Public Works

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ONSITE STORMWATER BMP GUIDANCE

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BMP T5.13 Post Construction Soil Quality & Depth

Purpose and Definition

Naturally occurring (undisturbed) soil and vegetation provide important stormwater functions including: water infiltration; nutrient, sediment, and pollutant adsorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are largely lost when development strips away native soil and vegetation and replaces it with minimal topsoil and sod. Not only are these important stormwater functions lost, but such landscapes themselves become pollution generating pervious surfaces due to increased use of pesticides, fertilizers and other landscaping and household/industrial chemicals, the concentration of pet wastes, and pollutants that accompany roadside litter.

Establishing soil quality and depth regains greater stormwater functions in the post development landscape, provides increased treatment of pollutants and sediments that result from development and habitation, and minimizes the need for some landscaping chemicals, thus reducing pollution through prevention.

Applications and Limitations

Establishing a minimum soil quality and depth is not the same as preservation of naturally occurring soil and vegetation. However, establishing a minimum soil quality and depth will provide improved on-site management of stormwater flow and water quality.

Soil organic matter can be attained through numerous materials such as compost, composted woody material, biosolids, and forest product residuals. It is important that the materials used to meet the soil quality and depth BMP be appropriate and beneficial to the plant cover to be established. Likewise, it is important that imported topsoils improve soil conditions and do not have an excessive percent of clay fines.

This BMP can be considered infeasible on till soil slopes greater than 33 percent.

Design Guidelines

- Soil retention. Retain, in an undisturbed state, the duff layer and native topsoil to the maximum extent practicable. In any areas requiring grading remove and stockpile the duff layer and topsoil on site in a designated, controlled area, not adjacent to public resources and critical areas, to be reapplied to other portions of the site where feasible.

- Soil quality. All areas subject to clearing and grading that have not been covered by impervious surface, incorporated into a drainage facility or engineered as structural fill or slope shall, at project completion, demonstrate the following:
    1. A topsoil layer with a minimum organic matter content of 10% dry weight in planting beds, and 5% organic matter content in turf areas, and a pH from 6.0 to 8.0 or matching the pH of the undisturbed soil. The topsoil layer shall have a minimum depth of eight inches except where tree roots limit the depth of incorporation of amendments needed to meet the criteria. Subsoils below the topsoil layer should be scarified at least 4 inches with some incorporation of the upper material to avoid stratified layers, where feasible.

    2. Mulch planting beds with 2 inches of organic material

    3. Use compost and other materials that meet these organic content requirements:
        a. The organic content for “pre-approved” amendment rates can be met only using compost meeting the compost specification for Bioretention (BMP T7.30), with the exception that the compost may have up to 35% biosolids or manure.

The compost must also have an organic matter content of 40% to 65%, and a carbon to nitrogen ratio below 25:1.

The carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region.

b. Calculated amendment rates may be met through use of composted material meeting (a.) above; or other organic materials amended to meet the carbon to nitrogen ratio requirements, and not exceeding the contaminant limits identified in Table 220-B, Testing Parameters, in WAC 173-350-220.

The resulting soil should be conducive to the type of vegetation to be established.

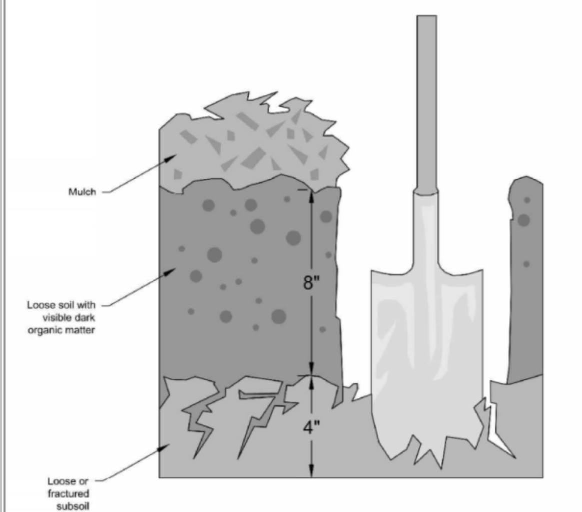
- **Implementation Options**: The soil quality design guidelines listed above can be met by using one of the methods listed below:
    1. Leave undisturbed native vegetation and soil, and protect from compaction during construction.
    2. Amend existing site topsoil or subsoil either at default “pre-approved” rates, or at custom calculated rates based on tests of the soil and amendment.
    3. Stockpile existing topsoil during grading, and replace it prior to planting. Stockpiled topsoil must also be amended if needed to meet the organic matter or depth requirements, either at a default “pre-approved” rate or at a custom calculated rate.
    4. Import topsoil mix of sufficient organic content and depth to meet the requirements.

More than one method may be used on different portions of the same site. Soil that already meets the depth and organic matter quality standards, and is not compacted, does not need to be amended.

Maintenance

- Establish soil quality and depth toward the end of construction and once established, protect from compaction, such as from large machinery use, and from erosion.
- Plant vegetation and mulch the amended soil area after installation.
- Leave plant debris or its equivalent on the soil surface to replenish organic matter.
- Reduce and adjust, where possible, the use of irrigation, fertilizers, herbicides and pesticides, rather than continuing to implement formerly established practices.

BMP T5.13 - POST CONSTRUCTION SOIL QUALITY AND DEPTH



Reprinted from *Guidelines and Resources For Implementing Soil Quality and Depth BMP T5.13 in WDOE Stormwater Management Manual for Western Washington*, 2010, Washington Organic Recycling Council

NOT TO SCALE

DEPARTMENT OF ECOLOGY State of Washington

Figure V-5.3.3
Planting Bed Cross-Section

Revised January 2016

ALL AREAS SUBJECT TO CLEARING AND GRADING THAT HAVE NOT BEEN COVERED BY IMPERVIOUS SURFACE, INCORPORATED INTO A DRAINAGE FACILITY OR ENGINEERED AS STRUCTURAL FILL OR SLOPE SHALL, AT PROJECT COMPLETION, SHALL DEMONSTRATE THE FOLLOWING:

SOIL QUALITY:
A TOPSOIL LAYER WITH A MINIMUM ORGANIC MATTER CONTENT OF 10% DRY WEIGHT IN PLANTING BEDS, AND 5% ORGANIC MATTER CONTENT IN TURF AREAS, AND A PH FROM 6.0 AND 8.0 OR MATCHING THE pH OF THE UNDISTURBED SOIL. USE COMPOST AND OTHER MATERIALS THAT MEET THE COMPOST GUIDELINES.

SOIL DEPTH:
THE TOPSOIL LAYER SHALL HAVE A MINIMUM DEPTH OF EIGHT INCHES EXCEPT WHERE TREE ROOTS LIMIT THE DEPTH OF INCORPORATION OF AMENDMENTS NEEDED TO MEET THE CRITERIA. SUBSOILS BELOW THE TOPSOIL LAYER SHOULD BE SCARIFIED AT LEAST 4 INCHES WITH SOME INCORPORATION OF THE UPPER MATERIAL TO AVOID STRATIFIED LAYERS WHERE FEASIBLE. PLANTING BEDS SHOULD HAVE 2 INCHES OF ORGANIC MATERIAL AS WELL.

COMPOST GUIDELINES:
MUST MEET THE DEFINITION OF "COMPOSTED MATERIAL" IN WAC 173-350-100 AND COMPLIES WITH TESTING PARAMETERS AND OTHER STANDARDS IN WAC 173-350-220. MUST BE PRODUCED AT A PERMITTED COMPOSTING FACILITY. ORGANIC MATTER CONTENT SHALL BE 40% TO 65%. CARBON TO NITROGEN RATIO OF MUST BE LESS THAN THAN 25:1. THE C:N RATIO MAY BE UP TO 35:1 FOR PLANTINGS COMPOSED ENTIRELY OF PUGET SOUND LOWLAND NATIVE SPECIES AND UP TO 40:1 FOR COARSE COMPOST TO BE USED AS A SURFACE MULCH (NOT IN A SOIL MIX).

IMPLEMENTATION OPTIONS

1) LEAVE AS MUCH NATIVE VEGETATION AND SOIL AS POSSIBLE AND PROTECT FROM COMPACTION DURING CONSTRUCTION.

2) AMEND EXISTING SITE TOPSOIL OR SUBSOIL EITHER AT DEFAULT RATES OR AT A CUSTOM CALCULATED RATES BASED ON TESTS OF THE SOIL AND AMENDMENT.

3) IN AREAS REQUIRING CLEARING AND GRADING REMOVE AND STOCKPILE THE DUFF LAYER AND TOPSOIL ON SITE IN A DESIGNATED, CONTROLLED AREA, NOT ADJECT TO PUBLIC RESOURCES AND CRITICAL AREAS. REPLACE IT PRIOR TO PLANTING AND AMEND IF NEEDED TO MEET THE ORGANIC MATTER OR DEPTH REQUIREMENTS.

4) IMPORT TOPSOIL MIX OF SUFFICIENT ORGANIC CONTENT AND DEPTH TO MEET THE REQUIREMENTS.

MORE THAN ONE METHOD MAY BE USED ON DIFFERENT PORTIONS OF THE SAME SITE.

Figure 1 BMP T5.13 Post Construction Soil Quality and Depth

BMP T5.30 Full Dispersion

This BMP works well for large lots - it allows for "fully dispersing" runoff from impervious surfaces and cleared areas of development sites to a protected forested area that is at least 65% of the site in a forest and native condition. This BMP should be considered as a first option but is a choice, the requirements are summarized below.

- Effective impervious surface is minimized to less than 10% of the development site
- 65% or more of the development site protected in forested or native condition (easement)
- Native vegetation flow path of 100 feet for impervious surface (no steeper than 33%)

If a development has less than 65% of a site available to maintain or create into a forested area, this BMP can still be used for a portion of the developed area. The ratio of the native vegetation area to the impervious area, which is dispersed into the native vegetation area, must not be less than 65 to 10. For more information see the Ecology Manual.

BMP T5.10A Downspout Full Infiltration

Purpose and Definition

Downspout full infiltration systems are trench or drywell designs intended only for use in infiltrating runoff from roof downspout drains. They are not designed to directly infiltrate runoff from pollutant-generating impervious surfaces.

Application

Projects subject to Minimum Requirement #5 must provide for individual downspout full infiltration systems or full dispersion if feasible. Evaluate the feasibility, or applicability, of downspout full infiltration unless full dispersion is proposed. Use the evaluation procedure below to determine the feasibility of downspout full infiltration.

Procedure for Evaluating Feasibility

1. Have one of the following prepare a soils report to determine if soils suitable for infiltration are present on the site:
    - A professional soil scientist certified by the Soil Science Society of America (or an equivalent national program)
    - A locally licensed on-site sewage designer
    - A suitably trained person working under the supervision of a professional engineer, geologist, hydrogeologist, or engineering geologist registered in the State of Washington.

    The report shall reference a sufficient number of soils logs to establish the type and limits of soils on the project site. The report should at a minimum identify the limits of **any outwash type soils** (i.e., those meeting USDA soil texture classes ranging from coarse sand and cobbles to medium sand) versus other soil types and include an inventory of topsoil depth.

2. If the lots or site does not have outwash or loam soils, and full dispersion is not feasible, then consider a rain garden or bioretention BMPs (the next lower priority on-site stormwater management system).
3. Complete additional site-specific testing on lots or sites containing outwash (coarse sand and cobbles to medium sand) and loam type soils.

    Individual lot or site tests must consist of at least one soils log at the location of the infiltration system, a minimum of 4 feet in depth from the proposed grade and at least 1 foot below the expected bottom elevation of the infiltration trench or dry well.

    Identify the NRCS series of the soil and the USDA textural class of the soil horizon through the depth of the log, and note any evidence of high ground water level, such as mottling.

4. Downspout infiltration is considered feasible on lots or sites that meet all of the following:
    - 3 feet or more of permeable soil from the proposed final grade to the seasonal high ground water table.
    - At least 1-foot of clearance from the expected bottom elevation of the infiltration trench or dry well to the seasonal high ground water table.
    - The downspout full infiltration system can be designed to meet the minimum design criteria specified below.

Design Criteria for Infiltration Trenches

Figure 2 shows a typical downspout infiltration trench system and Figure 3 shows an alternative infiltration trench system for sites with coarse sand and cobble soils. These systems should be designed according to the following specifications:

- The minimum lengths (linear feet) per 1,000 square feet of roof area based on soil type may be use for sizing downspout infiltration trenches.

Coarse sands cobbles	Medium sand	Fine or Loamy sand	Sandy loam	Loam
20 LF	30 LF	75 LF	125 LF	190 LF

- Maximum length of trench must not exceed 100 feet from the inlet sump.
- Minimum spacing between trench centerlines must be 6 feet.
- Filter fabric must be placed over the drain rock as shown on Figure 2 prior to backfilling.
- Infiltration trenched may be placed in fill material if the fill is placed and compacted under the direct supervision of a geotechnical engineer of professional civil engineer with geotechnical expertise, and if the measured infiltration rate is at least 8 inches per hour. Trench length in fill must be 60 L.F. per 1000 S.F. of roof area.
- Infiltration trenches should not be built on slopes steeper than 25% (4:1). A geotechnical analysis and report may be required on slopes over 15% or if located within 200 feet of the top of slope steeper than 40%, or in a landslide hazard area.

Design Criteria for Infiltration Drywell

Figure 4 shows a typical downspout infiltration drywell system. These systems should be designed according to the following specifications:

- Drywell bottoms must be a minimum of 1 foot above seasonal high groundwater level or impermeable soil layers.
- The minimum volume of gravel per 1,000 square feet of impervious surface served based on soil type may be used in sizing drywells. Coarse sands and cobbles: 60 CF or Medium Sand: 90 CF.
- Drywells must be at least 48 inches in diameter (minimum) and deep enough to contain the gravel amounts specified above for the soil type and impervious. At a minimum this would be a depth of 5 feet (4 feet of gravel and 1 foot of suitable cover material).
- Filter fabric (geotextile) must be placed on the top of the drain rock and on trench or drywell sides prior to backfilling.
- Spacing between drywells must be a minimum of 10 feet.
- Downspout infiltration drywells must not built on slopes greater than 25% (4:1). Drywells may not be placed on or above a landslide hazard area or slopes greater than 15% with evaluation by a professional engineer with geotechnical expertise or licensed geologist, hydrogeologist, or engineering geologist and jurisdiction approval.

Setbacks

- All infiltration systems should be at least 10 feet from any structure, property line, or sensitive area (except slopes over 40%).
- All infiltration systems must be at least 50 feet from the top of any slope over 40%. The setback may be reduced to 15 based on a geotechnical evaluation, but in no instances may it be less than the buffer width.

- For sites with septic systems, infiltration systems must be down gradient of the drain field unless the site topography clearly prohibits subsurface flows from intersecting the drain field.
- Adequate room for maintenance access and equipment should also be considered.

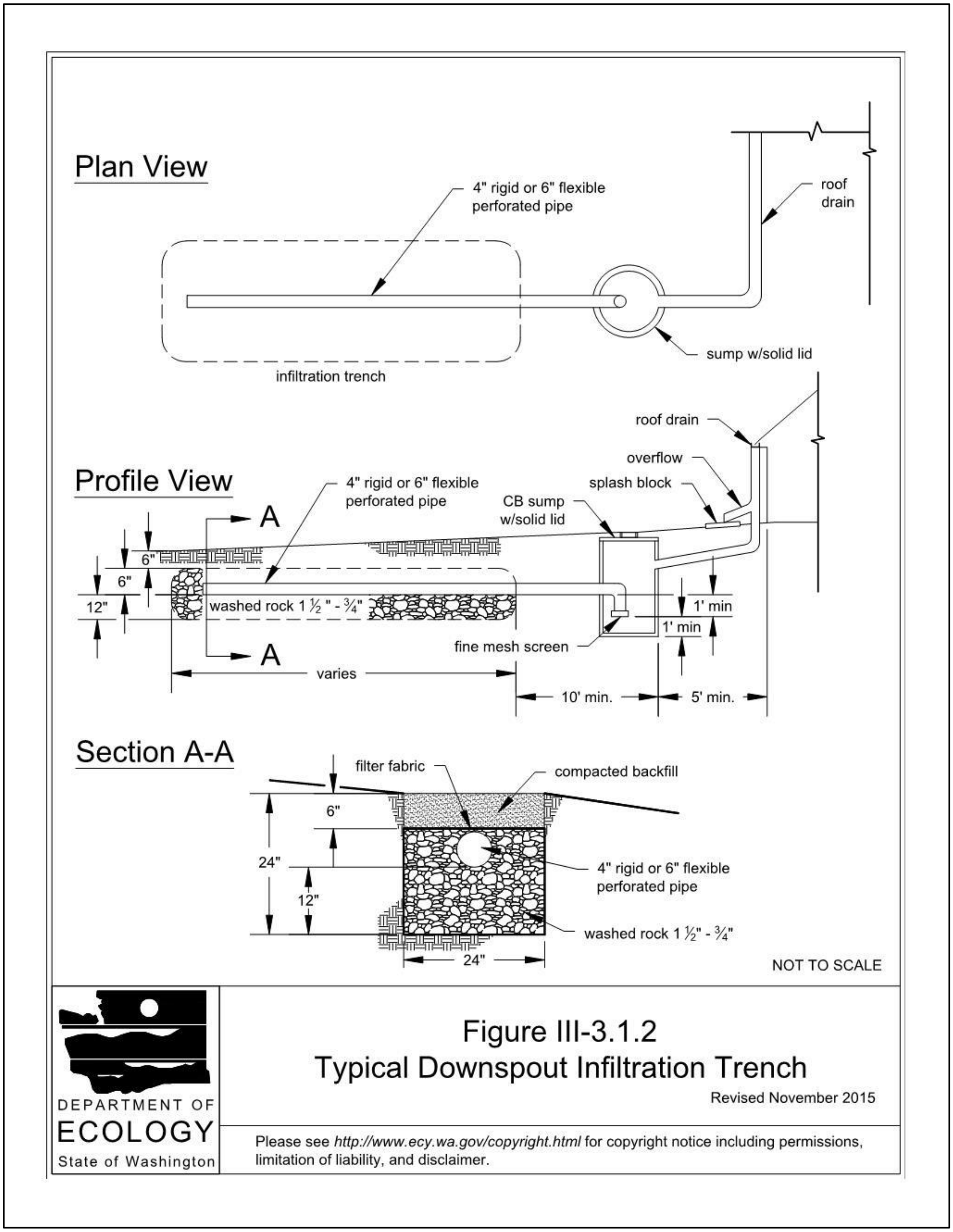


Figure 2 Typical Downspout Infiltration Trench

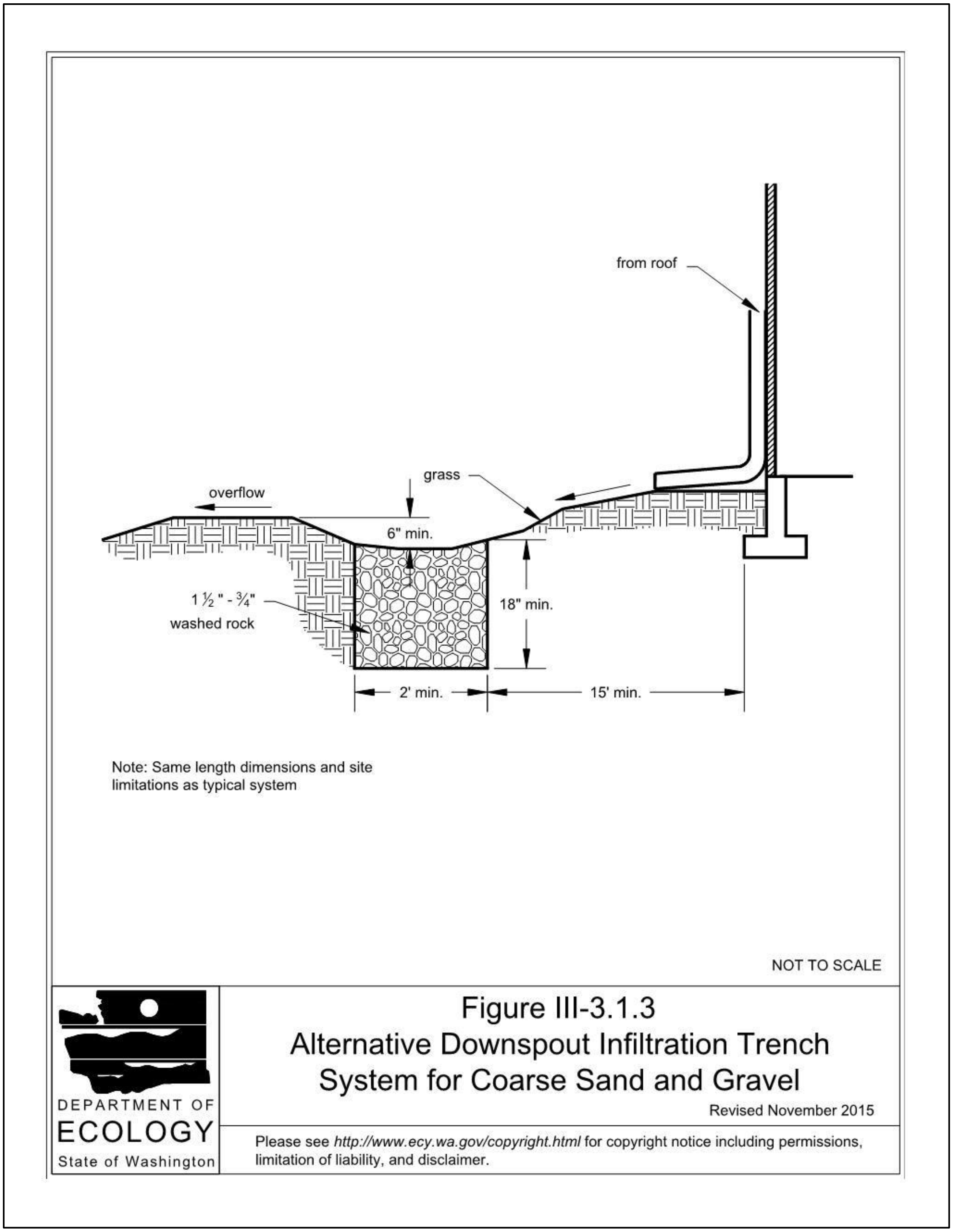


Figure 3 Alternative Downspout Infiltration Trench System for Coarse Sand and Gravel

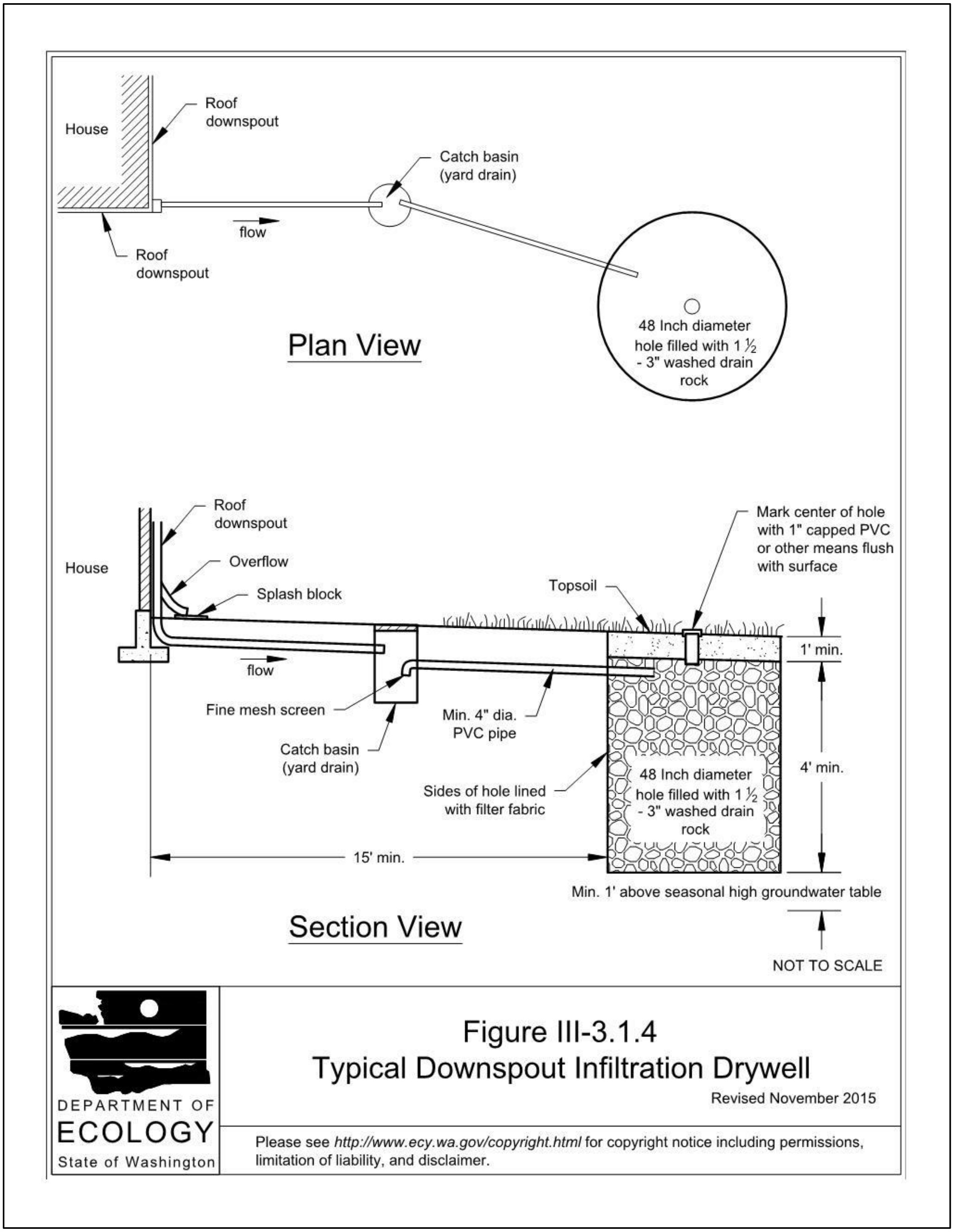


Figure 4 Typical Downspout Infiltration Drywell

BMP T5.14A Rain Gardens

Purpose and Definition

Rain gardens are an on-site stormwater management BMP that can provide effective removal of many stormwater pollutants, and provide reductions in stormwater runoff quantity and surface runoff flow rates.

Rain gardens are non-engineered, shallow, landscaped depressions with compost-amended soils and adapted plants. The depression ponds and temporarily stores stormwater runoff from adjacent areas. A portion of the influent stormwater passes through the amended soil profile and into the native soil beneath. Stormwater that exceeds the storage capacity is designed to overflow to an adjacent drainage system.

Bioretention areas are similar to rain gardens as they are shallow landscaped depressions, with a designed soil mix and plants adapted to the local climate and soil moisture conditions that receive stormwater from a contributing area. Bioretention cells, swales, and planters and planter boxes are an option instead of rain gardens but require an engineer, a typical Bioretention is shown in Figure 5. For more information see the Ecology Manual and BMP T7.30.

Applications and Limitations

Rain gardens are an on-site stormwater management BMP option for projects that have to comply with Minimum Requirements #1 - #5, but not Minimum Requirements #6 - #9. For projects electing to use List #1 of Minimum Requirement #5, rain gardens are to be used to the extent feasible for runoff from roofs and other hard surfaces unless a higher priority BMP is feasible.

Although not required, it is recommended to have the Rain Garden installed by a landscaping company with experience in rain garden construction.

Rain gardens constructed with imported compost materials should not be used within one-quarter mile of phosphorus-sensitive waterbodies like Lake Whatcom. Preliminary monitoring indicates that new rain gardens can add phosphorus to stormwater. Therefore, they should also not be used with an underdrain when the underdrain water would be routed to a phosphorus sensitive receiving water.

Infeasibility Criteria

If a project proponent wishes to use a rain garden BMP though not required to because of these feasibility criteria, they may propose a functional design to the local government.

Citation of any of the following infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g., engineer, geologist, hydrogeologist):

- Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or down gradient flooding.
- Within an area whose ground water drains into an erosion hazard, or landslide hazard area.
- Where the only area available for siting would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, pre-existing structures, or pre-existing road or parking lot surfaces.
- Where the only area available for siting does not allow for a safe overflow pathway to the municipal separate storm sewer system or private storm sewer system.
- Where there is a lack of usable space for rain garden/bioretention facilities at re-development sites, or where there is insufficient space within the existing public right-of-way on public road projects.
- Where infiltrating water would threaten existing below grade basements.
- Where infiltrating water would threaten shoreline structures such as bulkheads.

The following criteria can be cited as reasons for a finding of infeasibility without further justification (though some require professional services):

- Within setbacks from structures.
- Where they are not compatible with surrounding drainage system as determined by the City (e.g., project drains to an existing stormwater collection system whose elevation or location precludes connection to a properly functioning rain garden or bioretention facility.
- Where land for bioretention/rain garden is within area designated as an erosion hazard, or landslide hazard.
- Where the site cannot be reasonably designed to locate bioretention facilities on slopes less than 8%.
- Within 50 feet from the top of slopes that are greater than 20% and over 10 feet of vertical relief.
- For properties with known soil or ground water contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
    - Within 100 feet of an area known to have deep soil contamination
    - Where ground water modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the ground water
    - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area
    - Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant under Chapter 64.70 RCW.
- Within 100 feet of a closed or active landfill.
- Within 100 feet of a drinking water well, or a spring used for drinking water supply.
- Within 10 feet of small on-site sewage disposal drainfield, including reserve areas, and grey water reuse systems.
- Within 10 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is 1100 gallons or less. (As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.
- Within 100 feet of an underground storage tank and connecting underground pipes when the capacity of the tank and pipe system is greater than 1100 gallons.
- Where the minimum vertical separation of 1 foot to the seasonal high water table, bedrock, or other impervious layer would not be achieved below bioretention or rain gardens that would serve a drainage area that is: 1) less than 5,000 sq. ft. of pollution generating impervious surface, and 2) less than 10,000 sq. ft. of impervious surface; and, 3) less than ¾ acres of pervious surface.
- Where the a minimum vertical separation of 3 feet to the seasonal high water table, bedrock or other impervious layer would not be achieved below bioretention that: 1) would serve a drainage area that meets or exceeds: a) 5,000 square feet of pollution-generating impervious surface, or b) 10,000 square feet of impervious surface, or c) three-quarter (3/4) acres of pervious surfaces; and 2) cannot reasonably be broken down into amounts smaller than indicated in(1).
- Where the field testing indicates potential bioretention/rain garden sites have a measured (a.k.a., initial) native soil saturated hydraulic conductivity less than 0.6 inches per hour.

Design Guidelines

Refer to the *Rain Garden Handbook for Western Washington (2013)* for rain garden specifications and construction guidance.

For amending the native soil within the rain garden, Ecology recommends use of compost that meets the compost specification for bioretention (see BMP T7.30). Compost that includes biosolids or manures shall not be used.

For design on projects subject to Minimum Requirement #5, and choosing to use List #1 of that requirement, rain gardens shall have a horizontally projected surface area below the overflow which is at least 5% of the total impervious surface area draining to it. If lawn/landscape area will also be draining to the rain garden, we recommend that the rain garden's horizontally projected surface area below the overflow be increased by 2% of the lawn/landscape area.

Maintenance

Please refer to the Rain Garden Handbook for Western Washington (2013) for tips on mulching, watering, weeding, pruning, and soil management. The “Western Washington Low Impact Development (LID) Operation and Maintenance (O&M) Guidance Document” may be consulted for more detailed guidance.

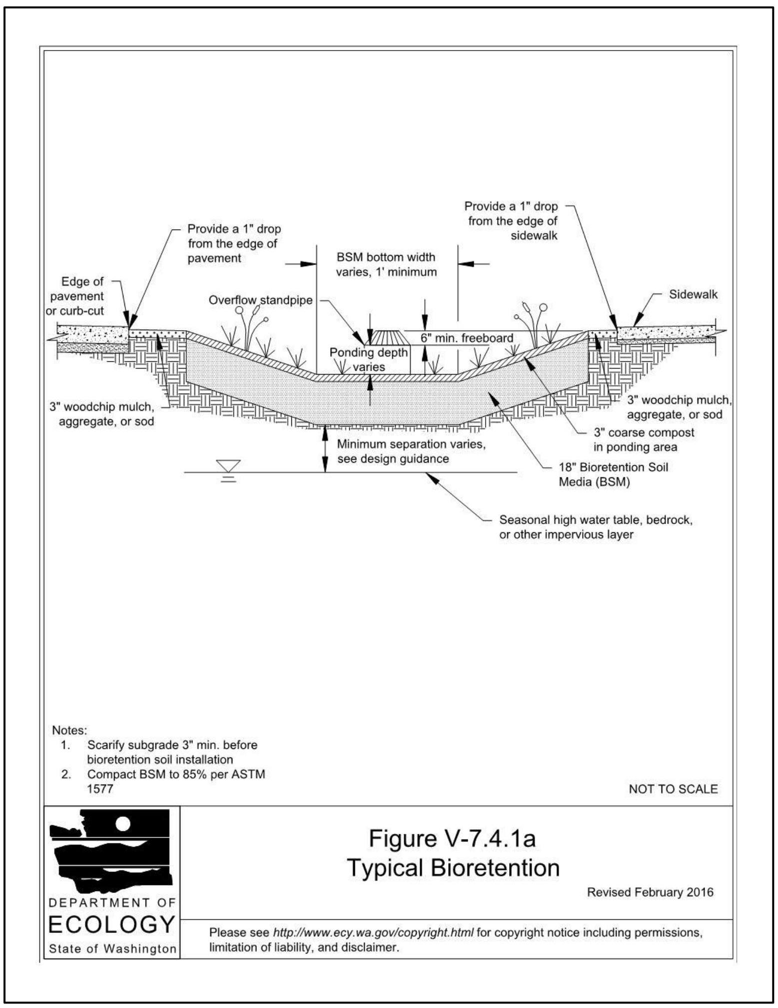


Figure 5 Typical Bioretention Design

BMP T5.10B Downspout Dispersion Systems

Purpose and Definition

Downspout dispersion systems are splash blocks or gravel-filled trenches, which serve to spread roof runoff over vegetated pervious areas. Dispersion attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits.

Applications and Limitations

Downspout dispersion may be used in all lots where downspout full infiltration, full dispersion, and bioretention/rain gardens are not feasible.

Design Criteria General

1. Use downspout trenches designed as shown in Figure 6 and 7 for all downspout dispersion applications except where splash blocks are allowed below.
2. Splash blocks shown in Figure 8 may be used for downspouts discharging to a vegetated flowpath at least 50 least 50 feet in length as measured from the downspout to the downstream property line, structure, slope over 15%, stream, wetland, lake or impervious surface). Sensitive area buffers may count toward flowpath lengths.
3. Cover the vegetated flowpath with well-established lawn or pasture, landscaping with well-established groundcover, or native vegetation with natural groundcover. The groundcover shall be dense enough to help disperse and infiltrate flows and to prevent erosion.
4. If vegetated flowpath (measured as defined above) is less than 25 feet, a perforated stub-out connection (see next section) may be used in lieu of downspout dispersion. A perforated stub-out may also be used where implementation of downspout dispersion might cause erosion or flooding problems, either on site or on adjacent lots. For example, this provision might be appropriate for lots constructed on steep hills where downspout discharge could culminate and might pose a potential hazard for lower lying lots, or where dispersed flows could create problems for adjacent off-site lots. This provision does not apply to situations where lots are flat and on-site downspout dispersal would result in saturated yards. Perforated stub-outs are not appropriate when seasonal water table is <1 foot below trench bottom.

Design Criteria for Dispersion Trenches

Dispersion Trenches should be designed according to the following specifications:

1. A vegetated flowpath of at least 25 feet in length must be maintained between the outlet of the dispersion trench and any property line, structure, stream, wetland, lake or impervious surface. A vegetated flowpath of at least 50 feet in length must be maintained between the outlet of the trench and any steep slope. Sensitive area buffers may count towards flowpath lengths.
2. Trenches serving up to 700 square feet of roof area may be simple 10-foot-long by 2-foot wide gravel filled trenches as shown in Figure 6. For roof areas larger than 700 square feet, a dispersion trench with notched grade board as shown in Figure 6, or alternative material if approved, may be used. The total length of this design must not exceed 50 feet and must provide at least 10 feet of trench per 700 square feet of roof area.
3. Maintain a setback of at least 5 feet between edge of trench and any structure or property line.
4. No erosion or flooding of downstream properties may result.
5. Have a geotechnical engineer or a licensed geologist, hydrogeologist, or engineering geologist evaluate runoff discharged towards landslide hazard areas. Do not place the discharge point on or above slopes greater than 15% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist.

6. For purposes of maintaining adequate separation of flows discharged from adjacent dispersion devices, the outer edge of the vegetated flowpath segment for the dispersion trench must not overlap with other flowpath segments, except those associated with sheet flow from a non-native pervious surface.

Design Criteria for Splashblock Dispersion

A typical downspout splashblock is shown in Figure 6. In general, if the ground is sloped away from the foundation and there is adequate vegetation and area for effective dispersion, splashblocks will adequately disperse storm runoff. If the ground is fairly level, if the structure includes a basement, or if foundation drains are proposed, splashblocks with downspout extensions may be a better choice because the discharge point is moved away from the foundation. Downspout extensions can include piping to a splashblock/discharge point a considerable distance from the downspout, as long as the runoff can travel through a well-vegetated area as described below.

Splashblocks should be designed according to the following specifications:

1. Maintain a vegetated flowpath of at least 50 feet between the discharge point and any property line, structure, slope steeper than 15%, stream, wetland, lake, or other impervious surface. Sensitive area buffers may count toward flowpath lengths.
2. A maximum of 700 square feet of roof area may drain to each splashblock.
3. For purposes of maintaining adequate separation of flows discharged from adjacent dispersion devices, the vegetated flowpath segment for the splashblock must not overlap with other flowpath segments, except those associated with sheet flow from a non-native pervious surface.
4. Place a splashblock or a pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) at each downspout discharge point.
5. No erosion or flooding of downstream properties may result.
6. Have a geotechnical engineer or a licensed geologist, hydrogeologist, or engineering geologist evaluate runoff discharged towards landslide hazard areas. Do not place Splashblocks on or above slopes greater than 15% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or a licensed geologist, hydrogeologist, or engineering geologist, and approval by the Local Plan Approval Authority.

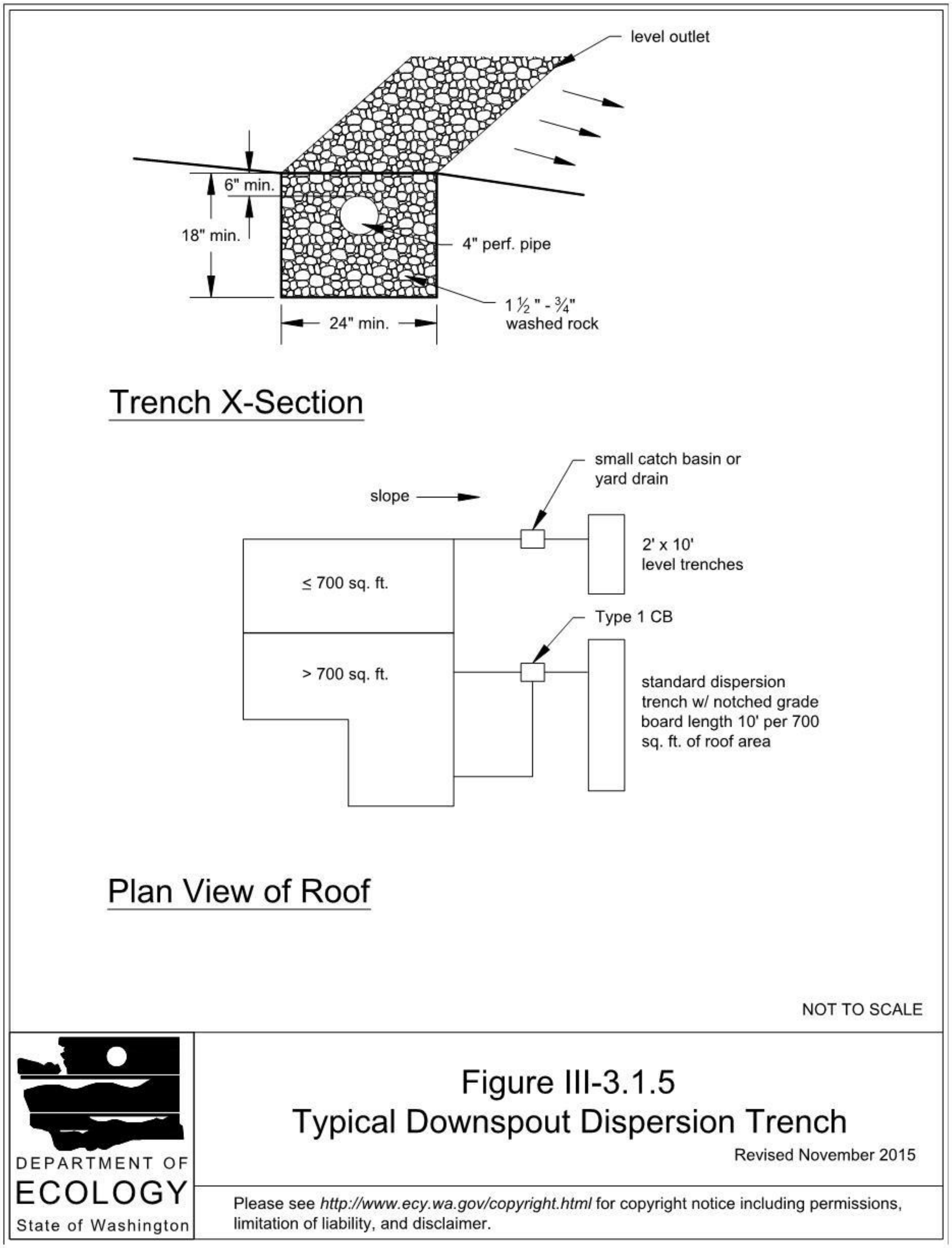


Figure 6 Typical Downspout Dispersion Trench

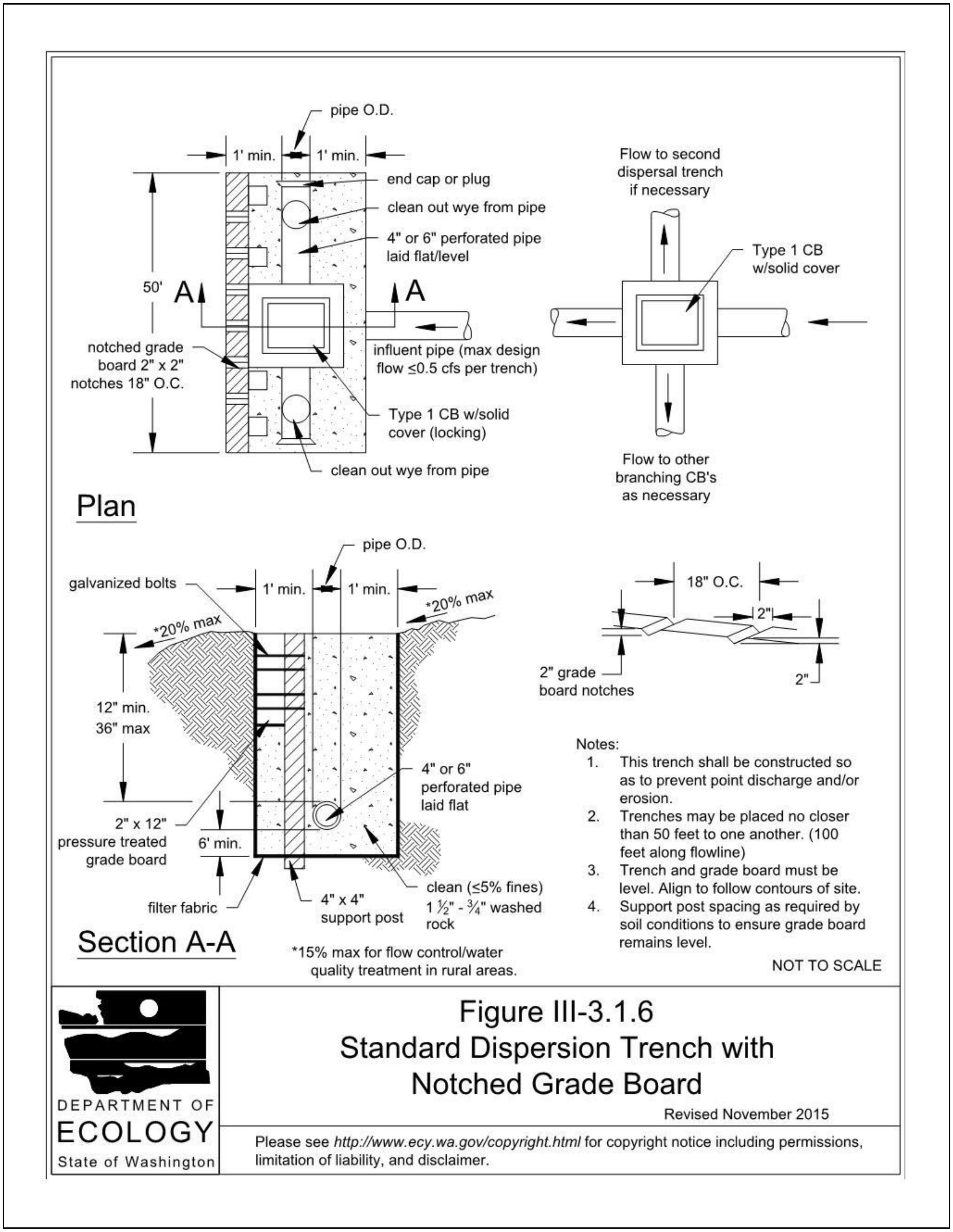


Figure 7 Standard Dispersion Trench with Notched Grade Board

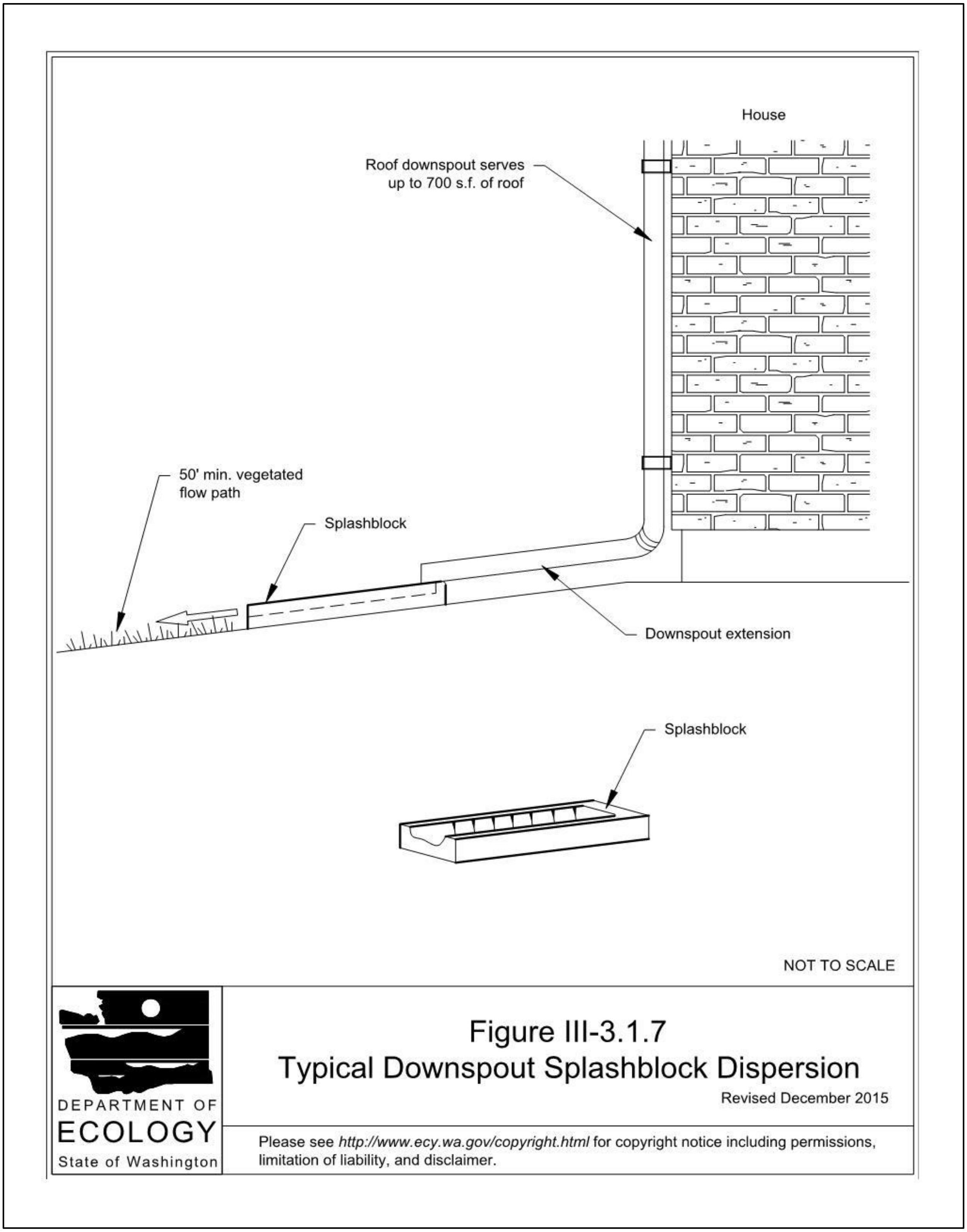


Figure 7 Typical Downspout Splashblock Dispersion

BMP T5.10C Perforated Stub-Out Connections

Purpose and Definition

A perforated stub-out connection is a length of perforated pipe within a gravel-filled trench that is placed between roof downspouts and a stub-out to the local drainage system. Figure 9 illustrates a perforated stub-out connection. These systems are intended to provide some infiltration during drier months. During the wet winter months, they may provide little or no flow control.

Applications and Limitations

Perforated stub-outs are not appropriate when seasonal water table is less than one foot below trench bottom.

In projects subject to Minimum Requirement #5, perforated stub-out connections may be used only when all other higher priority on-site stormwater management BMPs are not feasible, per the criteria for each of those BMPs.

Select the location of the connection to allow a maximum amount of runoff to infiltrate into the ground (ideally a dry, relatively well drained, location). To facilitate maintenance, do not locate the perforated pipe portion of the system under impervious or heavily compacted (e.g. driveways and parking areas) surfaces. Use the same setbacks as for infiltration trenches.

Have a licensed geologist, hydrogeologist, or engineering geologist evaluate potential runoff discharges towards landslide hazard areas. Do not place the perforated portion of the pipe on or above slopes greater than 20% or above erosion hazard areas without evaluation by a professional engineer with geotechnical expertise or qualified geologist and jurisdiction approval.

Design Criteria

Perforated stub-out connections consist of at least 10 feet of perforated pipe per 5,000 square feet of roof area laid in a level, 2-foot wide trench backfilled with washed drain rock. Extend the drain rock to a depth of at least 8 inches below the bottom of the pipe and cover the pipe. Lay the pipe level and cover the rock trench with filter fabric and 6 inches of fill (See Figure 8).

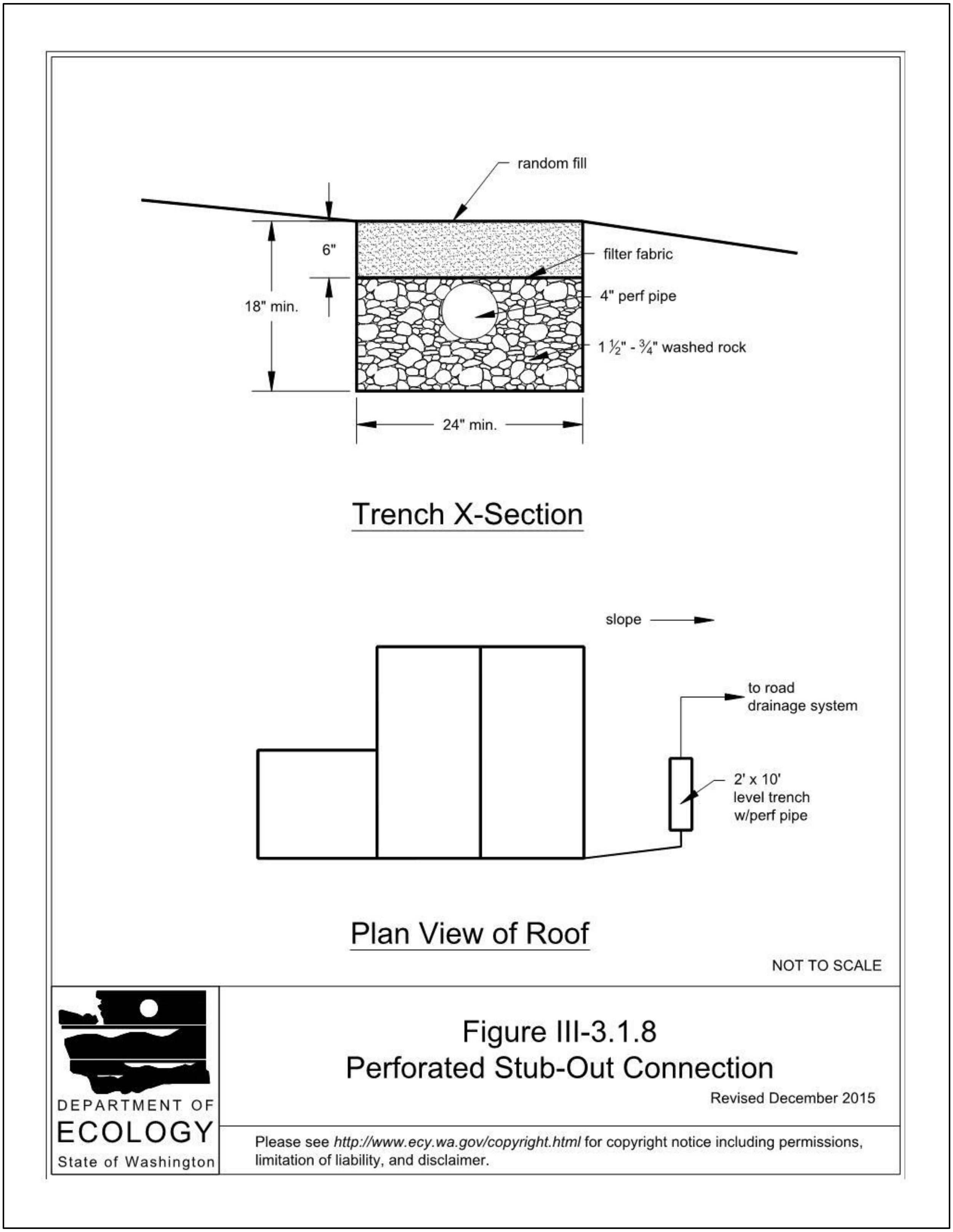


Figure 8 Perforated Stub-Out Connection

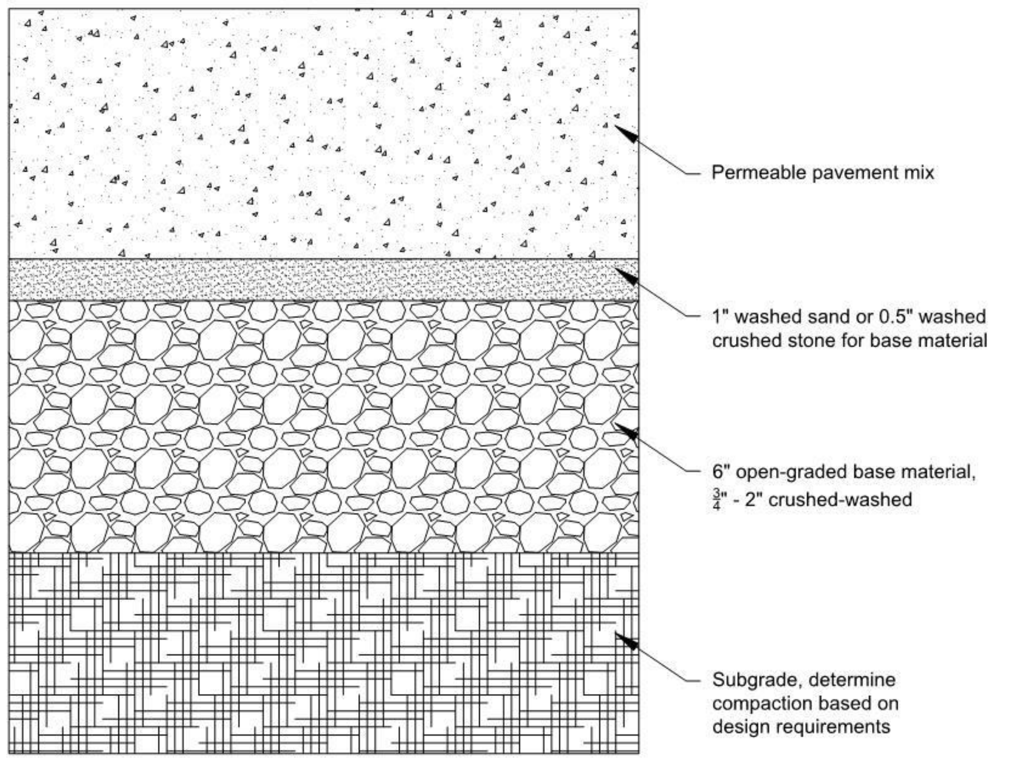
BMP T5.15: Permeable Pavements

Purpose and Definition

Pavement for vehicular and pedestrian travel occupies roughly twice the space of buildings. Stormwater from vehicular pavement can contain significant levels of solids, heavy metals, and hydrocarbon pollutants. Both pedestrian and vehicular pavements also contribute to increased peak flow durations and associated physical habitat degradation of streams and wetlands. Optimum management of stormwater quality and quantity from paved surfaces is, therefore, critical for improving fresh and marine water conditions in Puget Sound.

The general categories of permeable paving systems include:

- **Porous hot or warm-mix asphalt pavement** (see Figure 10) is a flexible pavement similar to standard asphalt that uses a bituminous binder to adhere aggregate together. However, the fine material (sand and finer) is reduced or eliminated and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate.
- **Pervious Portland cement concrete** (see Figure 10) is a rigid pavement similar to conventional concrete that uses a cementitious material to bind aggregate together. However, the fine aggregate (sand) component is reduced or eliminated in the gradation and, as a result, voids form between the aggregate in the pavement surface and allow water to infiltrate.
- **Permeable interlocking concrete pavements (PICP) and aggregate pavers**. (see Figure 11) PICPs are solid, precast, manufactured modular units. The solid pavers are (impervious) high-strength Portland cement concrete manufactured with specialized production equipment. Pavements constructed with these units create joints that are filled with permeable aggregates and installed on an open-graded aggregate bedding course. Aggregate pavers (sometime called pervious pavers) are a different class of pavers from PICP. These include modular precast paving units made with similar sized aggregates bound together with Portland cement concrete with high strength epoxy or other adhesives. Like PICP, the joints or openings in the units are filled with open-graded aggregate and placed on an open graded aggregate bedding course. Aggregate pavers are intended for pedestrian use only.
- **Grid systems** include those made of concrete or plastic. Concrete units are precast in a manufacturing facility, packaged and shipped to the site for installation. Plastic grids typically are delivered to the site in rolls or sections. The openings in both grid types are filled with topsoil and grass or permeable aggregate. Plastic grid sections connect together and are pinned into a dense-graded base, or are eventually held in place by the grass root structure. Both systems can be installed on an open-graded aggregate base as well as a dense-graded aggregate base.



NOT TO SCALE

DEPARTMENT OF ECOLOGY
State of Washington

Figure V-5.3.4
Example of a Permeable Pavement (Concrete or Asphalt) Section

Revised January 2016

Figure 9 Example of a Permeable Pavement (Concrete or Asphalt) Section

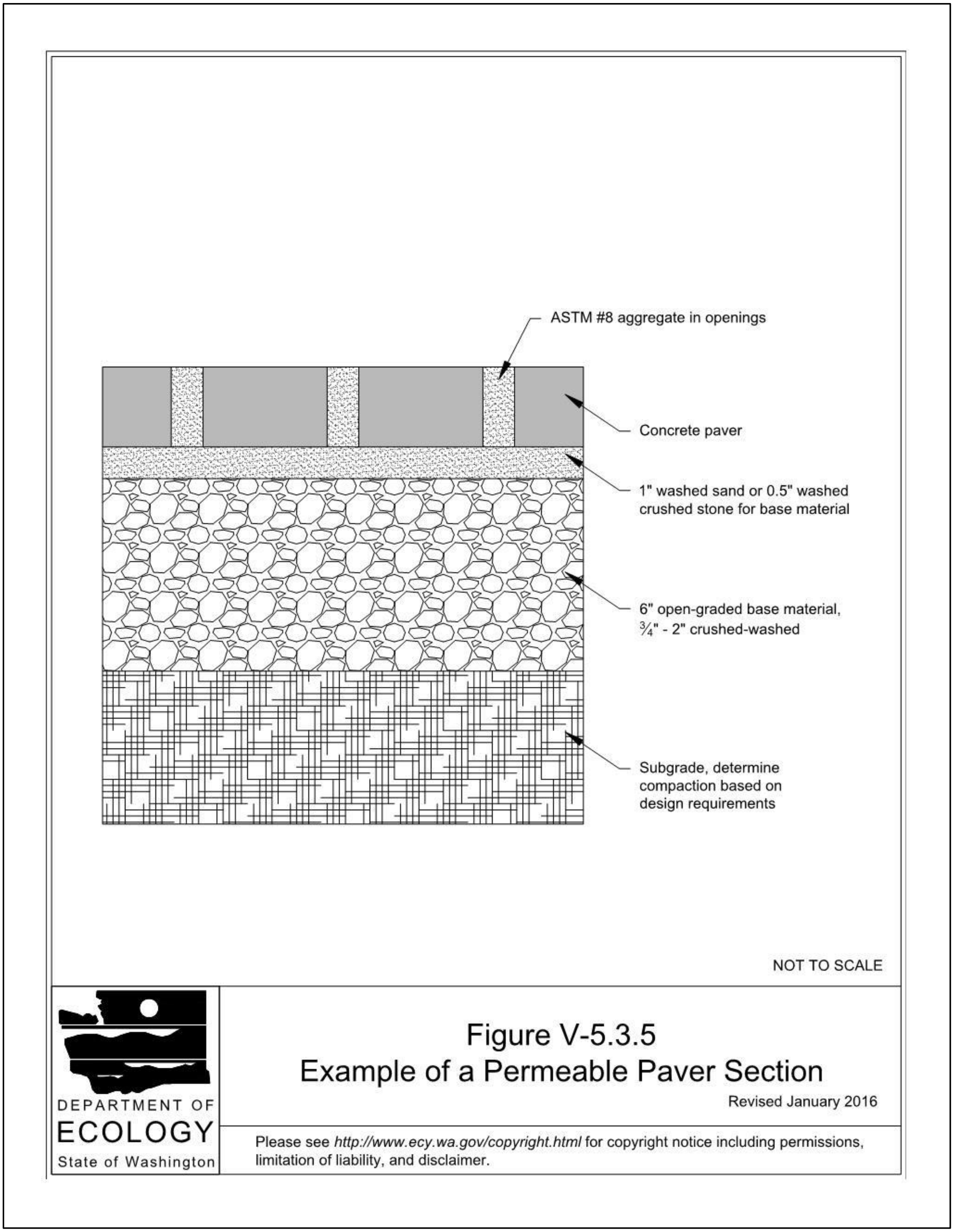


Figure 10 Example of a Permeable Paver Section

Applications and Limitations

Permeable paving surfaces are an important integrated management practice within the LID approach and can be designed to accommodate pedestrian, bicycle and auto traffic while allowing infiltration, treatment and storage of stormwater.

Permeable pavements are appropriate in many applications where traditionally impermeable pavements have been used. Typical applications for permeable paving include parking lots, sidewalks, pedestrian and bike trails, driveways, residential access roads, and emergency and facility maintenance roads.

Limitations:

- No run-on from pervious surfaces is preferred. If runoff comes from minor or incidental pervious areas, those areas must be fully stabilized.
- Unless the pavement, base course, and subgrade have been designed to accept runoff from adjacent impervious surfaces, slope impervious runoff away from the permeable pavement to the maximum extent practicable. Sheet flow from up-gradient impervious areas is not recommended, but permissible if the permeable pavement area is greater than or equal to the impervious pavement area.
- Soils must not be tracked onto the wear layer or the base course during construction.

Infeasibility Criteria

These are conditions that make permeable pavement not required. If a project proponent wishes to use permeable pavement - though not required to because of these feasibility criteria - they may propose a functional design to the City.

These criteria also apply to impervious pavements that would employ stormwater collection from the surface of impervious pavement with redistribution below the pavement.

Citation of any of the following infeasibility criteria must be based on an evaluation of site-specific conditions and a written recommendation from an appropriate licensed professional (e.g, engineer, geologist, hydrogeologist)

- Where professional geotechnical evaluation recommends infiltration not be used due to reasonable concerns about erosion, slope failure, or down gradient flooding.
- Within an area whose ground water drains into an erosion hazard, or landslide hazard area.
- Where infiltrating and ponded water below new permeable pavement area would compromise adjacent impervious pavements.
- Where infiltrating water below a new permeable pavement area would threaten existing below grade basements.
- Where infiltrating water would threaten shoreline structures such as bulkheads.
- Down slope of steep, erosion prone areas that are likely to deliver sediment.
- Where fill soils are used that can become unstable when saturated.
- Excessively steep slopes where water within the aggregate base layer or at the sub-grade surface cannot be controlled by detention structures and may cause erosion and structural failure, or where surface runoff velocities may preclude adequate infiltration at the pavement surface.
- Where permeable pavements cannot provide sufficient strength to support heavy loads at industrial facilities such as ports.
- Where installation of permeable pavement would threaten the safety or reliability of pre-existing underground utilities, pre-existing underground storage tanks, or pre-existing road sub-grades.

The following criteria can be cited as reasons for a finding of infeasibility without further justification (though some require professional services to make the observation):

- Within an area designated as an erosion hazard, or landslide hazard.
- Within 50 feet from the top of slopes that are greater than 20%.
- For properties with known soil or ground water contamination (typically federal Superfund sites or state cleanup sites under the Model Toxics Control Act (MTCA)):
    - Within 100 feet of an area known to have deep soil contamination
    - Where ground water modeling indicates infiltration will likely increase or change the direction of the migration of pollutants in the ground water
    - Wherever surface soils have been found to be contaminated unless those soils are removed within 10 horizontal feet from the infiltration area
    - Any area where these facilities are prohibited by an approved cleanup plan under the state Model Toxics Control Act or Federal Superfund Law, or an environmental covenant.
- Within 100 feet of a closed or active landfill.
- Within 100 feet of a drinking water well, or a spring used for drinking water supply, if the pavement is a pollution-generating surface.
- Within 10 feet of a small on-site sewage disposal drainfield, including reserve areas, and grey water reuse systems.
- Within 10 feet of any underground storage tank and connecting underground pipes, regardless of tank size. As used in these criteria, an underground storage tank means any tank used to store petroleum products, chemicals, or liquid hazardous wastes of which 10% or more of the storage volume (including volume in the connecting piping system) is beneath the ground surface.
- At multi-level parking garages, and over culverts and bridges.
- Where the site design cannot avoid putting pavement in areas likely to have long-term excessive sediment deposition after construction (e.g., construction and landscaping material yards).
- Where the site cannot reasonably be designed to have a porous asphalt surface at less than 5 percent slope, or a pervious concrete surface at less than 10 percent slope, or a permeable interlocking concrete pavement surface (where appropriate) at less than 12 percent slope. Grid systems upper slope limit can range from 6 to 12 percent; check with manufacturer and local supplier.
- Where the native soils below a pollution-generating permeable pavement (e.g., road or parking lot) do not meet the **soil suitability criteria** for providing treatment. See SSC-6 in Section 3.3.7 of Volume III. Note: In these instances, the local government has the option of requiring a six-inch layer of media meeting the soil suitability criteria or the sand filter specification as a condition of construction.
- Where seasonal high ground water or an underlying impermeable/low permeable layer would create saturated conditions within one foot of the bottom of the lowest gravel base course.
- Where underlying soils are unsuitable for supporting traffic loads when saturated. Soils meeting a California Bearing Ratio of 5% are considered suitable for residential access roads.
- Where appropriate field testing indicates soils have a measured (a.k.a., initial) native soil saturated hydraulic conductivity less than 0.3 inches per hour. (Note: In these instances, unless other infeasibility restrictions apply, roads and parking lots may be built with an underdrain, preferably elevated within the base course, if flow control benefits are desired.)
- Roads that receive more than very low traffic volumes, and areas having more than very low truck traffic. Roads with a projected average daily traffic volume of 400 vehicles or less are very low volume roads (AASHTO, 2001)(U.S. Dept. of Transportation, 2013). Areas with very low truck traffic volumes are roads and other areas not subject to through truck traffic but may receive up to weekly use by utility trucks (e.g., garbage, recycling), daily school bus use, and multiple daily use by pick-up trucks, mail/parcel delivery trucks, and maintenance vehicles. Note: This infeasibility criterion does not extend to sidewalks and other non-traffic bearing surfaces.

- Where replacing existing impervious surfaces unless the existing surface is a non-pollution generating surface over an outwash soil with a saturated hydraulic conductivity of four inches per hour or greater.
- At sites defined as "high use sites" in Volume I of this manual.
- In areas with "industrial activity" as identified in 40 CFR 122.26(b)(14).
- Where the risk of concentrated pollutant spills is more likely such as gas stations, truck stops, and industrial chemical storage sites.

Design Guidelines

Subgrade

- Compact the subgrade to the minimum necessary for structural stability. Two guidelines currently used to specify subgrade compaction are "firm and unyielding" (qualitative), and 90- 92% Standard Proctor (quantitative). Do not allow heavy compaction due to heavy equipment operation. The subgrade should not be subject to truck traffic.
- To prevent compaction when installing the aggregate base, the following steps (back-dumping) should be followed: 1) the aggregate base is dumped onto the subgrade from the edge of the installation and aggregate is then pushed out onto the subgrade; 2) trucks then dump subsequent loads from on top of the aggregate base as the installation progresses.
- Use on soil types A through C.

Separation or Bottom Filter Layer (recommended but optional)

- A layer of sand or crushed stone (0.5 inch or smaller) graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect underlying soil from compaction, and serve as a transition between the base course and the underlying geotextile material.

Base material

- The material must be free draining and compliant with WSDOT specifications.
- To increase infiltration, improve flow attenuation and reduce structural problems associated with subgrade erosion on slopes, impermeable check dams may be placed on the subgrade and below the pavement surface (See Figure 12). Check dams should have an overflow drain invert placed at the maximum ponding depth. The distance between berms will vary depending on slope, flow control goals and cost.

Wearing layer

- For all surface types, a minimum initial infiltration rate of 20 inches per hour is necessary. To improve the probability of long-term performance, significantly higher initial infiltration rates are desirable.
- ***Porous Asphalt:*** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 16 – 25% is typical.
- ***Pervious Concrete:*** Products must have adequate void spaces through which water can infiltrate. A void space within the range of 15 – 35% is typical.
- ***Grid/lattice systems filled with gravel, sand, or a soil of finer particles with or without grass:*** The fill material must be at least a minimum of 2 inches of sand, gravel, or soil.
- ***Permeable Interlocking Concrete Pavement and Aggregate Pavers*:** Pavement joints should be filled with No. 8, 89 or 9 stone.

Drainage conveyance

Roads should still be designed with adequate drainage conveyance facilities as if the road surface was impermeable. Roads with base courses that extend below the surrounding grade should have a designed drainage flow path to safely move water away from the road prism and into the roadside drainage facilities. Use of perforated storm drains to collect and transport infiltrated water from under the road surface will result in less effective designs and less flow reduction benefit.

Underdrains

Note that if an underdrain is placed at or near the bottom of the aggregate base in a permeable pavement design, the permeable pavement is no longer considered an LID BMP and cannot be used to satisfy Minimum Requirement #5. However, designs utilizing an underdrain that is elevated within the aggregate base course to protect the pavement wearing course from saturation is considered an LID BMP and can be used to satisfy Minimum Requirement #5. See Appendix III-C and the WWHM User's Manual for guidance in modeling permeable pavements with underdrains.

Acceptance test

- Driveways can be tested by simply throwing a bucket of water on the surface. If anything other than a scant amount puddles or runs off the surface, additional testing is necessary prior to accepting the construction.
- Roads may be initially tested with the bucket test. In addition, test the initial infiltration with a 6-inch ring, sealed at the base to the road surface, or with a sprinkler infiltrometer. Wet the road surface continuously for 10 minutes. Begin test to determine compliance with 20 inches per hour minimum rate. Use of ASTM C1701 is also recommended.

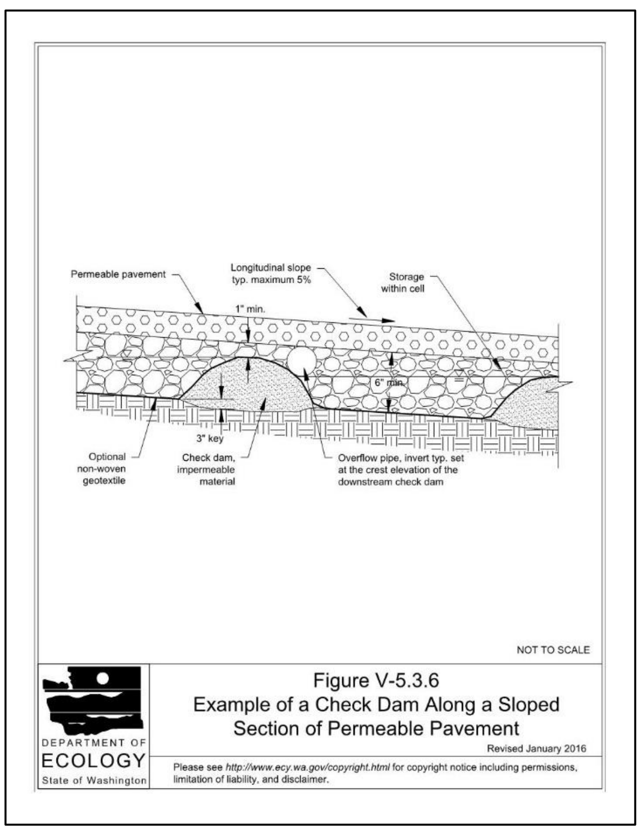


Figure 11 Example of a Check Dam Along a Sloped Section of Permeable Pavement

Maintenance

Please see table 22 within Table 4.5.2 in Chapter 4 of this Volume V.

Maintenance recommendations for all facilities:

- Erosion and introduction of sediment from surrounding land uses should be strictly controlled after construction by amending exposed soil with compost and mulch, planting exposed areas as soon as possible, and armoring outfall areas.
- Surrounding landscaped areas should be inspected regularly and possible sediment sources controlled immediately.
- Installations can be monitored for adequate or designed minimum infiltration rates by observing drainage immediately after heavier rainstorms for standing water or infiltration tests using ASTM C1701.
- Clean permeable pavement surfaces to maintain infiltration capacity at least once or twice annually following recommendations below.
- Utility cuts should be backfilled with the same aggregate base used under the permeable paving to allow continued conveyance of stormwater through the base, and to prevent migration of fines from the standard base aggregate to the more open graded permeable base material (Diniz, 1980).
- Ice buildup on permeable pavement is reduced and the surface becomes free and clear more rapidly compared to conventional pavement. For western Washington, deicing and sand application may be reduced or eliminated and the permeable pavement installation should be assessed during winter months and the winter traction program developed from those observations. Vacuum and sweeping frequency will likely be required more often if sand is applied.

Porous asphalt and pervious concrete

- Clean surfaces using suction, sweeping with suction or high-pressure wash and suction (sweeping alone is minimally effective). Hand held pressure washers are effective for cleaning void spaces and appropriate for smaller areas such as sidewalks.
- Small utility cuts can be repaired with conventional asphalt or concrete if small batches of permeable material are not available or are too expensive.

Permeable pavers

- ICPI recommends cleaning if the measured infiltration rate falls below 10 in/hr.
- Use sweeping with suction when surface and debris are dry 1-2 times annually (see next bullet for exception). Apply vacuum to a paver test section and adjust settings to remove all visible sediment without excess uptake of aggregate from paver openings or joints. If necessary replace No 8, 89 or 9 stone to specified depth within the paver openings. Washing or power washing should not be used to remove debris and sediment in the openings between the pavers (Smith, 2000).
- For badly clogged installations, wet the surface and vacuumed aggregate to a depth that removes all visible fine sediment and replace with clean aggregate.
- If necessary use No 8, 89 or 9 stone for winter traction rather than sand (sand will accelerate clogging).
- Pavers can be removed individually and replaced when utility work is complete.
- Replace broken pavers as necessary to prevent structural instability in the surface.
- The structure of the top edge of the paver blocks reduces chipping from snowplows. For additional protection, skids on the corner of plow blades are recommended.
- For a model maintenance agreement see "Permeable Interlocking Concrete Pavements" (Smith, 2011).

Plastic or Concrete grid systems

- Remove and replace top course aggregate if clogged with sediment or contaminated (vacuum trucks for stormwater collection basins can be used to remove aggregate).
- Remove and replace grid segments where three or more adjacent rings are broken or damaged.
- Replenish aggregate material in grid as needed.
- Snowplows should use skids to elevate blades slightly above the gravel surface to prevent loss of top course aggregate and damage to plastic grid.
- For grass installations, use normal turf maintenance procedures except do not aerate. Use very slow release fertilizers if needed.

BMP T5.11 Concentrated Flow Dispersion

Purpose and Definition

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of the runoff into the conveyance system, allowing for some infiltration, and providing some water quality benefits.

Applications and Limitations

Use this BMP in any situation where concentrated flow can be dispersed through vegetation. Figure 13 shows two possible ways of spreading flows from steep driveways.

Design Guidelines

- Maintain a vegetated flowpath of at least 50 feet between the discharge point and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface.
- A maximum of 700 square feet of impervious area may drain to each concentrated flow dispersion BMP.
- Provide a pad of crushed rock (a minimum of 2 feet wide by 3 feet long by 6 inches deep) at each discharge point.
- No erosion or flooding of downstream properties may result.
- Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. Do not place the discharge point on or above slopes greater than 20%, or above erosion hazard areas, without evaluation by a geotechnical engineer or qualified geologist.
- For sites with septic systems, the discharge point must be ten feet down gradient of the drain field primary and reserve areas, unless if site topography clearly prohibits flows from intersecting the drain field.

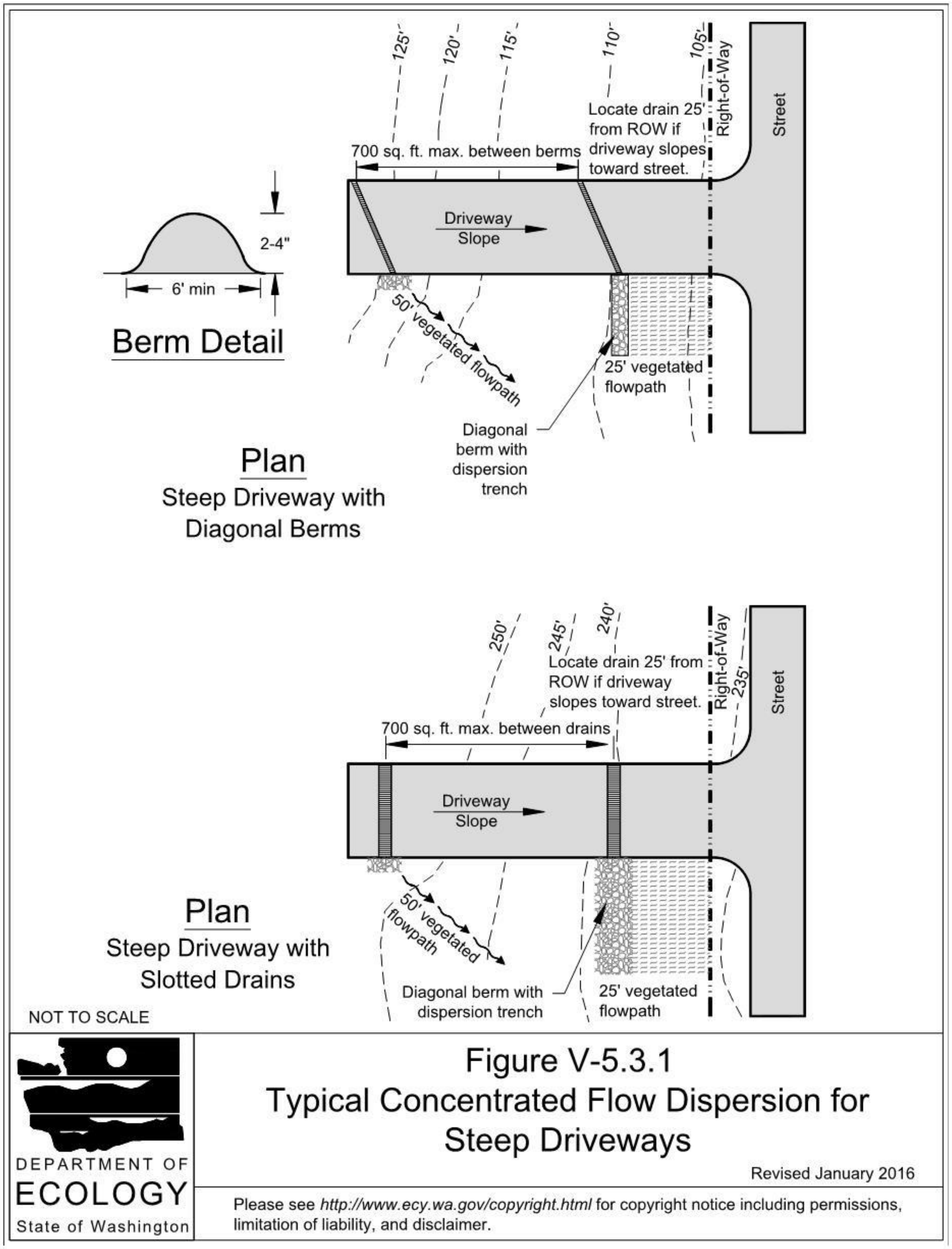


Figure 12 Typical Concentrated Flow Dispersion for Steep Driveways

BMP T5.12 Sheet Flow Dispersion

Purpose and Definition

Sheet flow dispersion is the simplest method of runoff control. This BMP can be used for any impervious or pervious surface that is graded to avoid concentrating flows). Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective attenuation and treatment.

Applications and Limitations

Use this BMP for flat or moderately sloping (< 15% slope) surfaces such as driveways, sports courts, patios, roofs without gutters, lawns, pastures; or any situation where concentration of flows can be avoided.

Design Guidelines

- See Figure 13 or Figure 14 for details for driveways.
- Provide a 2-foot-wide transition zone to discourage channeling between the edge of the impervious surface (or building eaves) and the downslope vegetation. This transition zone may consist of an extension of subgrade material (crushed rock), modular pavement, drain rock, or other material if approved.
- Provide a 10-foot-wide vegetated buffer for up to 20 feet of width of paved or impervious surface. Provide an additional 10 feet of vegetated buffer width for each additional 20 feet of impervious surface width or fraction thereof. (For example, if a driveway is 30 feet wide and 60 feet long provide a 20-foot wide by 60-foot long vegetated buffer, with a 2-foot by 60-foot transition zone.)
- No erosion or flooding of downstream properties may result.
- Runoff discharge toward landslide hazard areas must be evaluated by a geotechnical engineer or a qualified geologist. Do not allow sheet flow on or above slopes greater than 20%, or above erosion hazard areas, without evaluation by a geotechnical engineer or qualified geologist.

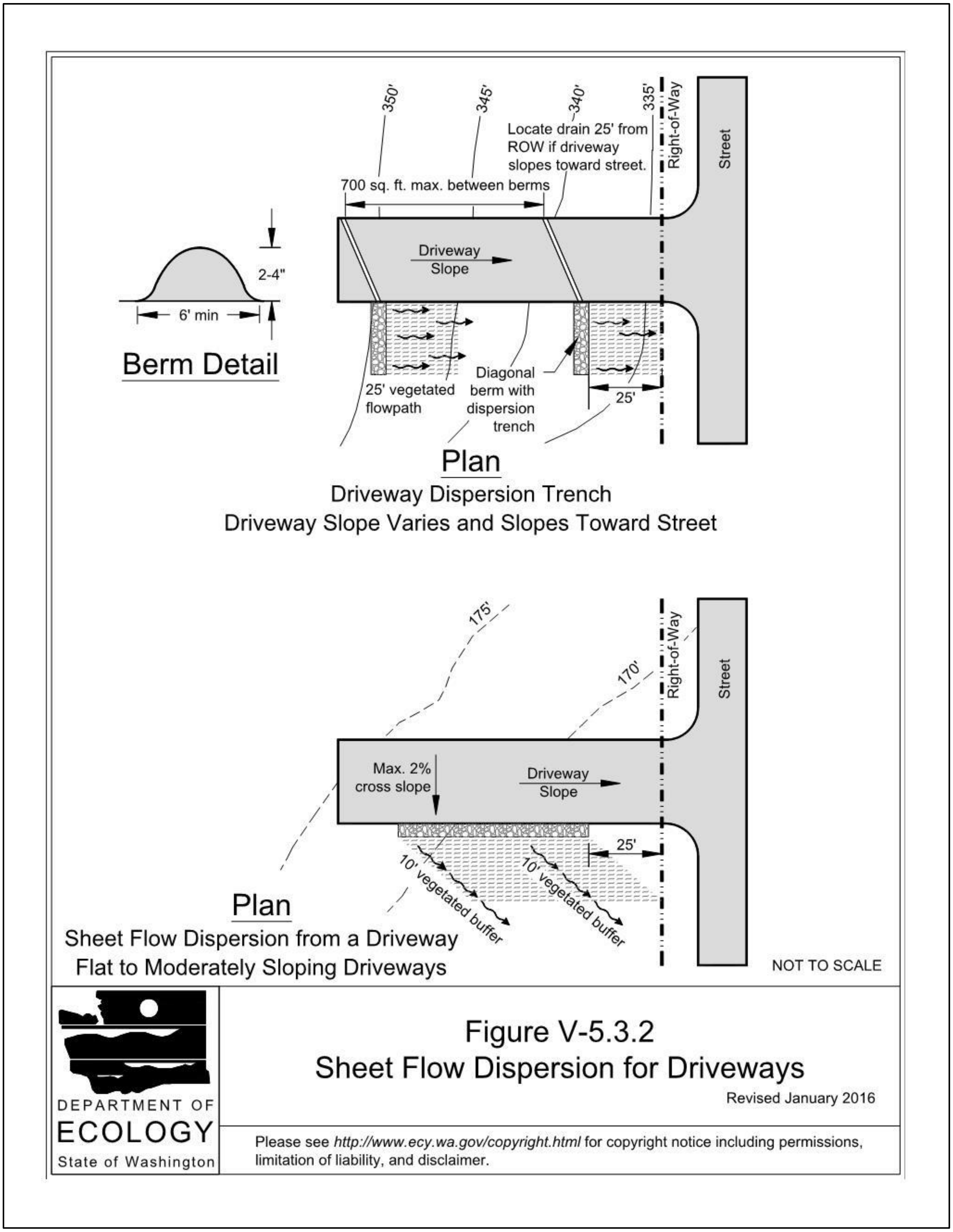


Figure 13 Sheet Flow Dispersion for Driveways