APPENDIX C
MEDIA FILTRATION FACILITIES

1.0 Introduction

This appendix provides information for the design of media filtration facilities such as bioretention ponds or cells, and bioslopes.

Media filtration, where stormwater flows through soil, amended soil, compost or a special mix of materials, allows for maximum absorption of dissolved pollutants, as well as physical trapping of particles. It is a major component of treatment by infiltration. Media filtration BMPs may infiltrate into the soil all, some or none of the stormwater they treat.

2.0 Bioretention Facility

A bioretention facility is a roadside depression, cell, basin, or pond constructed with amended soils, plantings, and may either include an underdrain system or dispose of stormwater entirely through infiltration. They are designed to capture the water quality design volume and filter out the pollutants by filtering the runoff through the water quality mix. The filtration process removes a variety of pollutants through physical, biological and chemical treatment mechanisms. The water in the facility exits through an under drain pipe below the water quality mix or infiltration into the soils underneath. The appropriate discharge method, infiltration, underdrains, or a combination of the two, is based on site infiltration rates determined from infiltration testing at the proposed facility location.

Bioretention is a BMP that can be utilized as a LID or conventional treatment facility. It is categorized as an LID when several small facilities are placed at relatively short intervals along the highway, and as a conventional BMP when the stormwater is collected and conveyed to a single, large facility.

A typical bioretention facility has the following facility features and components:

- **Storage –** The provided facility volume necessary to temporarily store the runoff from the water quality design storm until it filters through the Treatment Zone.
- **Treatment Zone using water quality mix –** The layer of the water quality mix covering the bed of the facility. Stormwater runoff flows down through the treatment zone and either infiltrates into underlying soils or is collected into the under drain pipe.
- **Underdrain Pipe –** The perforated pipe placed beneath the Treatments Zone to collect the treated stormwater and discharge it into a conveyance system. This is put in place when the underlying soils are not adequate or suitable for infiltration.
- **Auxiliary Outlet –** Provided to bypass high flows.

Figure 1 is a general configuration of a bioretention facility. The actual configuration will vary depending on site constraints and applicable design criteria.

Bioretention ponds or cells can be placed:

- adjacent to roadways
- in medians,
- within interchanges,
- adjacent to ramps, and
- away from the highway

2.1 Design Criteria

This section describes the features of bioretention facilities and the design criteria that apply specifically to these installations. Also apply the general requirements discussed in Section 14.10.

2.1.1 Site Selection

Area Requirement

1. The site must be of sufficient size to accommodate the facility and also to provide adequate setback distances. The proper setback distances are important to ensure slope stability, and maintenance access. General siting requirements are discussed in Section 14.9.

Slope

1. A Bioretention facility may sit on flat to moderately sloping ground. Slopes will require the use of an embankment or wall on at least one side, which will increase the cost and footprint of the facility (see Embankments below).

Groundwater

1. A minimum distance of 3 feet from the pond bottom or drain rock bed bottom to bedrock or seasonally high water table is required.

Infiltration Rate of the Existing Soil

1. Soils in NRCS hydrologic soil groups A and B are appropriate for Bioretention facilities using only infiltration for stormwater disposal. Underdrains are required for hydrologic soil groups C and D. Final determination of the need for underdrains requires establishing the existing soil's long term infiltration rate.
2. The long term infiltration rate of the native soil can be established with field testing or estimated as outlined in Design Procedure Section 2.2, Step 5.

3. Design or long term infiltration rate of 9 inches per hour or less is acceptable outside of groundwater protection areas and is acceptable at providing water quality treatment for groundwater protection. See Appendix E, Section 2 regarding organic matter content requirement. Place water quality mix over soils with a design or long term infiltration rate greater than 9 inches per hour. Determine any special requirements for groundwater protection areas and wellhead protection zones. Also see Water Quality Mix section for guidance on organic content requirements.

Inappropriate Site Conditions

1 Geotechnical stability. Bioretention facilities should not be placed on potentially unstable slopes

2 Hazardous materials. Bioretention facilities should not be placed in areas with hazardous material contamination of the soil or groundwater.

2.1.2 Facility Components

Pretreatment

1. A pretreatment facility component is required to be installed upstream of the proposed facility. Design a pretreatment facility component according to guidance provided in Appendix E.

Pond (basin) or Cell Geometry

1. The **facility bottom** must be flat.

2. The facility **storage volume** is designed to temporarily store the water quality volume. This is the volume between the bottom of the pond up to the start of the freeboard volume. The water quality volume is the predicted volume of runoff for the proposed conditions using the appropriate water quality design storm. Freeboard volume is in addition to the storage volume of the water quality volume.

3. The maximum water quality depth is 3 feet (not including freeboard). Other considerations when setting the depth include public safety, land availability, land value, present and future land use, water table fluctuations, soil characteristics, shading, maintenance requirements, and freeboard. Aesthetically pleasing features are also important in urbanized areas.

4. The **freeboard** required is 1 foot minimum between the water quality design storm water surface elevation to the top of embankment. Freeboard is the vertical distance between the design water surface and the top of embankment, as shown in Figures 1.

5. The **minimum bottom width** for ponds is 10 feet to provide the needed storage and allow for maintenance. For bioretention cells (LID application) the minimum width is 4 feet.

6. **Interior side slopes** should not be steeper than 1V:4H unless approved by the project design team and the maintenance district.

7. **Facility walls** may be retaining walls designed in accordance with the ODOT Geotechnical Design Manual. A fence is typically provided along the top of the wall.

Embankments

Pond or cell berm embankments are often needed to obtain sufficient storage volume. Facility berm embankments must meet the following criteria:

1. Vegetated berm embankments must be less than 20 feet in height and have exterior side slopes no steeper than 1V:3H and interior side slopes no steeper than 1V:4H. Riprap-protected embankments should be no steeper than 1V:4H.

2. Facility berm embankments higher that 6 feet shall be **designed by a geotechnical enginee**r.

3. The **minimum top width** shall be 6 feet for facility berms 6 feet high or less, or as recommended by a geotechnical engineer for higher berms.

Maintenance Access

Note: Heavy equipment is not allowed along the bottom of these facilities. Note this limitation in the facility's operation and maintenance manual.

1. An **access road** shall be provided to the primary and auxiliary outlet control structures of bioretention ponds. The proposed access road must be able to support heavy equipment such as a vactor truck, dump truck, track how, or large mower. Bioretention cells may not need an access road if the Maintenance District concurs site conditions are acceptable for access.

2. Access road must be 16 feet in **width**.

3. The access road **maximum longitudinal slope** must be:

   a) 2 percent (edge of pavement to a longitudinal distance of 20 feet)
   b) 10 percent (20 feet from edge of pavement to end of access road)

4. The access road **maximum cross slope** is 4 percent.

5. An access ramp is required for mowing, repairs, and sediment removal. The ramp must extend to the pond bottom.
6. **Maximum grade** of an access road or ramp shall be 10 percent.

7. **Manhole lids** located in non-traffic areas such as grassed areas or behind guardrail must be set 1 foot above finish ground so that manhole location is visible for locating and for maintenance. This should be coordinated with the maintenance districts, lids may be placed flush with the finished grade at the request of the serving maintenance district. Lid elevations must match proposed finish grade in traffic areas. No manholes should be placed in ponds or cells.

Bottom Marker

1. A **bottom marker** is required to indicate the bottom elevation of the facility. The marker must be a minimum 1.5 foot by 1.5 foot concrete pad placed along the bottom of pond. The elevation of the top of concrete pad must be equal to the facility bottom elevation.

2. Porous pavers are not allowed in bioretention facilities.

3. Note the following in the facility's operation and maintenance manual:

   - the location of the bottom marker
   - check and restore bottom elevation referencing bottom marker after performing sediment removal work

Water Quality Mix

There are three design options to establish a "Water Quality Mix" that meets criteria for organic content, long term hydraulic conductivity and other soil characteristics. See Appendix E.

Planting Requirements

1. Grass shall be established along the sides and bottom of facility unless the local climate is unsuitable. Where grass is not appropriate, side slopes should be protected against erosion by other means. Note that urban jurisdictions may require plants and shrubs instead of grass.

2. Permanent seeding is best performed as follows:

   - West of the Cascades – March 1 through May 15 and September 1 through October 31 if grass areas are watered regularly during the establishment period.
   - East of the Cascades – October 1 through February 1 or March 1 through October 1 if grass areas are watered regularly during the establishment period

Field Markers

1. Field Markers are required to be installed at the start and end of a facility's maintenance area. Marking guidance is provided in Chapter 17.

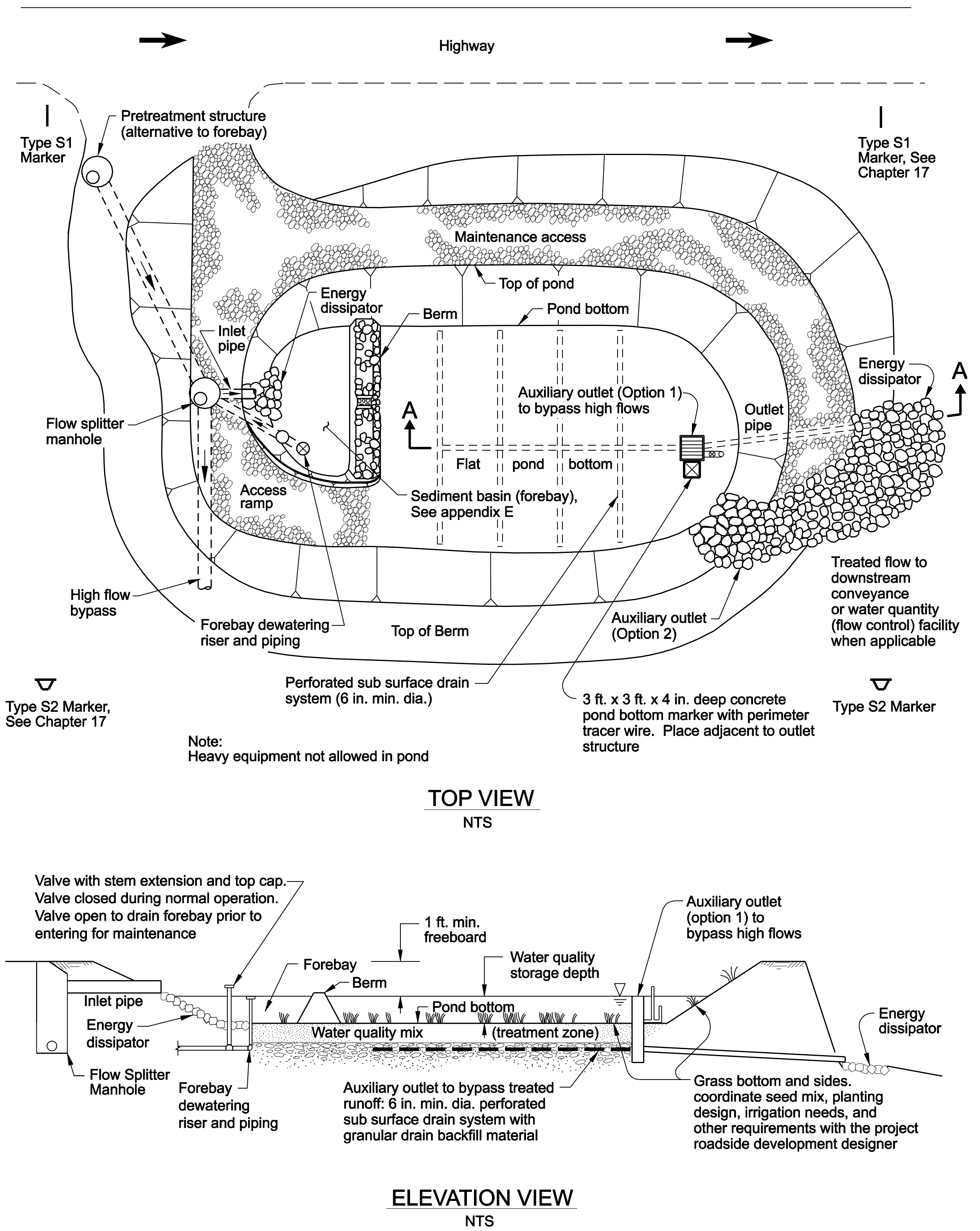
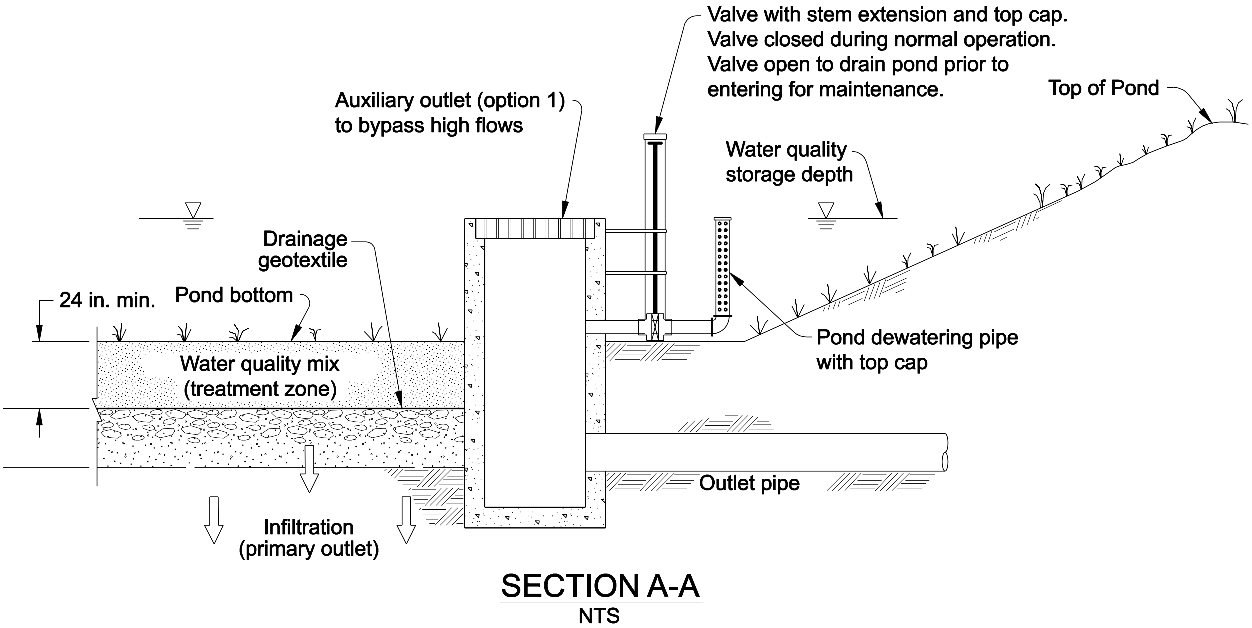
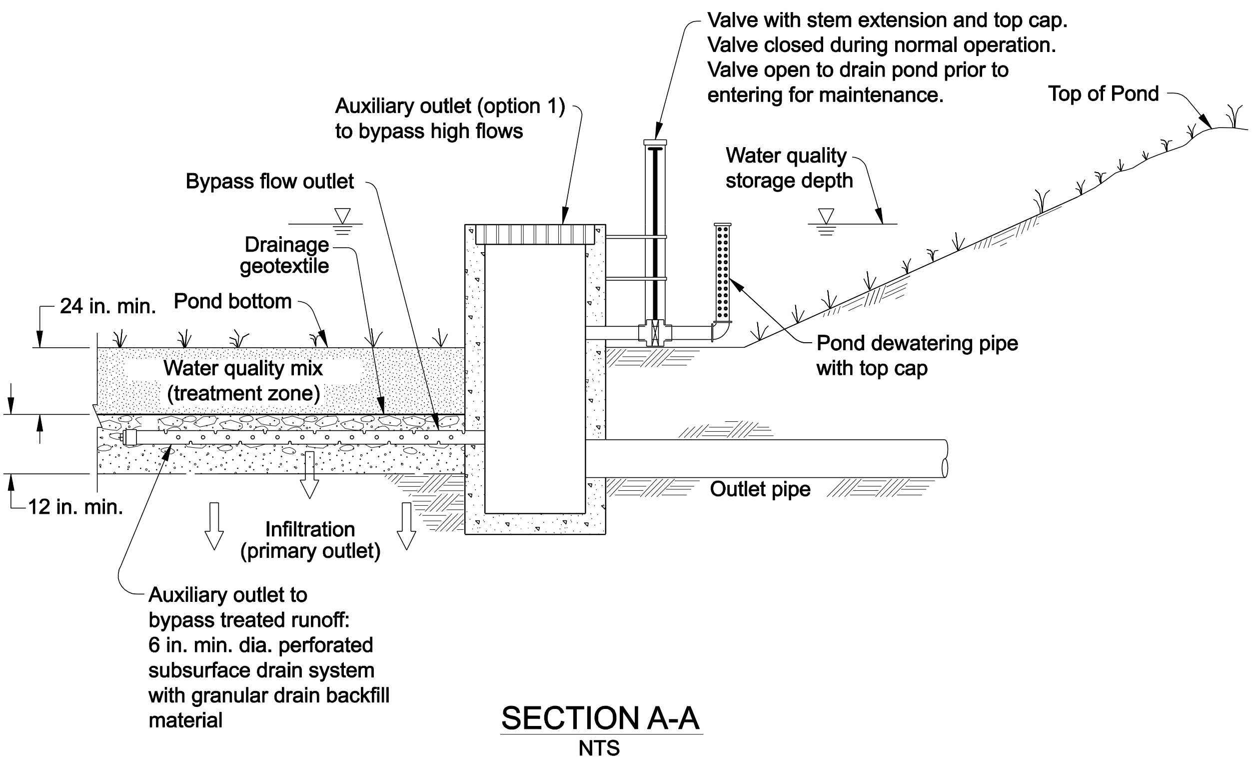


Figure 1 Bioretention Facility



(Cross-Section without a perforated subsurface drain system)



(Cross-Section using a perforated subsurface drain system)

Figure 2 Bioretention Facility Cross-Sections

Sub Surface Drain

A sub surface drain pipe system is required to prevent standing water conditions when the subsoil infiltration rate is less than 0.5 inches/hour. Subsurface drains must meet the following criteria:

1. The sub surface drain pipe must be perforated pipe, laid in a grid pattern, and backfilled and bedded with granular drain backfill material

2. The sub surface drain pipe must be 6 inches or greater in diameter.

3. The sub surface drain pipe must drain freely to an acceptable discharge point.

Safety Features

1. Exclusionary measures may be required to prevent entry to facilities that present a hazard to children and, to a lesser extent, all persons. Fences are recommended for basin areas where one or more of the following conditions exist:

   - areas where small children are present, particularly residential areas, and near playgrounds and schools.
   - areas where rapid water level increases would make escape difficult,
   - side slopes steeper than 1V:3H and have water depths greater than 3 feet for more than 24 hours or are permanently wet.

2.2 Design Procedure

The procedure for designing a bioretention pond is presented below.

Step 1 – Establish the location of the facility according to the site suitability requirements

Step 1a – Determine any special requirements for groundwater protection areas and wellhead protection zones.

Step 2 – Determine water quality design storm. See Section 14.10.2.

Step 2a - Determine the Contributing Impervious Area for the facility. See Section 14.10.1.

Step 3 – Determine the water quality volume (V_{wq}). Use hydrology guidance in Chapter 7 and the design recurrence interval from step 2.

Step 4 – Estimate the dimensions of the pond that will contain the required storage. The method of determining the dimensions of a basin is presented in subsection 12.8.2.

Step 5 – Coordinate with the project geologist to perform a subsurface soil characterization analysis at the location(s) determined in Step 1 and estimate the Long Term Infiltration Rate of the site's soils. Determine:

- The soil gradation characteristics at the proposed location(s) of the facility. One grain-size analysis per soil stratum in each test hole must be conducted within 2.5 times the maximum design water depth, but not less than 6 feet.
- The stratification of the soil/rock below the facility
- The depth of the seasonally high water table and bedrock. Monitor groundwater during at least one wet season. **Note that at least 3 feet vertical separation is required between the bottom of the facility and annual high groundwater.**
- Determine the long term infiltration rate using one of the following options:

Note: Design or long term infiltration rate of 9 inches per hour or less is acceptable at providing water quality treatment for groundwater protection. See Appendix E, Section 2 regarding organic matter content requirement. Place water quality mix over soils with a design or long term infiltration rate greater than 9 inches per hour. This criteria is applicable outside of groundwater protection areas. Determine any special requirements for groundwater protection areas and wellhead protection zones. This applies to option 1 or 2 below.

Option 1

A Pilot Infiltration Test (PIT). **This is required for facilities with a contributing area greater than 15,000 ft^2.** Coordinate test with the project geologist. The infiltration rate determined from this test must be adjusted using a safety factor to obtain the long term infiltration rate. The long term infiltration rate is used to design the facility. See below for safety factor guidance.

Table 1 Safety Factors for PIT Infiltration Rate Adjustment

Consideration	Partial Correction Factor
Confidence in site variability and number of test locations	CF = 1.5 to 6
Availability of maintenance to limit siltation and biofouling	CF = 2 to 6
Degree of influent control available to limit siltation and biofouling	CF = 2 to 6

To calculate the safety factor, use the following equation.

$$\text{Safety Factor} = \Sigma \text{ Correction Factors}$$

The following equation applies the safety factor to reduce the tested infiltration rate to the "adjusted" or long-term rate:

$$\text{Design or long term Infiltration Rate} = \text{PIT field infiltration rate} \div \text{Safety Factor}$$

Example:

PIT field infiltration rate = 10 inches per hour

Safety Factor Calculation, using engineering judgment:

- This site has low potential for bio-fouling as vegetation does not exist nearby to clutter with leaves and it is exposed to sun reducing moss buildup (CF = 2).
- The proposed facility has a vegetated swale to remove suspended solids before runoff enters infiltration facility (CF = 2).
- This site has low variability in soil types, groundwater depths and soil stratification. A safety CF of 1.5 is applied.

Safety Factor = Σ CF = 2 + 2 + 1.5 = 5.5

Calculate design or long term infiltration rate.

Design or long term Infiltration Rate = PIT field infiltration rate ÷ Safety Factor

10 inches/hour ÷ 5.5 = 1.8 in/hr (design or long term infiltration rate)

OR

Option 2

Use soil gradation results and Table 2 or Figure 3 to **determine the long term infiltration rate for facilities draining an impervious area of 15,000 square feet or less.** Do not use a reduction factor or factor of safety for the values noted in Table 2 or Figure 3.

Use Table 2 to estimate the long term infiltration rate unless the site has variable soil types and characteristics, low maintenance, high chance of biofouling, and no pretreatment. Biofouling is the accumulation of bacteria, algal, or other organics with the pore spaces of the soil matrix.

Table 2 was derived from a study conducted by Massmann and Butchart (2000) that compared infiltration measurements from infiltration facilities to soil gradation data using the ASTM D422 procedure. Massmann and Butchart used data from several counties (King, Clark, Thurston) in Washington (Wiltsie 1998).

D_{10} Size from ASTM D422 Soil Gradation Test (mm)	Estimated Long-Term (Design) Infiltration Rate (in/hr)
≥0.4	9
0.3	6.5
0.2	3.5
0.1	2.0
0.05	0.8

Table 2

Estimated Infiltration Rates Based on ASTM
Gradation Testing (Massmann and Butchart 2000)

Figure 3 can also be used for soils with a D_{10} of less than 0.05 mm. It plots the relationship between the infiltration rates and the D_{10} values noted in Table 2. Table 2 only provides estimated infiltration rates to a D_{10} of 0.05 mm.

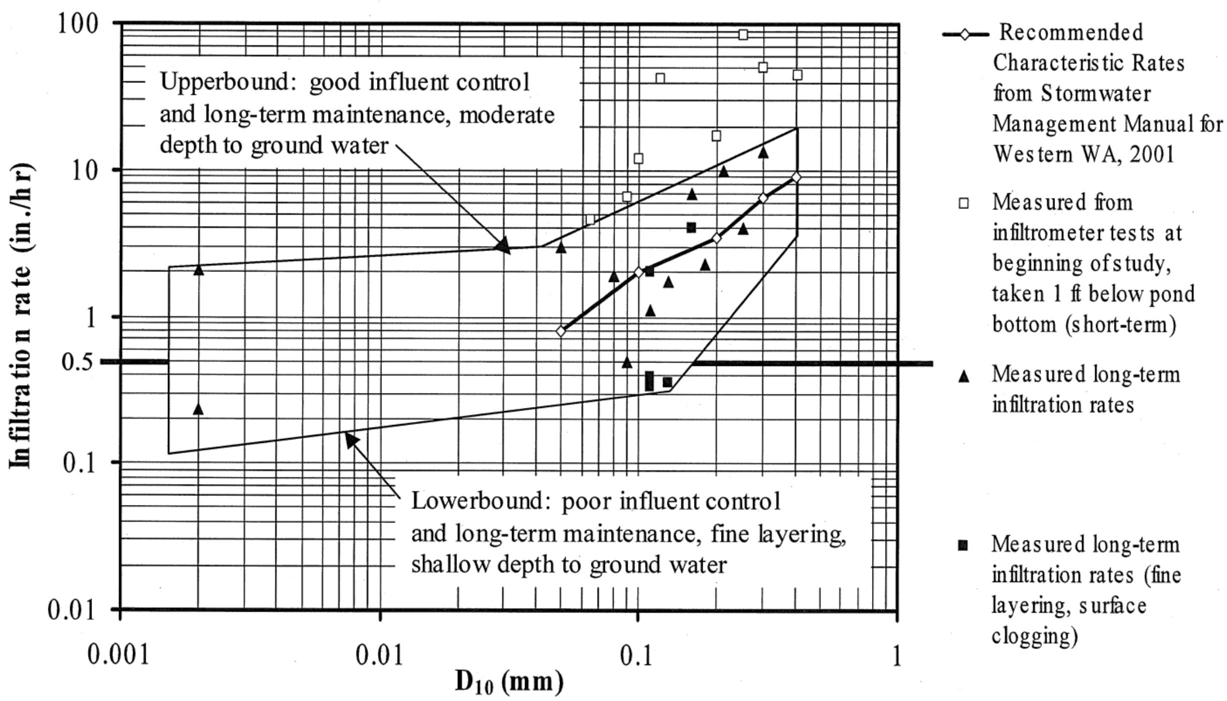


Figure 3. Infiltration Rate as a Function of the D_{10} Soil Size (Massmann, et al. 2003)

Use the lowerbound infiltration rate associated to the D_{10} of interest if the site has variable soil types and characteristics, low maintenance, high chance of biofouling, shallow groundwater and no pretreatment. The soil type with the lowest infiltration rate should be used to design the facility. Apply this criteria to a depth of 2.5 times the maximum design water depth, but not less than 6 feet.

The upperbound infiltration rates are not applicable for ODOT facilities.

Step 6 – Skip to step 10 if the infiltration rate is less than 0.5 inches per hour otherwise go to Step 7.

Step 7 – Determine the **infiltration flow rate Q** by developing a stage/discharge curve from the infiltration rate determined in Step 5. At a given stage the discharge may be computed using the pervious surface area through which infiltration will occur (which varies with stage) multiplied by the infiltration rate determined in Step 5 or the water quality mix infiltration rate estimated at 3 inches per hour. Use the smaller infiltration rate.

Step 8 – Determine the amount of time it takes the facility to empty. The facility must infiltrate the water quality design storm volume within 36 hours.

T = The time required to infiltrate the water quality volume (V_{wq})

$$T = \frac{V_{WQ}}{Q}$$

Where:

V_{wq} = Water quality volume in cubic feet

Q = Infiltration flow rate in cubic feet per second

Step 9 – Adjust pond cross-section to include freeboard.

Step 10 – Design a subsurface drain when the infiltration rate is less than 0.5 inches per hour. See subsurface drain section (Section 2.1).

Step 11 – Design the following facility components using the guidelines included in Appendix E:

- Pretreatment (sediment basin, pollution control manhole, or proprietary structure)
- Flow splitter manhole
- Auxiliary outlet
- Storm drain piping
- Outfall
- Energy dissipation at the outfall
- Coordinate soil preparation, seed mix, irrigation needs, and other requirements with the project roadside development designer
- Coordinate temporary and/or permanent erosion control measures with the project erosion control designer

Step 12 – Note in the Operation and Maintenance Manual that heavy equipment is not allowed within the facility.

Step 13– Prepare the Stormwater Design Report and Operations and Maintenance Manual as discussed in Section 14.10.15 and 14.11.

Step 14 – Coordinate the installation field markers at the start and end of a facility's maintenance area. Marking guidance is provided in Chapter 17.

3.0 Bioslope

This section provides information for the design of bioslopes. Figures 4, 5, and 6 are general configurations of a bioslope. Other names for bioslope that have been used include ecology embankment and media filter drain.

Bioslopes are flow-through stormwater treatment facilities incorporated into roadside embankments and placed between pavement and a downstream conveyance system. These facilities utilize physical straining or filtration, sorption, carbonate precipitation, vegetative uptake and microbial degradation to provide stormwater treatment. Bioslopes are recommended for highway application because of their minimal right-of-way requirements and maintenance schedule.

Bioslopes are designed to treat sheet flow from an adjacent impervious surface. A typical bioslope has the following facility features and components:

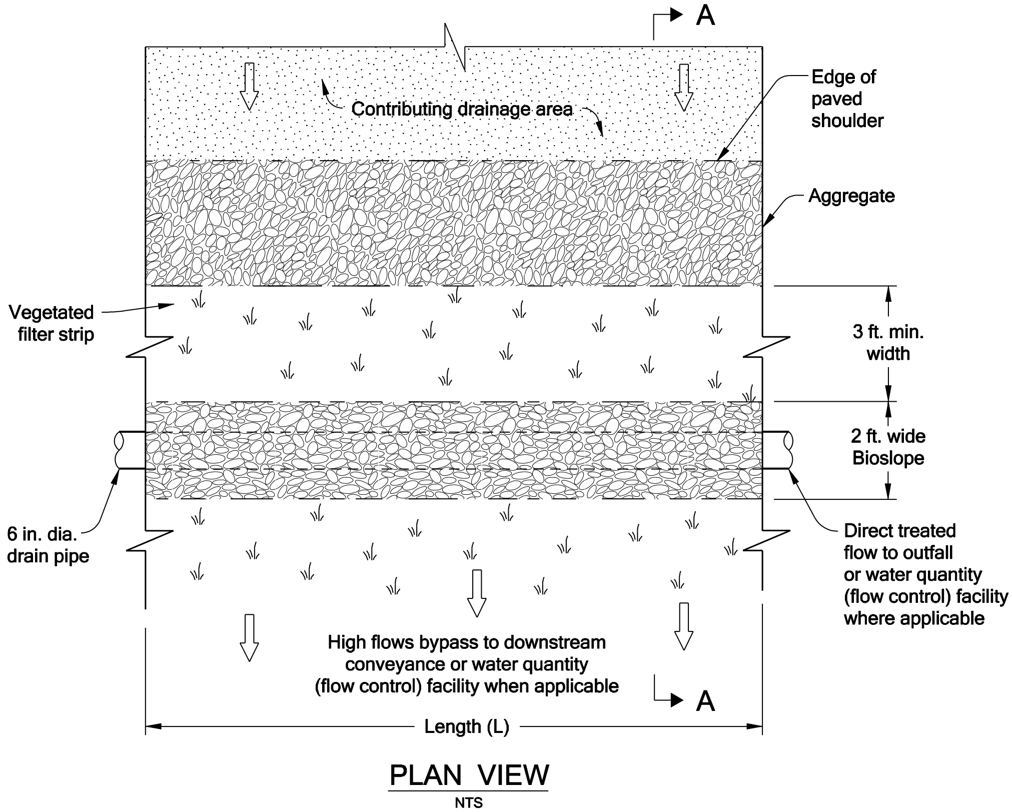
- **Vegetated filter strip –** It is provided upstream of the bioslope to evenly distribute flow into the treatment zone, reduce the runoff velocity, and provide pretreatment.
- **Treatment Zone using Ecology mix –** It is provided to remove pollutants as stormwater runoff drains through this zone. The ecology mix is a mixture of aggregate, dolomite, gypsum, and perlite.
- **Sub surface drain –** it is provided to allow positive outflow for runoff at the toe of the bioslope.

Bioslopes can be placed:

- Along existing roadway embankments, and
- Urban and suburban highway with adequate right-of-way
- Rural areas

Bioslopes would not be effective and should not be considered when:

- Sheet flow can not be maintained
- Steep slopes are proposed (side slopes will be greater than 4:1)
- Unstable slopes are present,
- Shallow groundwater is present



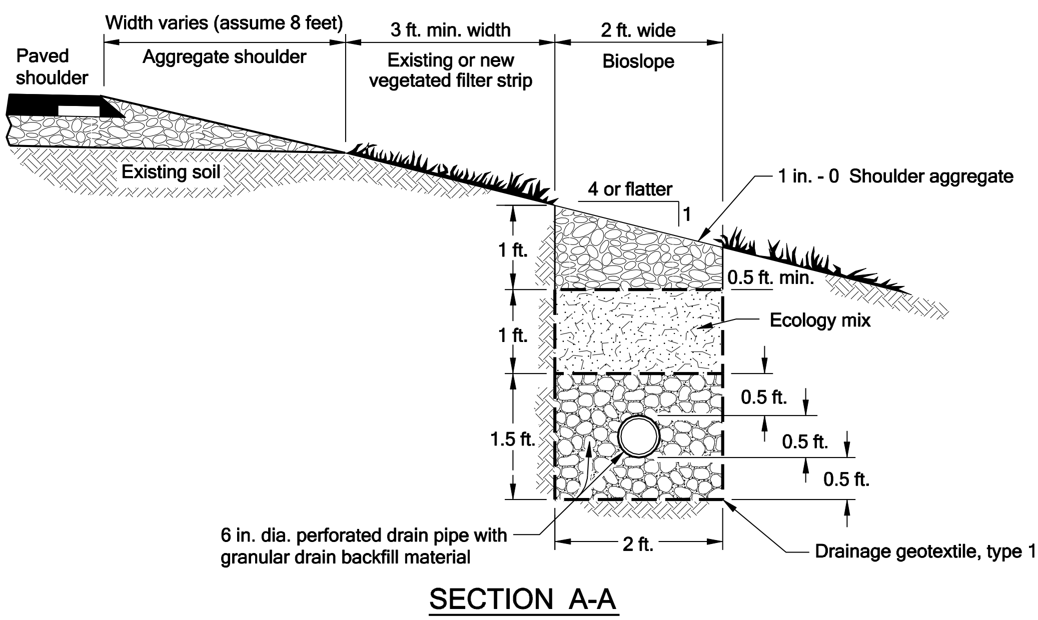


Figure 4 Bioslope (2 foot wide)

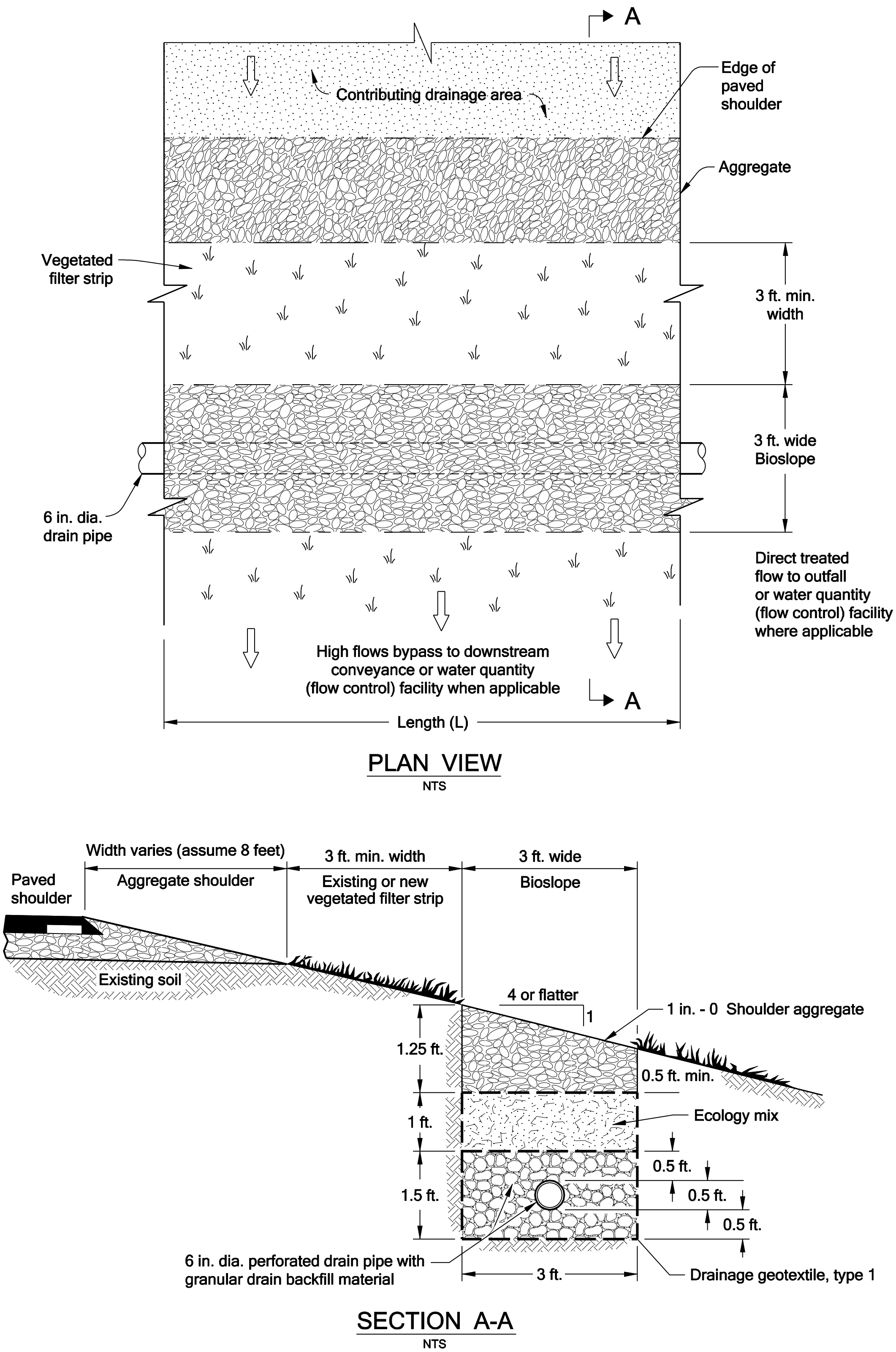


Figure 5 Bioslope (3 foot wide)

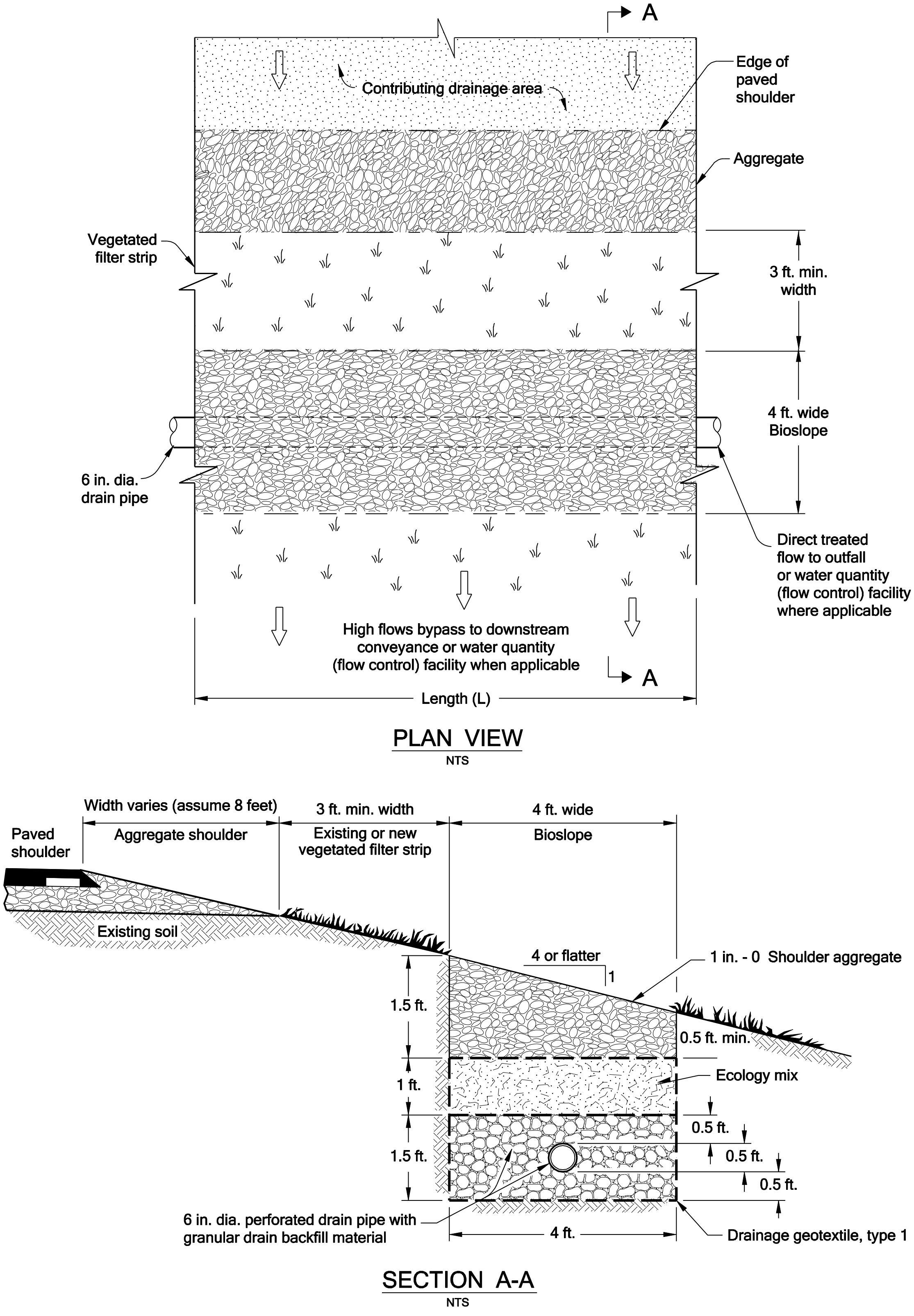


Figure 6 Bioslope (4 foot wide)

3.1 Design Criteria

This section describes the features of bioslopes and the design criteria that apply specifically to these installations. Also apply the general requirements discussed in Section 14.10.

Site Selection

1. General siting requirements are discussed in Section 14.9. Additional siting criteria that apply specifically to bioslopes include:

   a) Side slopes are 4:1 or less
   b) Side slopes are geotechnically stable
   c) Seasonal high groundwater table is 3 feet or more below the bottom of the bioslope granual drain backfill

Bioslope Geometry

1. The **minimum width** of the bioslope ecology mix bed is equal to or greater than 2 feet.

2. The **lateral slope of the roadside shoulder** along the placement of the bioslope should not be steeper that 1V:4H. Less than 1V:4H lateral slope is preferred.

3. The **longitudinal slope of the roadside shoulder** along the placement of the bioslope should not be steeper than 5 percent.

4. The **length** of the bioslope must be equal to the length of the contributing impervious or pavement area.

Vegetated Filter Strip

1. The **minimum width** of the grass filter strip is 3 feet. The grass filter strip must be located between the contributing impervious area and the bioslope. The vegetated filter strip will assist in maintaining uniform flow across the bioslope section and provide pretreatment.

Sub Surface Drain

A typical sub surface drain pipe system is shown in Figure 4. A sub surface drain pipe system is required to allow positive outflow for runoff at the toe of the bioslope. A sub surface drain may not be needed for Natural Resources Conservation Service (NRCS) Hydrologic soil groups A and B. A sub surface drain should be installed when the subsoil classification is C or D.

A subsurfance drain must meet the following criteria:

1. The sub surface drain pipe must be a perforated pipe, laid parallel to the bioslope length, and backfilled and bedded as shown in Figure 4.
2. The sub surface drain pipe diameter must be 6 inches or greater.
3. The granular drain backfill material must be wrapped with drainage geotextile.
4. The sub surface drain pipe must infiltrate or drain freely to an acceptable discharge point.
5. The minimum sub surface drain trench width is 2 feet.

Ecology Mix

Ecology mix is provided to remove pollutants as stormwater runoff drains through this media mix. General design criteria includes:

1. The ecology mix has an estimated long term filtration rate of 20 inches per hour due to siltation. Therefore, use a safety factor of two (2) or an infiltration rate of 10 inches per hour.
2. The long term infiltration capacity ($Q_{infiltration}$) must be greater than the water quality peak flow
3. The minimum mix thickness is 12 inches

The ecology mix consists of the following materials:

Amendment	Description	Quantity
Aggregates	3/8" – No. 8 aggregate meeting the requirements of ODOT Standard Specifications Section 00680	3 cubic yards (c.y.)
Perlite	• Horticultural grade, free of any toxic materials. (Course Gradation) • 0 – 29% passing No. 18 sieve • 0 – 10% passing No. 30 sieve	1 cubic yard per 3 cubic yards of aggregate
Dolomite	• Calcium magnesium carbonate – $CaMg(CO_3)_2$ (Ground) • Agricultural grade, free of any toxic materials. • 95 - 100% passing No. 8 sieve • 0 -5% passing No. 16 sieve	10 pounds per 1 c.y. of perlite
Gypsum	• Noncalcined, agricultural gypsum – $CaSO_4$-2(H_2O) (hydrated calcium sulfate). (Ground or Peletized) • Agricultural grade, free of any toxic materials • 95 - 100% passing No. 8 sieve • 0 – 5% passing No. 16 sieve	1.5 pounds per 1 c.y. of perlite

Aggregate

perlite

Dolomite

gypsum

Figure 6 Materials blended to produce ecology mix

3.2 Design Procedure

The procedure for designing a bioslope is presented below.

Step 1 – Determine water quality design storm. Highway runoff from impervious areas needs to address the most stringent standards or reference requirements summarized in Section 14.10.2.

Step 2 - Determine Contributing Impervious Area. See Section 14.10.1

Step 3 – Determine the water quality peak flow. Use hydrology guidance in Chapter 7 and the design recurrence interval from step 1.

Step 4– Calculate the long term infiltration capacity of the bioslope ($Q_{infiltration}$). Assume an initial bioslope ecology mix bed width and use a bioslope ecology mix bed length equal to the length of the contributing pavement area.

$Q_{infiltration}$ = long term infiltration capacity (cubic feet per second)

$$Q_{infiltration} = \frac{(LTIR_{EM})(L_{BIO})(W_{BIO})}{(C)(SF)}$$

Where:

$LTIR_{EM}$ = Long term infiltration rate of ecology mix (use 10 inches per hour)

L_{BIO} = Length of the bioslope ecology mix bed, parallel to roadway (feet)

W_{BIO} = Width of the bioslope ecology mix bed (feet)

C = Conversion factor of 43200 [(in/hr)/(ft/sec)]

SF = Safety Factor (equal to 1.0, unless unusually heavy sediment loading is anticipated)

Note: The long term infiltration capacity must be greater than the water quality peak flow. Increase width of bioslope ecology mix bed until the above condition is satisfied. The minimum media filter strip ecology mix bed is 2 feet.

Step 5 – Design or coordinate the following facility components using the guidelines included in Appendix E:

- Storm drain piping
- Outfall
- Energy dissipation
- Coordinate soil preparation, seed mix, planting requirements, irrigation needs, and other requirements with the project roadside development designer.
- Coordinate temporary and/or permanent erosion control measures with the project erosion control designer

Step 6– Prepare the Stormwater Design Report and Operations and Maintenance Manual as discussed in Section 14.10.15 and 14.11.

Step 7 – Coordinate the installation field markers at the start and end of a facility's maintenance area. Marking guidance is provided in Chapter 17.

4. **Proprietary Media Filter Systems**

Several media filter treatment systems developed by private firms are on ODOT's Qualified Products List and are approved for use on ODOT facilities. They are generally have a relatively small footprint, and are best suited for urban situations with limited space available for stormwater BMPs. Proprietary media filter BMPs do not support infiltration into the soil, but rather discharge treated stormwater into the main storm sewer system.

The cost of purchasing and maintaining a proprietary media filter system may be higher than for the generic media filter systems discussed earlier. On the other hand, the extra expense may be counterbalanced by reduced right of way requirements and the ability to provide required levels of treatment at all.

It is vital that designers discuss maintenance requirements with Maintenance before selecting a particular system. Of particular importance is making sure that the responsible Maintenance district has the equipment required to maintain the facility.

Design criteria for proprietary units will be specific to the particular system. Designers should follow the manufacturer's guidance.

If a proprietary system does not include a pre-treatment element, the designer should place a pre-treatment BMP upstream if at all possible.