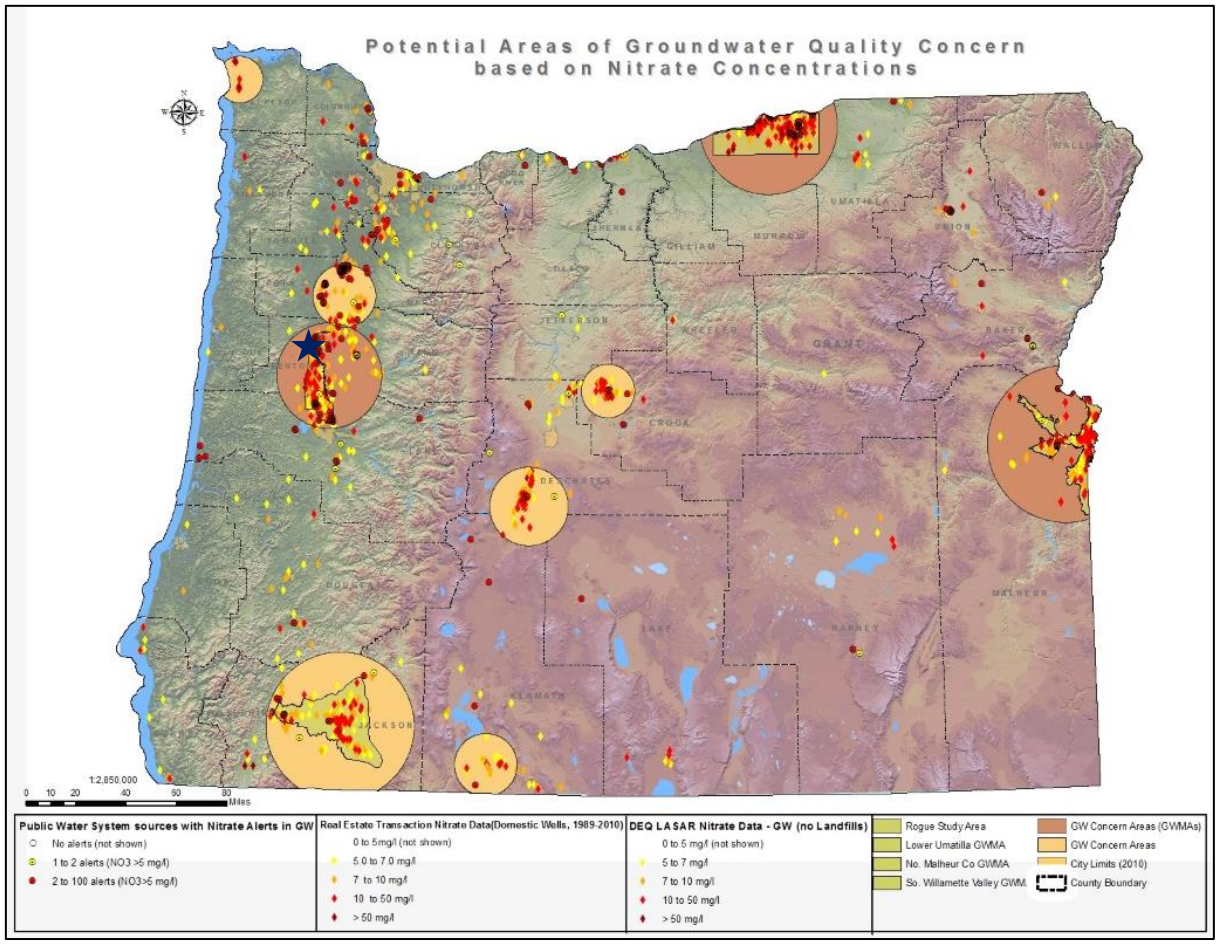

Figure 2- A map of Oregon indicating nitrogen problem areas. Philomath exists in one of the "at risk" circles, as shown with a star.

Detention Basins

To protect streams from high flows, regulations sometimes require the installation of large detention ponds. While detention ponds relieve flooding in theory, attenuating the peak flows from large storms, the much larger additional volumes coming from developed areas during small storm events can still cause flooding. These ponds don't reduce the overall volume of runoff, don't recharge aquifers, and don't remove pollutants as effectively as other, more affordable BMPs. Finally, detention ponds take up valuable land and can be more difficult to access and maintain than smaller, distributed BMPs. Additional information on detention facilities in the City of Philomath can be found in the Public Works Design Standards Stormwater Management 3.18.

Rainwater Harvesting

In Western Oregon, small tanks and rain barrels don't capture and store a significant volume of runoff, so excess runoff volumes are allowed to scour downstream banks. Large tanks capable of storing significant volumes of runoff are also problematic. Due to Philomath's seasonal rainfall patterns, runoff would be collected and stored for the 9 or 10 months when it should be evaporating back into the air or seeping into the ground to recharge streams and aquifers. Then, during the dry months, when our water systems should not receive water, water is applied to the landscape.

Drywells

A drywell is a well, assemblage of perforated pipes, or drain tiles that receive runoff from impervious surfaces and infiltrates that runoff underground[5]. Drywells reduce runoff flow rates and volumes, infiltrating it into the surrounding soils. For more information on drywells reference the Public Works Design Standards Stormwater Management 3.20.

Minimal Excavation Foundations

A foundation type that allows groundwater to move freely through soil underneath a building. Groundwater flows are a natural and necessary element of hydrology and the pores in the soil beneath a building with minimal excavation foundations provide temporary storage for rainfall and flowing groundwater.

Cluster Development

Cluster development is a BMP usually applied on a campus or subdivision scale that groups development on one place of the site and leaves undeveloped open space on another.

[5] Oregon Department of Environmental Quality website. Water Quality: Underground Injection Control Program: Identifying an Underground Injection Control. Available Retrieved from: http://www.deq.state.or.us/wq/uic/guidance.htm

1.6.5 THE COST OF LOW IMPACT DEVELOPMENT

New and redevelopment projects can see reduced up-front costs. Techniques like minimizing impervious surfaces, building over previously disturbed areas, reducing excavation, limiting compaction and aligning utilities in one trench reduce construction and landscape restoration costs. Without considering sewer overflows, an EPA analysis of 17 private developments with conventional stormwater management requirements around the U.S., found that, in most cases, LID project costs were lower than the compared conventional solution. Total capital cost-savings ranged from 15-80% when LID methods were used[6]. Most of the cost savings were due to "site grading and preparation, stormwater infrastructure, site paving, and landscaping".[7]

Table 1 below gives examples of typical cost-savings scenarios to developers and landowners for one runoff prevention and one runoff reduction BMP.

Table 1- LID BMP & Cost Savings Examples

LID Type	BMP	Cost Savings
Runoff Prevention	Reduce impervious pavement	• Reduced pavement area installed. • Less runoff to be managed results in smaller runoff reduction BMPs. • Long-term maintenance costs like seal coating and replacement are reduced.
Runoff Reduction	Install distributed infiltration rain gardens instead of a detention basin	• Rain gardens have a cost similar to conventional landscapes. • The space where a detention basin would be, becomes buildable land.

Maintenance costs vary widely across different BMP and often within the same BMP with a different design. Maintenance activities and costs to maintain BMPs vary with siting, design, construction, owner's aesthetic preferences, and approach to maintenance. One 6-year study at the University of New Hampshire[8] compared conventional stormwater management to LID BMPs and found consistently lower long-term costs for maintaining LID BMPs at an 11-acre commuter parking lot. Researchers found that vegetated swales, porous pavement, and vegetated stormwater facilities were the least costly to maintain, while retention ponds and dry detention ponds were the most expensive. In general, maintenance of LID BMPs can range from 4% to 8% of the capital costs while detention ponds averaged about 17%.

[6],[16] U.S. Environmental Protection Agency. (2007). Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. Retrieved from: http://water.epa.gov/polwaste/green/costs07_index.cfm

[8] Houle, J., Roseen, R., Ballestro, T., Puls, T. and J. Sherrard Jr. (2013). A Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management. Retrieved from: http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/Houle_JEE_July-2013.pdf

1.5 USING THIS DOCUMENT TO PREPARE A PLAN

This sections aims to assist applicant's planning efforts as they reference the manual. These steps are not required, but aid in organization and preparation of stormwater management plans. At any time during the LID planning, designing, or construction process, you may contact the City of Philomath for assistance.

Step 1 – Layout your footprint. Prepare a site plan that details existing and proposed development, slopes, and waterways. If the project will be large and/or complex see the Site Survey Plan Checklist in Appendix A.

Step 2 – Inventory and evaluate the site. Site assessment includes inventorying and evaluating various natural resources that may pose challenges and/or opportunities for stormwater management and site development. A Site Assessment Checklist may be found in Appendix A.

Step 3 – Select Best Management Properties. Select appropriate BMPs for the site in question from those provided in Chapter 2.0 of this manual.

Step 4 – Design. Design and size BMPs using Chapters 2.0 and 3.0. Modeling is used to size BMPs and predict how facilities will respond to and manage stormwater, and is often performed for the entire site. Ensure that any proposed overflow structures direct excess stormwater to an approved discharge point. Approved discharge points may be drainage ditches, nearby streams, or existing storm drain systems. Incorporate a safe overland route in designs for all stormwater facilities that allows water to take a route that will not damage property in the case of a large storm. Confirm that all applicable permit and drawing requirements are met.

Step 5 – Construction. Reference Chapter 2.0 "Construction" sections of relevant BMPs. If guidance conflicts with standard industry practice, the contractor should consult with the design team and find acceptable means to implement facilities so its long-term function is achieved.

Step 6 – Develop an Operation & Maintenance Plan. Landowners are responsible for on-going operation and maintenance of BMPs. Outline an appropriate Operation & Maintenance Plan as detailed in Chapter 4.0. All BMPs and contributing drainage areas should be maintained to protect water quality and maximize function as follows:

- Maintain BMPs and sites with integrated pest management using little to no herbicides, pesticides, or fertilizers. Avoid spraying any pest management products on impervious surfaces.
- Maintain plants with little to no irrigation after establishment to conserve water and reduce weeding.
- Encourage vegetation to grow and become dense. Unless flows into the facility are blocked, vegetation doesn't need to be thinned. Preferably, plants are allowed to grow tall since this will encourage root penetration into native soils increasing the infiltration rate of the facility over time.[9]

[9] Conversation with Tom Liptan on a tour

Chapter 2.0

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2.1 CRITERIA FOR CHOOSING BMPS

Many BMPs in this guidance are suitable for a variety of conditions. The **BMP Suitability Matrix, Table 2** should be especially useful during planning to help identify the appropriate best management practices for your situation. The matrix includes a relative measure of water quality treatment and protection effectiveness (high, medium, or low) and predicted ease of implementation (1, 2, or 3). DELETE DRYWELL FROM TABLE

BMP SUITABILITY MATRIX

Effectiveness level ***
H Very Effective
M Moderately Effective
L Supports Function
Not Applicable

Suitability level****
3 Well Suited to Condition
2 Moderately Suited to Condition
1 Less Suited to Condition
Not Applicable

	Water Quality		Water Quantity			Challenging Site Conditions						Drainage Area				Land Use			Develop-ment Type		
	On-site	Downstream	Flood Control	Evaporation	Aquifer Recharge	Steep Slopes	High Groundwater	Shallow Bedrock	Slow Draining Soils	Expansive Clay Soils	Contaminated Soils	Rooftops	Roadways	Sidewalks	Landscapes	Single-family Residential Lot	Subdivisions & Campuses of any land use	Roads and Public Right-of-Way	Retrofit	Redevelopment	New Development
Prevent Runoff: Minimize Impervious Area BMPs																					
2.2.1 Share Parking Spaces BMP	M	H	L	M	L	3	3	3	3	3					3		2		2	2	3
2.2.2 Minimize Pavement Widths BMP	M	H	L	M	L	3	3	3	3	3						3	3	3	2	2	3
2.2.3 Minimize Front Setbacks BMP	M	H	L	M	L	3	3	3	3	3						3			1	1	3
2.2.4 Share a Driveway BMP	M	H	L	M	L	3	3	3	3	3			3	3		3	3		1	2	2
2.2.5 Minimize Building Footprint(s) BMP	M	H	L	M	L	3	3	3	3	3		3				2	3			1	2
2.2.6 Minimize New Pavement BMP	M	H	L	M	L	3	3	3	3	3			3	3		3	3	2			3
Prevent Runoff: Limit Disturbance BMPs																					
2.3.1 Construction Sequencing BMP	H	H	L	L	L	3	3	3	3	3						3	3	1	3	3	3
2.3.2 Conserve Fast(er) Draining Soils	M	H	L	M	L	3	3	3	3	3					3	3	3	3	3	3	3
2.3.3 Tree Protection BMP	H	H	L	M	L	3	3	3	3	3		2	3	3	3		3	3	2	2	2
Prevent Runoff from Landscape and Hardscape Areas																					
2.4.1 Restored Soils BMP	H	H	L	M	M	3	3	3	3	3						3	3	3	3	3	3
2.4.2 Tree Planting BMP	M	H	M	M	M	3	3	3	3	3					1	2	3	2	3	3	3
2.4.3 Depave Existing Pavement BMP	M	H	M	M	M	3	3	3	3	3					3	2	2	2	3	3	2
2.5.1 Porous Pavement (Rainfall) BMP	H	H	H	M	H		1	1	3	3			3	3		2	2	2	1	1	3
Reduce Runoff from Landscape and Hardscape Areas																					
2.5.1 Porous Pavement (Runoff) BMP	H	H	H				1	1	3			3	2	2		2	3	3	1	1	3
2.5.2 Infiltration Rain Garden, LID Swale, or Stormwater Planter BMP	H	H	H	M	H				2	3		3	3	3	3	3	3	2	3	3	3
2.5.3 Soakage Trench BMP*	H	H	H				1	1	2			3	3	3	3	3	3	3	3	3	3
2.5.4 Drywell BMP**	H	H	H				1	3		2		3	2	2	1	3	3	3	3	3	3
2.5.5 WQ Conveyance Swale BMP	M	L	L	L		3	3	3	3	3		3	3	3	3	1	3	3	3	3	3
2.5.6 Dispersion: Vegetated Filter Strips BMP	M	L	L	L			1	1	3	3		1	3	3	3	3	3	3	3	3	3
2.5.6 Dispersion: Downspout Disconnection BMP	M	L	L	L			1	1	3	3		3				3	3		3	3	3

*Soakage trenches under pavement are not suitable for expansive soils, but are well suited under landscape areas with expansive soils.
** With adaptations, drywells may sometimes be used below contaminated soils. See Chapter 2 "Drywells BMP".
*** Effectiveness level assumes the BMP is acting as a stand alone BMP under average conditions. When BMPs are used in a conjunction with others their effectiveness tends to increase.

Table 2- BMP Suitability Matrix

The following elaborates on the categories of the BMP Suitability Matrix:

BMP Suitability for Water Quality. Each BMP addresses water quality on-site; downstream water quality can be improved by reducing runoff volumes that cause excess streambank erosion.

BMP Suitability for Water Quantity. Most BMPs will reduce runoff to some extent; however, some are far more effective than others. If a BMP has received a mark in the BMP suitability table under "Flood Control", then, when implemented per the guidance provided here, it serves as a substitute for a detention basin for the drainage area it manages.

BMP Suitability for Challenging Site Conditions. Some sites are not suitable for infiltration of runoff. These sites may be challenged by steep slopes (which are prone to landslides); seasonal or permanent high groundwater tables; shallow bedrock (where runoff has insufficient soil voids to flow into); inadequate setbacks (where infiltrated water could flood a nearby structure); and/or contaminated soils (where infiltrated water could mobilize contaminants). Contaminated sites are sites where hazardous chemicals have accumulated in the soil as a result of historic activities. On a site with polluted soils, stormwater should not be infiltrated into the ground to protect groundwater. When the site history does not include industrial activity or known spills, it is not necessary to test for soil contamination in areas planned for infiltration. But if staining, discoloration, or unusual odors are noted when soil is disturbed, consulting with DEQ prior to completing work on an infiltration facility is advised. Meanwhile, slow draining soils are not automatically a barrier to infiltration, but will make runoff management facilities, like rain gardens larger, which may lead to inadequate setbacks.

BMP Suitability by Drainage Area. Each BMP may be applied to a certain stormwater runoff surface.

BMP Suitability by Land Use. There are many appropriate land uses/zoning classifications where LID can and has been implemented in Oregon, including residential, institutional, and public right-of-way.

BMP Suitability by Development Type. Implementation of BMPs is often similar regardless of whether it is being used in a retrofit, redevelopment or new development, although site preparation can vary tremendously. For example, in a retrofit situation, replacing existing impervious pavement with a porous pavement will require some soil restoration techniques or additional excavation to reach a layer of soil that has not been compacted. Where implementation considerations are different by development type, this has been noted in the detailed guidance for BMPs that follows.

2.2 MINIMIZE IMPERVIOUS AREAS BMPs

Minimizing impervious pavement on sites reduces runoff by replacing what is, or would be, impervious, with a better draining land cover. Thoughtful site design can reduce the amount of impervious surface to no more than what is necessary, both preserving open ground and reducing construction costs. Opportunities to limit disturbance by reducing impervious areas exist for a variety of different land uses.

These BMPs include:

1. Share Parking Spaces BMP
2. Minimize Pavement Widths BMP
3. Minimize Front Setbacks BMP
4. Share a Driveway BMP
5. Minimize Building Footprints BMP
6. Minimize New Pavement BMP

Cost Considerations (Common to all BMPS)

In new developments, minimizing impervious pavement offers cost-savings or, at least, requires no additional expenditures. Developers save money twice. For every square foot of pavement they don't build, they save money on excavation and grading operations, compaction, materials, and labor.

2.2.1 SHARING PARKING SPACES

In commercial districts, it may be possible to share parking with another organization that has different peak hour use from your land use (*e.g*. a church and movie theater). Refer to the City of Philomath City Code 18.75.03.C.04 for information on sharing parking spaces.

2.2.2 MINIMIZE PAVEMENT WIDTHS

Siting

Minimized pavement widths may be appropriate for private and public roadways, parking lots, and sidewalks.

Design

Ensure that all appropriate permits are obtained (appendix). When designing paved areas, do not exceed the minimum parking area dimensions described in the Philomath Municipal Code 18.75.03(E) or the pavement width guidelines in PWDS 2.11.

Land Use	Min. Sidewalk Width	Min. Roadway Width	Min. Driveway Width
Residential	5 ft	18 ft	14 ft
Institutional, Commercial	5 ft	18 ft	20 ft
Industrial	5 ft	18 ft	24 ft

Table 3- minimum pavement widths

2.2.3 MINIMIZE FRONT SETBACKS

The closer a building is to the street, the shorter the driveway and sidewalk to it. The greater the setback the less street noise. This is sometimes addressed with architectural design to place noise sensitive rooms, such as bedrooms, away from the street, or by using berms or other sound insulating approaches[10].

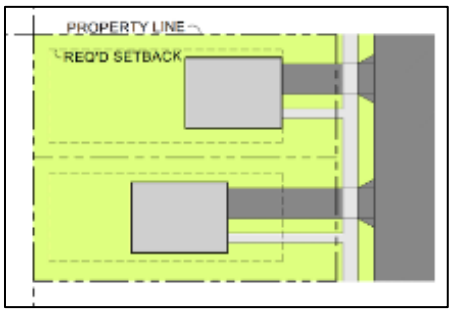

Figure 3- Exceeding required setbacks generates additional paved sidewalks and driveways.

2.2.4 SHARE A DRIVEWAY

In some cases, sharing a driveway with your neighbor, especially for buildings far from the road can be very effective. The driveway may be owned by one party and the adjoining property owner is granted an access easement or a portion of the driveway is owned by both parties and they grant each other an access easement. While the graphic below refers to two residences the practice of sharing driveways and parking areas could apply to other land uses too.

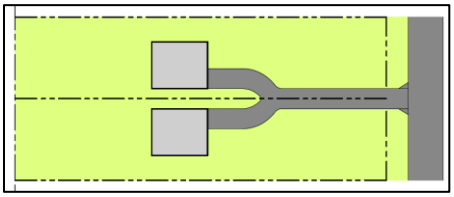

Figure 4- Share a driveway.

[10] Federal Highway Administration guidance, document. The Audible Landscape for Retrieved from: https://www.fhwa.dot.gov/environment/noise/noise_compatible_planning/federal_approach/audible_landscape/al04.cfm

2.2.5 MINIMIZE BUILDING FOOTPRINTS

A two-story house is better for the watershed than a ranch style house of the same total square footage. While many conventional houses are built with a two story footprint that encompasses the entire allowable building area within the defined setbacks, small and tiny houses are gaining popularity both for their affordability and energy efficiency. Zoning codes dictate the maximum height of buildings. This practice may not be suitable for physically challenged residents. This BMP may also apply to land uses other than residential.

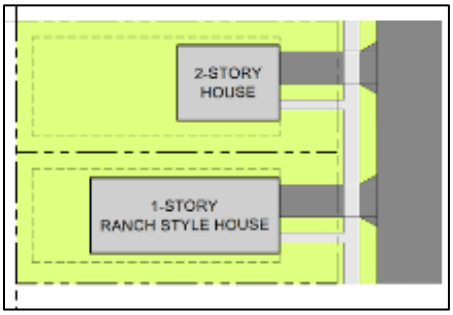

Figure 5- Go up, not out, with your floor plan.

2.2.6 MINIMIZE NEW PAVEMENT

On many public roads and private property, areas of pavement were paved as a convenience for the asphalt installer, but are not really needed or used by cars or pedestrians. Consider this when laying out paved areas.

2.3 LIMIT DISTURBANCE BMPS

These best management practices limit disturbance in areas of the site that don't need to be altered. When land is in an undisturbed well-vegetated condition, the vegetation and soil work together to capture almost all rainfall and reduce runoff through infiltration and evaporation. Unnecessarily clearing vegetation or disturbing soils will greatly impact this balance and affect the long-term habitat value of downstream waterways and overall watershed health.

There are a variety of opportunities to limit disturbance during the planning, design and construction phases of development; limit disturbance BMPs include:

1. Construction Sequencing BMP
2. Conserve Fast Draining Soils BMP
3. Tree Protection and Planting BMP

2.3.1 CONSTRUCTION SEQUENCING

Construction sequencing represents a specified work schedule that coordinates the timing of land-disturbing activities and the installation of erosion prevention and sediment control (EPSC) measures. Throughout construction, appropriate erosion prevention and sediment control measures are implemented per the Oregon Construction Stormwater Erosion and Sediment Control Manual[11]. The goal is to prevent erosion and control sediment by minimizing the extent of cleared land at one time and to install EPSC measures before land clearing begins.[12].

Siting

Construction sequencing might be used throughout any site large enough that some cleared areas of the site would be "open" without construction activity for more than a month during the rainy season from September to early July.

Design

Design could be impacted by array of construction considerations, for example, when materials can be delivered or where and how they can be stored on-site. Consider the following elements of this BMP during planning and design phases and communicate this information on the construction/bid/permit set. If the site is over 1 acre, a construction sequence narrative and other related information must be included on the 1200C permit drawings.

Phase disturbances. Construction site phasing involves disturbing only a portion of the site at a

[11] Oregon Department of Environmental Quality. Water Quality Permit Program. Erosion and Sediment Control. Retrieved from: http://www.deq.state.or.us/wq/wqpermit/docs/general/npdes1200c/ErosionSedimentControl.pdf

[12] Smolen, M.D., Miller, D.W., Wyall, L.C., Lichthardt, J., and A.L. Lanier. (1988.). *Erosion and Sediment Control Planning and Design Manual*. North Carolina Sedimentation Control Commission; North Carolina Department of Environment, Health, and Natural Resources; and Division of Land Resources, Land Quality Section, Raleigh, NC.

time to prevent erosion from areas where no work will take place in the near future. Grading activities and construction are completed and soils are stabilized on this portion before grading and construction begin in another area. When phasing construction activities, the following should be kept in mind: runoff is managed separately in each phase, water and sewer connections are accommodated, completed downhill phases are protected, and wet weather erosion prevention and sediment control techniques are incorporated if excavation cannot be scheduled for the dry season.

Minimize grading. In general, grading should be minimized. Design proposed site improvements to work with existing grades, as much as possible. If buildings are proposed, this may mean working with that designer to step building foundations.

Cut and fill grading activities should be coordinated and, if possible, conducted during the dry season, to minimize the movement and storage of soils on, off, and around the site. Keeping soils in-place for as long as possible protects the quality and infiltration rate; thereby reducing runoff during and after construction. It also reduces long-term maintenance effort and costs.

Develop a schedule. Construction sequencing schedules should address proposed EPSC measures, when they will be implemented and their compatibility with the general contract construction schedule.

Delineate staging and stockpile areas. This is critical for protecting vegetation and soils. The designer and contractor would ideally collaborate on this plan during the design phase. The contractor should share this plan with the team, especially subcontractors. Stockpiling areas, the haul road, and other construction equipment such as site trailers should be located in the footprints of demolished infrastructure or areas of future disturbance. Sensitive areas and tree canopies need to be fenced off.

Construction

Depending on the project type, the sequence of construction events is often as follows:

1. Preconstruction meeting. Hold a preconstruction meeting to explicitly review the construction sequence, identification of no-work and restricted work areas, and the erosion and sediment control plans.
2. Fencing. Place fencing around areas to be protected. Fencing off areas can effectively limit disturbance. Fence off:
    - Sensitive areas such as wetlands, floodplains, riparian areas, habitat conservation areas, steep slopes, etc.
    - The critical root zone of trees (see 2.4.2)
    - Future infiltration facility areas where rain gardens, stormwater planters, LID swales, vegetated filter strips, or porous pavement may be located.
    - Any other areas not proposed for improvements
1. Build construction access, entrance to site, construction routes, and areas designated for equipment parking.
2. Protect bare soil. As soon as construction begins, stabilize any bare areas with straw, compost, gravel and/or temporary vegetation.
3. Install sediment traps and barriers, basin traps, outlet protection.

4. Runoff control diversions, perimeter dikes, water bars, outlet protection. Install key practices after installing principal sediment traps and before land grading. Install additional runoff control measures during grading.
5. Runoff conveyance system, stabilize stream banks, storm drains, channels, inlet and outlet protection, slope drains.
6. Land clearing and grading, site preparation (cutting, filling, and grading, sediment traps, barriers, diversions, drains, surface roughening). Implement major clearing and grading after installing principal sediment and key runoff-control measures, and install additional control measures as grading continues. Clear borrow and disposal areas as needed, and mark trees and buffer areas for preservation.
7. Surface stabilization, temporary and permanent seeding, mulching, sodding, riprap, shredded wood chips. Apply temporary or permanent stabilizing measures immediately to any disturbed areas where work has been either completed or delayed. Permits may have explicit duration limits for unprotected ground that is not being actively worked on.
8. Building construction, buildings, utilities, paving. During construction, install any erosion and sedimentation control measures that are needed.
9. Landscaping and final stabilization, top-soiling, trees and shrubs, permanent seeding, mulching, sodding, riprap. This is the last construction phase. Stabilize all open areas, including borrow and spoil areas, and remove and stabilize all temporary control measures.

Cost Considerations

Construction sequencing is a low-cost measure because it requires a limited amount of a contractor's time to provide a written plan for coordinating construction activities and management practices while protecting them from potential permit violation fines.

Traffic easily compacts soils. If future natural areas are compacted, establishing vegetation can be more difficult. For the owner, this means higher maintenance costs for landscaped areas because they'll need more irrigation and will be more susceptible to diseases. For the watershed, extra irrigation can be an unnatural source of summer stream flows and means that more pesticides, fertilizers, and herbicides are likely to be used by the landowner, subsequently entering the waterways.

2.3.2 CONSERVE FAST DRAINING SOILS

This BMP strategy places impervious surfaces on the slower draining areas of a site. Faster draining soils are left open to the sky to manage rainfall more efficiently than slow draining soils, therefore preventing runoff. Runoff reduction BMPs are strategically positioned on fast draining soils.

Siting

Existing soil or geologic maps are often used in the planning phase to evaluate the site's potential for infiltration; however, these maps don't accurately reflect the conditions at the site scale. Infiltration testing is the best way to identify faster draining soils. To discover the areas of fast draining soils, multiple areas throughout the site should be tested for the infiltration rate. Infiltration testing is outlined in **Appendices B and C.**

Design

Once the location of fast draining soils have been identified and mapped, establish landscape areas in faster draining soils. Place impervious surfaces such as roads, roofs, and sidewalks on slower draining soils.

To reduce the size of vegetated infiltration facilities such as rain gardens, stormwater planters, and LID swales, locate them in the landscape areas with soils that drain quickly (up to 12 inches/hour). If an area drains faster than 12 inches/hour, the water quality treatment capability of the facility is less, so plan to amend or replace those soils. (See Chapter 2.5.2 and Appendix D: Specifications "Treatment Soil" for more information.)

Construction

Fence off areas of fast draining soils that do not need to be accessed by equipment. Regardless of the site's various infiltration rates, contractors should take great care to limit compaction in any future landscape areas (see Appendix B: BMP Implementation Criteria, "Construction").

Contractors should choose equipment that reduces loads transferred through the soil. Light equipment, track equipment and vehicles with floatation tires are preferred.

On infiltration areas or areas identified as fast draining soils, avoid blade grading, working instead from outside the infiltration footprint.

Cost Considerations

Protecting soils from compaction is likely to save money in maintenance costs. For infiltration facilities, a faster infiltration rate will result in a smaller facility, which means up-front cost savings for the developer.

2.3.3 TREE PROTECTION

Protecting individual and groves of trees can help maintain existing hydrology and water quality functions. Preserving groves often provides greater economic and environmental benefit than preserving individual trees; however, both are beneficial.

Construction around trees can be difficult, but protecting trees reduces site preparation and grading costs while decreasing long-term tree maintenance and replacement costs. The presence of trees aids in retaining runoff and dissipating runoff energy, ultimately lowering stormwater temperatures. Trees also provide immediate aesthetic and economic benefits.

Siting

Forest Remnants and Stands. Stands, groves, or patches of the native Pacific Northwest forests that previously covered the area are often found in urban or urbanizing areas.

High tree densities with an undisturbed understory are some characteristics of a high-quality forest remnant worth preserving (Figure 4). An excellent stand to protect has the following characteristics:

Trees structurally support one another.
Soil remains undisturbed.
Wildlife uses are relatively unimpaired.
Shady microclimate.
Natural forest succession continues and forest regeneration is ongoing.
Ecological functions are relatively unimpaired.

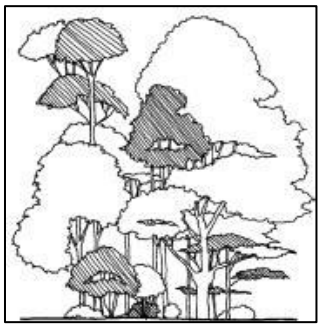

Figure 6- A stand to protect. Reproduced with permission by the city of Chattanooga.

Individual Trees. When planning to protect individual trees, plan to protect trees located on adjacent property, including those portions of the roots, trunk, and crown growing into or over the developing property. Evaluate existing on-site trees and protect the healthiest, largest trees.

Design

Unless an arborist report indicates otherwise, plan infrastructure outside the Critical Root Zone (CRZ). The International Society of Arboriculture (ISA) defines the critical root zone as an area equal to 1-foot radius from the base of the tree's trunk for each 1 inch of the tree's diameter at 4.5 feet above grade. A tree's dripline may also be used to estimate the CRZ (**Figure 5**). We recommend that you evaluate both of these and choose whichever provides the larger CRZ.

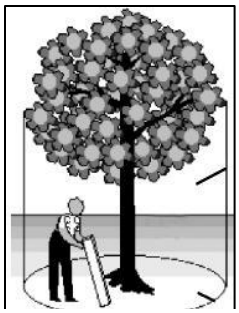

Figure 7- Using the dripline to estimate the CRZ.
Adapted with permission from the City of Chattanooga.

Forest Remnants and Stands. Forest remnants and stands should be designed so that a fence line around the CRZ on every site plan is displayed. Stury materials should be used for the fence, such a cyclone fencing. Refer to an arborist report to identify trees and vegetation to be avoided during

construction.

Individual Trees. Individual trees are primarily protected in the design phase by developing a thoughtful and informed grading plan. Grade changes within the CRZ, where possible, should be avoided to prevent serious damage or death to a tree. When raising the existing grade, avoid or minimize fill within the CRZ, which smothers roots. Never place fill against the tree trunk. When lowering the existing grade**,** do not expose or damage large amounts of root. Removing 1 to 2 inches of soil normally will not affect a tree adversely.

Trees that are within 10 feet of the proposed building or structure, trees that cannot be adequately protected, and trees that are significantly wounded should be removed.

Standard Details. See standard details *[BMP 11.01, 11.02, and/or 11.03]* to include applicable details in construction documents. These are available in *[pdf, jpg, and AutoCAD dwg format]*.

Construction

Forest Remnants and Stands. To protect forest remnants and stands during construction, fence the entire stand, grove, or patch, to protect understory vegetation and soil as well as trees. Unless directed by an ISA certified arborist, do not apply fertilizers, pesticides, or irrigation. Isolated single, tall, spindly trees do not need to be retained.

Individual Trees. To protect individual trees during construction:
Erect barriers or sturdy fencing around individual trees to define and protect CRZs before construction begins.
Never place any fill or organic materials directly against the tree.
Never compact the soil within the CRZ.
Protect high-value trees with stem, branch, and root padding or wraps in addition to fencing around the CRZ. Protect the trunks of high-value trees from scraping and gouging to a height of at least 8 feet.
Establish one access route into the site and one exit route out of the site outside of the CRZ.
Do not trench through the CRZ of protected trees. Alter routes of underground infrastructure or tunnel or bore at least 18 inches beneath CRZs to install utility lines.
Where tree roots must be cut, make only sharp, clean cuts to promote root callusing and regeneration.
Spread 2 to 3 inches of mulch over the exposed root area to prevent soil erosion, reduce moisture loss, and keep soil temperatures lower.
Prune roots according to the arborist report to reduce pruning stress when lowering grades.
Prune exposed jagged roots back to the point of emergence from the soil using a handheld pruner or pruning saw to make sharp, clean cuts.

Cost Considerations

Protecting trees can incorporate additional costs and effort throughout the development process. In addition to many social and environmental benefits, trees provide positive cost benefits to a variety of land uses that may offset some or all of the implementation costs.

"While development costs can be greater for lots where trees were preserved (5.5% in one study[13]), additional costs can be recovered through higher sales prices and faster sales for houses on wooded lots"[14].
Trees reduce air conditioning needs for building owners and operators[15].
Larger street and yard trees can add from 3% to 15% to home values throughout neighborhoods[16].
Homes adjacent to naturalistic parks and open spaces are valued at 8-20% higher than comparable properties, with the positive price effect declining to near zero about ½ mile away."[17]

2.4 PREVENT RUNOFF BMPs

These best management practices are used to control stormwater discharge by restoring a site a site so that it better resembles its natural hydrological state. These methods include:

1. Restored soil
2. Tree planting
3. Depaving existing pavement

2.4.1 RESTORED SOIL

The practice of amending disturbed soils (*i.e.,* any soil in a populated area) is a simple, cost-effective practice for restoring and preserving the long-term permeability of soils compacted by traffic. The practice also conserves water and reduces pesticide, herbicide, and fertilizer use. Soil health is a key element of watershed health[18,19]; however, soils at developed sites are highly impacted. Loss of topsoil and compaction can be addressed by restoring soil quality.

Compaction reduces soil voids, reducing permeability. Restoring soil to a healthy condition is

[13] Hardie, I., and C. Nickerson. 2004. The Effect of a Forest Conservation Regulation on the Value of Subdivisions in Maryland. WP 03-01 (Revised). Department of Agricultural and Resource Economics, University of Maryland, College Park, 35 pp.
[14] Seila, A.F., and L.M. Anderson. 1982. Estimating Costs of Tree Preservation on Residential Lots. Journal of Arboriculture 8:182-185.
[15] EPA (2008). "Reducing Urban Heat Islands: Compendium of Strategies" Retrieved from: http://www2.epa.gov/heat-islands/heat-island-compendium
[16] Wolf, K.L. 2007 (August). City Trees and Property Values. *Arborist News* 16, 4:34-36.
[17] University of Washington, Urban Forestry/Urban Greening Research. Green Cities: Good Health. Retrieved from: http://depts.washington.edu/hhwb/Thm_Economics.html

[18] EPA. (2011). Evaluation of Urban Soils: Suitability for Green Infrastructure or Urban Agriculture. EPA Publication No. 905R1103. Retrieved from: http://water.epa.gov/infrastructure/greeninfrastructure/upload/Evaluation-of-Urban-Soils.pdf
[19] USDA NRSC. (2005). Urban Soil Primer: For homeowners and renters, local planning boards, property managers, students, and educators. Retrieved from: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052835.pdf

important because[20]:

- Plant establishment depends on roots' access to air and water in soil voids. Thus compaction results in unhealthy plants by leading to diseased leaves, poor or no flowering, or even early death. Landowners often respond to unhealthy plants by applying pesticides, herbicides, fertilizers and additional irrigation, which increases runoff pollution.
- Rain falling on compacted soil can no longer be absorbed and conveyed downward into the soil, but instead runs off, carrying pollutants with it. In fact, out of a number of different land uses, lawns are the most likely to export sediment to waterways. This is significant, because many pollutants attach to sediment and sediment is a pollutant itself.

Siting

With a few exceptions noted below, restored soils should be used anywhere soils have been disturbed and where a future landscape area is proposed. Any soil texture will benefit from compost amendment, but sites with clay will benefit the most. Soil restoration should not be performed within sensitive areas or on slope greater than 2:1. Avoid performing soil restorations over utilities with any material that may be less than 12 inches deep.

Design

Grading plans should show a 5% minimum slope away from buildings for a distance of 10 feet in landscape areas to ensure adequate drainage during large storms, which are expected to generate high volumes of runoff.

Incorporate Organic Matter Compost. For all proposed landscape areas in the disturbed area, specify compost to be tilled into the top few inches of native soils. The ideal organic content is 10% for landscaped beds. A lower target rate for turf areas of 5% is recommended since a higher organic content could make mowing more difficult. (See Appendix D "Specifications", "Organic Matter Compost".)

Construction

Like all stormwater management facilities, special care must be taken to properly construct BMPs. See Appendix B: BMP Implementation Criteria, "Construction", "Protecting Permeability" for specific steps that should be taken on every LID project.

Amending soils should happen at the end of construction or at least at the completion of concrete work. Soil moisture will ideally be lower than 50% of field capacity, at the time of amendment[21].

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[20] Center for Watershed Protection (CWP). (1999.). Diazinon sources in runoff from the San Francisco Bay region. Technical Note 106. Watershed Protection Techniques 3(1): 613-616, and Schueler, T. 1995a(1995). Nutrient movement from the lawn to the stream. Watershed Protection Techniques 2(1): 239-246.

[21] USDA NRCS. Deep Tillage. Conservation Practice Standard, Code 324. (2011). Retrieved from: http://efotg.sc.egov.usda.gov/references/public/OR/324std_OR-Jan11.pdf

The following guidance is a method that can safely and easily be applied, without calculations or lab testing, to all soils. To amend proposed gardens:

1. Till or scarify soil 12 inches deep.
2. Place 3 inches of compost and till into 5 inches of soil (a total amended depth of about 9.5 inches, for a settled depth of about 8 inches).
3. Rake beds smooth and remove surface rocks larger than 2 inches in diameter.
4. Mulch planting beds with 2 – 3 inches of organic mulch.
5. Install plants.
6. Water plants

Figure 8- Lawn or garden, the same cross section of loosened and amended soils applies.

To amend proposed turf areas that will be mowed:

2. Till or scarify 12 inches deep.
3. Place 1.75 inches of composted material and till into 6.25 inches of soil.
4. Water or roll to compact to 85% of maximum dry density. Rake level, and remove surface woody debris and rocks larger than 1 inch diameter.
5. Install plants or seed.
6. Water plants or seed.

Protect areas from compaction by heavy equipment with fencing and signage. Apply appropriate erosion prevention and sediment control techniques, as appropriate, until landscape stabilizes the soil, usually in 3-6 months, but more time may be required depending on the vegetation and the time of year.

2.4.2 TREE PLANTING

New trees are often required for a variety of reasons during the development process, for example, to screen conflicting uses, improve livability and health, reduce energy demand (windbreaks and shading), or to express a community's historical and cultural identity. Trees also provide important water quantity regulation and water quality treatment benefits. The benefits of new trees are often small when first planted and accrue over time. Proper tree planting, using the following guidance, is essential to long-term tree survival, health, and safety.

Siting

Plant trees where they have plenty of room to grow to maturity. Make sure there is now, and will be at tree maturity, adequate clearance from overhead utility lines, pedestrian and vehicular traffic, buildings, signs, street lights, and any other permanent infrastructure, as well as sight lines at intersections. Refer to the Philomath Arboricultural Specifications Manual for more information on locating trees.

Provide trees with adequate soil volume for tree growth and stability. Recommended volumes provide 2 cubic feet of soil volume for each square foot of mature canopy in conjunction with an

adequate soil depth[22]. While tree root depths vary with species, a general minimum depth is 3 feet. If planting a street tree, refer to both the Philomath Municipal Code 18.70.040 and the Philomath Arboricultural Specifications Manual for guidance on planting requirements.

Design

Site Design to Achieve Adequate Soil Volume for Constrained Spaces. When planted in spaces with inadequate soil volume, many trees will push up the surrounding pavement to access air and water, causing expensive damage. To prevent future damage, for tree planting in locations with no new development planned, choose long linear areas that are at least 4 feet wide and 30 feet long. Since most existing tree pits are much shorter than this, special design consideration may be required for trees in redeveloped constrained spaces.

On new and redevelopment projects, to achieve the recommended soil volume and depth, provide a long linear area where soil may be shared by multiple trees. Provide multiple root paths underneath sidewalks and other narrow pavement areas that have soil on the opposite side of the pavement where the mature canopy is projected to grow.

Figure 9- Open soil areas can be continuous or separated by pavement. Open soil areas can be planted with groundcover, ornamental plants or grass, or covered with mulch as shown in the images above. Photos courtesy of Casey Trees.

Tree Selection. To maximize stormwater value, consider using evergreen trees, which actively manage stormwater in the winter, instead of deciduous trees.

Using the following guidance to select trees for your site:
Select a tree with a 1.5 inch caliper.
Select the right plant for the right place. Refer to the City of Philomath Tree List. For sites with overhead utility lines, choose a tree species whose maximum height at maturity will be less than the height of the overhead utility line. Additionally, see Appendix E: Planting Specifications for more information on choosing the best kind of tree for your site.
Use a diversity of tree species and varieties to build resilience to such common challenges as pest or disease infestation and to add visual interest.

Standard Details. See standard details *[BMP 10.01, 10.02, 10.03, and/or 10.04]* to include

[22] Lindsey, P. and N. Bassuk. (1991). Specifying Soil Volumes To Meet The Water Needs Of Maturing Urban Street Trees And Trees In Containers. *Journal of Arboculture.* 17(6):141-149. Retrieved from: http://www.hort.cornell.edu/uhi/research/articles/JArb17(6).pdf

applicable details in construction documents. These are available in *[pdf, jpg, and AutoCAD dwg format]*.

Construction

Site Preparation. The following guidance should be used to plant any tree, regardless of how adequate soil volume is provided:

Call your local utility locate service – dial 811[23] – before digging. Always have utilities located prior to installing trees on any site.

Break up compacted soils in an area 5 to 10 times the width of the new tree's root ball or container.

Dig a planting hole that is at least twice the width of the new tree's root ball or container.

Dig the planting hole no deeper than the height of the root ball from its base to the bottom of the root collar.

Do not add fertilizer or other soil amendments to the planting hole.

Tree Planting. Tree planting procedures are found in the Philomath Arboricultural Specifications Manual.

Cost Considerations

Tree planting material costs may include the tree, staking, mulch. The cost of a tree varies with region and caliper. Labor costs associated with planting trees may include excavation, planting, pruning, disease control, establishment irrigation (see Appendix E: Plant Specifications, "Establishment Maintenance"). Pruning is more costly for tall trees that cannot be pruned simply by standing on the ground[24]. Tree removal and stump grinding, and disposal of an existing failed tree may also be a part of planting a new tree and is a future cost to consider.

Trees supply numerous cost benefits that can help offset initial and long-term maintenance costs[25]. Trees can reduce energy demand when planted on the west, south, or east side of a building. Land use is not as important as the shape and height of the building being shaded. The older and larger a tree, the greater the benefit. Residential property values have been consistently found to be higher when landscaping and trees are on the property or the property is located on a tree-lined street. Increase in property value ranges from 3% to 15%.

[23] Oregon 811-Utility Notification Center. Retrieved from: http://digsafelyoregon.com/

[24] Western Washington and Oregon Community Tree Guide: Benefits, Costs and Strategic Planting. Retrieved from: http://www.treesearch.fs.fed.us/pubs/45962.

[25] For more detailed information on the cost benefits of trees and for references on the percentages found in the bullets in this section, visit University of Washington, Urban Forestry/Urban Greening Research. Green Cities: Good Health. Retrieved from: http://depts.washington.edu/hhwb/Thm_Economics.html

2.4.3 DEPAVE EXISTING PAVEMENT

Tearing out pavement and replacing it with landscaping is known as depaving. Depaving reduces the amount of runoff from an existing developed site by allowing infiltration and evaporation of rainfall and by providing area for runoff BMPs, such as rain gardens. Key steps to take during a depaving project are included in Appendix A.

Siting

There may be many small and large paved areas throughout the watershed that no one needs or uses, but that collectively impact water quality. Investigate how people use or don't use different sections of paved areas.

Design

Stormwater flows. Determine where water currently flows on-site. If runoff flows to the proposed depaved area, see 2.5.2, 2.5.5, and 2.5.6 for additional design considerations.

Developing Plans and a Budget. Develop a landscape plan (see Appendix E: Plant Specifications). Avoid lawn, if possible. Plan to restore the permeability of the soil according to 2.4.1.

Pavement edge stabilization. In asphalt areas with a pavement thickness of less than 2 inches, consider stabilizing the pavement edge. Approaches for this include installing extruded curbs around the top edge to redirect runoff, placing a flush curb adjacent to the pavement, cutting the pavement at a 45 degree angle, or installing a 12-inch level spreader (see 2.5.6, 2.6.1).

Deconstruction

Removing pavement by hand is not as difficult as it may seem, and can be a cost effective way to add permeability through a hands-on community building process.

To effectively implement depaving:

1. Locate both public and private utility lines on the site. Take care when removing pavement over utility lines.
2. Notify neighbors about the proposed work and observe noise regulations.
3. Implement erosion prevention and sediment control measures. Keep soil covered with a natural, breathable material like jute. Install wattles, biobags, or compost socks at the bottom of stockpiles and encircle catch basins and area drains.
4. Remove the pavement. Prepare the surface by cutting it into manageable 2-to-3 foot square pieces with a diamond-blade pavement saw. Asphalt removal can be done using a backhoe or with simple tools and cooperative muscle power. Once asphalt is pried up, it typically breaks down into smaller manageable pieces fairly easily. Concrete is much tougher to remove by hand and will require a jackhammer to break it into smaller pieces. Asphalt and concrete can be readily recycled, often by recycling companies and pavement contractors.
5. Remove any rock installed below the pavement. Rock can be recycled or repurposed; however, avoid re-using crushed concrete in stormwater facilities.
6. Amend the soils with organic matter compost (see 2.4.1) or shredded wood chips.
7. Depending on the pavement and rock depth removed, clean topsoil may need to be imported so that the landscape area can meet and match existing grades.

8. Re-vegetate the area with native grasses and grass-like plants, flowers, and shrubs. If the space permits, plant trees (see 2.4.2).
9. Mulch the area with 2 – 3 inches organic matter compost or mulch per specifications in Appendix D.

Cost Considerations

Depaving existing pavement will always be more expensive than doing nothing, but your watershed is probably already impacted from the pavement that exists. Only reducing impervious pavement in new development will probably not result in meeting desired water quality goals in a meaningful timeframe.

Many depaving projects have been done with volunteer labor as a way to raise awareness about the connection between impervious pavement and watershed health. There are still costs associated with using volunteer labor, including materials such as imported soils, compost and other soil amendments; erosion-control vegetation; and services such as volunteer management, waste removal, and equipment rental (*e.g.* diamond-blade saw, jackhammer, additional hand tools). If volunteer labor is not used, then heavy equipment such as a backhoe will likely be the most cost-effective approach. Equipment rental and operation will add to the expense. Hiring a private utility locater can cost as little as $200 for sites up to 5,000 square feet.

2.5 REDUCE RUNOFF BMPs

Write intro.

2.5.1 POROUS PAVEMENT

Porous pavement (also known as permeable pavement and pervious pavement) is a stormwater management facility that allows water to move through void spaces within the pavement surface and rock below and infiltrate into underlying soils. It has many applications and in many cases, it can be used instead of conventional, impervious pavements for both vehicular and pedestrian traffic. There are two varieties of porous pavement, those that manage rainfall and those that manage both the rainfall and runoff received.

There are several types of porous pavement surfaces, including porous asphalt, pervious concrete, permeable pavers, flexible pavement systems, and porous gravel.

Porous Asphalt and Pervious Concrete. Porous asphalt and pervious concrete are similar to their impervious counterparts but are made with "open-graded aggregate", which includes few to no fines (*i.e.* small particles). When bound together, interconnected voids between the aggregate allow water to flow through. The larger pieces of crushed aggregate provide the structural stability for conventional and porous pavements alike, even for loadings such as large trucks and semi-trailers. The fines in a conventional mix only serve to make compaction easier, which would prevent infiltration.

Permeable Pavers. Permeable pavers are paver units of stone, concrete or other durable impervious material with gaps between or within the pavers that provide voids for water to reach sub-soils. Porous commercial pavers, like porous asphalt or pervious concrete discussed above, are now available and need no space between them.

Figure 10- Permeable pavers.

Porous Flexible Paving Systems. Porous flexible paving systems are prefabricated grids made of plastics or other solid materials finished with clean sand/gravel or turf. Grids with porous media provide a stable surface and sometimes resemble lawn.

Porous Gravel. Conventional gravel pavements (*i.e.* without a permeable sub-base) are not inherently free draining, as many assume. During conventional gravel pavement installation, soil is compacted to support vehicular loads, making the pavement essentially impervious. Gravel with many small particles (usually a material like "¾-inch minus drain rock") is installed, compacting it in lifts (*i.e.* smaller portions of the total

Figure 11- Flexible paving systems are often made of plastic grids with numerous openings, as shown here. Photo credit: Teresa Huntsinger

depth). This results in a low void ratio with little storage for stormwater, even if the soil could infiltrate, and may cause fine particles from the pavement to pollute downstream waterways, especially on slopes.

Siting

Infiltration Testing. Perform an infiltration test to determine the soil's capacity to absorb and percolate water down into the lower layers. See Appendix C for detailed guidance on field testing to find the rate that water can pass through the soil and how to interpret that data.

Site Suitability for Porous Pavements Managing Runoff. Porous pavements that receive runoff from impervious areas in addition to rainfall should be located using the same criteria as soakage trenches (see 2.5.3).

Site Suitability for Porous Pavements Managing Only Rainfall. Porous pavements can be used in a variety of conditions[26] , such as:

Where the seasonal high groundwater table, bedrock, or other impermeable layer is more than 18 inches from the bottom of the base rock.

On uncompacted soil. Porous pavement should never be placed on areas of proposed fill that is not specifically designed to protect the porosity of the fill, because this kind of fill is compacted so much that it is no longer capable of infiltrating water.

Where infiltration rates are 0.3 inches/hour or greater.

In limestone bedrock.

Under trees to be protected, when carefully excavated in the presence of an International Society of Arboriculture certified arborist.

On projects where spills are not an issue.

Where the pavements will be hydraulically isolated, meaning that they do not receive run-on from any other areas. These have been known to be maintenance free for decade[27].

On slopes under 8%.

Because porous pavement is an infiltration technique, situations where groundwater contamination could occur or be exacerbated should be avoided. In addition, the seasonal elevation of groundwater and other conditions that could lead to saturation, clogging, or other failure must be considered.

A decision tree to assist with locating porous pavements is available online at the OSU Extension Stormwater Solutions website: http://extension.oregonstate.edu/stormwater/porous-pavement-1. Detailed information for assessing a number of the conditions above can be found there.

Design

Porous pavement is an assembly of materials that includes not only the pavement surface, but

[26] Pennsylvania Stormwater Best Management Practices Manual. (2006). Publication No. 363-0300-002.

[27] Miller, A.R. (1997). Porous Pavement: Pavement That Leaks. Retrieved from: http://www.millermicro.com/porpave.html

also the rock, geotextile fabric, and soil below and conveyance structures, if necessary. Like all pavements, porous pavements should be designed and detailed by one or more qualified licensed engineers with experience in civil and geotechnical engineering.

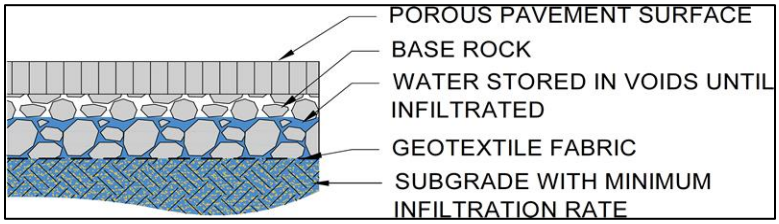


Figure 12- A typical porous pavement section.

Required Structural Design for Porous Pavements. Porous pavement surface thicknesses and base rock are calculated relative to estimated traffic weight and frequency[28]. Consult a qualified licensed engineer with experience in geotechnical engineering to recommend the appropriate pavement section for the site's soils. Pavement design thicknesses for the surface and base rock will vary by porous pavement surface type. As with conventional pavements, structural capacity can be increased with a thicker pavement surface and/or a thicker base rock depth.

When implementing porous pavement, resources are available to assist in structural design and development. "Asphalt Pavement Design Guide", The Asphalt Pavement Association of Oregon's guidance is available for download along with PerviousPave, cross section development software produced by The American Concrete Pavement Association.

Base Rock Depth. Structural and hydrologic design criteria drive the depth of base rock (see Appendix D: Specifications, "Coarse and Choker Aggregate") beneath a porous pavement.

The following sections provide information on hydrology design criteria. The porous pavement surface thickness and depth of base rock needed to meet both criteria are usually different. Choose the deeper of the two.

Hydrologic Design for Managing Rainfall. The depth of base rock for porous pavements that only manage the rain that falls on them may be calculated using the simplified hydrologic design approach described in detail in Chapter 4 as long as the tested design infiltration rate (see Appendix C: Infiltration Testing) is at least 0.3 inches/hour.

Hydrologic Design for Managing Runoff**.** There are several ways to direct runoff to a porous pavement rock base. The depth of base rock for porous pavements that manage runoff from other areas in addition to rainfall on the surface, must be designed and modeled by a qualified licensed engineer.

Geotextile. Install a geotextile fabric to separate the native soils from the base rock. Without it, water infiltrating through the cross section will cause soil particles to migrate up into the voids of the aggregate, filling them and reducing storage volume for stormwater. The geotextile fabric also adds structural stability to the pavement. Specifications for geotextile fabric are provided in Appendix D: Specifications, "Geotextile Fabric". Take special care to wash the base rock as directed in Appendix D: Specifications, "Geotextile","Very Clean Rock Required" or the geotextile

[28] Urban Drainage and Flood Control District. Drainage Criteria Manual (Vol 3). (Revised 2008). Denver, CO,.

is likely to be clogged with dirt from the rock, creating an impermeable membrane at the bottom of the pavement and defeating the purpose of porous pavement.

Design Specific to Sloping Sites. The following design guidance is offered for porous pavements installed on slopes less than 8%.

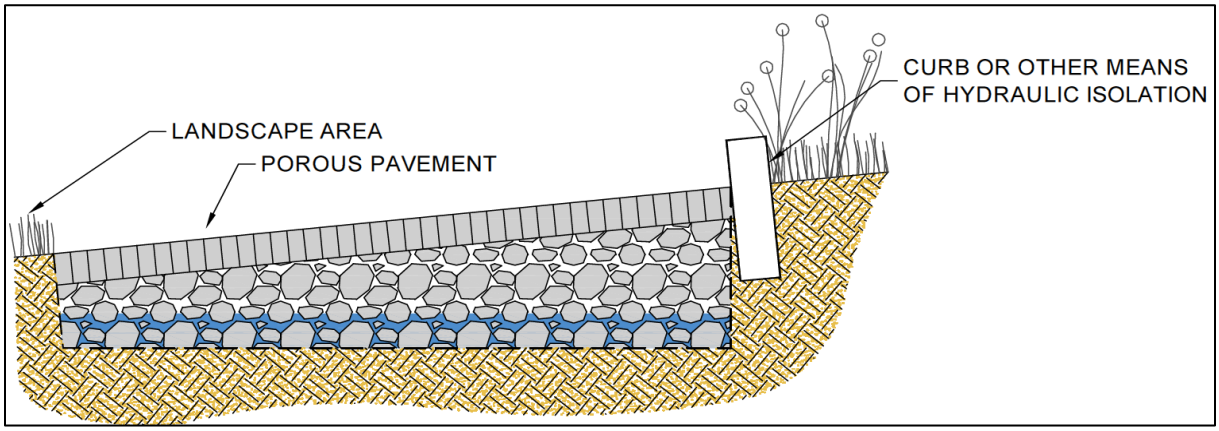


Figure 13- While the surface may slope, the bottom of the porous pavement (where the water is being stored before it infiltrates) should be flat. Porous pavement with a sloped bottom cannot be hydrologically sized using the simplified approach in Chapter 3.

As can be seen on the right side of **Figure 11**, a large quantity of rock, which will never be available to pond water for infiltrating might be needed to bring the grades up to the desired finished elevation. To save on rock, the bottom of the facility can be stepped down the hill with a series of berms as in **Figure 12** below. Adding a sub-surface grading plan to the construction plan set can be helpful for conveying critical information to the excavation contractor.

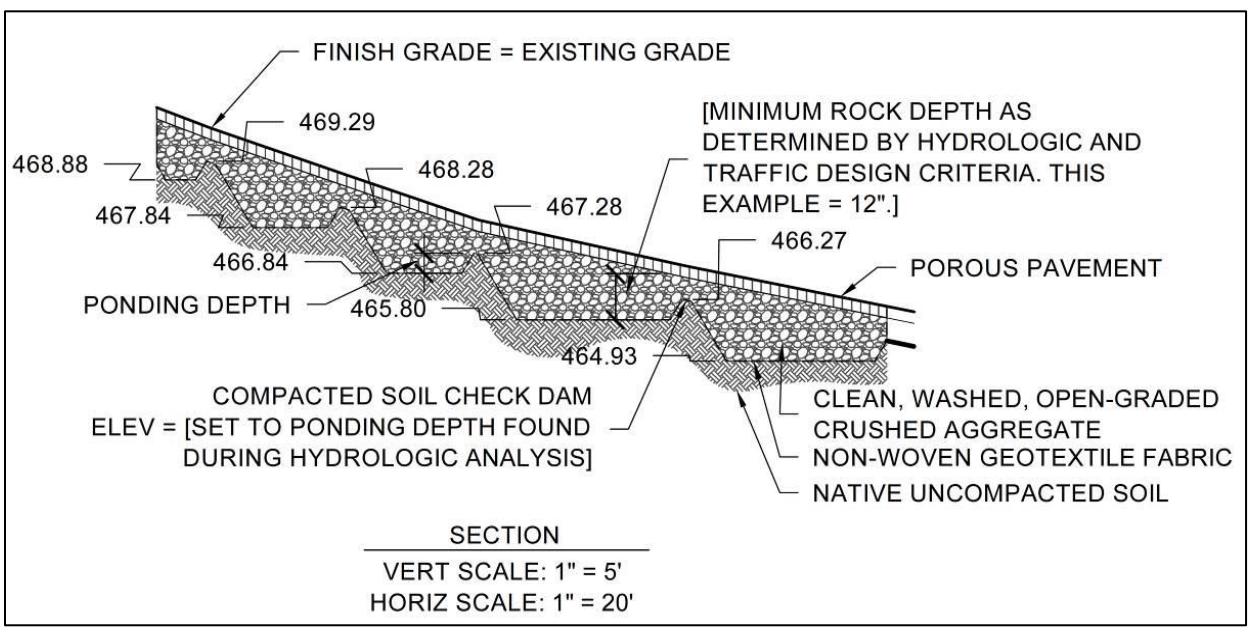


Figure 14- Cross section example on sloping sites. Underground berms 6 inches below the pavement surface hold water back and spread it out to infiltrate before excess volumes overflow

the dams during large storms. To significantly reduce excavation costs, the shape of the berms should follow *existing* contours, even though finish grade may not equal existing grade.

Grading Plans. A careful grading plan is needed to ensure that porous pavement adjacent to conventional pavements are hydraulically isolated and that dirt from any landscape areas above a porous pavement can be captured behind a curb or depression.

Subsurface Grading Plan. If the site is sloped and underground berms are used, as described in "Design Specific to Sloping Sites", an additional grading plan of the subgrade will be needed. With a subgrade grading plan, the contractor can fully understand the differences between subgrade elevations, where water will be stored to infiltrate, and proposed finish grades of the pavement surface.

Routing for All Porous Pavements. Porous pavements should convey the 24-hour flood design storm of *[jurisdiction's 25-year 24-hour storm]* inches. For vehicular applications, this requires the construction of overflow and control structures to ensure the pavement infiltrates the desired volume, but does not saturate and potentially destabilize the pavement. Provide a safe overland route per Appendix B, "Design", "BMP Design Criteria", "Safe Overland Route".

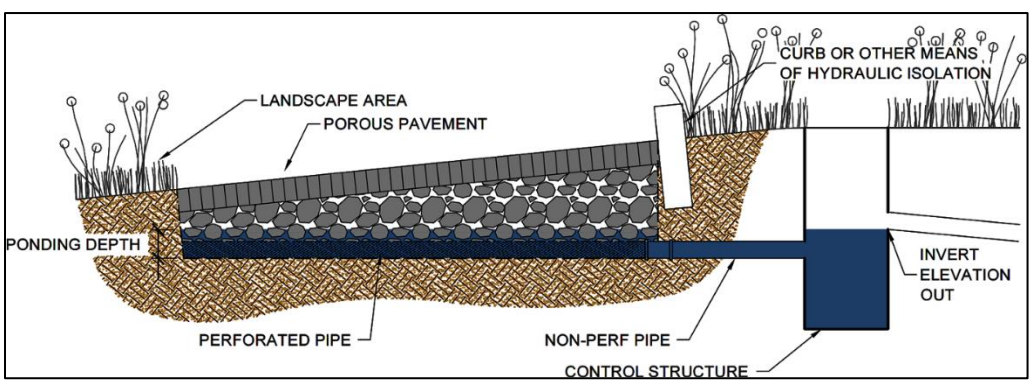
Adequate Cover. To protect its structural integrity, bury pipes to provide adequate cover of 12 inches minimum.

Underdrains. Underdrains are pipes perforated on the top half and encased in gravel filled trenches. They can be used for overflow, routing excess volumes in the base rock to a stormwater conveyance system, or inflow, conveying runoff from other impervious areas into the base rock

Underdrains for Overflow. Underdrains are recommended for all vehicular applications, regardless of whether they manage rainfall or runoff, to convey excess water from storms larger than the design storm.

In pedestrian applications that manage only rainfall, loads are usually light enough for the fully saturated rock section to provide structural support; therefore, an underdrain is not needed. If there is a possibility that the pedestrian application could be driven over, then the pavement should be designed as if it were a vehicular pavement.

It is desirable to place the pipe on the bottom of the facility for adequate cover of 12 inches minimum to protect its structural integrity. In this case, use a control structure such as a catch basin with a weir or another structure that will back up as much water as desired to infiltrate within the desired time (Figure 13) . To avoid UIC requirements, use perforated pipes that are



only perforated on the top and side instead of on all sides.

Underdrains for Inflow. Water can be conveyed directly to the base rock via a perforated pipe. This design must be hydrologically modeled by a qualified licensed engineer; however, this can be an effective use of land to infiltrate large volumes of runoff and protect water quality, since more rock is usually needed for structural capacity than hydrologic needs.

Design Approaches to Address Clogging. The infiltration rate of porous asphalt and concrete may be as high as 1500 inches/hour[29] while long-term infiltration rates have been observed to fall to as low as 2 inches/hour[30]. Considering the high void ratio when first installed, a "mostly clogged" surface can still be very effective.

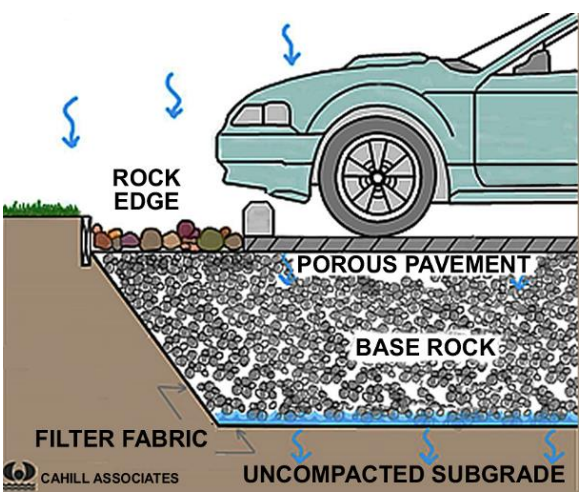
Nonetheless, the design phase is a good time to address long-term clogging issues:

Runoff from other areas should never be via overland flow onto the pavement surface. Even the small, frequent water quality sized storm will convey sediment into the pavement voids, clogging them.

Runoff conveyed by underground piping should be pretreated to settle out sediments, even if the surface areas are roofs.

Design landscape slopes around porous pavements, so that if they erode, the sediment will not reach the pavement surface. This is referred to as "hydraulic isolation" and can be achieved with a curb or a deep swale.

Provide short-term and permanent signage to prevent workers from dumping construction and landscaping materials on it.



UIC Regulations. Underground Injection Controls (UIC) are described generally in Chapter 1.8. Dimensions can trigger a UIC registration, to avoid this process, when sizing porous pavement, avoid designing a facility that is deeper than the widest surface dimension. Registration with UIC is also required if underdrains composed of perforated pipe that convey runoff from impervious areas without pretreatment for sediment and debris. This includes routing runoff from large events exceeding the storage capacity of the rock base to a stormwater conveyance system using perforated pipe with perforations all around.

[29] Environmental Protection Agency (2010). Surface Infiltration Rates of Permeable Surfaces: Six Month Update (November 2009 through April 2010). Retrieved from: http://nepis.epa.gov/Adobe/PDF/P1008CH4.pdf

[30] Bean, E., Hunt, B., Bidelspach, D. and J. Smith. (2004). Surface Infiltration rates of Permeable Pavement. North Carolina State University. Retrieved from: http://www.usawaterquality.org/conferences/2004/posters/beanNC.pdf

Figure 16- A permeable perimeter will carry runoff from a clogged pavement to the subsurface. Including an area called out as "rock edge," which is wider than the base rock is deep, does not trigger UIC requirements. Photo credit and adapted with permission from Thomas H. Cahill.

Standard Details. See standard details *[BMP 5.01, 5.02, 5.03, 5.04, and 5.05]* to include applicable details in construction documents. These are available in *[pdf, jpg, and AutoCAD dwg format]*. See also *[BMP 8.01]* if a control structure is needed.

Design Specific to Porous Pavement Type

Porous Asphalt. In addition to the design guidance provided above, additional considerations for porous asphalt, addressed through the specifications are as follows:
Porous asphalt (aka Porous Asphaltic Concrete) is a mixture of crushed aggregate (without the fines) and asphalt binder. The surface of a successfully designed and installed porous asphalt typically will have a void ratio of 10-20%. To reduce scuffing, use an additional polymer modified Performance Graded Asphalt Binder (PGAB).
Because asphalt is a flexible pavement, the base rock serves not only as storage for stormwater, but also as an integral part of the structural support for the pavement surface.

Pervious Concrete. Concrete mixtures are made of aggregate and Portland cement. Because concrete is a rigid pavement, the base rock may only be needed to store stormwater, not to support the surface structurally. In soils draining at a rate that matches or exceeds the fastest rate at which rain from the *[design storm in inches]* design storm might fall on the pavement, the base rock may not be needed. Nonetheless, the design specifications from the National Ready Mixed Concrete Association recommend a minimum of 6 inches of base rock in pervious concrete installations.

Permeable Pavers. Pavers can be made of many different materials and can be bought new from a manufacturer or salvaged (*e.g.* bricks, stones, or sawcut concrete sidewalk squares).

In vehicular applications, the entire facility area should be contained by a 6-inch wide perimeter of concrete or equivalent permanent structure to hold the pavers in place. (See Detail BMP 5.05 Vehicular Permeable Paver Edges).

Avoid paver products that recommend native soil compaction and/or do not include a drainage/storage area as these are not likely to infiltrate sufficient rainfall volumes. Check with the manufacturer to make sure that they offer a warranty without compaction.

Porous Flexible Paving Systems. These concrete or plastic frameworks or matrices are filled with turf grass or gravel. Climate may drive the choice between grass and gravel, since the landowner may want to water turf through the summer. Plastic units tend to provide better turf establishment and longevity, since plastic doesn't absorb soil moisture the way concrete does.

Construction

Like all stormwater management facilities, special care must be taken to properly construct BMPs. Protecting the infiltration capacity of the soil is crucial to the long-term functioning of any infiltration facility.

Construction Approaches to Address Clogging. The construction phase is a good time to address

long-term clogging issues:
Never stockpile landscape, soil, or other materials on porous pavements.
Develop a circulation plan for different construction phases**.** (See 2.3.1) Construction of the porous surface and base rock is ideally completed at the very end of a project, because it may be difficult to protect from getting clogged with dirt. Alternate access roads should to be planned ahead of time. Protect the soils beneath porous pavement from compaction. Porous pavement design is based on infiltration testing done before construction. All on-site contractors are responsible for maintaining that infiltration rate throughout the construction phase.

Construction Steps. Construction varies with each pavement surface type; however, the first few steps are the same for all porous pavements:

1. Excavate to the lowest elevation as shown on the plans to install the geotextile.
2. Install the geotextile. (See Appendix D: Specifications, "Geotextile Fabric".) Overlap sheets at least 18 inches on the bottom and sides. At the sides, lay an additional 4 feet beyond the bed to ensure sediment and runoff do not enter the bed during construction.
3. Wash the base rock. (See Appendix D: Specifications, "Coarse Aggregate".) (Note: Depending on the structural capacity and drainage characteristics of your native soils, base rock may not be needed for pervious concrete installations.) Dust or fine particles not washed away could clog the geotextile[31], so not only should the base rock be delivered clean from the quarry it should also be washed carefully on-site.
4. Place the base rock in 6-inch lifts[32] by dumping rock at the beginning of the porous pavement area and backing over it to dump and spread the next 6-inch lift. Do not compact with vibratory equipment. Light compaction can be achieved by driving back over each 6-inch lift. Place lifts to the top of the base rock elevation as indicated on the plan set.

   If porous gravel is being implemented, the pavement construction is complete. If another porous pavement surface type is being implemented, continue with the corresponding step 5 below.

Construction by Porous Pavement Type

Asphalt. An ODOT Certified Mix Design Technician (CMDT) should install porous asphalt. For those not able to find a certified installer, porous asphalt installation is very similar to conventional asphalt; it's rolled into place, but more lightly compacted. Follow additional guidance provided in Appendix D: Specifications, "Porous Asphalt (Bituminous) Pavement Specification".

5. Install choker course. When the base rock is lightly compacted, it may be difficult to roll asphalt on top of it. The base rock rolls, causing a wavy appearance to the asphalt surface. The choker course sits between the base course and pavement surface to lock

[31] Hicks, P.C. and JamesJ.R. Lundy..(Revised Oct. 2003 by Jim Huddleston). Asphalt Pavement Design Guide. Prepared for: Asphalt Pavement Association of Oregon.
[32] Lifts is a common term in construction and refers a depth of material, usually a portion of the total depth.

in, or choke, the larger base rock aggregate below and stabilize the surface for rolling. Field experimentation is sometimes needed, but depths will generally range from 1 to 2 inches[33] and should be composed of a smaller, uniformly graded, clean and washed crushed aggregate. The choker course is not needed in all situations. Consider asking a qualified licensed geotechnical engineer to determine if the base rock you will source needs a choker course.

6. Place porous asphalt. Porous asphalt placement is similar to the process of placing impervious asphalt. It should be placed and rolled, but care must be taken to not over compact the surface by using a small roller and limiting the passes, usually to two. Careful construction staging will ensure installation happens during a time of the year when temperatures will not drop below 55 degrees F during placement.

Pervious Concrete. Hiring an experienced, certified technician is important because pervious concrete installation is significantly different from conventional concrete. The National Ready Mixed Concrete Association (NRMCA) trains and certifies technicians to install pervious concrete nationwide. Find a certified technician in your area by going to their website[34].

5. Place pervious concrete. Pervious concrete uses a low cement to water ratio. The mixture should be used within an hour of adding water. Water should only be added once, since additional water can cause the cement to weaken and fail. Depending on weather conditions, the concrete should be covered within 15 minutes or less.

Permeable Pavers. Manufactured permeable pavers should be installed per manufacturer guidelines. Guidance for salvaged or poured concrete pavers are as follows:

5. Place bedding course. Permeable pavers should be placed atop a lightly compacted leveling course of AASHTO No. 8 or equivalent crushed rock. (See Appendix D: Specifications, "Crushed Aggregate".)
6. Place pavers. Space between pavers, called the infill course, should be between 8-20% of the paver size to allow for infiltration per the paver spacing plan on Detail BMP 5.04. The infill is a course sand, AASHTO No. 8 or equivalent crushed rock.
7. Lightly compact pavers. The area should be lightly compacted with a handheld vibratory compactor.

Figure 17- One cost-effective solution for permeable pavers is this poured-in-place installation. (See Detail BMP 5.04.)

[33] Puget Sound Action Team, (January 2005, Revised May 2005). Low Impact Development: Technical Guidance Manual for Puget Sound. Publication No. PSAT 05-03. Olympia, WA: Washington State University Pierce County Extension.

[34] National Ready Mixed Concrete Association website. Retrieved from: http://www.nrmca.org/

8. Refill infill space. If the AASHTO No. 8 or equivalent crushed rock drops below the surface of the pavers, refill infill space to meet the paver grade.

Porous Flexible Paving Systems. Flexible pavers should be installed per manufacturer guidelines. Use light compaction of the soil, by water compaction, saturating the soil and causing it to settle, or by a lightweight vibratory compactor.

Cost Considerations

Relative costs are difficult to analyze across different pavement types, because a porous pavement is not just porous at the surface, but is porous through the entire rock section. Since different pavement types have different sub-base requirements with different site conditions, simply comparing costs by surface is not always useful. Permeable pavers, porous flexible paving systems, and porous asphalt are flexible pavements that require base rock to achieve adequate strength and durability when supporting vehicular loads. Pervious concrete, on the other hand, is a rigid pavement that doesn't necessarily require additional base rock for structural stability.

The best way to know how much porous pavement will cost is to do a preliminary design for all appropriate pavement designs and engage a contractor to provide a cost estimate.

2.5.2 RAIN GARDEN, STORMWATER PLANTER, AND LID SWALE

There are a variety of approaches to managing runoff in depressions in the ground. This section provides detailed guidance on three approaches – rain gardens, stormwater planters, and LID swale BMPs– which function in similar ways to reduce runoff volume and pollution in stormwater runoff.

These BMPs collect stormwater runoff in a depression to first settle and filter out sediment and pollutants. As stormwater comes into contact with soil and plants, pollutants are reduced further through chemical and biological means. Stormwater quantity is reduced through evaporation, infiltration, and evapotranspiration.

While rain gardens, stormwater planters, and LID swales are very similar in the high quality of treatment achieved through ponding (*i.e.* holding water in pond until it can infiltrate and evaporate), the volume of water ponded differs, which affects how large they are (*i.e.* sizing). Stormwater planters have the smallest footprint, while rain gardens and LID swales have larger footprints.

Differences between the three vegetated stormwater facilities are described next.

Rain gardens have gentle side slopes and may be any shape. They have a single area where water is ponded before it infiltrates or, in large storms, overflows. A rain garden should be installed on flat ground.

Figure 18- A rain garden.

An LID swale has gentle side slopes but is linear in shape. LID swales are installed on sloping areas, using check dams that allow water to back up. Each cell created by the check dam ponds up before water cascades over the check dam and into the next cell, infiltrating and evaporating along the way. At the last cell at the bottom of the LID swale, stormwater finally may overflow.

A stormwater planter may be either in- or above-ground, but it has vertical sides instead of gentle side slopes. Stormwater planters can be any shape. Those above-ground tend to be square or rectangular. A single stormwater planter cell may be installed on flat areas. On sloping ground, a stormwater planter may incorporate check dams to create a series of cells where overflow may occur in the lowest elevation cell.

Figure 20- A residential above-ground stormwater planter. This facility is lined to prevent infiltration too close to the basement.

Figure 21- An in-ground stormwater planter with concrete check dams in a public street, right before planting. The centerline slopes at less than 1%. Concrete check dams were

Figure 19- An LID swale. Dense plantings of grasses, shrubs and trees are ideal.

Siting

Vegetated stormwater facilities have been used successfully on private property, public property, and within the public right-of-way. They may be built in new construction, re-developments, and retrofits.

<u>Unsuitable Locations for All Facilities.</u> Vegetated stormwater facilities should NEVER be installed in the following locations:

In floodways, defined by the Federal Emergency Management Agency as "the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height."[35]
In other sensitive areas (*i.e.* wetlands, riparian areas or buffers, designated native habitat areas.)
Over septic systems.
In seasonally wet areas.
One-quarter mile of phosphorus-sensitive water bodies if the underlying native soil does not meet the "Treatment Soil" specifications in Appendix D: Specifications.
100 feet of a drinking water well or a spring used for a drinking water supply.

Suitable Locations for Infiltration Facilities. Vegetated stormwater facilities that infiltrate can be located:
Where the seasonal high groundwater table, bedrock is greater than 24 inches from the bottom of a vegetated stormwater facility.
Where the bedrock or other impermeable layer is greater than 18 inches from the bottom of a vegetated stormwater facility.
In soils that infiltrate at least 0.5 inches/hour for the sizing factor approach provided in Chapter 4. Soils with lower infiltration rates may be acceptable but must be designed by a qualified licensed engineer.
Where they are at least 10 feet away from an existing building foundation (including slab foundations unless designed by a qualified licensed engineer)
Where they are least 10 feet away from a possible future building foundation (including slab foundations unless designed by a qualified licensed engineer). Check setback requirements in the City of Philomath Municipal Zoning Code for the proposed development site and all neighboring properties to ensure that a vegetated stormwater facility will be 10 feet from a building foundation in the future.
Where they are at least 10 feet from an underground tank or a site wall.
Where they are at least [5 feet] from underground utilities.
On retrofits, where they will be directly over existing electrical lines that can be easily and cost-effectively relocated to be outside of the new facility.
Directly adjacent to pier footings.
For runoff from vehicular areas, within a horizontal distance of 2x the depth of any nearby wells.
[In any location approved by a qualified licensed engineer or geologist who has signed and stamped a geotechnical investigation report or letter clearly designating the location in narrative and/or by graphical means (i.e. site plan).]

Design

Sizing and Hydrological Design. The size of a facility must be determined through hydrologic modeling (Appendix B: BMP Implementation Criteria, "Design", "Hydrologic Modeling") based on the infiltration rate found by infiltration testing per Appendix C: Infiltration Testing. For vegetated stormwater facilities meeting the criteria above in "Siting", "Suitable Locations for Infiltration Facilities *[without Underdrains]*" and designed in accordance with this guidance, size the facility using the LID Implementation Form (see Chapter 4: LID Implementation, Step-by-Step).

[35] Federal Emergency Management Agency website. Floodway definition. Retrieved from: https://www.fema.gov/floodplain-management/floodway

A qualified licensed professional should sign and stamp design drawings and drawings should be based on a hydrologic model using the criteria in Appendix B: BMP Implementation Criteria, "Design", "Hydrologic Modeling", Hydrologic Criteria when Simplified Sizing Not Applicable" when any of the following conditions exist:

A vegetated stormwater facility cannot be sized using the simplified sizing approach according to Table 3-9 below.

The tested infiltration rate per Appendix C: Infiltration Testing is less than 0.5 inches/hour.

The facility incorporates a rock trench (described in later sections below) beneath the vegetated stormwater facility.

Surface Geometry and Water Quality Function. Surface geometry affects the health of plants and soil, which affects water quality. Design criteria for surface geometry are as follows:

The depth of water allowed to accumulate in a vegetated stormwater facility, known as the ponding depth, should be between 6 to 12 inches. Plants suitable for vegetated stormwater facilities are often healthier when not inundated beyond 12 inches.

For rain gardens and LID swales, side slopes should be less than 33% (3 horizontal:1 vertical). Steeper soil slopes require mechanical compaction, which will impact the infiltration capacity of soil. This reduces the effective infiltration and/or treatment area, which can be measured from the top of the facility, and also makes it much more difficult to establish plantings.

Stormwater planters have vertical sides made of structural material like concrete, not soil.

Vegetated stormwater facilities may be any shape that meets the sizing criteria for vegetated stormwater facilities. Shape is more often dictated by the available space and budget. "Corners" made of soil should be designed with a rounded radius of at least 5 feet.

Ponding Depth (in)	Minimum Width (ft)	Min Area (sf)
6	3	9
9	4.5	20.3
12	6	36

Table 4-- Using the above guidance, minimum geometry for rain gardens and LID swales are as follows below

Vegetation. Plants and the beneficial microbes that concentrate on plant roots remove pollutants through biological breakdown and/or uptake – the more plants, the more treatment. Plants also promote infiltration and evaporation. Design criteria for vegetation is as follows:

Vegetation should cover a minimum of 95% of the facility within three years. The better the plant coverage, the less effort needed for weeding.

Avoid the dry creek bed look where rocks line the bottom and plants are sparse or located only around the top edges of the slopes. This approach doesn't provide adequate treatment for the small, frequent storms with ponding depths that may never reach the plants on the side slopes. This strategy also creates a lot of maintenance (weeding and cleaning rock).

Vegetation should be selected based on its tolerance to flooding and drought cycles and other criteria listed in Appendix E: Plant Specifications.

Mulch. Mulch is often the top layer of a newly installed vegetated stormwater facility. In non-stormwater landscape areas, mulch is used to control soil temperature for seed germination, to control weeds, to feed the plants, and to reduce the erosion of soil that would be otherwise bare; however, in a vegetated stormwater facility, routine inundation can turn mulch into a

pollutant. During small storms, mulch floats and leaves soil bare as it is redistributed around the facility. During large storms, mulch is conveyed through the overflow structure. As with any organic material, as mulch breaks down in a waterway, it reduces the amount of available oxygen, which is one measure of water quality. Also, many pollutants, especially metal, attach easily to mulch.

Use mulch meeting the specifications in Appendix D: Specifications, "Mulch".

Apply mulch for only the first three years of a vegetated stormwater facility. After that, vegetation should have adequate structure to hold soil, cover it, and shade out most weeds. (Additional information is provided in the following sections on how to implement vegetated stormwater facility to slow flows and reduce soil erosion.)

Soil. Directly below the temporary mulch is soil, which may be:

Imported (Native soil is removed and replaced with a blended soil mix purchased from a supplier.)

Amended (Amendments are folded into existing native soil.)

Native and free-draining (Infiltration vegetated stormwater facilities allow water to flow down into the native soil.)

Infiltration testing. Perform an infiltration test to determine the soil's capacity to absorb and percolate water down into the lower layers. See Appendix C for detailed guidance on field testing to find the rate that water can pass through the soil and how to interpret that data.

If infiltration rates are high, the vegetated stormwater facility will have a smaller footprint, be less expensive to build, and will be able to accommodate ponding depths up to 12 inches, because water will drain through the soil within the required 30 hours.

If infiltration rates are low, a very shallow ponding depth will be desired to ensure that the plants will not have "wet feet" for excessive periods. In this case, expect to spread stormwater out in a shallow depth of just a few inches rather than trying to store the excess runoff volumes in a smaller footprint facility with a deeper ponding depth. This is the only way to ensure that the facility will be empty and ready for the next storm in 30 hours.

Imported Soil considerations. When purchasing soil to import to the site, the infiltration rate of both the imported soil and the native soil underlying it must be known. Investigate the site and decide if imported soil is needed. As described below in "Choosing the Best Vegetated Stormwater Facility", this may be done for a number of reasons:

The soils are compacted and instead of restoring the soil with compost per the Restored Soil BMP, a designer or contractor would prefer to import and place a purchased product.

The existing topsoil or surface material (*e.g.* gravel) does not have adequate nutrition to adequately support plant life.

The existing soils drain faster than the recommended 12 inches/hour. (Faster than this could pollute groundwater by reducing the time that pollutants are in contact with soil.)

To determine the infiltration rates of the different soils:

1. Perform an infiltration test on the native soil per Appendix C: Infiltration Testing.
2. Determine the imported soil infiltration rate. Infiltration rates (referred to in laboratories as the "long-term hydraulic conductivity") for imported soils may be found from laboratory testing.

3. Determine the design infiltration rate by comparing the infiltration rates of the different soil horizons per **Figures 3-88.**

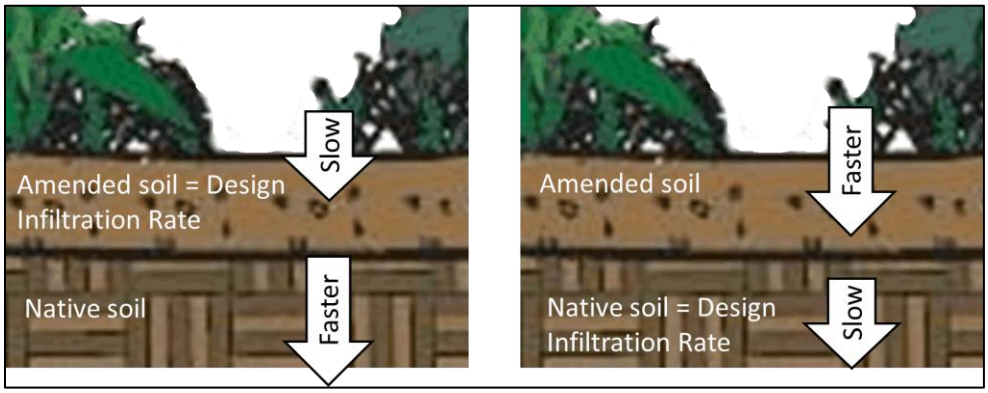
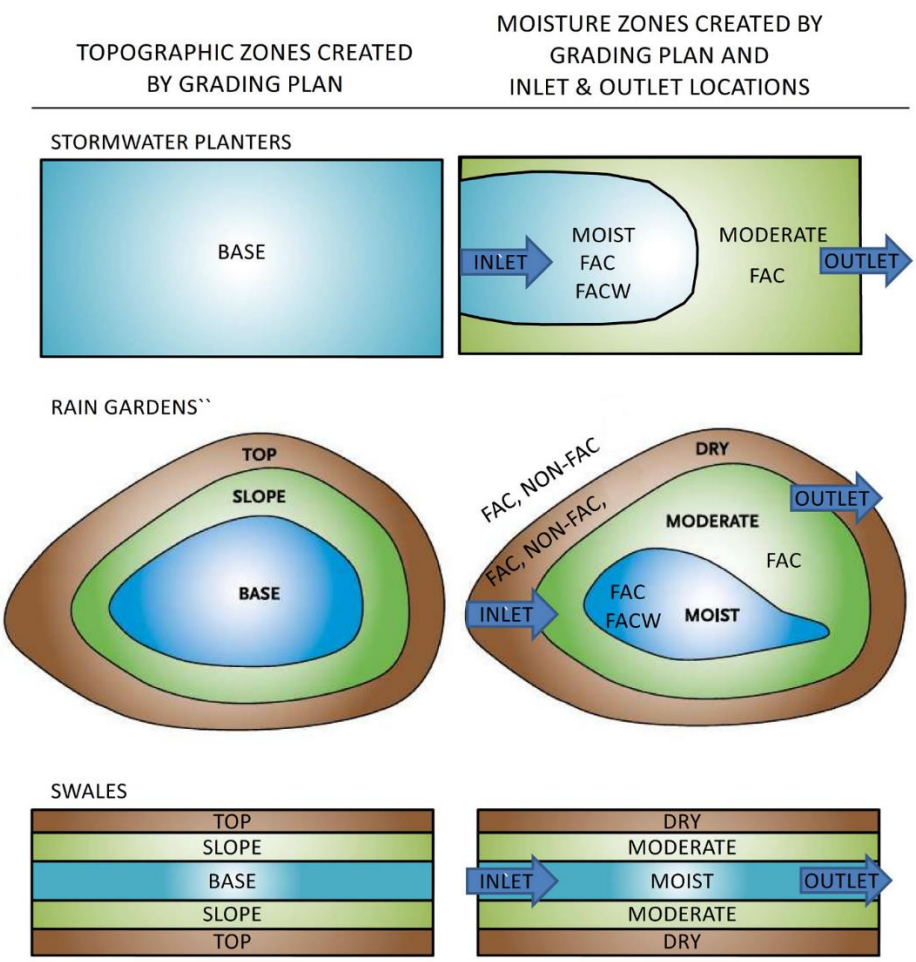


Figure 22- The design infiltration rate is always the slowest infiltration rate of the different soil horizons (imported or native).

4. Size the facility based on the design infiltration rate (*i.e*. the slowest infiltration rate within the rain garden footprint) using the appropriate worksheets when completing the LID Implementation Form (see Chapter 4).



Wetland status indicator for the moisture zones found in a vegetated stormwater BMP.

Pretreatment. Where stormwater enters a facility in a concentrated fashion (*i.e.* piped or flow from a gutter), a pretreatment structure to settle out sediment and trap trash improves water quality treatment, extends the life of the facility and reduces maintenance times by concentrating potential clogging agents in one place, making them easier to remove. (See "Maintenance" below for additional information on sediment disposal.)

A number of different pretreatment strategies are shown below. Choose one that is appropriate for the level of sediment expected for the surface draining to the facility and one that can be maintained by the landowner. Pretreatment strategies pictured below are characterized as:
"High sediment loads" come from lawns and roads with greater than 7,000 cars per day.
"Low sediment loads" come from roofs.
All other surfaces may be considered to be "medium sediment loads".

Design criteria for pretreatment is as follows:
Allow water to pool in a sump or equivalent structure such as a carefully shaped concrete pad.
Avoid rip rap placed at the entrance of the facility, especially in high traffic roads or other areas with high sediment loads. If designed properly, many solids will settle out as runoff passes over the rip rap but the primary purpose of rip rap is to slow flows to prevent erosion. Cleaning dirt between the nooks and crannies of the rip rap (or for that matter, any rock in a facility) is a time consuming and expensive maintenance task and once the rip rap is full of dirt, it doesn't slow the flows much and erosion happens anyway. If rip rap is used, a qualified licensed engineer should provide calculations for the length, width, depth, and rock diameter to account for the predicted velocity.
Vegetation to slow flows at the inlet is not permitted.
Consider creating rough surfaces to slow flows. Avoid smooth concrete channels unless designed to tip back slightly towards the inlet, since they will simply transfer erosive flows from the entrance to the end of the channel.

Inlets. Careful inlet design will ensure that runoff enters the facility as expected.

Design criteria for inlets is as follows:
Avoid curb cuts where water must make a 90-degree turn into an adjacent facility, since very small amounts of sediment will build up at the entrance, which can prevent the shallow flowing, frequent water quality flows from entering the facility.
Design the facility so that high flows, generated by storms larger than the design storm, can bypass the system. This will reduce erosion, the re-suspension of sediment, and maintenance. One method for incorporating a bypass is to develop a grading plan that will automatically block excess flows from entering the ponding area. (See Appendix B: BMP Implementation Criteria, "Design","High Flow Bypass".)
For inlets to vegetated stormwater facilities in the public right-of-way, the inlet should be a standard City of Philomath catch basin per standard detail of a storm outlet energy dissipater basin modified to drain from the back into the vegetated stormwater facility at an elevation equal to the bottom of the vegetated stormwater facility (**Figure 3-96**).

Figure 3-96. This catch basin inlet is ideal to serve as an inlet, pretreatment, and high flow bypass for high sediment areas. A sump in the bottom allows sediment to collect and be easily removed with standard vacuum truck equipment. A slot cut in the back just a bit lower than the gutter line allows water to enter the facility cleaner and with less erosive power than a conventional curb cut. If the bottom of the weir/slot is located at the same elevation as the desired maximum ponding depth, then this will also serve as high flow bypass during large storms, allowing relatively clean water to bypass the facility instead of entering it and causing erosion.

Vegetated Stormwater Facility on Slopes: Check Dams. Check dams are structures usually used in linear shaped vegetated stormwater facilities to pond water and prevent erosion on slopes.

Design criteria for check dams is as follows:
Horizontal spacing should be based on the ponding depth and centerline slope of the vegetated stormwater facility (see example for a rock check dam in **Figure 3-98**)

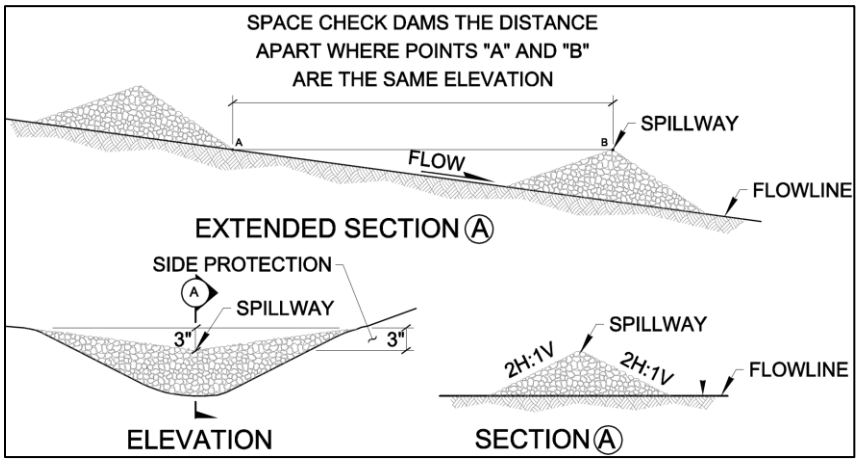


Figure 3-98. Check dam spacing depends on ponding depth and the facility's centerline slope, as shown in "Extended Section A" above. Adapted from City of Portland standard detail.

The top elevation of the check dam should not be so high that water cannot crest and flow into the next cell and not so low that the desired ponding depth is not achieved.

On slopes exceeding 5%, install check dams made of:
Concrete

Stone
Untreated, rot resistant wood such as juniper
Stainless steel

Because they contribute a variety of pollutants to stormwater, avoid using the following materials for check dams:
Treated wood. Even wood treated with environmentally friendly products, like copper, is not suitable for stormwater facilities. Copper has very high impacts to endangered fish at very low levels.
Any metal other than stainless steel. Copper, zinc (from galvanized materials), and iron are all water quality pollutants.
Crushed concrete. This can raise the pH of water flowing through it.
Bare compacted clay or soil. These will easily erode and soil and sediment are both pollutants.

Overflow structures. Overflow structures such as a catch basin within a vegetated stormwater facility should be incorporated when storm events could cause damage to a structure (by backing up into it or flowing down into it) or create a dangerous condition (*e.g.* excess stormwater flowing over a public sidewalk) (**Figure 3-101**). Overflow structures cannot be relied upon during a storm larger than the design storm; instead, a safe overland route per Appendix B: BMP Implementation Criteria, "Design", "BMP Design Criteria", "Safe Overland Route" must be provided.

Overflow structures should drain to an approved discharge point and may include:
A berm. To build a berm, establish a minimum of 2 inches of freeboard above the ponding depth (6 to 12 inches) controlled by the outlet[36]. Earthen berms should be stabilized with vegetation or otherwise designed to reduce erosion. Berms should not be designed to be compacted bare soil.
An overflow channel such as a water quality conveyance swale (see Chapter 3 "Water Quality Conveyance BMP") or a hard channel such as runnel. The centerline elevation of the channel should be set at an elevation for maximum ponding depth.
Catch basin and pipe. Set the rim elevation of the catch basin equal to the desired ponding depth to store and infiltrate the full design storm.

Storage Rock. Storage rock is rock that provides adequate voids (per Appendix D: Specifications, "Coarse Aggregate") placed underneath the ponding area and soil of a vegetated stormwater facility, used to store large storm volumes until runoff can infiltrated. A qualified licensed engineer is required for designs that incorporate rock storage beneath a vegetated stormwater facility to size the depth of rock using hydrologic modeling.

In slow draining soils (generally less than 1.0 inch/hour but it depends on the design storm size), storage rock will not reduce the footprint of the vegetated stormwater facility. Since a facility must empty in 30 hours, shallow ponding depths (usually less than 6 inches) control the size of the facility. In this case, water must be spread out. Increasing the depth of water (either by increasing the ponding depth or by employing a rock trench below the pond) is more likely to cause the emptying time to exceed 30 hours.

For this reason, storage rock is best used in faster draining soils on projects with constrained

[36] Barr Engineering Company. (2001.). Minnesota Urban Small Sites BMP Manual: Stormwater Best Management Practices for Cold Climates. Metropolitan Council Environmental Services, St. Paul, Minnesota.

infiltration area where the requirement to empty in 30 hours is easily met, even if additional ponded water is added to the same vegetated stormwater facility footprint.

Rock separation. A strategy to prevent the soil above and below the rock trench from migrating into the voids meant to store water is required when employing a rock trench. Avoid geotextile fabrics on the top and bottom, which have been found to clog in numerous studies[37]. Instead a 4-inch thick layer of separation rock (see Appendix D: Specifications for information for infill and separation rock under "Aggregates") should be installed between the facility soil and the rock trench. In the case of fine graded soils (*i.e.* clayey or silty soils), this separation rock layer should also be installed at the bottom of the rock trench. As shown in the standard detail (see Appendix F), geotextile fabric may be used on the sides of the rock.

Careful subsurface grading of rock trenches on slopes must be implemented to ensure that rock will be available to store runoff for subsequent infiltration (**Figure 3-102**).

[37] Two Rouhi, A. and D. Schwartz. (2007). Physical Assessment of Selected Rain Gardens in Fairfax County, Virginia. The Northern Virginia Soil and Water Conservation District. Fairfax, VA. Retrieved from: http://www.fairfaxcounty.gov/nvswcd/raingardenstudy.pdf and the University of New Hampshire Stormwater Center. 2009 Biannual Report. Retrieved from: http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/pubs_specs_info/2009_unhsc_report.pdf

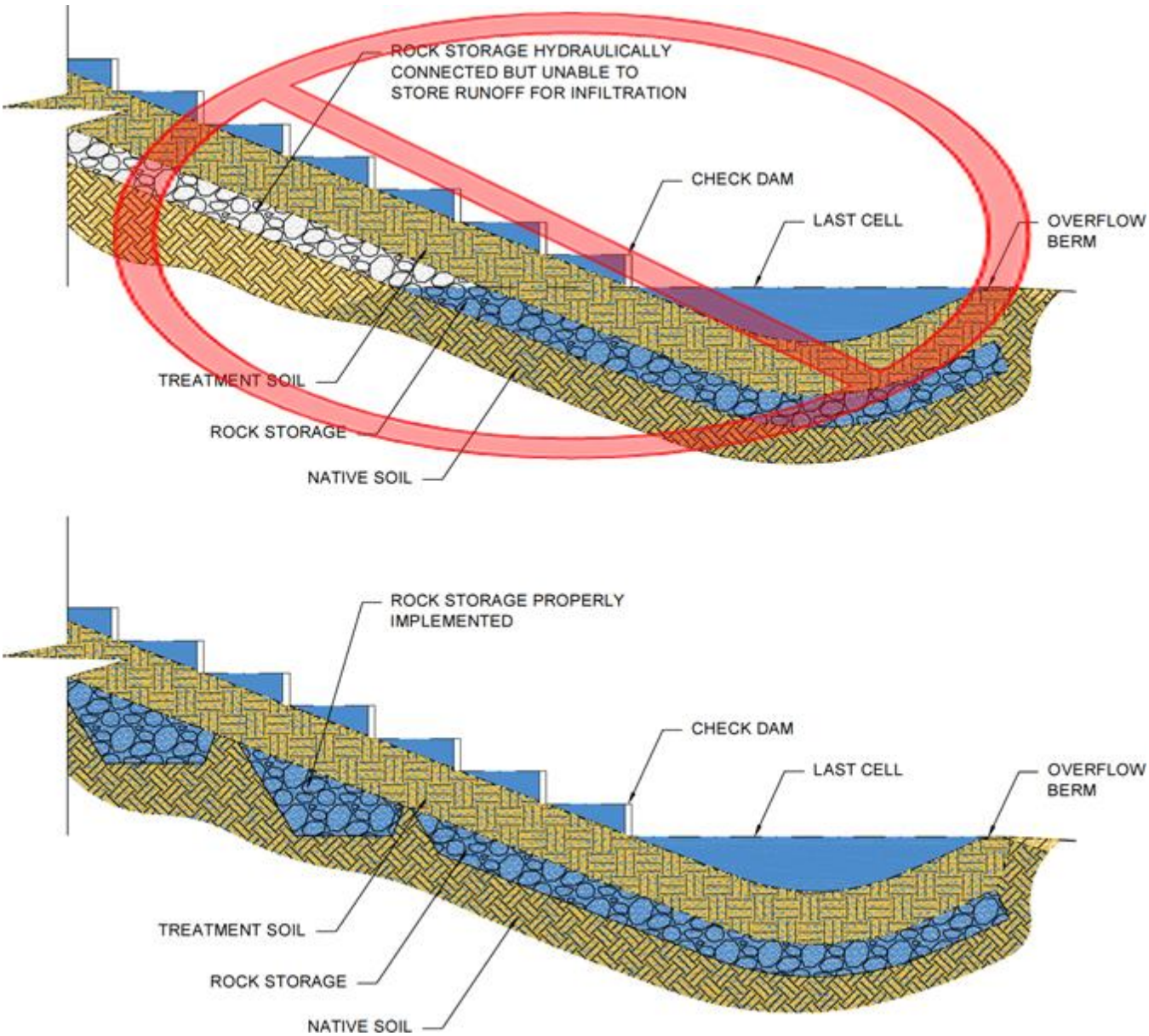


Figure 3-102. In the top figure, the desired rock trench depth has been installed with the same depth along the entire length of the facility; however, the overflow berm of the lowest cell will overflow before rock above that elevation can store and infiltrate water. Per the bottom figure, rock trenches are stepped down the hill with existing contours to ensure storage availability. In this case, a subsurface grading plan may be useful to include in the permit/construction drawing set.

Impermeable Liner. Impermeable liners are sometimes used in infiltration facilities to limit horizontal flow. (See Appendix D: Specifications, "Impermeable Liner".)

Vertical installations in infiltration vegetated stormwater facilities. Because water moves through soil twice as fast horizontally as it does vertically, when installing vegetated stormwater facilities next to conventional roadways, it is prudent to block flows from entering the conventional pavement sections. Along public roads, this is often done by pouring continuous concrete curbs around the vegetated stormwater facility. Concrete curbs do pass moisture through them and some designers wish to block this as well, so an impermeable liner is

mechanically attached to the curb as an extra precaution against moisture. The liner is only as deep as the curb and does not cover the bottom.

Partial infiltration vegetated stormwater facilities. Where site areas are constrained, one strategy for infiltrating at least some runoff is to partially line a vegetated stormwater facility (**Figure 3-103**). Some infiltration is better than none, where feasible.

Figure 3-103. This recently installed rain garden retrofit includes a partial liner on the right side and for a distance of about 5 feet out horizontally from the sidewalk. The sidewalk is 5 feet wide, so the 5-foot liner ensures that water cannot infiltrate closer than the recommended 10 feet from the building. The rest of the facility area is able to infiltrate. The vertical portion of this liner runs at least 12 inches deep so that adequate soil volume can be placed on top to grow the chosen grasses. A deeper liner would be needed to plant tall grasses, shrubs, or trees in this zone. The horizontal portion of the liner is installed tipped with 1% slope away from the building/sidewalk so water can drain out of this area as the rain garden empties. No perforated pipe is needed to ensure proper drainage when the liner is tipped toward a column of soil that can infiltrate.

Standard Details and Sizing. A variety of standard details for rain gardens, stormwater planters, and LID swales are included in Appendix F and can be downloaded[38]. Designs range from simple facilities with no formal overflow structure or amended soils to complex lined facilities that require an underdrain, a large storm overflow structure, and imported, engineered soil.

The table below summarizes which standard details include which components and whether this facility configuration can be sized using the simplified sizing approach, described in Chapter 4.

Table 3-9. Summary of Standard BMP Details.

[38] *[Provide the website where details can be downloaded.]*

Detail #	Title	Sizing Factor on LID Implementation Form Applies? Yes or No
Rain Gardens		
BMP 1.01	Simple Infiltration Rain Garden	Yes
BMP 1.02	Infiltration Rain Garden with Area Drain	Yes*
BMP 1.06	Infiltration Rain Garden with Amended or Imported Soil	Yes
BMP 1.03	Infiltration Rain Garden with Amended or Imported Soil and Area Drain	Yes*
BMP 1.05	Infiltration Rain Garden with Rock Trench	No
Stormwater Planters		
BMP 2.06	Simple Infiltration Stormwater Planter	Yes
BMP 2.01	Infiltration Stormwater Planter with Area Drain	Yes*
BMP 2.05	Infiltration Stormwater Planter with Amended or Imported Soil	Yes
BMP 2.02	Infiltration Stormwater Planter with Amended or Imported Soil and Area Drain	Yes*
BMP 2.04	Infiltration Stormwater Planter with Rock Trench	No
LID Swales		
BMP 3.03	Simple Infiltration LID Swale	Yes
BMP 3.04	Infiltration LID Swale with Amended Native or Imported Soil	Yes
BMP 3.07	Simple Infiltration LID Swale – Lowest Elevation Cell with Area Drain	Use this detail with BMP 3.03 (area in last cell can be included to meet sizing requirements)**
BMP 3.08	Infiltration LID Swale with Amended or Imported Soil -- Lowest Elevation Cell	Use this detail with BMP 3.04 (area in last cell can be included to meet sizing

	with Area Drain	requirements)**
BMP 3.02	Unlined Filtration LID Swale – Lowest Elevation Cell with Area Drain	Use this detail with BMP 3.01 (area in last cell can be included to meet sizing requirements)**
BMP 3.05	Infiltration LID Swale with Amended or Imported Soil and Rock Trench	No
BMP 3.06	Infiltration LID Swale with Amended or Imported Soil and Rock Trench– Lowest Elevation Cell with Area Drain	Use this detail with BMP 3.05 (area in last cell can be included to meet sizing requirements)**
*Area drain rim or alternative overflow structure elevation must be set to a height that allows the chosen ponding depth (either 6 inches, 9 inches, or 12 inches) to accumulate in ponding area. ** Since the check dams in LID swales create a series of small ponded areas that cascade from one LID swale cell to the next, only the last cell needs an overflow structure.		

Choosing the Best Vegetated Stormwater Facility Configuration

Vegetated stormwater facilities have a range of complexity. This section provides information so that the level of complexity can be properly assessed, since well designed, simple facilities are less costly to build and easier to maintain than overly complicated systems and can perform just as well, or sometimes better, to protect watershed health.

Simple Infiltration Vegetated Stormwater Facility. A simple infiltration facility (detail BMP 1.01 (rain garden), BMP 2.06 (stormwater planter), or BMP 3.03 (LID swale)) may be used when the following criteria are met:

The native soil infiltrates between 0.5 and 12 inches/hour

AND

The native soil meets applicable criteria of Appendix D: Specifications, "Treatment Soil"

AND

In a large storm or in the case of a clogging failure, when water flows over the berm and/or low point of the facility, it will not cause damage to any structures downhill (**Figure 3-101**)

AND

In a large storm or in the case of a clogging failure, water will not back up to flood any nearby structures uphill (**Figure 3-101**).

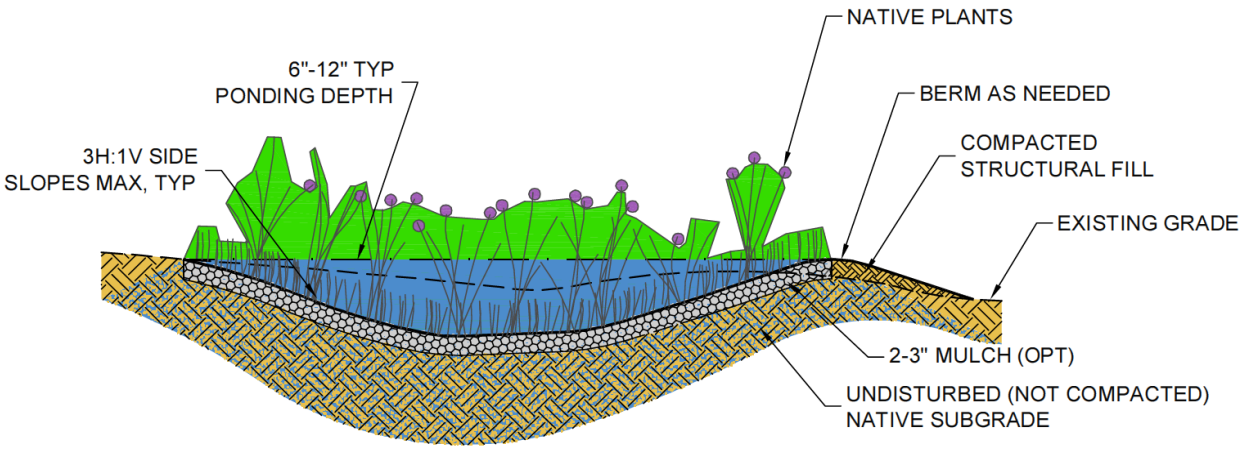


Figure 3-104. Example of a "Simple Infiltration Rain Garden". Not pictured, but also applicable to the above criteria are versions of a stormwater planter or LID swale (see Appendix F Standard Details).

Infiltration Vegetated Stormwater Facility with Area Drain. Using detail BMP 1.02 (rain garden), BMP 2.01 (stormwater planter), or BMP 3.03 with BMP 3.07 (LID swale details), an area drain or equivalent large storm overflow structure should be added to the facility whenever:

The native soil infiltrates between 0.5 and 12 inches/hour

AND

The native soil meets applicable criteria of Appendix D: Specifications, "Treatment Soil"

AND

In a large storm or in the case of a clogging failure, when water flows over the berm and/or low point of the facility, it WILL cause damage to any structures downhill (**Figure 3-101**)

OR

In a large storm or in the case of a clogging failure, water WILL back up to flood any nearby structures uphill (**Figure 3-101**)

OR

The facility is the last, lowest elevation cell of an LID swale.

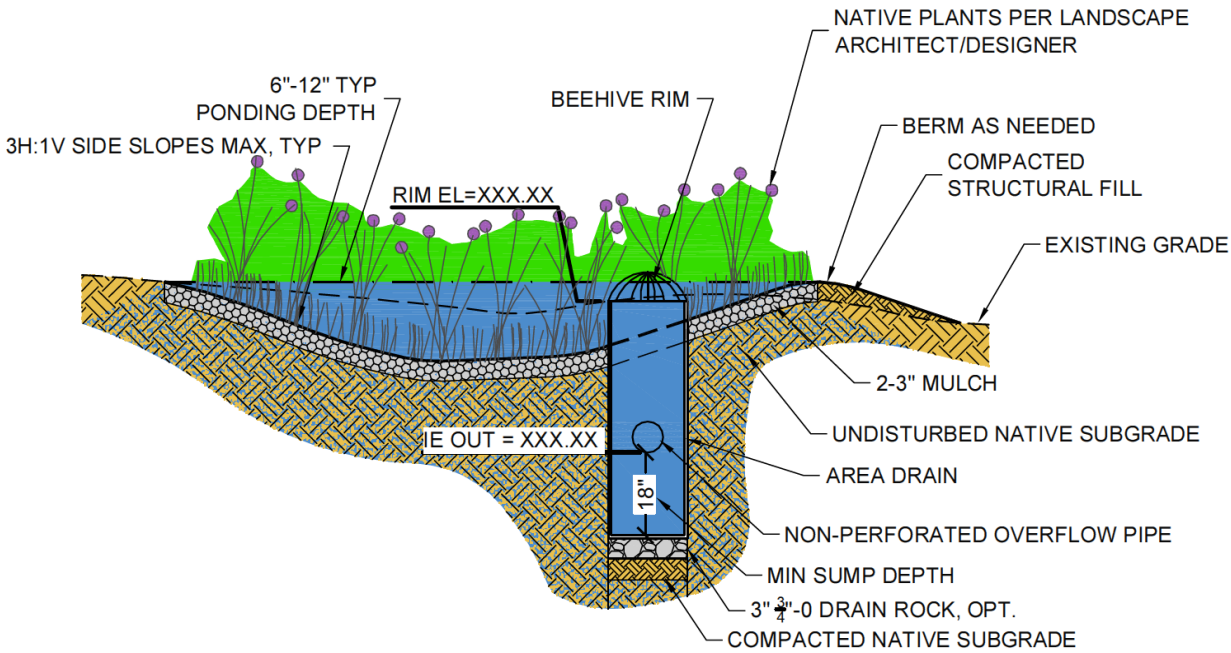


Figure 3-105. Example of an "Infiltration Rain Garden with Area Drain". In this case, the water level is above the rim elevation of the outlet because a storm larger than the design storm is overwhelming the downstream system (*i.e*. the non-perforated overflow pipe, which would be connected to an approved discharge point) with either intensity or volume or both. During the water quality design storm, water depth should be less than the rim elevation. Not pictured, but also applicable to the above criteria are versions of a stormwater planter or LID swale (see Appendix F Standard Details).

Infiltration Vegetated Stormwater Facility with Amended Planting Soil. Using detail BMP 1.06 (rain garden), BMP 2.05 (stormwater planter), or BMP 3.04 (LID swale), soil should be amended to a minimum depth of 18 inches when:

Native soils infiltrate 1 inch/hour or slower and will be kept in place but amended (see Appendix D: Specifications, "Treatment Soil"). Soil amendments can increase the facility's storage capacity (and therefore the infiltration capacity). This approach is most often used in tight clay soils to provide more voids in the soil for storage and restore permeability, but it does not necessarily increase the rate that water will infiltrate. (**Figure 3-88**)

OR

Native soils infiltrate at 12 inches/hour or faster and should be replaced with "Imported Soil" (see Appendix D: Specifications, "Treatment Soil"). Soil amendments are needed to slow flow to achieve adequate retention time in the soil for water quality treatment

OR

A simple infiltration vegetated stormwater facility was designed, but during construction, the soil was not protected from compaction (*i.e.* durable fencing and signage).

Soil may be optionally amended when:

You believe that the plants will be healthier with amendments or imported soil (*e.g.* replacing rocky fill)

OR

A faster draining soil is beneath a slower draining surface soil and you wish to decrease the footprint of your facility, accessing the faster draining soil by replacing the native soil with an imported soil mix (see Appendix D: Specifications, "Treatment Soil"). In this case, to avoid unintentionally creating an

Underground Injection Control (UIC), ensure that the facility is at least as wide as the depth of the imported soil mix. (See Chapter 1 “Underground Injection Controls”.)

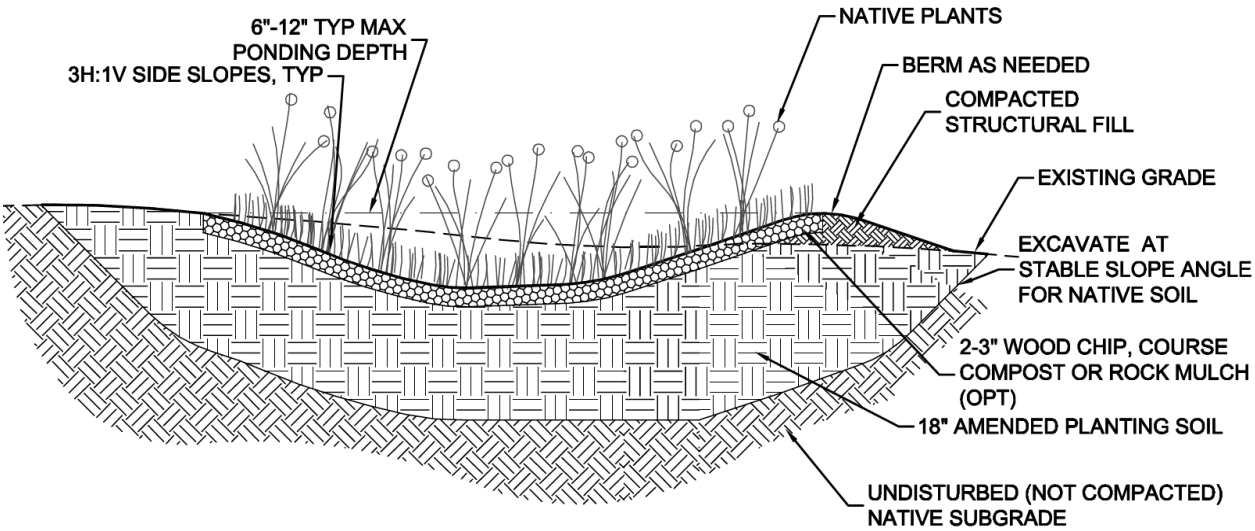


Figure 3-106. An example of an “Infiltration Rain Garden with Amended Planting Soil”. Not pictured, but also applicable to the above criteria are versions of a stormwater planter or LID swale (see Appendix F Standard Details).

Infiltration Vegetated Stormwater Facility with Amended Planting Soil and Area Drain. Use this configuration when:

Soils are amended for the same reasons as “Infiltration Vegetated Stormwater Facility with Amended Planting Soil” above

AND

When overflows must be carefully directed for the same reasons listed in “Infiltration Vegetated Stormwater Facility with Area Drain” above.

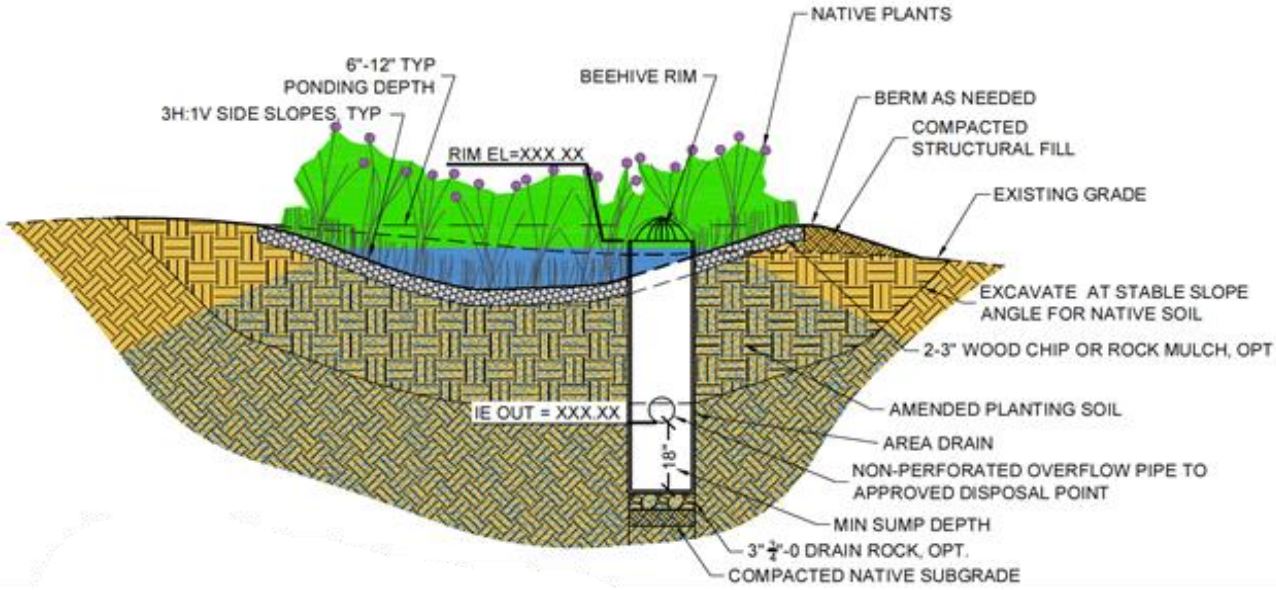


Figure 3-107. An example of an "Infiltration Rain Garden with Planting Soil and Area Drain". Not pictured, but also applicable to the above criteria are versions of a stormwater planter or LID swale (see Appendix F Standard Details).

Infiltration Vegetated Stormwater Facility with Rock Storage. Using detail BMP 1.05 (rain garden), BMP 2.04 (stormwater planter), or BMP 3.06 (LID swale), include rock storage when:
Space for infiltration is limited, but retention of larger volumes of stormwater runoff is desired or required
AND
The infiltration rate is at least 1.5 inches/hour.

As described already above, these should not be used in soils draining slower because the facility is unlikely to be empty and ready to manage another storm by the required 30 hours. The limit of 1.5 inches/hour used here is based on modeling and experience and is not a typo. It is intended to be different from the 0.5 inch/hour limit for vegetated stormwater facilities that require a qualified licensed engineer.

This facility configuration is usually not cost-effective unless the remaining drainage area (described in Chapter 4) is large and stormwater management is required.

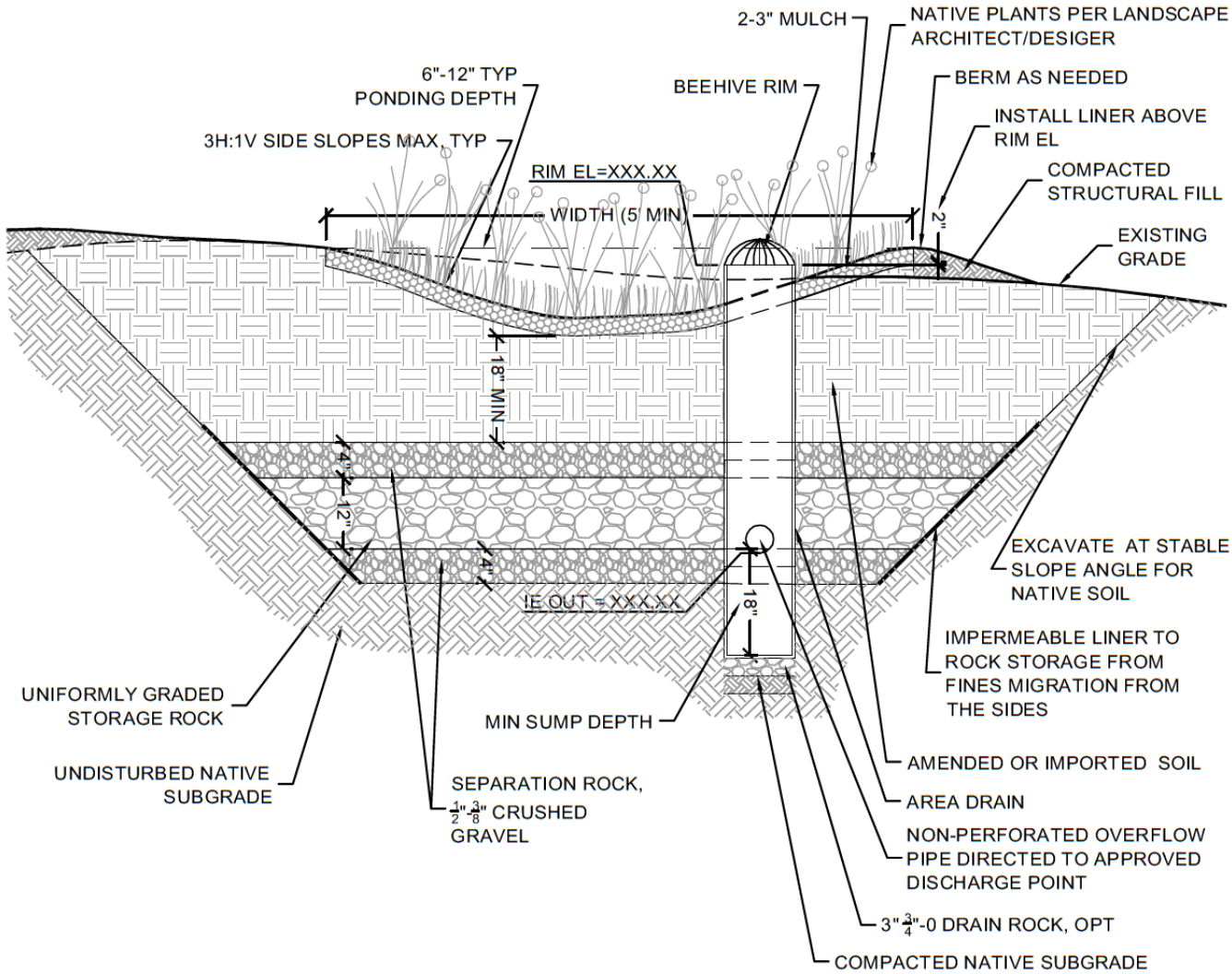


Figure 3-108. An example of an "Infiltration Rain Garden with Rock Trench". Not pictured, but also applicable to the above criteria are versions of a stormwater planter or LID swale (see Appendix F Standard Details).

Construction

To construct an infiltration vegetated stormwater facility:

1. Install temporary erosion prevention and sediment control measures upstream from the infiltration facility, as needed per Chapter 2, "The LID Construction Process", "Erosion Prevention and Sediment Control".

2. Excavate to the depth shown on plans, which may vary from 6 to 48 inches, depending on the facility configuration.

For in-ground stormwater planters, at first, excavate only the area where the deep curbs and poured concrete check dams (if included) will be installed. Frame and pour curbs and check dams. After the concrete is cured, excavate to the elevation shown on plans.

If vegetated stormwater facility is a simple infiltration facility with no structures or amendments, skip to step 6.

3. Install area drains, perforated pipe, non-perforated piping, and/or cleanouts per plans and details.

4. If coarse aggregate rock trench, separation rock, and treatment soil are included in design, install layers as shown on plans according to guidance provided in Appendix D: Specifications.

5. If plans and details call for native amended soil, amend soil per the Restored Soils BMP or specifications provided on the plans. If plans call for treatment soil to be imported, place per guidance provided in Appendix D: Specifications, "Imported Soil Mix" under "Treatment Soil". Place the amended planting soil in two lifts, to lightly compact it (i.e. 85% compaction). Boot packing or light tamping may also be used but never apply vibratory compaction.

6. If facility is a rain garden or LID swale, shape the side slopes to match plans and details but do not exceed a slope of 3:1 (horizontal: vertical). Water must be able to pass through the sides, so do not compact side slopes.

7. Rake (sandy soils) or compost amend (clayey, more compactable soils) using the Restored Soils BMP in any facility dug by hand, since foot traffic in the facility area is probably unavoidable. (To determine soil texture, see Appendix C: Infiltration Testing, "Ribbon Testing".)

8. If facility incorporates check dams that sit on the surface (*i.e*. rock, wood), install per details and plans.

9. Install erosion prevention and sediment control to stabilize the surface of the facility.

10. Remove protection fencing.

11. Plant facility and protect it from stormwater flows for 3 months after planting using sand bags to block flows or piping around the facility. This will help plants establish and prevent erosion.

12. Mulch the facility per plans.

13. Remove temporary erosion prevention and sediment control.

14. Unblock inlets to allow stormwater flows to enter facility 3 months after planting.

15. Remove temporary erosion control if soil is stabilized.

16. Water plants as needed through dry months for a minimum establishment period of 2 years. See Appendix E: Plant Specifications "Watering" under "Establishment Maintenance".

Cost Considerations

As the section "Choose the Best Vegetated Stormwater Facility Configuration" shows, the natural and built conditions on- and off-site will dictate the choice of facility. Up-front construction costs increase with compost amendment, area drains, piping, walls, and curbs. Stormwater planters may be in-ground (less expensive) or above ground (more expensive due to

needing a structural wall to hold soils and saturated water). Each additional structural component such as an area drain, pipe, perforated pipe, wall, curb, or curb cut adds to the maintenance expense.

2.5.3 SOAKAGE TRENCH

Soakage trenches (*i.e.* infiltration trenches, recharge beds) are excavated trenches filled with coarse stone (*i.e.* storage rock) and wrapped in geotextile that receive runoff via a pipe and store it in the rock voids until it is able to infiltrate into surrounding soils. The EPA defines soakage trenches as an assemblage of perforated pipes, drain tiles or other similar mechanisms that distribute fluids below the ground surface.

The space occupied by soakage trenches is often available for another use at the surface, such as parking on porous or impervious/conventional pavement or as lawn or a perennial groundcover or shrub area. Soakage trenches are preferential because they are an invisible way to manage stormwater. However, because of their poor accessibility, they are more costly to maintain[39].

The primary difference between a soakage trench and a vegetated stormwater facility is that water is injected underground via a pipe, rather than infiltrating through the soil surface.

Several variations of soakage trenches are briefly described below.

<u>Soakage Trench at the Surface.</u> This variation incorporates rock all the way to the existing or proposed grades and usually receives runoff from an adjacent surface.

<u>Soakage Trench beneath Landscape Areas.</u> These facilities have a cover of soil and vegetation.

<u>Soakage Trench beneath Porous Pavement.</u> This variation adds additional rock underneath porous pavements and directs concentrated runoff from other areas to the bottom of the rock with perforated pipes laid out along the bottom[40]. This variation is covered in more detail in Chapter 2.5.1, "Underdrains for Inflow", "Additional Routing Considerations for Porous Pavements that Manage Runoff".

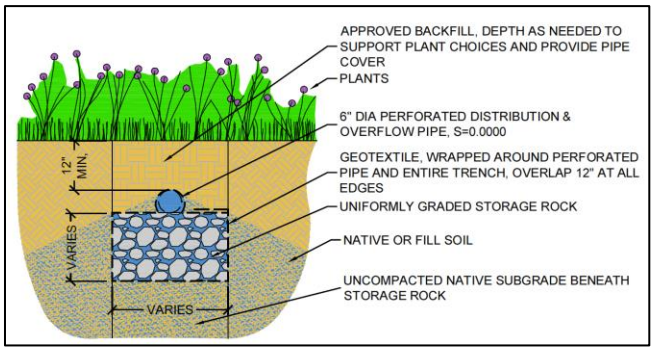


Figure 23- A typical soakage trench cross section beneath a landscape area. A perforated distribution pipe at the top may also be connected to a non-perforated pipe to handle overflows during larger storms without the use of a control structure.

<u>Soakage Trench beneath Impervious Pavement.</u> Soakage trenches may be installed beneath impervious pavement; however the rest of the pavement section

[39] Field, R., Tafuri, T.N., Muthukrishnan, S., Acquisto, R.A., and A. Selvakumar,. (2006). *The Use of Best Management Practices (BMPs) in Urban Watersheds*,. DEStech Publications, Inc. Lancaster, PA,.

[40] More information about this approach can be found at:,Stormh2o.com website. Porous Asphalt Pavement with Recharge Beds, 20 Years and Still Working. Retrieved from: http://www.stormh2o.com/SW/Articles/Porous_Asphalt_Pavement_With_Recharge_Beds_20_Year_228.aspx

(base rock, geotextile fabric, and subgrade) must be installed as if it were porous pavement. Since conventional pavements compact the subgrade, a soakage trench underneath this construction assembly would not be capable of infiltrating into the subgrade. To ensure that infiltration can occur, implement the pavement section according to all the guidance provided in Chapter 2.5.1.

Siting

Runoff from any surface may be directed to a soakage trench, as long as hazardous materials, toxic substances, or petroleum products are not used, stored, or handled in the area drained by the soakage trench. Soakage trenches may be located:

In soils infiltrating at least 0.5 inches/hour.
On land slopes with less than 10% grade.
Where the bedrock or other impermeable layer is lower than 24 inches from the bottom of the soakage trench.
At least 100 feet uphill from a steep slope. (But, locating a soakage trench at the bottom of a hill is encouraged.)

The following restrictions apply to soakage trenches that DEQ authorizes by rule[41]:
Cannot be located within 500 feet of a water supply well.
Cannot be located within the two-year time of travel for a public supply well.
Cannot intersect the groundwater table. DEQ recommends that soakage trenches have at least five feet of vertical separation from the seasonal high groundwater table.

Other areas where soakage trenches may NOT be located:
Where the bedrock is higher than 24 inches from the bottom of the soakage trench
Within 10 feet of a building foundation or within 10 feet of where a neighboring building foundation could be allowed by zoning code in the future. Consider the setback requirements of the zoning codes of your property and the neighboring property or properties. For shallow soakage trenches draining a small area, this setback may be reduced if a qualified licensed engineering or engineering geologist deems it appropriate. For buildings downhill from the facility, the setback of 10 feet increases to 20 feet.
Adjacent to the public right-of-way
Over karst bedrock.
In septic fields.
In contaminated soils.
In landslide areas.
Under the canopy of existing trees.

Bear in mind that tree roots will often seek out water in pipes, damaging them. Soakage trenches without perforated pipes may be located within the projected mature canopy area of a

[41] There are two options for soakage trench authorization: authorization by rule and authorization by permit. Soakage trenches authorized by rule are subject to default horizontal setbacks between the soakage trench and water wells, and default vertical setbacks between the soakage trench and groundwater. The default setbacks may be modified if a soakage trench is authorized by permit, as long as the permittee can demonstrate that the soakage trench is protective of groundwater resources. Authorization by permit is relatively rare, and is more expensive than authorization by rule. Additional information about authorization by rule and authorization by permit is available on DEQ's UIC webpage: http://www.deq.state.or.us/wq/uic/uic.htm

newly planted tree; however, soakage trenches with perforated pipes should be located at a distance of 1.5 times the projected mature canopy spread (*i.e.* how big the canopy will be when the tree is fully grown) from the trunk to the perforated pipe to avoid root damage to the pipe.

Design

Hydrologic Modeling and Sizing. The size of a facility must be determined through hydrologic modeling (Appendix B: BMP Implementation Criteria, "Design", "Hydrologic Modeling") based on the infiltration rate found by infiltration testing. For soakage trenches meeting the criteria above in "Siting" and designed in accordance with this guidance, size the BMP using the LID Implementation Form (see Chapter 4: LID Implementation, Step-by-Step).

UIC Authorization (not always required)

Soakage trenches are relatively shallow facilities and are not automatically considered an Underground Injection Control (UIC, see Chapter 1 "Underground Injection Controls Overview"). Even though the trench may inject stormwater into the subsurface, it is not generally considered a UIC unless injection occurs via a perforated pipe. If runoff other than from roofs is directed to a trench, pretreatment for sediment and debris should be included in the design and is expected to extend the life of the design by reducing the amount of fine sediments that reach the facility and could contribute to clogging.

If incorporated perforated pipe discharges water to the subsurface, then the soakage trench IS considered a UIC and requires authorization, unless it accepts only single-family residential or duplex roof runoff. For more information, see Chapter 2.5.4 "UIC Authorization".

Preventing Clogging During Design. For soakage trenches collecting roof runoff, incorporate gutter screens to filter debris. Pretreatment for sediment is suggested to prolong the life of the soakage trench. This could be as simple as directing runoff to a catch basin with a sump (a settling basin below the lowest elevation of the outflow pipe) before conveying runoff to the facility, such as a sumped catch basin**.** This structure should be 12 inch square minimum for small drainage areas. An open grated top will help ensure that the structure is not buried by mulching activities in landscape areas. Proprietary treatment facilities with a filtering media are a common pretreatment strategy. A lined rain garden or stormwater planter could also serve this pre-treatment need.

Routing and Piping. For soakage trenches adjacent to a drainage area that is graded towards the soakage trench, no piping is needed. To distribute runoff concentrated in a conveyance system such as a pipe or swale, a rigid perforated pipe, embedded in the trench, is usually used. Refer to the 2014 Oregon Plumbing Specialty Code[42] for specifications on piping materials and cleanout sizing and spacing requirements. For maintenance purposes, a minimum diameter of 6 inches is recommended to ensure that a variety of maintenance activities (*e.g.* inspecting the pipe with

[42] IAPMO. 2014 Oregon Plumbing Specialty Code website. Retrieved from: http://www.iapmo.org/pages/2014OregonPlumbingSpecialtyCode.aspx

video, or removing sediment if it can't be pressurized out the end of the pipe) are possible to perform.

Pipes installed too shallow can be crushed by loads at the surface such as cars or riding mowers. All pipes need adequate cover (*i.e.* soil, rock, and/or pavement above the top of the pipe) to ensure that they will remain structurally sound. Refer to *[manufacturer requirements]* to determine adequate cover for the piping material specified on construction documents.

If your jurisdiction has a sewer manual or other guidance that dictates cover requirements in your jurisdiction, modify the text above to refer end users to that instead.

If perforated pipes placed at the bottom of the facility are used to both spread in-flows over the trench and will also serve as a large storm overflow connected to a downstream conveyance system (*e.g*. outlets to a ditch or connects to a non-perforated pipe), the soakage trench should incorporate a control structure (see "Catch Basin Control Structure" in Appendix F "Standard Details"). Otherwise, runoff will be conveyed off-site before it can infiltrate. An overflow structure is not needed if:

Adequate cover exists and a perforated pipe placed at the top of the facility can double as the underdrain and overflow pipe because it will only overflow when it reaches this higher elevation.

A perforated pipe is placed at the bottom and is not connected to any other structure.

Non-perforated overflow pipes that direct runoff to an approved discharge point may be needed to ensure that during an intense storm, water will not flood a building or other critical structure. Even when the system is designed to infiltrate "all" of the stormwater, a larger storm than the maximum design storm will overwhelm the system. Alternatively, water may back up out of the system and overflow overland as long as on-site finished grades are such that no critical structures are flooded by this configuration. For more information, see Appendix B, "Design", "BMP Design Criteria", "Safe Overland Route".

Standard Details. See standard details *[BMP 6.01, 6.02, 6.03]* to include applicable details in construction documents. These are available in *[pdf, jpg, and AutoCAD dwg format]*.

Change this designation if your jurisdiction renumbered the drywell details. Modify the file format to reflect the formats your jurisdiction will offer the details in.

Dimensions. A soakage trench in a landscape area may be any dimension, although a minimum width of 2 feet is often recommended. (Many excavation equipment buckets are 2 feet wide.)

For soakage trenches beneath porous or impervious pavements, the width is likely to equal the pavement area, unless a building or other critical piece of infrastructure drives a setback requirement for the trench.

Sub-surface and Ground Slopes. The facility bottom should be sloped between 0 and 0.5%. Design the bottom elevation of the trenches to match existing contours to achieve this desirable flat bottom, reduce excavation, and allow for the maximum effective storage volume as water infiltrates.

Soakage trenches running across contours that exceed 0.5% slope should be stepped down the slope by creating underground berms. This will ensure that the soakage trench infiltrates

intended runoff volumes instead of just conveying it to the lowest elevation. Excess runoff cascades over berm after berm.

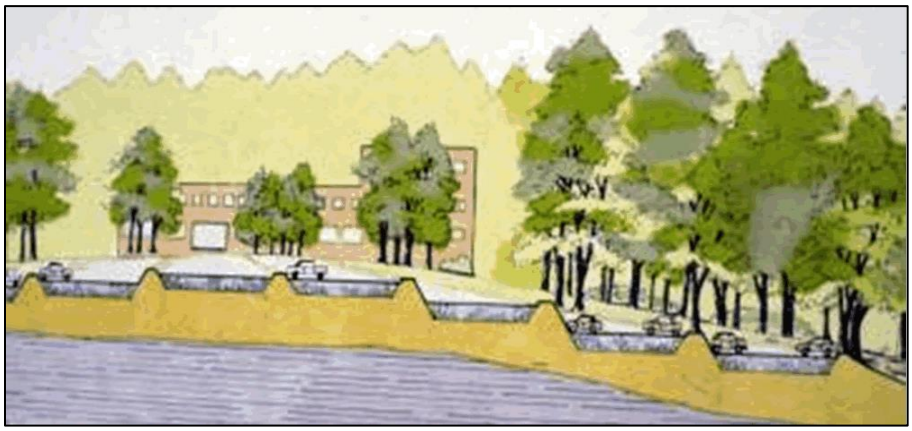


Figure 24- Soakage trenches below pavement are shown here. Stepping along existing contours reduces excavation and increases infiltration capacity. Graphic courtesy of Cahill & Associates.

Slopes at the ground surface may exceed 0.5% without impacting facility function; however, for soakage trenches at the surface, additional rock will be needed to backfill to surface grades.

Coarse aggregate (*i.e.* storage rock). Coarse aggregate provides structure to support surfaces above the soakage trench and stores runoff in the voids between the rocks until it infiltrates. This material should meet the coarse aggregate specifications provided in Appendix D: Specifications under "Aggregates". In place of this uniformly graded aggregate, concrete or plastic vaults with open bottoms can be used. These chambers may be useful in areas with high water tables or shallow impermeable layers where the facility needs to be shallower to be installed high enough above these barriers. Lightweight plastic vaults are also useful in difficult-to-access areas, such as backyards where transporting and placing aggregate is difficult, expensive, or damaging to existing landscaping and hardscaping.

Vegetation. Since runoff doesn't pass through a ground surface (as in a vegetated stormwater facility, for instance) but is delivered to the facility underground via a pipe, vegetation doesn't play a direct role in improving water quality. For this reason, soakage trenches have more flexible finish grade elevations and landscape choices than other BMPs. Vegetation planted over trenches should tolerate drier conditions since the rock below will tend to drain the area. Deep rooting systems can ruin piping systems, so avoid planting shrubs and trees over soakage trenches with piping.

If larger vegetation is desired, and conditions will allow for the bottom of the soakage trench to be deeper, then additional soil can be provided to accommodate the roots of shrubs (24 inches minimum soil depth) and trees (36 inches minimum soil depth). The presence of the larger vegetation and the greater depth of the rock trench will make initial construction and future replacement more costly.

If the soakage trench does not have a pipe, experience with trees in porous pavement has shown that they do not impact the ability of those facilities to infiltrate. The roots of shrubs and trees enhance infiltration, so some roots growing into the gravel of a soakage trench is

acceptable, just not the piping.

Geotextile Fabric (aka Filter fabric). Geotextile fabrics should line the trench. This provides separation between the soil and the coarse aggregate and prevents clogging. Geotextile segments should overlap a minimum of 12 inches. Alternatively, because geotextiles tend to clog if the coarse aggregate isn't clean enough when installed, the bottom layer of filter fabric can be replaced with 6 inches of separation rock (see Appendix D: Specifications for information for infill and separation rock under "Aggregates").

For soakage trenches where pretreatment settles out debris and sediment and runoff is conveyed via a perforated pipe, clogging should not pose much of a problem. For soakage trenches at the surface, the geotextile IS likely to clog so a means of removing and replacing this is shown on the detail *[BMP 6.03 Soakage Trench at Surface].*

Update this if you've renumbered or renamed this detail.

Observation Wells/Cleanout Pipes. An observation well is vertical piping installed to observe whether the facility is infiltrating. This is especially important for facilities with overflow pipes. If the soakage trench stopped infiltrating, then it would always be full and subsequent runoff would bypass the system with no water quantity or flow management.

Design criteria for observation wells/cleanout pipes are as follows:
Install at least 1 observation well near the center of the facility or in its lowest point and every 50 feet.
Observation well piping should be a 6 inch diameter non-perforated pipe. Properly attach this to the horizontal perforated pipe in the soakage trench using a tee-connection.
Equip the end above ground with an operable cap, which may need to be a locking cap depending on whether tampering is likely to occur (*e.g.* at schools).

Even with a minimum 6-inch diameter perforated pipe in the soakage trench, conventional cleanouts with many bends may not provide adequate access for maintenance if the pipe becomes clogged. A catch basin is recommended as pretreatment for the soakage trench. If incorporated, this will also serve as an additional, more accommodating pipe access point.

Construction

The following guidance is provided to inform the contractor about the differences between low impact development and conventional stormwater approaches. If guidance conflicts with standard industry practice, the contractor should consult with the design team and find acceptable means to implement the BMP so its long-term function is achieved.

To construct a soakage trench:

4. Install temporary erosion prevention and sediment control measures upstream from the infiltration facility, as needed per Chapter 2 "The LID Construction Process", "Erosion Prevention and Sediment Control".
5. Excavate to the depth or depths (in the case of facilities that step down a hill), as shown on plans.
6. Install control structures (only needed if perforated pipe is placed at bottom of trench), non-perforated piping, and/or cleanouts as called for on details and plans.
7. Install geotextile fabric or separation rock on bottom and sides per guidance provided in Appendix D: Specifications "Geotextile Fabric" or "Aggregates".

10. Place coarse aggregate per guidance provided in Appendix D: Specifications "Aggregates" and details and plans.
11. Install perforated pipe as shown on plans and detail. (Or, if perforated pipes are to be placed at the bottom, this will be done as step 5.)
12. Place geotextile fabric over the top of the soakage trench per Appendix D: Specifications "Geotextile Fabric".
13. Backfill with approved backfill (mostly likely native soil, imported topsoil, or aggregate). If native soil or imported soil is placed, install in 12 inch lifts (*i.e.* depths) and lightly compact with water compaction or boot compaction. Do not compact with vibratory equipment.
14. Install finish surface, such as lawn, garden, or pavement per plans.

Cost Considerations[43]

Construction costs range from medium to high. For sites with limited area, these facilities can be easily installed in small narrow spaces or underneath pavements, and can be cost effective compared with alternatives, especially when facilities are installed along existing contours.

For soakage trenches with perforated pipes located at the bottom of the rock that are also connected to a non-perforated large storm overflow pipe, a control structure such as a concrete catch basin with a weir per standard detail LID 8.01, must be used to ensure that water backs up into the rock and is stored for infiltration. This will add cost to order a custom catch basin.

Facilities with clogged bottoms cannot be unclogged without excavating the entire system and replacing it. This will increase the lifecycle cost of the system.

The cost of UIC registration, if required, for soakage trenches varies from $100 to $300 and the cost of preparing the required documentation can be as high as $2,000. Purchasing spill response materials to be kept on-site and training employees or maintenance staff in spill response measures will also add cost.

[43] 2015 dollars

2.5.5 WATER QUALITY CONVEYANCE SWALE

Figure 25- Water quality conveyance swales are long, linear facilities that treat stormwater primarily by settling sediments, and the pollutants that attach to them, along their length.

Water quality (WQ) conveyance swales are linear vegetated channeled depressions that convey and treat runoff from a variety of surfaces. Runoff may be piped, channeled, or flow overland to a swale. Water quality treatment is mainly achieved by filtration and settling of solids provided by the plant structure. These might be used instead of the more preferred ponding facilities where ponded water might be considered a hazard. Because water does not pond, runoff reduction via infiltration and evaporation is less than in an LID swale, so this BMP provides less protection of downstream watersheds. Water quality conveyance swales may be unlined or partially lined depending on where they are located.

Siting

Suitable Locations for WQ Conveyance Swales. Even though WQ conveyance swales are not specifically designed to infiltrate, the soils are not compacted, so where facilities are unlined and infiltration is a possibility, these facilities should be located:

Where they are at least 10 feet away from an existing or possible building foundation.

Check setbacks requirements in the Philomath Municipal Code Chapter 18 Division 2 for the proposed development site and all neighboring properties to ensure that a vegetated stormwater facility will be in compliance.

Where they are at least 10 feet from an underground tank or a site wall

Where they are at least 5 feet from utilities

Directly adjacent to pier footings

Where slopes along the centerline are or can be constructed to be up to 6%

Where they are at least 100 feet away from down-gradient slopes of 10%. Add 5 feet of setback for each additional percent up to 30%. Avoid installing a WQ conveyance swale where the down-gradient slope exceeds 30%.

For runoff from vehicular areas, greater than a horizontal distance of 2x the depth of any nearby wells. Locate these wells in relation to your site using the DEQ well log database[44].

[44] Oregon Water Resources Department. Well Log Query. Retrieved from: http://apps.wrd.state.or.us/apps/gw/well_log/

In any location approved by a qualified licensed engineer or geologist who has signed and stamped a geotechnical investigation report or letter clearly designating the location in narrative and/or by graphical means.

Figure 26- This ideal unlined WQ conveyance swale is located away from buildings and other critical infrastructure. Mowing has been performed up to the swale (left); however, the swale itself (unmowed center) is allowed to grow tall and dense.

Unsuitable Locations. WQ conveyance swales of any type should never be installed over septic tanks or in the locations defined as floodways. Floodways are defined by the Federal Emergency Management Agency as "the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height."[45]

Design

Generally, the slower the water flows through the facility, the higher the water quality treatment achieved.

Hydrologic Modeling and Sizing. Multiple design aspects such as shape, width, slope, and channel roughness are related to flow velocity. These variables also define the depth of water flow during the design storms. For these reasons, a WQ conveyance swale must be designed by a qualified licensed engineer using criteria provided in Appendix B: BMP Implementation Criteria, "Design", "Hydrologic Modeling", Hydrologic Criteria when Simplified Sizing Not Applicable".

An additional design criteria specific to WQ conveyance swales is a residence time of 9 minutes, which determines the minimum length of the swale. When designing swales with multiple places for stormwater to enter, take care to account for the shortened length and accumulating volumes when calculating residence time.

To size the facility, perform hydrologic modeling to determine the peak flow from the drainage area during the water quality design storm and the flood storm. Then, incorporate the design aspects listed above, using Manning's equation to determine the average velocity and depth of flow. From this, calculate the required length adequate to treat the water quality design storm and convey the flood storm.

Shape. The recommended cross-sectional shape of a swale is trapezoidal mainly because it is the

[45] Federal Emergency Management Agency website. Floodway definition. Retrieved from: https://www.fema.gov/floodplain-management/floodway

easiest to maintain, causes the least scouring and creates the least runoff[46]; however, this shape is the most difficult to build, because soil doesn't tend to conform to hard angles, even with compaction. The wider the facility the more surface area runoff will be in contact with and therefore pollutant removal levels will be higher.

Dimensions. Bottom width is generally between 1 to 8 feet wide. The wider the facility, the more shallow and slow the flow will be, which will improve the water quality treatment capacity of the swale.

Side Slopes. Side slopes for the facility should be 3 feet horizontal to 1 foot vertical, which is the angle at which most soils will stand on their own without compaction. Avoid compacting the side slopes, which removes voids in the soil and impacts or even prevents healthy plant establishment.

Longitudinal Slope. The longitudinal slope of the facility should be whatever is necessary to control erosive flow velocities considering the other design elements that will influence erosion, but should limit flows to 3 feet per second or less during the 25-year storm.

Depth and Freeboard. The minimum depth of a swale is impacted by the method of conveyance to it. For instance, if the swale receives overland or concentrated flow through an open-ended trench drain at the surface, it may be shallower than a swale that has runoff piped to it, since pipes need a minimum of 12 inches of cover.

If no high-flow bypass is provided (see Appendix B, "Design", "BMP Design Criteria", High-Flow Bypass") the swale depth must be capable of safely conveying the [25-year frequency] flood storm, which adds to the overall depth of the swale.
Provide freeboard (the depth from the maximum flow depth to the top of the facility) of 12 inches, to convey the very large storm.
The maximum flow depth for water quality treatment is 6 inches.

Pretreatment and Energy Dissipation to Reduce Erosion. Runoff at inlets can be erosive, especially when concentrated to enter the swale at a particular place. See Chapter 3 "Rain Garden, Stormwater Planter, and LID Swale BMP", "Design", "Pretreatment" for detailed guidance on low- maintenance methods to reduce erosion at inlets.

Vegetation. Vegetation plays a key role in slowing water and allowing sediment to drop out before reaching the end of the swale. If a facility is not vegetated, then it is considered a ditch or simply a conveyance swale and does not provide adequate water quality.

Design criteria for vegetation is as follows:
Vegetation should cover a minimum of 95% of the facility within three years per planting density guidance provided in Appendix E: Plant Specifications. The better the plant coverage, the less effort needed for weeding during the maintenance phase.
Avoid the dry creek bed look where rocks line the bottom and plants are sparse or located only around the top edges of the slopes. This approach doesn't provide adequate treatment for the small, frequent

[46] Field, R., Tafuri, T.N., Muthukrishnan, S., Acquisto, R.A., and A. Selvakumar,. (2006). *The Use of Best Management Practices (BMPs) in Urban Watersheds*,. DEStech Publications, Inc.,., Lancaster, PA,.

storms with flow depths that may never reach the plants on the side slopes and significantly increases maintenan**ce** (weeding and cleaning rock).
Choose vegetation with a sturdy above ground structure able to withstand and slow flowing water. The mature height of this vegetation should be at least the height of the flow depth. Avoid sod, lawn, and weakly structured grasses.
Vegetation should be selected based on its tolerance of flooding and drought cycles and other criteria listed in Appendix E: Plant Specifications.

Soils. Swales are appropriate for any soil type. Soils may be native or imported topsoil. Do not compact soil, which will not prevent erosion, as flowing water is very good at carving canyons out of soil or bedrock. Instead, planting per "Vegetation" section above will be more effective at holding soil.

To support plant health, soils may be optionally amended with compost following the same guidance in the footprint of the swale as provided in Chapter 3 "Restored Soils BMP". ODOT has found this also improves removal of dissolved metals.

Mulch. Mulch is used in landscape areas to make weeding easier and to reduce watering demands. When compost is used as mulch, it replaces chemical fertilizers.

Mulch of any kind – even rock mulch – will be carried around, if not out of, the facility. If this mulch is made of organic matter such as compost, then it also carries attached pollutants out of the facility, polluting the downstream waterway.

Specify compost mulch per in Appendix D: Specifications, "Compost" on plans and/or specifications to provide nutritional support to plants. Avoid rock mulch, which will not feed new plants and is difficult to pull weeds from. Reference mycorrhizae on plans and/or specifications to reduce irrigation demand.

Impermeable Liners. Impermeable liners such as plastic, rubber, or bentonite clay are required when facilities are within 10 feet of a building foundation or other critical infrastructure. Use minimum 45 millimeter plastic or rubber sheeting or bentonite clay. Avoid petroleum sealants, which are digested by microbes in the soil and can leach pollutants. WQ Conveyance swales can be partially lined to convey runoff through an area where infiltration is not recommended (see "Siting", "Suitable Locations for Infiltration WQ Conveyance Swales"). Beyond these areas, the liner is no longer needed.

Outlets. Since runoff volume will not be significantly reduced, all WQ conveyance swales require an outlet to direct treated stormwater to an approved discharge point, protected from erosion. This outlet structure is most often a ditch inlet.

If the bottom section of the WQ conveyance swale can be designed to infiltrate and pond water, essentially turning the lower length of swale into an infiltration rain garden, then an area drain (catch basin) may also serve to redirect excess volumes of runoff to an approved discharge point.

Standard Details. See standard details [BMP 9.01 through 9.04 and related details BMP 3.02 and 3.07] available in [pdf, jpg, and AutoCAD dwg format] to include in construction documents:

Table 10. Description of WQ Conveyance Swale Standard Details.

Detail #	Title	Additional Information
BMP 9.01	Water Quality Conveyance Swale	For conveyance across areas suitable for infiltration
BMP 9.02	Water Quality Conveyance Swale with Amended Soil	For conveyance across areas suitable for infiltration and soils are restored using the "Restored Soils BMP" to support plant health.
BMP 9.03	Partially Lined Water Quality Conveyance Swale	For conveyance across areas not suitable for infiltration to areas that are
BMP 9.04	Fully Lined Water Quality Conveyance Swale	For conveyance across areas not suitable for infiltration in watersheds not limited for nutrients
BMP 3.07	Simple Infiltration LID Swale – Lowest Elevation Cell with Area Drain	Optional outlet detail if site conditions allow: Use this detail with BMP 9.01, 9.02, and 9.03 to use the bottom (*i.e.* the last length of the facility) of the WQ conveyance swale to infiltrate. The area capable of ponding water and infiltrating water between 6 inches and 12 inches can be included to meet the sizing requirements on the LID Implementation Form (see Chapter 4) as if it were an LID Swale per Chapter 3 "Rain Garden, Stormwater Planter, and LID Swale BMP")

Construction

Like all stormwater management facilities, special care must be taken to properly construct BMPs. Protecting the infiltration capacity of the soil is crucial to the long-term functioning of any infiltration facility.

Water Quality Conveyance Swale. Protecting the infiltration capacity of the native soils is crucial to the long-term functioning of any infiltration facility. See Appendix B: BMP Implementation Criteria, "Construction", "Protecting Permeability" for specific steps that should be taken on every LID project.

To construct a WQ conveyance swale:

1. Install temporary erosion prevention and sediment control measures upstream from the WQ conveyance swale, as needed per Chapter 2, "The LID Construction Process", "Erosion Prevention and Sediment Control".
2. Excavate to the depth shown on plans.
3. Install area drains, perforated pipe, non-perforated piping, and/or cleanouts as called for on details and plans.

4. If separation rock and treatment soil are included in design, install layers as shown on plans according to guidance provided in Appendix D: Specifications.
5. If plans and details call for native amended soil, amend soil per the Restored Soils BMP or specifications provided on the plans.
6. Shape the side slopes to match plans and details, but do not exceed a slope of 3:1 or compact the side slopes. Plant establishment is difficult to achieve on compacted slopes.
7. If facility incorporates check dams on the surface *(i.e.* rock, wood), install these per details and plans.
8. Install erosion prevention and sediment control to stabilize the surface of the facility.
9. Remove protection fencing.
10. Plant facility and protect it from stormwater flows for 3 months after planting using sand bags to block flows or piping around the facility. This will help plants establish and reduce erosion. Make sure that wherever the water is flowing for this three-month period that it will not cause a dangerous condition (*e.g.* water flowing over a sidewalk, tripping hazard, *etc.)*, flooding or erosion.
11. Mulch the facility per plans.
12. Remove temporary erosion prevention and sediment control.
13. Unblock inlets to allow stormwater flows to enter facility 3 months after planting.
14. Remove temporary erosion control if soil is stabilized.
15. Water plants through dry months for a minimum of *[2-year]* establishment period per Appendix E: Plant Specifications, "Establishment Maintenance", "Watering".

Lined Water Quality Conveyance Swale. The infiltration capacity of soils beneath partially lined facilities does not need to be protected. However, as with all soil, unnecessary compaction should be avoided since soil below ground conveys groundwater to waterways. A loss of voids in the soil still impacts watershed health.

To construct a lined facility:

Install temporary erosion prevention and sediment control measures upstream of the facility, as needed per Chapter 2, "The LID Construction Process", "Erosion Prevention and Sediment Control".

1. Excavate between 40 and 48 inches depending on the flow depth. If stockpiling soil for another use, cover stockpile with a breathable fabric to prevent erosion and protect the permeability of the soil.
2. Install the outlet structure or cleanout and non-perforated piping using standard construction techniques.
3. Install impermeable liner per Appendix D: Specifications, "Impermeable Liner".
4. Place a perforated underdrain pipe on top of the liner and connect it to the outlet structure.
5. Place 12 inches of coarse aggregate that meets or exceeds specifications in Appendix D: Specifications "Coarse Aggregate".
6. Place 4 inches of separation rock that meets or exceeds specifications in Appendix D: Specifications "Separation Rock".
7. Place imported treatment soil or amended native soil per guidance provided in Appendix D: Specifications, "Treatment Soil".

8. Place the amended planting soil in two lifts, saturating each lift with water to lightly compact it (*i.e*. 85% compaction). Boot packing or light tamping may also be used but never apply vibratory compaction.
9. Place a final lift as needed to reach desired elevations and lightly compact as above.
10. Plant facility and protect it from stormwater flows for 3 months after planting using sand bags to block flows or piping around the facility. This will help plants establish and prevent erosion. Make sure that the water flow during this 3-month period will not cause a dangerous condition (*e.g.* water flowing over a sidewalk, tripping hazard, *etc.)*, flooding, or erosion.
11. Mulch the facility per plans.
12. Remove temporary erosion prevention and sediment control.
13. Unblock inlets to allow stormwater flows to enter facility 3 months after planting.
14. Remove temporary erosion control if soil is stabilized.
15. Water plants in dry months during minimum establishment period of *[2]* years. See Appendix E: Plant Specifications "Watering" under "Establishment Maintenance".

Cost Considerations

The construction of WQ Conveyance Swales may be less costly or cost neutral when grades, site design and programmatic needs, and adequate space allow them to replace piping or curb and gutter. Construction costs can be reduced in compaction, rock and piping material costs and placement. Regardless of whether conveying water in a pipe or a swale, vegetation must be established on the ground surface, so the costs for vegetation may not be dramatically different.

Because water quality treatment is provided as water flows through the facility instead of ponding, the footprint of a water quality conveyance swale is much larger than that of an LID swale. (See Chapter 3 "Rain Garden, Stormwater Planter, and LID Swale BMP".) Depending on site conditions, spatial constraints can sometimes add cost. For instance, steep slopes could result in costly retaining walls to make space for a gently sloping WQ conveyance swale.

Upfront construction costs increase with compost amendment, outlet structures and piping, and walls, and can increase further when a lined facility is placed next to a building due to the need for additional waterproofing.

For partially lined facilities, excavation is much greater than for unlined facilities, which increases cost.

2.5.6 DISPERSION

Dispersion is a BMP that spreads runoff over a landscape area specifically to reduce pollution and runoff. Dispersion is suitable for a variety of roadside applications and development densities; however, due to setbacks, the volume of water that can be dispersed generally decreases with density. Dispersion is carried out with designed vegetated filter strips.

Figure 27- A vegetated filter strip.

Siting

Dispersion relies on the soil's ability to absorb adequate volumes of runoff, which is related to the flow path or the distance runoff travels over a pervious or hard surface before entering the dispersion area. To function properly, dispersion areas should be located as follows:

Over soils with a minimum infiltration rate of 2.0 inches/hour. (See Appendix C: Infiltration Testing.)
In areas where the seasonal groundwater table is at least 2 feet from the surface.
10 feet from a building with a basement.
2 feet from a building without a basement (*i.e.* slab on grade, crawl space, pier, or post foundations)
On slopes < 15%, except where that slope is a historical site and/or is found to be a landslide hazard by a licensed geotechnical engineer, licensed geologist.
Downhill of pervious areas with a maximum flow path of 150 feet.
Not over or towards septic drain fields or neighboring private properties.
Dispersion areas must slope away from buildings.
Not over contaminated groundwater plume (check with Regional DEQ Cleanup program).
[In any location approved by a qualified licensed engineer or geologist who has signed and stamped a geotechnical investigation report or letter clearly designating the location in narrative and/or by graphical means (i.e. site plan).]

Design

Dispersion design is driven by the type of impervious drainage area and whether the runoff is flowing in sheet or concentrated form. All runoff starts as sheet flow, which can occur on any surface. Eventually, runoff becomes concentrated flow, either because it has flowed over the surface for a relatively long distance or because it has been captured and intentionally concentrated in a roof gutter and downspout, a catch basin and a pipe, and/or a curb.

Facilities that manage sheet flow are known as "vegetated filter strips". Facilities that manage concentrated flow are called "disconnection".

Temporary Mulch. Mulch is often the top layer of a newly installed dispersion technique. Mulch is used to control soil temperature for seed germination, control weeds, feed the plants, and reduce the erosion of soil that would be otherwise bare; however, in dispersion BMPs, routine flows across the facility redistribute mulch around and out of the BMP, which makes maintenance difficult. Use mulch meeting the specifications in Appendix D: Specifications, "Mulch". Apply mulch during the establishment period of 2 years. After that, vegetation should have adequate structure to hold and cover soil, shading out most weeds.

Soil. Directly below the temporary mulch is soil, which may be imported, amended or native and uncompacted.

For design criteria for soil, see Appendix D: Specifications, "Treatment Soil".

Infiltration testing. Perform an infiltration test to determine the soil's capacity to absorb and percolate water down into the lower layers. See Appendix C for detailed guidance on field testing to find the rate that water can pass through the soil and how to interpret that data.

Standard Details and Sizing. Standard details for vegetated filter strips (described below) in native and uncompacted soil (BMP 4.01) and in imported or amended soil (BMP 4.02) are included in the Appendix.

Vegetation. Plants and the beneficial microbes that concentrate on plant roots remove pollutants through biological breakdown and/or uptake and also physically slow the water to filter it – the more plants, the more treatment.

Place less dense vegetation directly at the inlet or front of the inlet strip. Flooding can occur when dense vegetation at the mouth of a downspout extension or the edge of a vegetated filter strip causes water to back up. To reduce erosion, choose plants with a robust above-ground structure, like tall grasses, to slow water when it flows overland. Some grass species lay over under flow conditions, so rushes, sedges, shrubs, and trees are all good choices. Vegetation in the dispersion area should be well established with at least 95% cover of lawn or perennial native landscape (groundcover, ornamental grasses, shrubs, and/or trees) within 3 years. The better the plant coverage, the less weeding needed. See Appendix E for additional design.

When implementing dispersion near existing forested areas, be aware of the species that will receive runoff. The health of most established trees, especially Oregon White Oak, are impacted by additional volumes of water. Some species of trees that can tolerate additional water after establishing include willows, ashes, alders, poplars, and some maples.

Design Specific to Vegetated Filter Strip

Design criteria for sheet flow dispersion areas (**Figure 3-152**) are as follows:
Maximum impervious area flow paths of 75 feet.
Maximum impervious lateral slope of 5%.
Maximum impervious longitudinal slope of 4%.
Maximum vegetated filter strip lateral slope of 15%.
Maximum vegetated filter strip longitudinal slope of 2%.
The length of the vegetated filter strip should match the length of the impervious area draining to it.

Incorporate a level spreader (described in next section).
See **Figure 3-152** for additional materials and widths for highways.

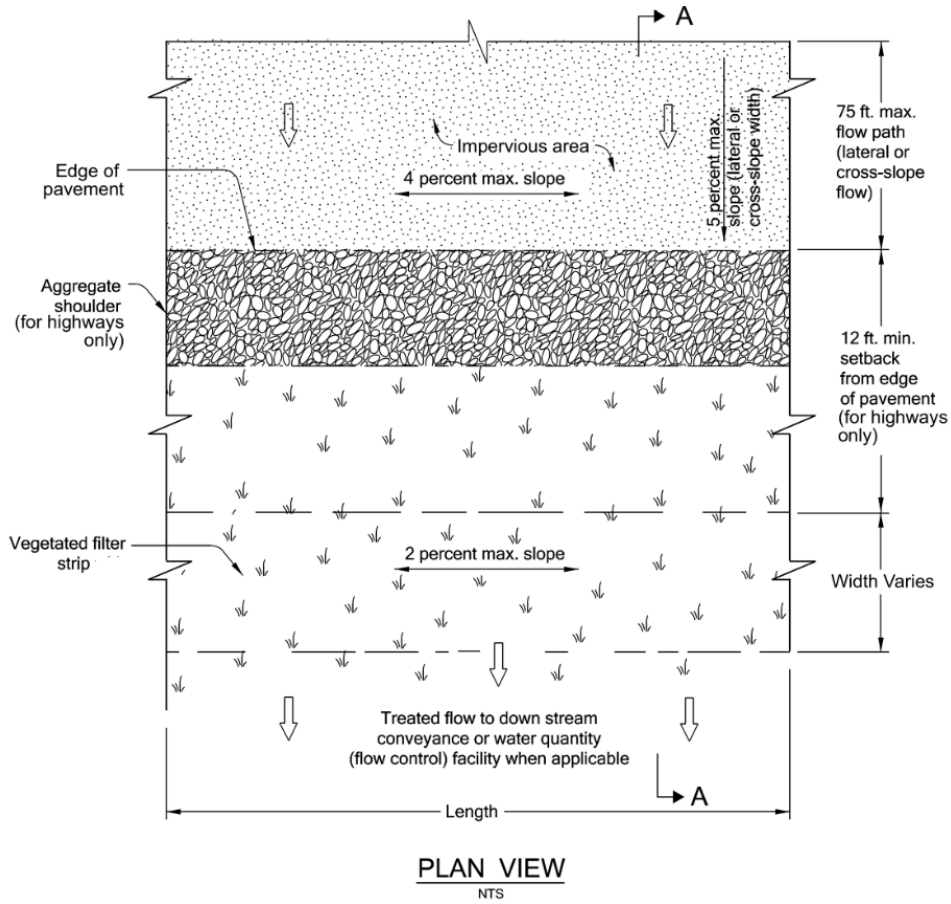
Design Specific to a Vegetated Filter Strip for Roofs. In many rural areas, where pipe infrastructure is limited, roofs with no gutters or downspouts are common. Specific architectural design must be incorporated into the overhang and the roofing and siding materials to ensure that water flowing over the edge doesn't run down the siding and cause damage to the building. This practice can be used in new and re-development projects when there is no basement adjacent to the roof area that overhangs.

Design Specific to Vegetated Filter Strip for Sidewalks or Patios. Tip a sidewalk or patio towards a landscape area, not towards a curb or catch basin inlet.

Design Specific to Vegetated Filter Strips for Parking Lots and Driveways. To use dispersion on parking lots and driveways, avoid using curbs and gutters. Since drivers must turn more to navigate parking lots and driveways than roads and highways, curbs may be desired. If so, some specific guidance for minimizing curbs is as follows:

Use curbs on radii for turning into or out of a parking lot or around landscape islands.
Taper the curb ends from a height of 6 inches (typical) to flush with the pavement over a distance of 3 feet as soon as a driver is likely to stop their turning motions.
Tip pavement towards a landscape area, not towards a valley in the drive aisle draining to a catch basin inlet.
Since a level spreader should be included with a vegetated filter strip, curbs with cuts might be used as well and erosion that would result from concentrated flows at these points will be controlled by the level spreader.

Design Specific to Vegetated Filter Strips for Roads or Highways. Some roads and many highways already have no curbs and can be designed or may already meet most of the design criteria for vegetated filter strips.



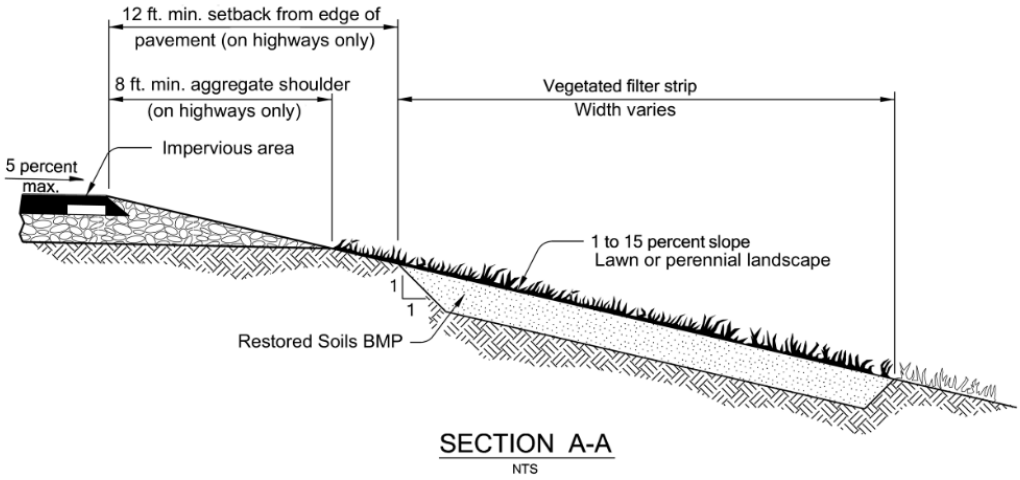


Figure 28- Design parameters for sheet flow dispersion (*i.e.* vegetated filter strip). Adapted from ODOT Hydraulics Manual 2014 (Chapter 14, Figure 7). The aggregate shoulder serves as a level spreader.

Design Specific to Downspout Disconnections

Disconnecting a downspout or pipe causes runoff to be directed to a landscape area in a concentrated form. Design criteria for disconnections are as follows:
Maximum impervious area of 700 square feet/downspout
Include a splash block or pad
Include downspout extensions to protect against flooding the adjacent building. A 10-foot long extension should be used for buildings with full basements.
Provide a minimum vegetated flow path of 50 feet sloping between 2% and 5% away from buildings. This may include natural areas or riparian buffers.

Construction

The following guidance is to inform the contractor about the differences between low impact development and conventional stormwater approaches. If guidance conflicts with standard industry practice, the contractor should consult with the design team and find acceptable means to implement the BMP so its long-term function is achieved.

To construct dispersion BMPs:

1. If included in the construction plan set, fence off the dispersion area with a durable fence (chain link, wood, *etc*.) at least 3 feet high to prevent vehicular and foot traffic that will compact soils and reduce the infiltration rate of the existing soils.
2. Install temporary erosion control such as erosion control fabric, temporary seeding, biobags, wattles, and compost berms.
3. Make sure the erosion control method is weed seed free. Avoid plastic, especially plastic mesh, where possible; amphibians and other animals are harmed by it.
4. Amend soils per the Restored Soils BMP if organic matter is less than 10% or if the area was not fenced off.
5. Plant facility per Appendix E: Plant Specifications "Planting Techniques"
6. Protect plants from stormwater flows for 3 months after planting using sand bags to block flows or piping around the facility. This will help plants establish and prevent erosion. This practice may not be feasible along roads.
7. Apply 3 inches of mulch. See Appendix D: Specifications, "Mulch" for mulch specifications.
8. After 3 months, allow stormwater flows to enter dispersion area.
9. Remove temporary erosion control when soil is stabilized.

Cost Considerations

Vegetated filter strips are relatively low cost. Construction costs includes grading; seeding, sodding and/or landscaping; and, if needed, constructing a level spreader. Additional costs may range from zero to thousands of dollars per acre. The annual cost of maintaining filter strips (mowing, weeding, inspecting, litter removal, etc.) generally runs from $100 to $1,400 per acre[47] and may overlap with standard landscape maintenance costs. Maintenance costs are highly

[47] 2008 costs from Southeast Michigan for commercial sites. Southeast Michigan Council of Governments. "Low Impact Development Manual for Michigan. A Design Guide for Implementers and Reviewers". 2008. Retrieved from: http://library.semcog.org/InmagicGenie/DocumentFolder/LIDManualWeb.pdf

variable. They depend on frequency, local labor rates, proper construction of the original facilities, and preventative maintenance.

2.6 PROVIDE MINIMAL WATER QUALITY TREATMENT BMP

Intro

2.6.1 LEVEL SPREADER

Pavement is often not as regular as it appears. Even very small dips and inconsistencies can concentrate sheet flow, forming channels and causing erosion. A level spreader will intercept runoff, slow it down, and spread it out. Level spreaders are most often used with vegetated filter strips, but may be useful anywhere water flows overland into a landscape area to reduce erosion.

Siting

Install a level spreader between the contributing pavement area and the landscape area, such as the vegetated filter strip in **Figure** .

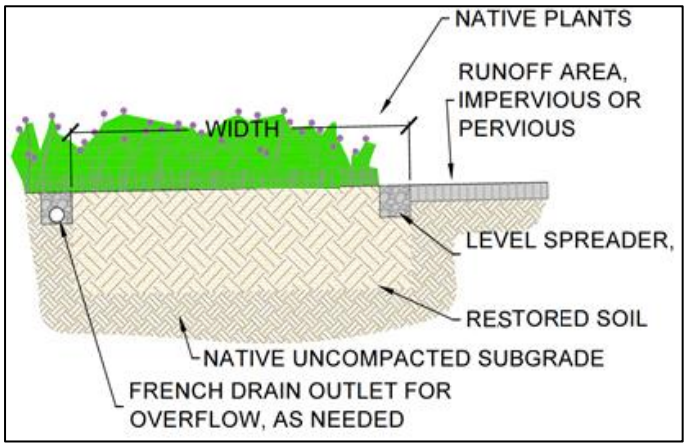


Figure 29- Cross section of a vegetated filter strip with level spreader.

Design

Design criteria for level spreaders are as follows:
Include with all vegetated filter strips except on highways and roads with a gravel strip or on roads with gravel parking edges.
Length = Match length of vegetated filter strip and impervious area.
Width = 1 foot, Depth = 9 inches (This will ensure that the level spreader is wider than it is deep, avoiding a UIC.)
Use crushed aggregate meeting the coarse aggregate specification in Appendix D: Specifications or any other open-graded rock with a maximum diameter of 3 inches. Pea gravel or other rounded river rock is not recommended since it will not perform as well as angular rock in slowing flows.
To encourage water to enter the level spreader and ensure that a mound of rock is not blocking inflows, set the elevation of the level spreader ¼ inch lower than the pavement, which meets ADA accessibility requirements.

Construction

Construction is as follows:

1. Excavate a 12-inch wide by 9-inch deep trench the entire length of the vegetated filter strip.
2. Lightly compact the soil in the area of the level spreader by tamping or boot compaction. Avoid mechanical compaction such as the use of a jumping jack or vibratory compactor,

even small ones.

3. Place an impermeable liner vertically along the upstream side (pavement side, not landscape side) of the trench, overlapping the liner a few inches.
4. Place coarse aggregate in the trench.
5. Cut the excess liner to be level with finish (*i.e.* final) grade.

Chapter 3.0

SIZING AND IMPLEMENTING LID FACILITIES

3.1 THE STORMWATER MANAGEMENT HIERARCHY 84

3.2 FACILITY SIZING APPROACHES 84

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3.2.2 HYDROLOGICAL APPROACH 1

3.3 HYDROLOGICAL DESIGN ..... ERROR! BOOKMARK NOT DEFINED.

3.1 THE STORMWATER MANAGEMENT HIERARCHY

The stormwater management hierarchy reminds designers to blend a variety of practices in the order that they should be considered, since a single BMP will not achieve a key goal of LID implementation, which is to mimic predevelopment hydrology. Though the use of multiple BMPs on a site is encouraged, and often logical, installing a single BMP may be a more practical plan in some situations that will still positively impact watershed health.

Choose BMPs based on their ability to mimic pre-development hydrology following the preferred hierarchy:

1. Lay out the site to minimize impacts to natural resources and to minimize impervious areas.
2. Prevent runoff by intercepting, evaporating, and/or infiltrating rainfall.
3. Reduce runoff using BMPs with surface storage (*i.e.* ponding) that infiltrate and to a lesser extent, intercept and evaporate runoff and the rainfall they receive.
4. Reduce runoff using BMPs with underground storage that infiltrate runoff.
5. Reduce runoff using flow-based BMPs without storage (*i.e.* conveyance) that infiltrate lower volumes and to a lesser extent, intercept and evaporate runoff and the rainfall.

3.2 HYDROLOGICAL DESIGN

Modeling is used to size BMPs and predict how facilities will respond to and manage stormwater, and is often performed for the entire site, which should include runoff prevention and runoff reduction BMPs. While models may give us very specific values of interest, such as peak flows before and after development, use these values cautiously. All models must always leave something out and should be considered a rough estimate of the real world, good for comparing different practices on one site or for comparing across different sites with similar conditions.

The Santa Barbara Urban Hydrograph (SBUH) method, which uses a very similar approach to the Soil Conservation Service (SCS) method described in "Urban Hydrology for Small Watersheds"[48], doesn't account for evaporation and the complexities of plant and soil animal interaction. This shortcoming of modeling is one of the reasons that employing runoff prevention BMPs is so heavily emphasized. Even so, the SBUH is the most common model in use today by jurisdictions in western Oregon.

3.3 FACILITY SIZING APPROACHES

Best management practices often need to be designed and sized to adequetly serve their environment. Sizing is not always a required step in the LID process (especially if using a single BMP). When implementing exclusively one of the following, sizing is not applicable:

- Minimizing pavements BMP
- Fast draining soils BMP
- Construction sequencing BMP
- Tree protection BMP

[48] http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

- Tree planting BMP
- Restored soils BMP
- Depaving BMP

When sizing is necessary, this guidance offers two design approaches. The first method, the simplified approach, is recommended for small, simple projects and can be especially useful for sizing rain gardens, stormwater planters, LID Swales, and/or porous pavement (rainfall). The hydrological approach is a more complex sizing process that shall be used for large projects (impervious area over 10,000 sq ft) or projects that include porous pavement (runoff), dispersion, and/or water quality conveyance swales. A licensed qualified engineer is required to execute the hydrological approach in conjunction with a stormwater analysis report.

3.3.1 SIMPLIFIED APPROACH

The Simplified Approach uses simple area ratio calculations to size stormwater facilities and is provided on the Simplified Approach Form provided in this chapter. This sizing method may be used when the impervious surface area is less than 10,000 square feet (.34 acre), including but not limited to: roofs, patios, parking areas, and driveways. This approach is a relatively easy process for selecting and sizing stormwater quality and flow control facilities and is intended to save the project time and expense. The Simplified Approach is best used for small residential and commercial development. It is not intended to be used on large, complex projects with multiple catchments or challenging soils and topography. The Simplified Approach is not allowed for public improvement projects. Sizing may be done by the landowner or any other qualified licensed professional or contractor.

SIMPLIFIED STORMWATER MANAGEMENT SIZING FORM

INSTRUCTIONS

1. Enter square footage of the site's total impervious area into Box 1.

2. Fill out the tree credit calculations section of the form to determine a tree credit value. Enter the square footage in the appropriate blank under impervious area reduction techniques.

3. Enter square footage affected by any of the listed BMPs on site (fast draining soils, restored soils, depaving, and/or permeable pavements).

4. Enter sum of the impervious area reduction techniques into Box 2.

5. Subtract Box 2 from Box 1 to find Box 3, the amount of impervious area that requires stormwater management.

6. Select appropriate stormwater management facilities.

7. Enter the square footage of impervious area managed that will flow into each facility type.

8. Multiply each impervious area managed by the corresponding sizing factor. Enter this area as the facility surface area. This is the size of facility required to manage runoff.

9. Enter the sum of the total of all the impervious area managed into Box 4. **Box 4 must be greater than or equal to BOX 3.**

10. When applicable, describe the point of discharge location.

SIMPLIFIED STORMWATER MANAGEMENT SIZING FORM

Application: _____ Tax Lot #: _____

Address: _____ Building Permit #: _____

Residential or Commercial: _____ Measured Infiltration Rate: _____

FACITILITY SIZING

Total proposed impervious surface area → [ ] 1

Total impervious area reduction

Tree credit _____ sq ft

Fast draining soils/restored soils/depaving _____ sq ft → [ ] 2

Permeable pavements _____ sq ft

Total impervious area requiring stormwater management → [ ] 3

Facility Sizing for Water Quality:

Surface Facility	**Impervious Area Managed**			**Sizing Factor**		
Rain Garden	_____	sq ft	x	0.05	=	_____
Stormwater Planter	_____	sq ft	x	0.04	=	_____
LID Swale	_____	sq ft	x	0.06	=	_____

Facility Sizing for Water Quality and Flow Control:

Surface Facility	**Impervious Area Managed**			**Sizing Factor**		
Rain Garden	_____	sq ft	x	0.10	=	_____
Stormwater Planter	_____	sq ft	x	0.06	=	_____

Sum of Total Impervious Area Managed → [ ] 4

Describe point of discharge: _____

TREE CREDIT CALCULATION

New Evergreen Trees

To receive impervious area reduction credit, new evergreen trees must be planted within 25 feet of the impervious surfaces. New trees cannot be credited against rooftop areas. Minimum tree height (at the time of planting) to receive credit is 6 feet.

Enter number of new evergreen trees that meet above requirements → [ ] A

Multiply Box A by 200 and enter result in Box B → [ ] B

New Deciduous Trees

To receive impervious area reduction credit, new large deciduous trees must be planted within 25 feet of impervious surfaces and new small deciduous trees must be planted within 10 feet of impervious surfaces. New trees cannot be credited against rooftop areas. Minimum tree caliper (at the time of planting) to receive credit is 2 inches.

Enter number of new deciduous trees that meet above requirements → [ ] C

Multiply Box C by 100 and enter result in Box D → [ ] D

Existing Tree Canopy

To receive impervious area reduction credit, existing large tree canopies must be within 25 feet and existing small tree canopies must be within 10 feet of ground level impervious surfaces (cannot be credit against roof top surfaces). Existing tree canopy credited towards impervious area reduction must be preserved during and after construction, throughout the life of the development. Minimum tree caliper to receive credit is 4 inches.

Enter square footage of existing tree canopy that meet above requirements → [ ] E

Multiply Box E by 0.5 and enter result in Box F → [ ] F

Total Tree Credit

Add Boxes B, D and F and enter the result in Box G → [ ] G

Enter the value from Box G in the Tree Credit blank on the form.

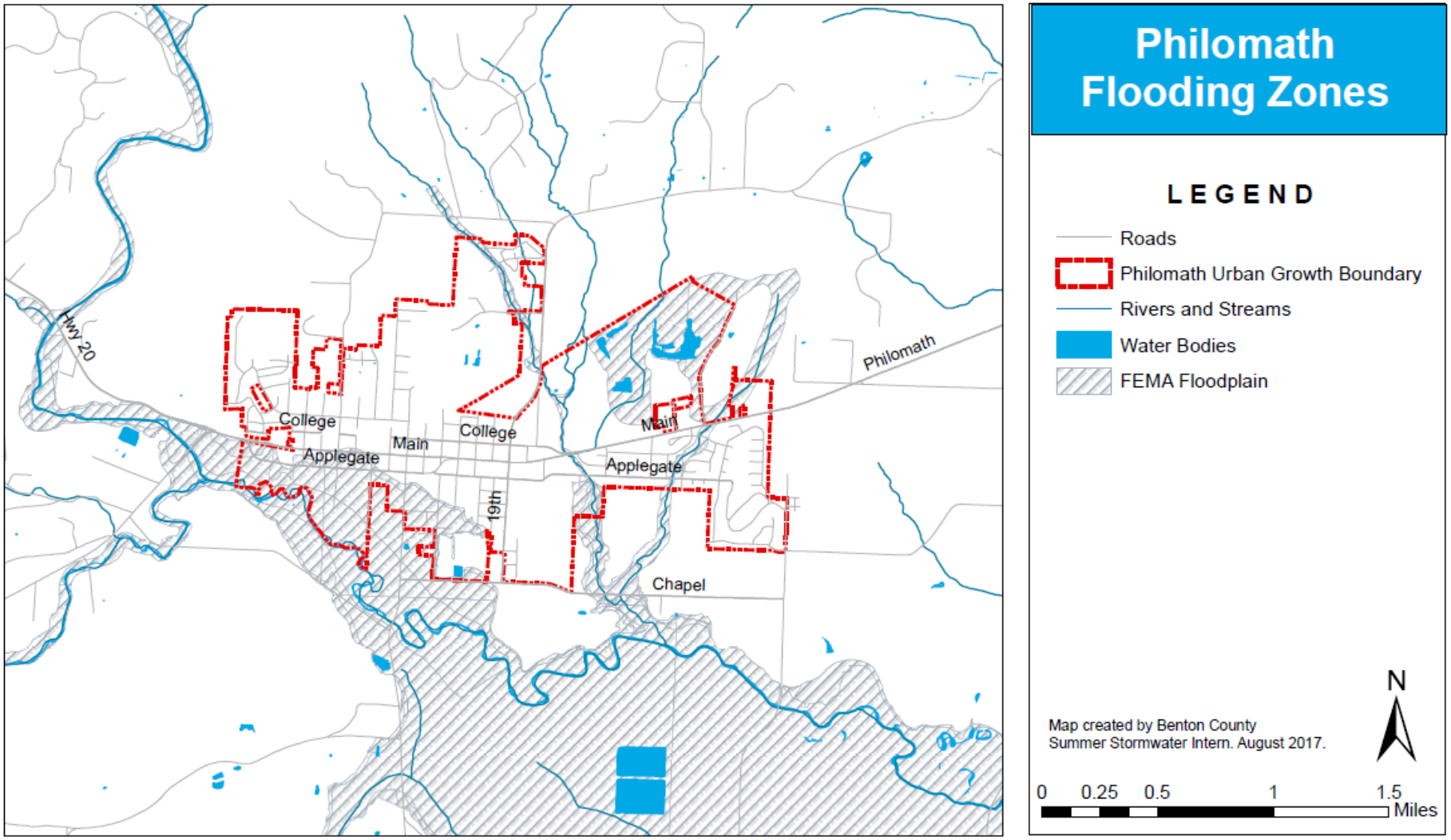
3.2.2 HYDROLOGICAL APPROACH

BMPs that do not follow siting, design, and/or construction criteria for BMPs per Chapter 2 and BMPs in the following list must be designed by a licensed qualified engineer:

- Porous Pavement (Runoff) BMP
- Dispersion BMPs
- Water Quality Conveyance Swales BMP

Use the following hydrologic criteria to size the above facilities:

- Designed by a qualified licensed engineer
- Apply a Santa Barbara Urban Hydrograph (SBUH) Type IA storm distribution.
- Assume a post-developed time of concentration of 5 minutes.
- Due to the continuous nature of Oregon's storms, facilities should drain the volume of the design storm in 30 hours or less to be ready for the next storm. To model infiltration facilities, assume infiltration is occurring all throughout the storm event.
- Based on the infiltration rate (for infiltration facilities) or a residence time of 9 minutes (for conveyance BMPS) design must infiltrate or convey the 24-hour design storm as follows:
    - For areas without localized flooding: 3 inches
    - For areas with localized flooding: 5 inches


Philomath
Flooding Zones
LEGEND
Roads
Philomath Urban Growth Boundary
Rivers and Streams
Water Bodies
FEMA Floodplain
Hwy 20
College
Main
Applegate
19th
Chapel
Philomath
Map created by Benton County
Summer Stormwater Intern. August 2017.
N
0
0.25
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1
1.5
Miles

Chapter 4.0

OPERATIONS AND MAINTENANCE

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4.1 OPERATIONS AND MAINTANCE RESPONSIBILITY

To function as intended over the long term, BMPs must be periodically maintained. Privately owned facilities such as rain gardens, stormwater planters, and porous pavements on private property are the sole responsibility of the property owner to maintain. Prior to issuance of a building permit, the owner must sign an O&M agreement with the City of Philomath (O&M Form, included below), committing the owner and future owners to certain operation and maintenance activities.

LID facilities located within public right-of-way or easements dedicated to the City are publicly owned and the City will be responsible for their maintenance and long term success. Private property owners and their agents are prohibited from removing or replacing vegetation, filling or tampering with the shape of a facility, and applying pesticides or fertilizers. If there is a question or concern associated with the condition or function of any best management practices citizens are encouraged to contact the City of Philomath.

4.2 OPERATIONS AND MAINTANCE FORM

Instructions for filling out the required O&M agreement are as follows:

Read the form thoroughly prior to filling it out. If you have any questions about how to fill it out, or the responsibilities the form commits the owner to, please call the City of Philomath at (541) 929-3579.
Fill out Box 1, including owner's name, telephone number, mailing address, site address, and site legal description.
For Box 2, depending on which types BMPs are being installed on the site, attach the corresponding BMP Maintenance Activities to Form O&M, and check the applicable box (or boxes).
Fill out Box 3, including party responsible for O&M, contact information if other than owner, anticipated installation date of the facility, and name of the person preparing the form.
In Box 4, either sketch the property or include a separate site plan sheet including street frontage (label street name); means of access and access easements, if necessary; buildings; parking lots; walkways; and driveways. Indicate with *'s and/or polygons where each BMP is to be located, and label each one.
Read the legal requirements in Box 5.
Under witness of a certified notary, sign the form in Box 6, and have it notarized.
Submit the completed Form O&M with the building permit application for review by the City of Philomath. The form will need to be recorded with Benton County and proof submitted to the City of Philomath prior to building permit issuance.

County Recorder's Office Contact Information:

Benton County Courthouse
120 NW 4th Street, Room 4
Corvallis, OR 97330

541-766-6831

https://www.co.benton.or.us/records

This Box for JURISDICTION Recording Use Only

AFTER RECORDING, RETURN TO:

City of Philomath
PO Box 400
Philomath, OR 97370

FORM O&M: Operations & Maintenance Agreement for Best Management Practices	
Permit Application #:	Project #:
BOX 1	
Owner's Name:	Phone Number: (_____) _____-_____
Mailing Address:	
Site Address:	
Site Legal Description:	
BOX 2	
Type of Practices. *Check all that apply:* ☐ Tree Protection ☐ Tree Planting ☐ Depaving and/or Restored Soils ☐ Porous Pavement (Type: _____) ☐ Rain Garden, Stormwater Planter, and/or LID Swale ☐ Soakage Trench ☐ WQ Conveyance Swale ☐ Dispersion BMP ☐ Level Spreader	
BOX 3	
Party Responsible for maintenance of Green Development Practice. *Check One:* ☐ Property Owner ☐ Homeowner's Association ☐ Other (describe) _____	
Contact Information (only if other than owner)	
Maintenance Contact Name:	Phone Number: (_____)_____-_____
Maintenance Contact Address:	
Estimated Date of Installation (mm/yyyy):	
Prepared By:	
BOX 4 Insert site plan here or attach separate sheet.	The practices located on this site plan are a required condition of permit approval for the identified property. The owner of the identified property is required to operate and maintain these facilities in accordance with the attached O&M plans. The requirement to operate and maintain these facilities in accordance with the O&M plans is binding on all current and future owners of the property. The O&M plan may be modified under written consent of new owners with written approval by and re-filling with the governing jurisdiction.

BOX 5: LEGAL REQUIREMENTS

I. OWNER INSPECTIONS. OWNER shall provide inspections of the Facilities as needed to ensure proper function on a continual basis. Proper function for each facility type is described in the Operations and Maintenance (O & M) Plan.

II. DEFICIENCIES. All aspects in which the Facilities fail to satisfy the O&M Plan shall be noted as "Deficiencies".

III. OWNER CORRECTIONS. All Deficiencies shall be corrected at OWNER'S expense within thirty (30) days after completion of the inspection. If more than 30 days is reasonably needed to correct a Deficiency, OWNER shall have a reasonable period to correct the Deficiency so long as the correction is commenced within the 30-day period and is diligently prosecuted to completion.

IV. JURISDICTION INSPECTIONS. OWNER grants to the JURISDICTION the right to inspect the private stormwater Facilities. The JURISDICTION will endeavor to give ten (10) days prior written notice (as courtesy to OWNER), except that no notice shall be required in case of an emergency. The JURISDICTION shall determine whether Deficiencies need to be corrected. OWNER (at the address provided in this Agreement, or such other address as OWNER may designate in writing to JURISDICTION) will be notified in writing through the US Mail of the Deficiencies and shall make corrections within 30 days of the date of the notice.

V. JURISDICTION CORRECTIONS. If correction of all OWNER or JURISDICTION identified Deficiencies is not completed within thirty (30) days after OWNER'S inspection or JURISDICTION notice, JURISDICTION shall have the right to have any Deficiencies corrected. The JURISDICTION (i) shall have access to the Facilities for the purpose of correcting such Deficiencies and (ii) shall bill OWNER for all costs reasonably incurred by JURISDICTION for work performed to correct such Deficiencies ("JURISDICTION Correction Costs") following OWNER'S failure to correct any Deficiencies in the Facilities. OWNER shall pay to JURISDICTION the Jurisdiction Correction Costs within thirty (30) days of the date of the invoice. If payment is not made within 30 days, the JURISDICTION shall collect pursuant to APPROPRIATE JURISDICTIONAL STATUTE OR CODE regarding enforcement of cost assessment. OWNER understands and agrees that upon non-payment, Jurisdiction Correction Costs shall be secured by a lien on OWNER'S property for the JURISDICTION Correction Cost amount plus interest and penalties.

VI. EMERGENCY MEASURES. If at any time the JURISDICTION reasonably determines that the Facilities create any imminent threat to public health, safety or welfare, the JURISDICTION may immediately and without prior notice to the Owner take measures reasonably designed to remedy the threat. The JURISDICTION shall provide notice to OWNER of the threat and the measures taken as soon as reasonably practicable, and charge OWNER for the cost of corrective measures.

VII. FORCE AND EFFECT. This Agreement has the same force and effect as any deed covenant running with the land and shall benefit and bind all owners of the site, present and future, and their heirs, successors and assigns.

VIII. ASSIGNMENT TO HOMEOWNERS ASSOCIATION; PROPERTY OWNERS LIABLE. The OWNER may assign this Agreement to a homeowners association comprised of the owners of the benefiting properties. However, the respective owners of each property shall be jointly and severally liable for JURISDICTION Correction Costs if not otherwise paid. All notices to OWNER shall be sent to the address designated in writing by the homeowners association.

IX. AMENDMENTS. The terms of this Agreement may be amended only by mutual agreement of the parties. Any amendments shall be in writing, shall refer specifically to this Agreement, and shall be valid only when executed by both parties to this Agreement and recorded in the Official Records of Multnomah County.

X. PREVAILING PARTY. In any action brought by either party to enforce the terms of this Agreement, the prevailing party shall be entitled to recover all costs, including reasonable attorney's fees as may be determined by the court having jurisdiction, including any appeal.

XI. SEVERABILITY. The invalidity of any section, clause, sentence, or provision of this Agreement shall not affect the validity of any other part of this Agreement, which can be given effect without such invalid part or parts.

BOX 6

BY SIGNING BELOW, filer accepts and agrees to the terms and conditions contained in this operations and maintenance plan and in any document executed by filer and recorded with it.

_____

Filer

NOTARIZATION: GIVEN under my hand and official seal
this _____ day of _____, _____.
Notary Public in and for the State of Oregon:
My Appointment Expires on:

4.3 BMP MAINTENANCE ACTIVITIES

Planning, designing, and constructing BMPs is the shortest phase in the life cycle of any BMP. In comparison to these phases, maintenance is at least equally important for securing a healthy watershed. It is certainly the longest and most costly phase. To prevent unintended consequences when implementing BMPs guidance is provided on the necessary maintenance activities. These pages define what is required to be performed by the O&M Form and the applicable list(s) of maintenance activities should be recorded with the O&M Form.

4.3.1 TREE PROTECTION BMP

The following activities apply to trees within the developed area of a project/development site, as shown on the site plan in Box 4. The level of maintenance of existing protected trees may vary with how well trees were protected in previous development phase. Activities include:

Fertilize trees immediately with phosphorus, potassium, calcium, magnesium, and other macro- and micro-nutrients as indicated by a soil test. Do not over fertilize with an off-the-shelf nitrogen-phosphorus-potassium (NPK) or weed-and-seed products, which can pollute downstream waterways and groundwater.

Fertilize lightly with nitrogen after 1 year. If recommended by an arborist, light annual applications of nitrogen may be made for the next 3 to 5 years.

Mulch trees once a year with organic matter compost or wood chips to maintain 2-4 inches of mulch. Pull mulch away from tree trunk to avoid rotting the trunk.

In the absence of adequate rainfall, apply at least 1 inch of water per week by deep soaking methods for a minimum of 2 (smaller trees) to 5 years (larger trees).

Inspect trees annually for at least 3 to 5 years after construction to look for changes in condition and signs of insects or disease.

Remove trees that are badly damaged or are in irreversible decline if unsuitable for wildlife habitat. For more information on proper tree removal and replacement, see the Oregon State University Extension publication "Tree Protection on Construction and Development Sites". If the tree is located in a less public area or can be cut to be short, consider leaving some of the trunk of removed trees standing, to serve as habitat for wildlife. All removals of existing public trees and trees or plants required by this ordinance shall require a permit application and approval by the Tree Committee and adhere to Philomath Municipal Code, Chapter 18.70.

Develop a regular maintenance program that incorporates fertilization and integrated pest management techniques to get best results at lowest cost.

Don't top trees. Cutting off the top of the main stem of trees makes trees hazardous and higher maintenance. Topping makes a tree more susceptible to storm damage and starves the tree by drastically reducing its ability to feed itself through photosynthesis. Open wounds make a tree more susceptible to internal rot, insects, and disease.

Pruning is the deliberate removal of tree branches and limbs to achieve a specific objective in the alteration of a tree's health and form. Regular inspections to determine a tree's pruning needs should be a part of every tree maintenance program. Always determine the objective for pruning before beginning the work. For detailed

information on pruning techniques, see the Oregon State University Extension publication "Tree Protection on Construction and Development Sites"[49].

4.3.2 DEPAVE EXISTING PAVEMENT & RESTORED SOILS BMPs

The following activities apply to landscape areas within the developed area of a project/development site where the Restored Soils BMP has been implemented, which includes the Depave Existing Pavement BMP.

Maintenance of restored soils is similar to any landscape area.

- Remove weeds twice a year, around May and October or as needed before weeds go to seed.
- Replenish compost in gardens to a depth of 2-3 inches and lawns 1/4 inch, annually.

Reduce or eliminate the use of fertilizers, herbicides, pesticides, and permanent irrigation, especially if using all or predominantly native plants.
Leaf litter left on grass over the winter may kill it; however leaf litter left to decompose landscape areas, instead of raking in the fall is an effective mulch.
Alternative: Mulch once a year with 2-4" of wood chips for perennial gardens and single trees. See Tree Planting BMP Maintenance Activities for more information on maintenance of individual trees.

4.3.3 TREE PLANTING

The following maintenance activities apply to newly planted trees, as shown on the site plan in Box 4. The amount of maintenance a tree requires depends on the species, the tree's location in the landscape, its age, and the care it has been given throughout its lifetime. Basic tree maintenance begins with regular inspections to determine a tree's needs, which may include pruning, mulching, fertilization, irrigation, and pest management.

<u>New Tree Care after Planting.</u> Maintenance specific to new trees is as follows:
Prune only dead, broken, crossed, or rubbing branches; inspect for pruning needs annually.
Irrigate trees during the 2-year establishment period. Irrigate trees more in the first year and less to much less in subsequent years. In addition, trees benefit from varying irrigation seasonally. At the beginning of summer, after the rains stop, water a little. Increase irrigation volume as the summer/dry season continues. Taper off irrigation as the rains return. Depending on your area and rainfall patterns, irrigation may be needed from May to October. Apply 5-10 gallons to each newly planted tree, once/week.
Inspect newly planted trees twice a year for the first 5 years to evaluate condition and maintenance needs.
Remove tree watering rings after one year.
Remove stakes and guying materials, if used, after one year.

<u>For long term maintenance.</u>

Remove trees that are badly damaged or are in irreversible decline if unsuitable for wildlife habitat. For more information on proper tree removal and replacement, see the Oregon State University Extension publication "Tree Protection on Construction and Development Sites". If the tree is located in a less public area or can be cut to be short, consider leaving some of the trunk of removed trees standing, to serve as habitat for wildlife. All

[49] Oregon State University, Extension Services. (2009). Tree Protection on Construction and Development Sites. Retrieved from: http://goo.gl/Tl5kOU

removals of existing public trees and trees or plants required by this ordinance shall require a permit application and approval by the Tree Committee and adhere to Philomath Municipal Code, Chapter 18.70.
Develop a regular maintenance program that incorporates fertilization and integrated pest management techniques to get best results at lowest cost.
Don't top trees. Cutting off the top of the main stem of trees makes trees hazardous and higher maintenance. Topping makes a tree more susceptible to storm damage and starves the tree by drastically reducing its ability to feed itself through photosynthesis. Open wounds make a tree more susceptible to internal rot, insects, and disease.
Pruning is the deliberate removal of tree branches and limbs to achieve a specific objective in the alteration of a tree's health and form. Regular inspections to determine a tree's pruning needs should be a part of every tree maintenance program. Always determine the objective for pruning before beginning the work. For detailed information on pruning techniques, see the Oregon State University Extension publication "Tree Protection on Construction and Development Sites"[50].

4.3.4 POROUS PAVEMENT

The following maintenance activities apply to all porous pavement types (*i.e*. porous asphalt, pervious concrete, permeable pavers, & porous gravel), as shown on the site plan in Box 4. Maintenance activities for porous pavements are as follows:
Inspect landscape areas twice a year for erosion. Implement erosion prevention and sediment control measures as needed per the Oregon DEQ Construction Stormwater Erosion and Sediment Control and replant as soon as possible.
Remove trash and litter, which may carry dirt. Frequency will vary with foot traffic. Busy commercial districts will need more frequent litter pick-ups than suburban or rural residential streets.
Never apply cinders to porous pavement. Remove snow and ice with snowplows or liquid deicers. Snowplowing is best; however, raise the plow when snowplowing over pavers, since the plow could catch edges. A number of environmentally sound, salt-free, liquid deicers are available and should be used.
Remove moss mechanically once a year during the dry season. Do not apply mossicides.
Maintain porous pavement and surrounding landscapes with integrated pest management. Fertilizers, pesticides, herbicides, or fungicides are all pollutants likely to leach through porous pavement.
Control structures, such as catch basins and manholes should be cleaned out twice a year.
Inspect and maintain permanent signage, if applicable.

4.3.4.1 Porous Asphalt and Pervious Concrete

In addition to the maintenance activities necessary for all porous pavements, perform the following maintenance activities for porous asphalt and pervious concrete areas.
Never seal coat porous asphalt.
Damaged areas of 50 square feet or less may be patched with conventional asphalt, up to 10% of the total porous pavement area.
Remove material on surface. The cleaning interval, which might range from every 6 months to every 3 years, should be based on possible exposure to sediments. Use one or more of the following methods:

[50] Oregon State University, Extension Services. (2009). Tree Protection on Construction and Development Sites. Retrieved from: http://goo.gl/Tl5kOU

- Vacuum twice per year. It's difficult to get suction on a porous pavement that hasn't at least partially clogged, so this may not be a useful alternative until years into the pavement's life cycle.
- Pressure washing can be done at an angle to the pavement and not directly into it. Employ erosion control measures when pressure washing. Vactor truck pressure washing once per year is especially good at removing moss. Leaf blowers during the dry season, when material can be blown, are also an option.
- Propane torches are useful to kill moss on concrete, but avoid using them on asphalt, which can be damaged by the heat.

If the infiltration rate of the pavement slows over time, it may be desirable to test the infiltration rate. When the pavement is still draining rather quickly, it may be acceptable to hose the pavement down and use intuition to determine that the rate of infiltration at the surface is still faster than the infiltration rate needed to pass the design storm through it.

4.3.4.2 Permeable Pavers

In addition to the maintenance activities necessary for all porous pavements, perform the following maintenance activities for permeable paver areas as shown on the site plan in Box 4.

Manage weeds. Permeable paver surfaces have a tendency to grow plants in the infill spaces. Use integrated pest management approaches such as hand-pulling or by using a torch. Commercial maintenance services with trucks that will burn all the weeds off at once are available in Oregon.

Remove material on surface for maintenance or to unclog a clogged surface. Vacuuming, pressure washing, and leaf blowing may all be used on these systems; however, operations may remove or disturb the infill rock. Replenish it with clean rock meeting the AASHTO No. 8 or equivalent specification (see Appendix D).

If the infiltration rate of the pavement slows over time, it may be desirable to test the infiltration rate. When the pavement is still draining rather quickly, it may be acceptable to hose the pavement down and use intuition to determine that the rate of infiltration at the surface is still faster than the infiltration rate needed to pass the design storm through it.

4.3.4.3 Porous Flexible Paving Systems

In addition to the maintenance activities necessary for all porous pavements, perform the following maintenance activities for porous flexible paving system areas as shown on the site plan in Box 4.

Refer the specific manufacturer's maintenance requirements to this O&M Agreement:

Manufacturer: _____

Some general guidance is as follows:

For porous flexible paving systems with grass, maintenance is similar to turf.

For flexible paving systems with gravel, broom or rake dislodged gravel back in place.

Manage weeds. Use integrated pest management approaches such as hand-pulling (during the wet weather when soils are more soft and roots can be effectively removed), or by burning or pouring hot water on weeds.

Inspect for bare soil, exposed rings, ruts, poorly growing grass from too much shade, and thatch.

In the case of spills, ruts, or disturbance to access underground utilities, the flexible paving systems may be cut with a sod cutter, set aside, and put back in placed after subgrade has been reconstructed.

Avoid aeration since this machinery will damage the pavement.
Snow plowing may be done by "using standard truck-mounted snow plowing blades with small skids on the corners to keep the bottom of the blade"[51] about 1" above the grass surface.

[51] Marine Amazing website. Stormwater Management. Retrieved from: http://www.psparchives.com/publications/our_work/stormwater/lid/2009_Local_Assitance/005_Appendices/Grasspave2MaintenanceGuide.pdf

4.3.4.4 Porous Gravel

In addition to the maintenance activities necessary for all porous pavements, perform the following maintenance activities for porous gravel areas as shown on the site plan in Box 4.

Manage weeds. Hand pull, burn with a torch, or pour hot water on them in May and October.

If the rock surface gets clogged, carefully shovel the first 1 to 2 inches of rock and rinse it off in a disconnected landscape area, which is an area that does not drain to any sort of structured inlet or towards any surface like a driveway or road that drains to a structured inlet. Employ appropriate erosion control techniques during the washing, as necessary to prevent erosion and capture sediments.

4.3.5 VEGETATED STORMWATER FACILITIES

The following maintenance activities apply to rain gardens, stormwater planters and/or LID swales, as shown on the site plan in Box 4.

Do not mow these facilities, regardless of whether they are planted with lawn/sod or bunch grasses. This greatly reduces the capacity for the facility to slow flows and settle out solids.

Inspect the facility a minimum of 4 times per year and perform needed maintenance as follows:
Maintain a calm flow of water entering the facility via downspout pipes or other inlets.
Identify erosion sources and control them when soil is exposed or erosion channels are forming. A settling basin or other effective means shall be placed around the point where water is discharged into the facility to slow the water and prevent erosion. Fill erosion channels with approved soil mix, not mulch, compost, or rock, and replant using a species of plant in the facility adjacent to the eroded channel.
Identify and correct sources of sediment and debris.
Remove sediment and debris from:

- The pretreatment sump
- Facility surface when more than 1" thick or damaging vegetation. Minimize damage to vegetation.
- The facility outlet, such as overflow drain or conveyance swale.
- Curb cuts when depth exceeds ¼ inch.

Stabilize slopes with plants and appropriate erosion control measures when soil is exposed or erosion channels are forming. Fill eroded channels with approved soil and replant. If flows can be redirected temporarily, redirect flows until plants establish. Check for erosion as a result of redirected flows on the next site visit.
Maintain the design ponding depth by:

- Repairing any structural elements that may leak from cracks or worn sealant
- Maintaining the design elevation of check dams

If the facility does not drain within 48 hours, scrape 1 inch of soil out of the facility and replace with imported soil meeting the specifications provided in Appendix D: Specifications “Treatment Soil”.

- If facility does not drain after scraping 1”, try another 1” depth.
- If facility does not drain after scraping 2”, salvage plants, till and replant the facility.

- Debris in quantities that inhibit infiltration shall be removed routinely or upon discovery.

Vegetation should be healthy and dense enough to provide filtering while protecting underlying soils from erosion with at least 95% coverage of bare soil in three years.

- Replenish mulch until vegetation is established and shading the bottom of the facility.
- Remove fallen leaves and debris from deciduous plant foliage, especially if the facility is in a roadway with trees located upstream from a curb.
- Don’t string trim ornamental grasses, sedges or rushes. These may be raked.
- Remove nuisance (*i.e*. plants blocking the inlet) and non-native and invasive vegetation (*i.e.* weeds such as Himalayan blackberries and English Ivy) when discovered.
- Remove dead vegetation and woody material before it covers 10% of the rain garden surface area. Vegetation shall be replaced within 3 months, or immediately if required to maintain cover density and control erosion where soils are exposed.
- Maintain vegetation using integrate pest management approaches such as hand pulling weeds. Avoid the use of fertilizers, pesticides, and herbicides, as these are common pollutants found in waterways.
- Irrigate during the establishment period. Watering and weeding may be needed frequently within the first 1 to 3 years during Oregon’s very dry summers, but this should taper off

dramatically if you choose native perennial plants. The goal during the establishment period is to make plants as “drought proof” as possible by watering deeply and infrequently. Shallow, frequent watering will only make plants dependent on continued watering.

To establish perennial plants, you’ll need to irrigate more in the first year and less to much less in subsequent years. In addition, plants benefit from varying irrigation seasonally. At the beginning of summer, after the rains stop, water a little. Increase irrigation volume as the summer/dry season continues. Taper off irrigation as the rains return. Depending on your area and rainfall patterns, irrigation may be needed from May to October.

The volume of water and frequency of watering varies with the type of plant:

Trees: 5-10 gallons, once/week
Shrubs: 3-5 gallons once/week
Groundcover: 1-2 gallons, once or twice/week
Perennial herbs: ½ gallon, twice/week.

After the 2 – 3 year establishment period, irrigation would theoretically not be needed; however plantings surrounded by impervious pavement will probably require occasional irrigation beyond the establishment period, indefinitely.

4.3.6 SOAKAGE TENCH

The following maintenance activities apply to soakage trenches, as shown on the site plan in Box 4. Inspect the facility a minimum of 4 times per year during each season and after major storms and perform needed maintenance as follows:

Confirm via the observation port or other structure that the facility is emptying out/infiltrating. Clogged facilities (*i.e.* not draining within *[30 hours]*) must be completely reconstructed or relocated.

Remove debris from pipes and other conveyance.

Repair or replace damaged pipes.

For soakage trenches that receive runoff from adjacent surfaces, sediment and debris will tend to clog the surface of the facility. Vacuum sediment from rocks. If water can no longer drain into the facility, clogging of the top geotextile has occurred. Using sediment control techniques such as compost berms and biobags, carefully remove and clean rock on the surface. Replace the geotextile fabric on the top, being careful not to damage the fabric on the sides. Place the cleaned rock back over the geotextile fabric. Dispose of sediment in trash.

Sweeping regularly will reduce the likelihood of clogging. High traffic areas will clog faster than low traffic areas.

Maintain manufactured structures like silt basins and water quality manholes per manufacturer's operations and maintenance guidelines. The manufacturers of structures on this site include (continue listing below if more than two):

Manufacturer: _____

Manufacturer: _____

4.3.7 WATER QUALITY CONVEYANCE SWALE

The following maintenance activities apply to water quality conveyance swales as shown on the site plan in Box 4.

Inspect the facility a minimum of twice per year and perform needed maintenance as follows:
Maintain a calm flow of water entering the facility via downspout pipes or other inlets.
Identify erosion sources and control them when soil is exposed or erosion channels are forming. A settling basin or other effective means should be placed at the point where water is discharged into the facility to slow the water and prevent erosion. Fill erosion channels with approved soil mix, not mulch, compost, or rock, and replant using a plant species found in the facility adjacent to the eroded channel.
Identify sources of sediment and debris and correct.
Remove sediment and debris from:

- Pretreatment sump
- Facility surface when more than 1" thick or damaging vegetation. Minimize damage to vegetation.
- Facility outlet, such as overflow drain or conveyance swale.
- Curb cuts when depth exceeds ¼ inch.

Stabilize slopes with plants and appropriate erosion control measures when soil is exposed or erosion channels are forming. Fill eroded channels with approved soil and replant. If flows can be redirected temporarily, redirect flows until plants establish. Check for erosion due to redirected flows on the next site visit.
Maintain the design ponding depth by:

- Repairing any structural elements that may leak from cracks or worn sealant
- Maintaining the design elevation of check dams

Vegetation should be healthy and dense enough to provide filtering while protecting underlying soils from erosion with at least 95% coverage of bare soil in three years.

- Replenish mulch until vegetation in the bottom of the WQ conveyance swale is established and shading the bottom of the facility.
- Remove fallen leaves and debris from deciduous plant foliage, especially if the facility is in a roadway with trees located upstream from a curb.
- Don't string trim ornamental grasses, sedges or rushes. These may be raked.
- Remove nuisance (*i.e.* plants blocking the inlet) and non-native and invasive vegetation (*i.e.* weeds such as Himalayan blackberries and English Ivy).
- Remove dead vegetation and woody material before they covers 10% of the rain garden surface area. Vegetation should be replaced within 3 months, or immediately if required to maintain cover density and control erosion where soils are exposed.
- Maintain vegetation using integrate pest management such as hand pulling weeds. Avoid use of fertilizers, pesticides, and herbicides, as these are common pollutants found in waterways.

Exercise spill prevention measures when handling substances that can contaminate stormwater. Correct releases of pollutants as soon as identified:

- Make sure the area is safe to enter
- Block the outflow of the BMP
- Block the inflow of the BMP
- Stop the release of the hazmat
- Clean up the flow path to the BMP
- Clean out the BMP, replacing soil, amended soil and vegetation as necessary.

4.3.8 DISPERSION

The following maintenance activities apply to dispersion BMPs (*i.e.* vegetated filter strips or downspout disconnection) as shown on the site plan in Box 4.

Common maintenance tasks are as follows:

Mow and trim grasses (when dry) to lengths appropriate to the type and species of grass. Longer grass is generally better and mowing is not required if it is not desired.

Identify and correct sources of sediment and debris.

Inspect for and remove excess sediment (maximum depth of 2 inches) that may affect vegetation growth in the dispersion area or the level spreader. Dispose of sediment in the trash.

Replace vegetation as needed. If a plant did not do well, choose a different plant.

Repair eroded areas where channels have formed by filling them with soil, lightly compacting them with tamping or boot compaction, and reestablish vegetation. Do not fill eroded channels with mulch. If possible, redirect flows around the establishing vegetation for three (3) months. Inspect other areas around redirecting device (ex. sandbag) to ensure that this redirection is not causing additional erosion. If plants receiving redirected flows are small or not very sturdy and erosion is or may occur, biobags (a sediment control measure, which is a bag with compost or wood chips) will allow water to enter the vegetated filter strip slowly and may be a better way to prevent erosion than redirecting flows.

Because vegetated filter strips look very similar to a regular garden, some sort of permanent demarcation, such as fencing (even something as simple and attractive as a 2 foot tall post and chain fence) should be installed if the area is receiving regular foot traffic that is compacting soils and/or impacting plant health.

4.3.9 LEVEL SPREADER

The following maintenance activities apply to level spreaders.

In high sediment areas, level spreaders will be high maintenance elements of a BMP. Spreading water out so that it cascades over a level spreader instead of concentrating at a single point and causing erosion is difficult to achieve. While the level spreader design recommended here may be high maintenance, it will reduce problems with erosion and is considered an effective means of spreading out flows.

The main maintenance activity with a level spreader is keeping the rock clean, so that the rough edges of the angular rock remain exposed to the runoff and are able to slow and spread it. This slowing of runoff causes sediments to settle out and serves as pretreatment for a best management practice such as a vegetated filter strip or a rain garden.

Maintenance activities include:

Remove weeds once a year if enough sediment accumulates to grow weeds but not enough accumulates to warrant cleaning the rock.

Clean rock before the angular rock is completely buried in sediment. Frequency will depend on the type of pavement and if any uphill landscape areas draining across the pavement are stabilized. Roofs generally contribute the least amount of sediment, although roofs near highways will have more particulates deposited on their surface. Generally for roads, sediment will increase with the number of cars on them. Lawns will contribute the highest volume of sediment, if they happen to be uphill of the pavement that drains to the vegetated filter strip.

Using a flat shovel, remove the rock to a depth of at least 6 inches. Install appropriate erosion control techniques (See the DEQ's "Construction Stormwater Erosion and Sediment Control Manual[52]) such as biobags or wattles. On a plastic tarp, hose off the rock, ideally located in an area that is hydraulically isolated and will not drain to a catch basin or other conveyance system. Place the clean rock back and dispose of sediment and organic matter in the trash.

Stabilize landscapes draining to the level spreader to reduce maintenance.

Maintain and re-establish, if necessary, if flows into the facility are not well distributed across the level spreader.

Sweep rocks back into place as needed to prevent a tripping hazard condition.

[52] Oregon Department of Environmental Quality. (2013). Water Quality Division. Construction Stormwater Erosion and Sediment Control manual. Retrieved from: http://www.deq.state.or.us/wq/wqpermit/docs/general/npdes1200c/ErosionSedimentControl.pdf

APPENDIX A

SITE PLANNING CHECKLISTS

The following checklists, a site assessment checklist and a site survey plan, are provided to help ensure that information critical to implementing LID sites is available during the early site planning phase.

SITE ASSESSMENT CHECKLIST

The following is a checklist of items that are directly or indirectly related to water quality and may be helpful to investigate when inventorying the site.

Consider on-site natural resources.

Water Resources:

- ☐ Wetlands?
- ☐ Floodplains?
- ☐ Wellhead protection areas?
- ☐ Existing well?
- ☐ Riparian buffers?
- ☐ Naturally vegetated swales/drainageways?
- ☐ Seasonal high water table?
- ☐ Problems with run-on from neighboring properties?

Land Forms:

- ☐ Steep slopes?
- ☐ Existing topography, contours?
- ☐ Depth to bedrock?
- ☐ Existing land cover/uses?
- ☐ How does size and shape of the site affect stormwater management?
- ☐ Are there areas where development should generally be avoided?
- ☐ Evidence of soil erosion/landslides?

Soils:

- ☐ Hydrologic soil groups?
- ☐ Tested infiltration rates?
- ☐ Erodability?
- ☐ Swell potential?
- ☐ Hydric soils present?
- ☐ Texture?
- ☐ Fertility?

Livability:

- ☐ Aesthetics?
- ☐ Sense of place?
- ☐ Opportunities to create private, semi-private, and public spaces?

Microclimate:

- ☐ Wind tunnels caused by vegetation/building orientation?
- ☐ Temperature variation?
- ☐ Evaporation/moisture variation?

Vegetation:

- ☐ Special status trees?
- ☐ Threatened or endangered species habitat?
- ☐ Blocks of habitat and corridors or connections between habitat patches?
- ☐ Native plant communities?
- ☐ Distinctive individual plants or communities?
- ☐ Vegetation that could overhang an impervious area?
- ☐ Invasive species/noxious weeds?
- ☐ Wildfire risks?

Consider on-site infrastructure/built environment.

Utilities:

- ☐ Wastewater system?
- ☐ Stormwater system?
- ☐ Structures with potential to serve as cisterns? (pools, spaces under existing buildings, etc.)
- ☐ Water?
- ☐ Gas?
- ☐ Electric?
- ☐ Communication?

Cultural:

- ☐ Archeological site?

Land Coverage/Uses:

Impervious area:

- ☐ Impervious area covered by evergreen tree canopy
- ☐ Impervious area covered by deciduous tree canopy
- ☐ Roof
- ☐ Sidewalks
- ☐ Vehicular pavement
- ☐ Other (swimming pools, basketball court, etc.)

Semi-porous area:

- ☐ Lawn
- ☐ Naturalized
- ☐ Ornamental beds
- ☐ Food gardens
- ☐ Paving surfaces (pavers, mulch, boardwalk)
- ☐ Other

Porous area:

- ☐ Forest

Project data:

- ☐ Contaminants from past uses (leaking tanks, pesticides, herbicides, etc.?

Water Resources:

- ☐ Fish/mammal barriers to passage?
- ☐ Off-site drainage?
- ☐ Drainage patterns before and after finish grading?
- ☐ Locations of discharge outfalls/points?
- ☐ Size of discharge outfalls/points?
- ☐ Type of discharge outfalls/points?
- ☐ Areas used for storage of soils or wastes?
- ☐ Erosion and sediment control facilities/structures including vegetative practices?

Staging/Storage Considerations:

- ☐ Disturbance area?
- ☐ Total surface area of the site, broken down by phases of development?
- ☐ Timetable for sequence of major events?
- ☐ Type of material used for fill?
- ☐ Volume of cut?
- ☐ Volume of fill?
- ☐ Recycling area?
- ☐ Composting area?

Consider regional natural resources.

Water Resources:

- ☐ Receiving water body for site drainage?
- ☐ Rare or endangered species or communities present?
- ☐ 303d/impaired stream listing classifications?
- ☐ Existing or planned TMDLs?
- ☐ Neighboring wells?

Consider regional infrastructure/built environment.

Utilities:

- ☐ Sanitary sewer system?
- ☐ Water?
- ☐ Storm drainage system?
- ☐ Gas?
- ☐ Electric?
- ☐ Communication?

Cultural:

- ☐ Certified historical values?
- ☐ Known/potential archaeological values?

Air Quality:

- ☐ Located on busy street?
- ☐ Located on truck route?

Consider municipal, state, and federal guidelines/laws.

Master plans:

- ☐ Is development concept consistent with the master plan?
- ☐ Consistent with goals/policies of the plan?
- ☐ Preservation of natural resources consistent with priority areas/maps?

Water Regulations:

- ☐ Consistent with local existing regulations?
- ☐ Wetland regulations?
- ☐ Tree/woodlands ordinance?
- ☐ Riparian buffer ordinance?
- ☐ Open space requirements?
- ☐ Clustering and/or PUD options?
- ☐ Overlay districts?
- ☐ Wellhead protection?
- ☐ Erosion and sedimentation requirements?
- ☐ Curbs required?
- ☐ Rain gardens, stormwater planters allowed?
- ☐ Street width, parking requirements, other impervious requirements?
- ☐ Grading requirements?
- ☐ Stormwater requirements?
- ☐ Contaminated sites have followed state "due care" requirements for soil and groundwater?
- ☐ Consistent with state and federal wetland and/or inland lakes and streams regulations?

Other Regulations:

- ☐ State and federal threatened and endangered species?
- ☐ Consistent with county/state road requirements?

Fire Department:

- ☐ Recommendations for wildfire areas?
- ☐ Vehicular circulation?
- ☐ Road widths?
- ☐ Cul-de-sac/hammerhead requirements?

Planning:

- ☐ Zoning ordinances?
- ☐ Urban renewal?
- ☐ Comprehensive plan overlay?
- ☐ Historic resource?
- ☐ Conservation overlay?
- ☐ Required minimum outdoor area

SITE SURVEY PLAN

The area of survey may vary and should include, at a minimum, at least 10 feet beyond the *area of disturbance* proposed. The *area of disturbance* may vary greatly from the *proposed project improvements* and can depend on such things as the proposed site layout, on-site slopes and existing grades, and locations of public utilities where proposed connections will be made. For all new development and re-development projects, a surveyor should survey the following minimum items and accurately map them, if present on-site:

Legal:

- ☐ Right of ways on both sides of all street frontages
- ☐ Property and lot lines with bearings & lengths
- ☐ All easements
- ☐ Legal description
- ☐ Tax lot info
- ☐ Street names

Surveyor data:

- ☐ Benchmarks
- ☐ Monuments
- ☐ Iron pipes
- ☐ Brass screws
- ☐ Basis of bearings & elevations
- ☐ North arrow
- ☐ Professional stamp
- ☐ Contact info for surveyor

Elevation data:

- ☐ Contours in appropriate intervals
- ☐ Spot elevations on a 25-foot grid and at changes in grade
- ☐ Both contours and spots should extend at least 10’ beyond the property line and/or across the street to the curb

Utilities:

- ☐ Utility vaults and above-grade fixtures
- ☐ Storm structures including catch basins, manholes, water quality facilities and devices, cleanouts, etc.
- ☐ Power poles, light poles, traffic poles, overhead lines.
- ☐ Sewer manholes and cleanouts.

Land Cover:

- ☐ Extent of buildings with dimensions of buildings and dimensions to property lines
- ☐ The boundaries of all land cover types such as asphalt, gravel, concrete, etc.
- ☐ Water features such as wetlands, streams, ditches, ponds, etc.
- ☐ Walls
- ☐ Site furniture such as bollards, benches, fences, etc.
- ☐ Trees with greater than 3” diameter, tree wells, and major vegetation such as hedges. Include type of tree and draw spread of branches to scale and outline of massed trees.

STORMWATER ANALYSIS REPORT REQUIREMENTS

Whenever the Hydrological Approach is used and a licensed engineer is involved in a project, a Stormwater Management Report is required. The report shall be prepared by a licsenced Civil Engineer in the State of Oregon. The following information should be included where applicable:

Cover Sheet:

- ☐ Project name and owner
- ☐ Site Address
- ☐ Associated permit numbers
- ☐ Engineer
- ☐ Contact information
- ☐ Oregon Proffesional Engineer's registration stamp

Project Overview and Description:

- ☐ Size and location of project site (see site survey plan)
- ☐ Type of development/proposed improvements
- ☐ Watershed description
- ☐ Permits required
- ☐ Existing vs. post-construction conditions

Methodology:

- ☐ Drainage at existing site
- ☐ Potential impacts on the proposed site from existing conditions
- ☐ Potential impacts from the proposed site on existing drainage
- ☐ Infiltration testing results
- ☐ Narrative that defines the proposed stormwater management techniques
- ☐ Stormwater hierarchy category justification

Analysis:

- ☐ Design Assumptions
- ☐ Design storms used
- ☐ Computation methods
- ☐ Software used
- ☐ Safety factors, curve numbers, and design coefficients
- ☐ Conveyance requirements and design
- ☐ Table of impervious area treated (differentiates public vs. private and roof vs. pavement)
- ☐ Comparison table of the flow rates for pre and post construction
- ☐ Determination of the flood control point of discharge and capacity of receiving system

Engineering Conclusions:

- ☐ How water quality, flow control, and flood control requirements are satisfied
- ☐ Stormwater Facility Details/Exhibits
- ☐ Contour maps of pre and post development
- ☐ Impervious area identification
- ☐ Existing and new drainageways
- ☐ Point(s) of discharge

APPENDIX B

INFILTRATION TESTING

APPLICABILITY

To properly size and locate stormwater management facilities, it is necessary to characterize the soil infiltration conditions at the location of the proposed facility. Perform infiltration testing to implement the following BMPs:

- Limit Disturbance: Conserve Fast Draining Soils BMP
- Porous Pavement BMP
- Rain Garden BMP
- LID Swale BMP
- Stormwater Planter BMP
- Soakage Trench BMP
- Dispersion BMP

TIMING

Tests should not be conducted in the rain, within 24 hours of a storm greater than 1/2 inch, or when the ground is frozen.

LOCATION

The test measures infiltration of a very small and specific area. In new developments and redevelopments with generous open space, infiltration tests should be performed across the proposed development area during the planning phase. Once the location of facilities is determined, additional design phase infiltration testing may be needed if the initial tests were not conducted within the footprint of the proposed facility. Never test under the canopy of a tree, since this could damage the tree.

NUMBER OF TESTS

The number of infiltration tests for large sites varies widely. More tests are needed for sites with variable soil conditions than for sites that are uniform. In urban sites, where soils may have been disturbed a number of times over many years, soil conditions may vary greatly over small distances, so more tests may be needed. A licensed qualified geotechnical engineer can assist with identifying soil uniformity and identifying the appropriate number of tests, also.

SAFETY

Always call 811 to locate utilities before testing begins[53]. Infiltration tests may require extensive excavation and can be potentially dangerous. Observe relevant Occupational Safety and Health Administration (OSHA) regulations. “Excavation should never be left unsecured and unmarked, and all applicable authorities should be notified prior to any work”.

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[53] Oregon 811, Utility Notification Center. Retrieved from: http://digsafelyoregon.com/

EQUIPMENT NEEDED

To perform an infiltration test, you will need:

- Shovel and/or post-hole digger
- Yardstick or ruler
- Water source
- Some clean gravel (in clay soils)
- Pencil
- Paper
- Watch or timer

TESTING DEPTH

Testing depth varies with existing and final conditions, testing goals, and BMP choices. An infiltration test depth of 6 inches to 12 inches into the soil just below the ground cover vegetation and topsoil, is a sufficient testing depth when performing the test for conserving fast draining soils. When doing infiltration testing for runoff reduction BMPs, infiltration testing should be performed at the expected depth of the bottom of the facility. However, infiltration testing may also determine the depth of the facility, as well as the location. For example, soils just 6" below existing grade may be suitable for infiltration and have enough nutrients to support plant growth in a rain garden.

RIBBON TESTING

To properly implement an infiltration facility, you need to approximately identify the soil texture of your existing native soils, which may range from more sandy to more clayey.

Determine soil texture:

1. Take a handful of the soil you have excavated from your infiltration test (described below). Pulverize it in your hand and remove any bits of organic matter or obvious rocks.
2. Wet it with a small amount of water and rub it between your thumb and index finger. Don't saturate it until it is runny mud. You might feel stickiness, grittiness, or smoothness. The grittier the feel, the more sand is present in your soil. The slicker the soil, the more clay in it. Smooth soils are sometimes an indicator of a fine silt or loam. Discard the soil.
3. Next, take another sample in your hand. Wet it until it has the consistency of dough. You should be able to form a ball that holds together with the soil in your palm. If you cannot get the ball to form, then your soil is very sandy. In most soils, however, you should be able to create a rough ball.
4. Knead the soil together between your thumb and fingers and attempt to form a ribbon. As you build the ribbon, it will either hold together or break off.
5. Compare the breakage length of the ribbon table __ to classify the soil texture.

Figure 30 – Step 3 of the ribbon test.

Figure 31- Step 4 of the ribbon Test.

Length of Ribbon before Breaking	Soil Texture Classification
<1 inch	Sandy/Silty
1-2 inches	Clayey
>2 inch	Clay

Table 5- Soil texture classifications.

FALLING HEAD TEST

The falling head test is one of the oldest and simplest methods for determinimg infiltration rates. It has been used successfully on LID projects for over 30 years by professionals in the field and is the method recommended here.

Perform a falling head test as follows:

1. Dig a test hole with a post hole digger or a larger area with a shovel. The area of the hole doesn't matter. Dig a hole to the appropriate depth as discussed above.
2. Perform a ribbon test.
3. If soils are clayey, scrape the sides of the hole a little (i.e. scarify). Remove the scraped material from the bottom of the hole and place an inch or so of clean gravel at the bottom; otherwise, the tiny clay particles will be suspended in the water to follow and form an impermeable barrier (appearing as a sheen) around the sides and bottom of the hole.
4. Push a pencil or nail into the side of the hole from which to measure the water level drop over time. The height above the bottom of the hole (or gravel if included) will determine the water level depth. Because water is so heavy, deeper water will result in faster overall infiltration rates.
5. Fill the hole with water gently to the top of the pencil or nail. Record the exact time you stop filling the hole (if soils are fast draining, measure time down to the second) and the time it takes to drain completely.
6. If testing during the rainy season and soils are saturated, go on to step 7. If testing during the dry season and soils are dry, refill the hole again and repeat steps 2 to 5 two more times. Averaging the results of the tests will give you the best measure of how quickly your soil absorbs water when it is fully saturated, as it would be during a rainy period of the year or during a series of storms that deliver a lot of rainfall in a short period of time. Occasionally, due to water changing the soil structure, infiltration rates can increase over short time periods during the test, but on average, the infiltration rate should generally decrease with each round.
7. To calculate the infiltration rate, divide the distance that the water dropped by the amount of time it took for it to drop. For example, if the water dropped 1 inch in 2 hours, then 1 divided by 2 equals 0.5 inches per hour.
8. For rain gardens and stormwater planters and porous pavements managing runoff, if the slowest infiltration rate measured is less than 0.5 inches per hour, then dig another hole nearby, but 3 to 6 inches deeper, and repeat steps 1 to 5 to see if there's a faster draining soil that could be over excavated to. Repeat this process at various depths down to another 2 feet, or until you have at least 0.5 inches per hour infiltration. If you can't find a suitable area with an infiltration rate of at least 0.5 inches per hour, infiltration BMPs must be designed and modeled by a qualified licensed engineer.
9. For porous pavements that infiltrate only rainfall, if the slowest infiltration rate measured is less than 0.3 inches per hour, consider relocating the porous pavement to a faster draining soil. If this is not possible and the infiltration rate below the porous pavement managing rainfall only is less than 0.3 inches per hour, then the porous pavement must be modeled by a qualified licensed engineer.

Additionally, two conditions for vertical separation should be met:

10. After infiltration testing is complete, dig the hole another 2 feet of depth from the bottom of the BMP (*i.e.* the elevation where water will begin to pond) to uncover bedrock that may impede infiltration. If the soil is pretty consistent all the way down then one criteria for vertical separation is met.
11. If testing during the winter, dig the hole one foot deeper to discover groundwater. If water doesn't seep into the hole, then groundwater is sufficiently deep and the second vertical separation criteria is met. If not testing during the winter, hire a registered soil scientist, licensed geotechnical engineer, registered geologist, or other qualified licensed professional to assist with assessing the depth of the seasonal high groundwater table.
12. Fill the hole back up, and leave the site in a safe condition.

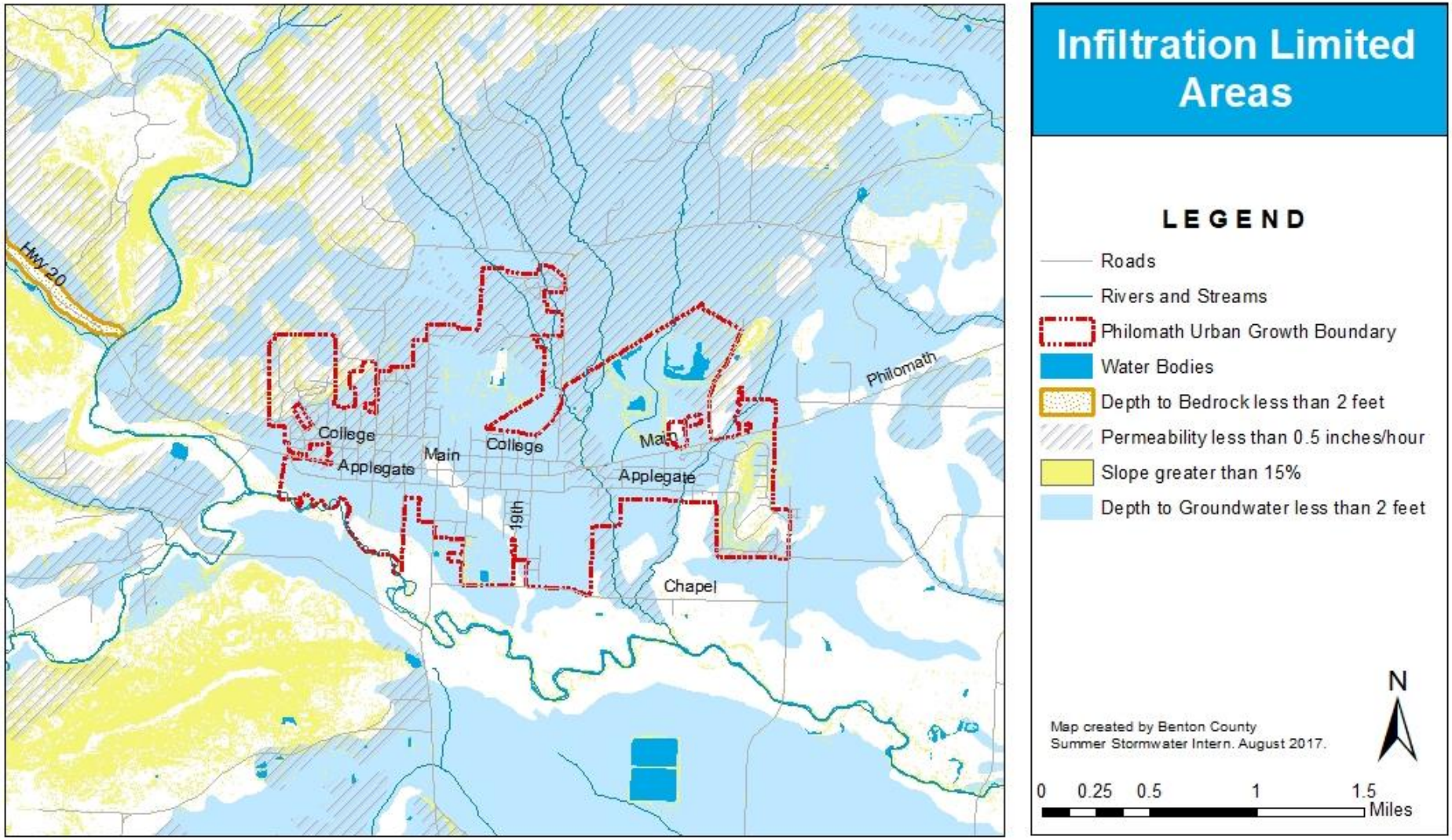

Figure 32- This map details places in philomath that will not likely meet infiltration design suggestions proposed in this guidance.

APPENDIX C

FACILITY PLANT DESIGN

CRITERIA FOR CHOOSING PLANTS

Above all, plants should be chosen using the motto "Right Plant, Right Place". Plants in BMPs provide many ecological, hydraulic, and social functions, which must be considered. When choosing the best plants as stormwater managers, first consider water quality function of the facility. A diverse assembly of long-lived plants should be chosen according to the guidance provided throughout this appendix.

Due to the availability of a variety of suitable species at nurseries[54], we recommend using native plants wherever possible. Native plants evolved over geologic time periods with other plants and animals in our watersheds, therefore they better support the local ecosystem that aids in managing our stormwater. Additionally native plants are generally easier to establish and often require less water and fertilizers.

Only use non-native plants with the following research:

- Avoid plants that reproduce readily. These are plants that spread by seeds, rhizomes or culms, etc.
- Avoid plants listed on the Native Plant Society's Emerald Chapter's website[55] for "Exotic Gardening and Landscaping Plants" that are emerging as problematic.
- Avoid plants listed on the invasive plant lists of Washington[56] and California[57].
- Consult with your local Benton County OSU Extension agent (541-766-6750), the Mary's River watershed council (541-758-7597) or the Benton soil and water conservation district (541-753-7208).
- Avoid invasive plants listed on the Oregon Department of Agriculture "Oregon Noxious Weed List"[58].

Provided below is a list of LID appropriate plants native to Philomath. This list is not a comprehensive planting guide, as the exact plants for each rain garden will vary depending on how much water the garden will hold and the soil conditions. Native flowers are not included in this chart, but more information on native forb is available on the Benton Soil and Water Conservation District website.

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[54] Native Plant Society of Oregon (NPSO) website. Retrieved from: http://www.npsoregon.org/landscaping5.php

[55] NPSO. Exotic Gardeining and Landscaping Plants Invasive in Native Habitats of the Southern Willamette Valley. Retrieved from: http://emerald.npsoregon.org/inv_ornmtls.html

[56] Washington State Noxious Weed Control Board. Retrieved from: http://www.nwcb.wa.gov/

[57] Invasive Species Council of California. The California Invasive Species List. retrieved from: http://www.iscc.ca.gov/species.html

[58] Oregon Department of Agriculture. Oregon Noxious Weed Profiles. Retrieved from: http://www.oregon.gov/ODA/programs/Weeds/OregonNoxiousWeeds/Pages/AboutOregonWeeds.aspx

Scientific Name	Common Name	Facility Planting Options					Plant Categories					Plant Zones		Exposure		
		Rain Garden	Stormwater Planters	LID Swale	Water Quality Conveyance Swale	Vegetated Filter Strip	Conifer Trees	Broadleaf Trees	Large Shrubs	Small Shrubs	Grasses & Groundcovers	Planting Zone A (wet to moist)	Planting Zone B (moist to dry)	Shade	Partial Shade	Sun
Abies grandis	Grand Fir						●						●	●	●	
Acer circinatum	Vine Maple							●				●	●	●	●	●
Acer macrophyllum	Big Leaf Maple							●					●		●	●
Achillea millefolium	Yarrow										●		●		●	●
Alnus rhombifolia	White Alder							●					●		●	●
Alnus rubra	Red Alder							●					●			●
Amelanchier alnifolia	Pacific Serviceberry								●				●		●	●
Arbutus menziesii	Pacific Madrone							●					●		●	●
Arctostaphylos uva-ursi	Kinnikinnik									●	●		●			●
Aruncus dioicus	Goat's Beard										●	●	●	●	●	
Asarum caudatum	Wild Ginger										●	●		●	●	
Baccharis pilularis	Coyote Bush								●				●			●
Blechnum spicant	Deer Fern										●	●		●	●	
Calocedrus decurrens	Incense Cedar						●						●		●	●
Carex, Juncus, Eleocharis, etc.	Rush-Sedge Grass Blend										●	●				●
Ceanothus cuneatus	Narrow-leaved Buckbrush								●			●				●
Ceanothus sanguineus	Redstem Ceanothus								●				●		●	●
Ceanothus thyrsiflorus	Blue Blossom								●				●		●	●
Cornus Canadensis	Bunchberry										●	●			●	
Cornus nuttalli	Pacific Dogwood							●					●	●	●	
Cornus sericea	Red-osier Dogwood								●			●	●	●	●	●
Corylus cornuta	Beaked Hazelnut								●				●		●	●
Crataegus douglasii	Black Hawthorn							●				●			●	●
Deschampsia cespitosa	Tufted Hair Grass (Kalapuya)										●	●	●		●	●

Festuca idahoensis ssp. roemeri	Roemer's Fescue										●	●			●	●
Fragaria vesca	Wood Strawberry										●		●		●	
Fragaria virginiana	Mountain Strawberry										●		●		●	●
Frangula purshiana	Cascara							●				●		●	●	●
Fraxinus latifolia	Oregon Ash							●				●	●			●
Garrya fremontii	Fremont's Silktassel								●				●		●	●
Gaultheria shallon	Salal										●		●		●	
Heuchera micrantha	Coral Bells										●		●		●	
Holodiscus discolor	Ocean Spray								●				●	●	●	
Hydropyllum tenuipes	Pacific Waterleaf										●	●		●	●	
Lonicera involucrata	Black Twinberry								●				●		●	●
Mahonia aquifolium	Tall Oregon Grape									●			●	●	●	●
Mahonia nervosa	Cascade Oregon Grape									●			●	●		
Mahonia repens	Dwarf Oregon Grape									●			●		●	
Maianthemum stellatum	Star Flower Solomon's Seal										●	●			●	
Malus (pyrus) fusca	Pacific Crabapple							●				●			●	●
Myrica californica	Pacific Wax Myrtle								●			●			●	●
Oemleria cerasiformis	Indian Plum								●				●	●	●	●
Oxalis oregana	Wood Sorrel										●	●		●	●	
Philadelphus lewisii	Mock Orange								●				●		●	●
Physocarpus capitatus	Pacific Ninebark								●			●	●	●	●	●
Pinus ponderosa	Willamette Ponderosa Pine						●						●			●
Polystichum munitum	Sword Fern										●	●	●	●	●	●
Populus trichocarpa	Black Cottonwood							●					●			●
Prunus virginiana	Choke Cherry							●					●		●	●
Pseudotsuga menziesii	Douglas Fir						●						●		●	●
Quercus garryana	Oregon White Oak							●					●			●
Rhododendron macrophyllum	Pacific Rhododendron								●			●			●	●
Ribes sanguineum	Red Flowering Currant									●			●		●	●
Rosa nutkana	Nootka Rose									●			●		●	●
Rosa pisocarpa	Clustered Rose									●		●	●			●

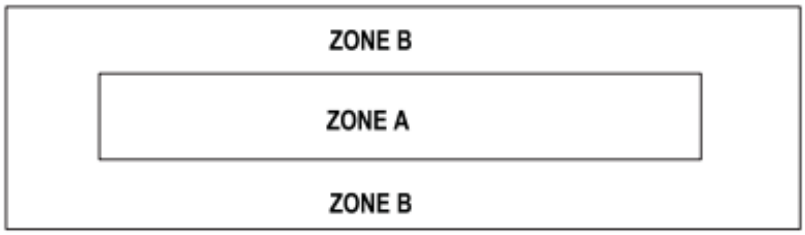
Rubus parviflorus	Thimbleberry									●		●		●	●	●
Rubus spectabilis	Salmonberry								●			●		●	●	
Salix lucida var. lasiandra	Pacific Willow							●				●				●
Sambucus caerulea	Blue Elderberry								●				●	●	●	●
Sambucus racemosa	Red Elderberry								●				●	●	●	●
Sedum oreganum	Stonecrop										●		●		●	●
Sisyrinchium bellum	Blue Eyed Grass										●	●			●	●
Spiraea douglasii	Douglas Spirea									●		●	●		●	●
Symphoricarpos albus	Snowberry									●			●	●	●	●
Tellima grandiflora	Fringecup										●		●	●	●	
Thuja plicata	Western Red Cedar						●					●			●	
Tolmiea menziesii	Piggyback Plant										●		●	●	●	
Tsuga heterophylla	Western Hemlock						●						●	●		●
Vaccinium ovatum	Evergreen Huckleberry									●			●	●	●	
Viola glabella	Stream Violet										●	●		●	●	

FACILITY PLANTING ZONES

Zone A: Area of the facility defined as the bottom of the facility to the designated high water mark. This area has wet to moist soils and plants located here shall be tolerant of mild inundation.

Zone B: Area of the facility defined as the side slopes from the designated high water line up to the edge of the facility. This area typically has drier to moist soils with the moist soils being located farther down the side slopes. Plants here should be drought tolerant and help stabilize the slopes.

SWALE PLANTING ZONES



PLANTER PLANTING ZONES

RAIN GARDEN PLANTING ZONES

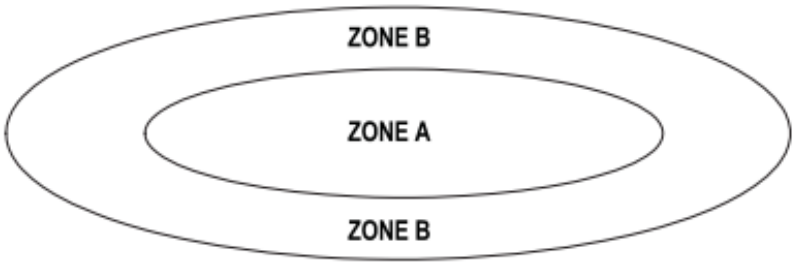


Figure 33- A diagram of planting zones to help interpret the native plant chart provided. Graphic created by the city of Eugene.

APPENDIX D

MATERIAL SPECIFICATIONS

This appendix details suitable materials and installation methods for a variety of BMPs including a description of the material, applicability to a particular BMP, criteria for selection, and/or installation recommendations.

SOIL AMENDMENT SPECIFICATIONS

Organic Matter Compost

Care should be taken to ensure that compost is clean and free of weeds, pollutants, or other harmful materials that may impact plant health and water quality.

Organic matter compost shall meet the following criteria:

- Weed seed and pollutant free.
- 100% should pass a 1/2-inch screen.
- pH between 5.5 and 7.0.
- Carbon nitrogen ratio between 30:1 and 35:1.
- Organic matter content between 40 and 50 percent.
- Fully composed. Earthy is good. Avoid compost that smells like ammonia.
- Metals should not exceed (mg/kg dry weight):
    - Arsenic ≤20 ppm
    - Cadmium ≤10 ppm
    - Copper ≤750 ppm
    - Lead ≤150 ppm
    - Mercury ≤8 ppm
    - Molybdenum ≤9 ppm
    - Nickel ≤210 ppm
    - Selenium1 ≤18 ppm
    - Zinc ≤1400 ppm

Organic matter compost should NOT be peat moss. Peat moss is extracted from wetlands; this has negative impacts on the watershed from which the peat moss was removed.

Mycorrhizae

Mycorrhizae are mushroom roots, and most plants in western Oregon have co-evolved with this material. Mushroom roots interact with the plant roots by feeding on the plant's waste and by bringing the plant nutrients, thereby expanding the effective root area of the plant by many fold. Plants receiving this kind of amendment consistently grow bigger and faster than plants without it.

Many manufacturers/suppliers have mycorrhizae products specific to a particular BMP, such as for landscapes or ecoroofs with a variety of applications methods that may include hydromulching, broadcasting, tilling, or watering. You can buy amendments as pellets or water soluble powder.

A non-BMP-specific mycorrhizae product with a mix of endo- and ectomycorrhizal species is acceptable for any plant based BMP in this guidance.

Mulch

Mulch should be:

- Shredded wood chips (preferred for trees and shrubs)
  OR
- Coarse compost (not bark dust or bark chips) meeting the specifications in this section for "Organic Matter Compost"

A 2 to 3-inch layer of coarse compost or shredded wood (not bark products) shall be used over the amended soil and between the plantings to completely cover the soil and prevent erosion and weed intrusion.

COARSE AGGREGATE

Coarse aggregate shall meet the following requirements:

1. All aggregates shall be clean and washed rock. For BMPs with geotextile fabric below rock, a maximum wash loss of 0.5% is required. Clean rock is generally delivered with a 2% wash loss, so rinsing in the truck or on-site, using appropriate erosion control methods, may be needed to prevent long-term geotextile clogging. For BMPs that do not incorporate a geotextile fabric, 2% wash loss as delivered is acceptable.
2. All aggregates in porous pavements shall exhibit a durability index of 35 and a maximum abrasion of 10% for 100 revolutions or a maximum of 50% for 500 revolutions
3. Base rock shall be uniformly graded with the AASHTO #3 gradation. If the aforementioned gradation cannot be met, the AASHTO # 5 gradation is acceptable with the approval of the licensed qualified engineer and minimum voids of 40%.

U.S. Standard Sieve Size	Percent Passing
2 ½" (63 mm)	100
2" (50 mm)	90-100
1 ½" (37.5 mm)	35-70
1" (25 mm)	0-15
½" (12.5 mm)	0-5

Table 7- AASHTO #3
Gradation specifications

U.S. Standard Sieve Size	Percent Passing
1 ½" (37.5 mm)	100
1" (25 mm)	90-100
¾" (19 mm)	20-55
½" (12.5 mm)	0-10
3/8" (9.5 mm)	0-5

Table 6- AASHTO #5
Gradation Specifications.

4. Choker course aggregate (porous pavement) or storage rock (rock trench) aggregate or French drain rock (vegetated stormwater facilities) shall have the following gradation (AASHTO # 57).

U.S. Standard Sieve Size	Percent Passing
1 ½" (37.5 mm)	100
1" (25 mm)	95-100
½" (12.5 mm)	25-60
4 (4.75 mm)	0-10
8 (2.36 mm)	0-5

Table 8- AASHTO #57
Gradation Specifications

5. Infill aggregate and bedding course (permeable pavers) or separation rock (vegetated stormwater facilities) shall have the following gradation (AASHTO # 8).

U.S. Standard Sieve Size	Percent Passing
½” (12.5 mm)	100
3/8” (9.5 mm)	85-100
4 (4.75 mm)	10-30
8 (2.36 mm)	0-10
16 (1.18 mm)	0-5

Table 9- AASHTO #4 Gradation Specifications

GEOTEXTILE FABRIC

Non-woven geotextile (drainage filter fabric) shall conform to the following criteria:

- Minimum flow rate of 95 gal/min/ft2 ASTM D-4491-85
- Grab tensile strength min 115 lb. ASTM D-4632-86
- Mullen Burst strength min 150 psi ASTM D-3786-80a
- Puncture resistance min 45 lb. ASTM D-4833-88
- Apparent opening size 60-90 U.S. Standard Sieve

Geotextile fabric shall be installed per the manufacturer's standards and recommendations. Adjacent strips of geotextile should overlap a minimum of 16 inches. Ensure that the geotextile is secured at least 4 feet outside of excavated area over exposed soil and take any steps necessary to prevent runoff or sediment from entering the pavement rock base.

The presence of a geotextile fabric requires that the base rock be delivered clean and washed on-site before placement, if necessary. Otherwise, as water moves through the cross section, it will carry dirt particles down to the fabric and clog it, creating an impervious layer beneath the area you intended to be porous. One successful method for this is to hose the rock off in the delivery truck when it arrives. Another method is to dump the rock and wash off the pile, pulling rock from the top and applying water again, depending on the size of the pile. Inspect it visually on a regular basis for small rocks and dirt to know at what point in the pile you should start washing again.

TREATMENT SOIL

A treatment soil is a naturally occurring or engineered mix which may include clay, silt, sand, gravel, compost, microorganisms, and mycorrhizae that has the desired physical and chemical properties needed to clean stormwater as it passes through it. It must have a variety of physical and chemical properties.

Treatment soils meeting the specifications below may include undisturbed native soil or amended planting soil.

Imported treatment soil mixes in Western Oregon have a variety of names, which may be marketed as bioretention soil mix (BSM), planting soil, amended soil, engineered soil, 3-way mix, or others.

All treatment soils should be:

- Tested and confirmed to infiltrate between 0.5 inches per hour and 12 inches per hour[59] per Appendix B.
- Be free of weed seeds. If soil is imported, the supplier should be able to certify this condition through industry standard best practices.
- Be free of contaminants & hazardous materials[1]

Imported Soil Mixes. All imported soil mixes should be tested for and meet the following criteria to a minimum depth:

- An organic content matter (OM) from 8-10% by weight[1]
- A cation exchange capacity (CEC) greater than 5 millequivalents/100 grams of dry soil[1]
- Between 2 – 5% clayey fines[1]
- pH between 5.5 and 7.5[60]
- 60% Loamy sand[1]
- 40% organic matter compost[1]
- Conform to the gradation shown in Table 10

U.S. Sieve Size	*Percent Passing*
3/8-inch	*100*
#4	*95-100*
#10	*75-90*
#40	*25-40*
#100	*4-10*
#200	*2-5]*

Table 10- Imported soil gradation specifications

Amended Native Soil. Amended native soil is the soil on the site mixed with organic matter compost (required) and gravelly sand (optional).

Material should meet the specifications described above for organic matter compost.

Use of gravelly sand is optional. For clayey soils, gravelly sand must be blended into the soil simultaneously with organic matter compost. Never fold sand alone into clayey soils. With insufficient quantities of sand, this action is likely to cement the soil creating a barrier to infiltration.

Gravelly sand should be free of organic material, contaminants, and hazardous materials, and should conform to the following gradation.

[59] Test undisturbed native soil for both the undisturbed native soil and amended native soil conditions per Appendix C. Test imported soil mixes in a lab according to the guidance provided in this memo retrieved from the State of Washington's Water Quality Manual: http://www.ecy.wa.gov/programs/wq/stormwater/bsmresultsguidelines.pdf

[60] Low Impact Development Center specifications. Retrieved from: http://www.lowimpactdevelopment.org/epa03/biospec_left.htm

U.S. Sieve Size	Percent Passing
2-inch	100
3/4-inch	70-100
1/4-inch	50-80
No. 40	15-40
No. 200	0-3

Table 11- Gravelly Sand Gradation Specifications.

Mix soil and amendments to a homogeneous consistency. Do not mix compost, sand, and native soil in the rain or wet conditions. Even in dry weather, soils and amendments themselves should not be overly wet.

Choose from two different soil blends as follows:

- Organic matter compost only = 2 (soil):1 (organic matter compost)
- Organic matter compost and gravelly sand = 2(soil):1(organic matter compost):1(sand)

Installation. Place amended native soil mix in lifts not exceeding 8 inches in loose thickness. Compact lightly after each lift. Do not over compact soil mix with mechanical equipment after placement; following the construction steps in this guidance, soils have already been compacted by spraying water on them or boot tamping. After all lifts have been placed, grade soil to finish grades as specified on the plans.

IMPERMEABLE LINER

Impermeable liners may be a 45-mil (minimum) low density polyethylene (LDPE), 45-mil (minimum) ethylene propylene diene monomer (EPDM) or bentonite clay mat per manufacturer guidance.

Make sure that the liner is installed securely at a height equal to the depth of water that may be ponded or flowing during any storm, not just the design storm. If an outlet structure is present, attach the liner to the outlet structure with the appropriate adhesive or mechanically.

If an LDPE or EPDM liner will be used, make sure that it's a single, solid piece big enough to be installed underneath the entire facility area or that pieces are glued or otherwise waterproofed together per manufacturer guidelines. Overlapping sheets will not adequately prevent infiltration.

If the design calls for a bentonite clay mat, follow the manufacturer’s guidance for installation.

POROUS ASPHALT PAVEMENT SPECIFICATION

This specification has been provided courtesy of Tom Cahill of Cahill Associates.

1.1 SUMMARY

A. The work of this Section includes subgrade preparation, and base course, choker base course, and porous bituminous paving.

1.2 SUBMITTALS

A. Submit a list of materials proposed for work under this Section including the name and address of the materials producer and the location from which the materials are to be obtained.

B. Submit certificates, signed by the materials producer and the paving subcontractor, stating that materials meet or exceed the specified requirements.

C. Submit samples of base rock and choker course aggregate, non-woven geotextile, and porous bituminous asphalt for review and approval by the Engineer.

D. The asphalt mixing plant shall certify the aggregate mix, abrasion loss factor, polymer additive, binder draindown, tensile strength ratio, resistance to stripping by water and asphalt content in the mix.

1.3 QUALITY ASSURANCE

A. Use adequate numbers of skilled workers who are thoroughly trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and the methods needed for proper performance of the work in this section.

B. Codes and Standards

1. All materials, methods of construction and workmanship shall conform to applicable requirements of Oregon Department of Transportation, unless otherwise specified.

1.4 PROJECT CONDITIONS

A. Protection of Existing Improvements

1. Protect adjacent work from splashing or paving materials. Remove all stains from exposed surfaces of paving, structures, and grounds. Remove all waste and spillage.
2. Do not damage or disturb existing improvements or vegetation. Provide suitable protection where required before starting work and maintain protection throughout the course of the work.
3. Restore damaged improvements, including existing pavement on or adjacent to the site that has been damaged as a result of construction work, to their original condition or repair as directed to the satisfaction of the Owner, and authority having jurisdiction at no additional cost.

B. Safety and Traffic Control

1. Notify and cooperate with local authorities and other organizations having jurisdiction when construction work will interfere with existing roads and traffic.

2. Provide temporary barriers, signs, warning lights, flaggers, and other protections as required to assure the safety of persons, vehicles, and bicycles around the construction area and to organize the smooth flow of traffic.

C. Weather Limitations

1. Do not place bituminous paving mixtures between November 1 and March 1, unless otherwise permitted in writing by the Engineer.
2. Do not place porous bituminous paving mixtures when surfaces are wet or when the ambient temperature is 55 degrees Fahrenheit of lower.

D. Annual Book of ASTM Standards, 1997 or latest edition; American Society for Testing and Materials, West Conshohocken, PA.

E. Standard Specifications, latest edition; Oregon Department of Transportation (ODOT)

F. Standards of the American Association of State Highway and Transportation Officials (AASHTO), 1998 or latest edition.

2.1 MATERIALS

A. Base Courses

1. All aggregates within reservoir course shall meet the following:

   a. Maximum Wash Loss of 0.5%
   b. Minimum Durability Index of 35
   c. Maximum Abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions

2. Unless otherwise approved by the Engineer, base rock shall be uniformly graded with the following gradation (AASHTO number 3):

U.S. Standard Sieve Size	Percent Passing
2 ½" (63 mm)	100
2" (50 mm)	90-100
1 ½" (37.5 mm)	35-70
1" (25 mm)	0-15
½" (12.5 mm)	0-5

Table 12- AASHTO #3 Gradation specifications

If the above gradation cannot be met, the following gradation (AASHTO size number 5) is acceptable with the approval of the Engineer and minimum void space of 40%:

U.S. Standard Sieve Size	Percent Passing
1 ½” (37.5 mm)	100
1” (25 mm)	90-100
¾” (19 mm)	20-55
½” (12.5 mm)	0-10
3/8” (9.5 mm)	0-5

Table 13- AASHTO #5 Gradation Specifications

3. Choker course aggregate shall have the following gradation (AASHTO size number 57).

U.S. Standard Sieve Size	Percent Passing
1 ½” (37.5 mm)	100
1” (25 mm)	95-100
½” (12.5 mm)	25-60
4 (4.75 mm)	0-10
8 (2.36 mm)	0-5

Table 14- AASHTO #57 Gradation Specifications

4. Non-woven geotextile (drainage filter fabric) shall conform to the following:
   a. Minimum flow rate of 95 gal/min/ft^2 ASTM D-4491-85
   b. Grab tensile strength min 115 lb ASTM D-4632-86
   c. Burst strength min 150 psi ASTM D-3786-80a
   d. Puncture resistance min 45 lb ASTM D-4833-88
   e. Apparent opening size 60-90 U.S. Standard Sieve
   f. Non-woven geotextile shall be Mirafi 160N, or approved equal.
5. 2-foot wide rock edge drain shall be 1 to 2 ½” diameter washed screen crushed aggregate with no fines.

B. Porous Bituminous Asphalt

1. In accordance with ODOT Section 00745, ½” Open Grade Level 3 HMAC mix except as modified by the following:

2. Bituminous surface course for porous paving shall be 2.5 inches thick with a bituminous mix of 5.5% to 6% by weight dry aggregate. In accordance with ASTM D6390, draindown of the binder shall be no greater than 0.3%. If more absorptive aggregates, such as limestone, are used in the mix then the amount of bitumen is to be based on the testing procedures outlined in the National Asphalt Pavement Association's Information Series 131 – "Porous Asphalt Pavements" (2003) or ODOT equivalent.
3. For traffic bearing surfaces, use neat asphalt binder modified with an elastomeric polymer to produce a binder meeting the requirements of PG 70-22 in accordance with ODOT Section 00744.11. The elastomeric polymer shall be styrene-butadiene-styrene (SBS), or approved equal, applied at a rate of 3% by total weight of the binder. The composite materials shall be thoroughly blended at the asphalt refinery or terminal prior to being loaded into the transport vehicle. The polymer modified asphalt binder shall be heat and storage stable. The contractor shall submit a certification letter from the polymer-modified asphalt supplier to the Engineer before the mix is placed on the project. The certification letter from the supplier will include the following:
   a. Type of elastomer polymer used to modify the asphalt.
   b. Quality control sampling and testing procedures used to certify the polymer modified asphalt prior to shipping to the Contractor's asphalt plant.
   c. Information on the storage and stability of the polymer modified asphalt.
   d. Recommended mixing and compaction temperatures.
   e. A statement saying that the polymer modified asphalt will comply with these specifications.
4. Add hydrated lime at a dosage rate of 1.0% b weight of the total dry aggregate to mixes containing granite. Hydrated lime shall meet the requirements of ASTM C977. The additive must be able to prevent the separation of the asphalt binder from the aggregate and achieve a required tensile strength ratio (TSR) of at least 80% on the asphalt mix.
   The asphaltic mix shall be tested for its resistance to stripping by water in accordance with ASTM D-3625. If the estimated coating area is not above 95 percent, anti-stripping agents shall be added to the asphalt.

3.1 INSTALLATION

A. Base Course

1. Owner shall be notified at least 24 hours prior to all base courses and porous paving work.
2. Subgrade Preparation
   a. Existing subgrade under pavement areas shall NOT be compacted or subjected to excessive construction equipment traffic prior to geotextile and stone bed placement.
   b. Where erosion of subgrade has caused accumulation of fine materials and/or surface ponding, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6" with a spring tooth rake or equivalent and a light tractor.
   c. Bring subgrade of base course to line, grade, and elevations indicated. Fill and lightly re-grade with aggregate base course material any areas damaged by erosion,

ponding, or traffic compaction before placing the aggregate. All bed bottoms are level grade.

3. Base Course Installation

a. Upon completion of subgrade work, the Engineer shall be notified and shall inspect at his discretion before proceeding with reservoir and choker course installation.

b. Geotextile and base course aggregate shall be placed immediately after approval of the subgrade preparation. Any accumulation of debris or sediment, which has taken place after approval of subgrade shall be removed prior to installation of geotextile at no cost to the Owner.

c. Place geotextile in accordance with manufacturer's standards and recommendations. Adjacent strips of geotextile shall overlap a minimum of sixteen inches (16"). Secure geotextile at least four (4) feet outside of excavated area and take any steps necessary to prevent any runoff or sediment from entering the storage bed.

d. Install reservoir base course in 8-inch maximum lifts. Lightly compact each layer with equipment, keeping equipment movement over storage bed subgrades to a minimum. Install aggregates to grades indicated on the drawings.

e. Install choker base course aggregate evenly over surface of rock trench, sufficient to allow placement of pavement, and notify Engineer for approval. Choker base course shall be sufficient to allow for even placement of asphalt, but no thicker than 1 inch in depth.

f. Following placement of base course aggregate, the geotextile shall be folded back along all bed edges to protect against sediment washout along bed edges. At least a four (4) foot strip shall be used to protect beds from adjacent bare soil. This edge strip shall remain in place until all bare soils contiguous to the rock trenches are stabilized and vegetated or the porous bituminous asphalt is installed. In addition, take any necessary steps to prevent sediment from washing into beds during site development. When the site is fully stabilized, temporary sediment control devices may be removed.

B. Porous Bituminous Asphalt

1. Transporting Material

a. Transporting of mix to the site shall be in vehicles with smooth, clean dump beds that have been sprayed with a non-petroleum release agent.

b. The mix shall be covered during transport to control cooling.

2. Porous bituminous asphalt shall not be stored in excess of 90 minutes before placement.

3. Asphalt Placement

a. The porous bituminous surface source shall be laid in one lift directly over the storage bed and stone base course to a 2.5 inch finished thickness.

b. The laying temperature of the bituminous mix shall be between 300 degrees Fahrenheit and 350 degrees Fahrenheit (based on the recommendations of the asphalt supplier).

c. Installation shall take place when ambient temperatures are 55 degrees Fahrenheit or above, when measured in the shade away from artificial heat.

d. The use of a remixing material transfer device between the trucks and the paver is highly recommended to eliminate cold lumps in the mix.

e. The polymer-modified asphalt is very difficult to rake; a well-heated screed should be used to minimize the need for raking, which can clog the pavement.

f. Compaction of the surface course shall take place when the surface is cool enough to resist a 10-ton roller. One or two passes is all that is required for proper compaction. More rolling could cause a reduction in the surface porosity, which is unacceptable.

4. After final rolling, no vehicular traffic of any kind shall be permitted on the surface until cooling and hardening has taken place, and in no case within the first 72 hours. Provide barriers as necessary at no extra cost to the Owner to prevent vehicular use; remove at the direction of the Engineer.

5. Work shall be done expertly throughout, without staining or injury to other work. Transition to adjacent impervious bituminous paving shall be merged neatly with flush, clean lines. Finished paving shall be even, without pockets, and graded to elevations shown on drawing.

6. Porous pavement area shall at no time be used for equipment or materials storage during construction, and under no circumstances shall vehicles be allowed to deposit landscape materials on paved porous surfaces.

7. Repair of Damaged Paving

a. Any existing pavement on or adjacent to the site that has been damaged as a result of construction work shall be repaired to the satisfaction of the Owner without additional cost to the Owner.

8. Field Quality Control

a. The full permeability of the pavement surface shall be tested by application of clean water at the rate of 5 gallons per minute over the surface, using a hose or other distribution device. Water used for the test shall be clean, free of suspended solids and deleterious liquids and will be provided at no extra cost to the Owner. All applied water shall infiltrate directly without puddle formation or surface runoff, and shall be observed by the Engineer and Owner.

b. Testing and Inspection: Employ at Contractor's expense an inspection firm acceptable to the Engineer and Owner to perform soil inspection services, staking and layout control, and testing and inspection of site grading and pavement work. Inspection and list of tests shall be reviewed and approved in writing by the Engineer prior to starting construction. A licensed Engineer must sign all test reports.

c. Test in-place base and surface course for compliance with requirements for thickness and surface smoothness. Repair or remove and replace unacceptable work as directed by the Owner.

d. Surface Smoothness: Test finished surface for smoothness and even drainage, using a ten (10) foot to centerline of paved area. Surface will not be accepted if gaps or

ridges exceed 3/16 of an inch.

9. Grade Control

a. Establish and maintain required lines and elevations. The Engineer shall be notified for review and approval of final stake lines for the work before construction work is to begin. Finished surfaces shall be true to grade and even, free of roller marks and free of low spots to form puddles. All areas must drain.

b. If, in the opinion of the Owner, based upon reports of the testing service and inspection, the quality of the work is below the standards, which have been specified, additional work and testing will be required until satisfactory results are obtained.

END OF SECTION 02725

STRUCTURAL TREE SOIL MIX SPECIFICATIONS

Structural soil shall consist of a mixture of gravel, soil and admixtures as described below. The following sources are approved to supply the materials. Other sources may be approved, based upon satisfactory test results however, it is the contractor's responsibility to provide the required information or testing needed to approve the source. Engage a licensed qualified engineer to provide site preparation specifications, pavement sections, and construction oversight as required by the following sections.

Structural soil shall consist of the following materials:

- Crushed rock (3/4" to 1 ¼" diameter)
- Loam/organic Topsoil
- Soil Binder such as "Stabilizer"
- Water

The major components of the structural soil mixture are crushed rock and topsoil. Since when mixed together some of the topsoil fills in the voids of the crushed rock material the sum of the rock and topsoil volumes does not equal the volume of the structural soil material. There is approximately a 10% volume reduction due to mixing the materials together.

Material	Amount for 1 CY of Structural Soil	Amount for 4.6 CY of Structural Soil
Crushed Rock	23.2 cubic feet	4 cubic yards
Topsoil	5.9 cubic feet	1 cubic yard
Coil Binder	13.7 oz	4 pounds
Water	1.6 gallon	46 gallons

Table 15- Structural Soil material ratios.

The target moisture content is 20% by weight of the topsoil weight. The above water content assumes the topsoil is dry. The amount of water that will need to be added depends on the moisture content of the raw materials.

Actual amounts of water used will be determined during mixing based on observations of the material through the mixing procedure below:

1. Mix structural soil in batches of an appropriate size for the equipment being used. The end result is to be a material that is uniformly blended together. Do not batch in quantities that will not allow the equipment to completely mix the material. Determine batch size and quantities of each material needed for the batch.
6. Start with half of the crushed rock material.
7. Add all of the topsoil material.
8. Add the soil binder.
9. Add half of the estimated water.
10. Add the other half of the crushed rock material.
11. Mix the material together.
12. Slowly add water to the mixture and continue to mix. The final amount of water will vary with moisture content of the crushed rock and topsoil. Add water in incremental amounts and mix the material between the additions of water.
13. Stop adding water and mixing when there is a minute amount of free topsoil remaining. The topsoil will coat the crushed rock and not fall out of the material. All of the crushed rock should be uniformly coated with topsoil. There should be no clumps of topsoil or uncovered crushed rock in the mixture.
14. If too much water is added to the mixture water will drain out of the material and the topsoil will wash off of the crushed rock. If this occurs this batch of material is to be discarded and shall not be incorporated into the completed work.

To install strucutral soil:

1. Protect soils and mixes from absorbing excess water and from erosion at all times. Do not store materials unprotected from rainfall events. Do not allow excess water to enter site prior to compaction. If water is introduced into the material after grading, allow material to drain or aerate to optimum compaction moisture content.
2. All areas to receive Structural Soil mixture shall be inspected by the qualified licensed engineer before starting placement of mixture. All defects such as incorrect grading, compaction and inadequate drainage, etc., shall be corrected prior to beginning placement of Structural Soil.
3. All areas to receive Structural Soil mixture shall be inspected by the qualified licensed engineer before starting placement of mixture. All defects such as incorrect grading, compaction and inadequate drainage, etc., shall be corrected prior to beginning placement of Structural Soil.
4. Confirm that the sub-grade is at the proper elevation and compacted or uncompacted, as indicated by the plans and/or site preparation specifications. Sub-grade elevations shall slope parallel to the finished grade. Clear the excavation of all construction debris, trash, rubble and foreign material. Fill any over excavation with approved fill and compact to the required sub-grade compaction.
5. Install Structural Soil in 6-inch lifts and compact each lift to 85 percent of maximum density using lightweight, handheld compaction equipment. Delay compaction 24 hours if moisture content exceeds maximum allowable and protect Structural Soil with plastic or plywood as directed by the Engineer. Do not overcompact. Engage a testing company to test field density of each lift, especially in the beginning when the contractor is “getting a feel” for compacting the material to the appropriate density.
6. The water service lines that cross the structural soil material fill area may be corroded and fragile. The contractor shall take particular care when working around the water service lines. If a service line is damaged, develops a leak or is bent, the service line shall be replaced as per City of Olympia standards at the contractor's expanse. The structural soil that will be the bedding for the water service lines shall compacted to conform to the grade of the water service line. The contractor shall not compact the immediate vicinity above a water service line until a fill depth of 12-inches above the water service line is reached.
7. Bring Structural Soils to finished grades as shown on the drawings. Immediately protect the Structural Soil material from contamination from water by covering with plastic or plywood as directed by the Engineer.
8. The Engineer may periodically check the material being delivered and installed at the site for mixture proportions and consistency with the material requirements of these specifications. In the event that the installed material varies significantly from the specified material, the Contractor shall remove the material and replace with the specified Structural Soil material at no extra cost to the Contracting Agency.

APPENDIX E

DETAILS