APPENDIX J

LINEAR APPLICATIONS STANDARDS AND PROCEDURES MANUAL

Preface

Charleston County has developed standard operating procedures and design criteria to ensure that County linear construction and maintenance projects meet the stormwater management and sediment/erosion control requirements adopted by the County. This manual is to be utilized by the Charleston County Stormwater Division as well as road/linear project designers, contractors, inspectors and maintenance personnel. The County has adopted the parameters in this manual for what alterations/improvements to roads and other linear projects will be required in regards to stormwater management best management practices (BMPs) in order to meet County, State and Federal standards.

This Manual is for stormwater management purposes only, and the requirements herein are specific to The Charleston County Stormwater Management Program and do not preclude either the Planning and Building Services Departments from performing their permit, plan review, inspection or other related duties and collecting applicable fees.

Every effort has been made throughout this Manual to cover the common conditions and information needed by those involved in linear construction activities. However, these design standards and the County Ordinances should be reviewed carefully to ensure that all requirements are being met. Projects may also be impacted by applicable state and federal requirements.

The selection and design process must be conducted to meet all the constraints and design considerations for a particular project. It is up to the developer's/designer's judgment to decide which design is the most appropriate for their particular site. Hydrologic functions such as infiltration, frequency and volume of discharges, and groundwater recharge become essential considerations when identifying and selecting BMPs. The following table provides a summary of potential site constraints for various BMPs.

Site Constraints of Best Management Practices (BMPs)

	Bio-retention	Vegetated Filter Strip	Enhanced Bioswale	Infiltration Trench
Space Required	Surface area range: 3% to 8% depending on the amount of impervious area	Minimum length of 15 to 20 ft. Minimum width of 4 ft.	Bottom width: 2 ft minimum, 6 ft maximum	Minimum width: 3 to 6 ft Minimum length: 2 to 190 ft
Slopes	4:1 Preferred, 3.5:1 Max	2% - 10%	Swale side slopes: 3.5:1 or flatter Longitudinal slope: 1.0% minimum; 5% maximum based on permissible velocities	Maximum slope of 5%
Water Table	Minimum vertical distance of 12", recommended 36" between bottom of BRA and seasonally high water table.	2ft clearance above water table recommended	2ft clearance above water table recommended	6 inches of clearance above water table required
Max. Depth	2 to 4 ft depth depending on soil type	Not applicable	Not applicable	8 ft. depending on soil type and water table
Maintenance	Low requirement	Lower requirement, routine landscape maintenance	Low requirement, routine landscape maintenance	Moderate to high

Road Categorization

Charleston County currently has six (6) classifications of roads: Private, County Non-Standard, Secondary Rural, Primary Rural, Secondary County, and Primary County. The purpose of this section is to outline the permitting requirements for improvement of County Non-Standard, Secondary Rural and Primary Rural roads. Each classification has requirements which limit development and improvement possibilities. The minimum requirements for these classifications are:

1. County Non-Standard - Maximum of ten (10) lots. Travel way minimum width determined on a per road basis.
2. Secondary Rural - Maximum of ten (10) lots. Travel way minimum width of eighteen (18) feet.
3. Primary Rural - No lot maximum. Travel way minimum width of twenty (20) feet.

The minimum right-of-way width for a roadway to be accepted into the County maintenance system is fifty (50) feet unless otherwise approved by the Public Works Director. The following criteria can be used for road categories other than those specified but must be approved by the Public Works Director.

Table 1: Charleston County Road Maintenance Categorization

	Recommended Lots		Length		Right of Way		Existing Material		
Road Classification	**≤10**	**>10**	**≤500'**	**>500'**	**<50'**	**≥50'**	**Earth**	**Rock**	**Category**
Non-Standard County Roads	X		X		X		X		2
	X			X	X		X		1 and (3, 4, or 5)
Secondary Rural Roads	X		X			X	X		2
	X			X		X	X		1 and (3, 4, or 5)
Primary Rural Roads	X		X			X	X	X	2
		X		X		X	X	X	1 and (3, 4, or 5)

Categories for Maintenance Plan

1. Install impervious pavement and maintain roadside ditch/swale with grass filter strip (if possible)
2. Install porous pavement or maintain roadside ditch with grass filter strip (if possible)
3. Install bioretention cell(s)
4. Install bioswale(s) or infiltration trench(es)
5. Install and maintain Manufactured Treatment Devices (MTD)

Porous Pavement

Description

Porous pavement is a permeable pavement surface with a stone reservoir underneath. The reservoir temporarily stores surface runoff before infiltrating it into the subsoil. Runoff is thereby infiltrated directly into the soil and receives some water quality treatment. Since the reservoir area underneath porous pavement stores and infiltrates surface runoff, using porous pavement can reduce the amount of land needed for traditional stormwater management measures. Porous pavement increases groundwater recharge, reduces pollutants in stormwater runoff, and helps alleviate flooding.

Design parameters that determine the applicability of porous pavement include the load-bearing and infiltration capacities of the subgrade soil, the infiltration capacity of the porous asphalt, and the storage capacity of the stone base/subbase. Additional subbase may be required to compensate for the lower structural support capacity of clay and sand soils. Alternate designs may be acceptable if approved by Public Works Director.

Subgrade Preparation

The main consideration in using porous pavement should be the subgrade soil properties as per AASHTO soil classifications. Native subgrade refers to materials beyond the limit of the excavation. The existing native subgrade material under all bed areas shall not be compacted or subject to excessive construction equipment traffic prior to geotextile and stone bed placement. Where erosion of the native material 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 six (6) inches with appropriate light equipment.

Bring subgrade to the line, grade, and elevations indicated. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction before the placing of the stone subbase. Subbase refers to materials below pavement surface and above native subgrade. All bed bottoms should be as level as feasible to promote uniform infiltration. For pavement subbases constructed on grade, soil or fabric barriers should be constructed along equal elevation for every six (6) to twelve (12) inches of grade change to act as internal check dams. This will prevent erosion within the subbase on slope.

The density of subbase courses shall be determined by AASHTO T 191 (Sand-Cone Method), AASHTO T 204 (Drive Cylinder Method), or AASHTO T 238 (Nuclear Methods), or other approved methods at the discretion of the supervising engineer or Public Works Director.

Porous Media Bed Installation

Upon completion of subgrade work, the Engineer or designee (a qualified/certified inspector) shall be notified and should perform an inspection before proceeding with the porous media bed installation. Sideslope geotextile and porous media bed aggregate shall be placed immediately after approval of subgrade preparation. Any accumulation of debris or sediment which has taken place after approval of subgrade shall be removed prior to installation of geotextile.

Place sideslope geotextile in accordance with manufacturer’s standards and recommendations. Adjacent strips of geotextile shall overlap a minimum of sixteen (16) inches. Secure geotextile at least four feet outside of the bed excavation and take any steps necessary to prevent any runoff or sediment from entering the storage bed.

Install filter course aggregate to grades indicated on the design drawings. Choker should be placed evenly over surface of filter course bed, sufficient to allow placement of pavement, and notify the Engineer for approval. Choker base course thickness shall be sufficient to allow for even placement of the porous asphalt but no less than two (2) inches in depth.

The infiltration rate of the compacted subbase shall be determined by ASTM D3385 or approved alternate at the discretion of the supervising engineer or Public Works Director.

Following placement of the subbase aggregate, the sideslope geotextile shall be folded back along all bed edges to protect from sediment washout along bed edges. At least a four (4) foot edge strip shall be used to protect beds from adjacent bare soil. This edge strip shall remain in place until all bare soils contiguous to beds are stabilized and vegetated. In addition, take any other necessary steps to prevent sediment from washing into beds during site development. When the site is fully stabilized, temporary sediment control devices shall be removed.

Porous Asphalt Pavement Installation

Contact surfaces such as curbing, gutters, and manholes shall be painted with a thin, uniform coat of Type RS-1 emulsified asphalt immediately before the asphalt mixture is placed against them.

The temperature of the asphalt mixture, at the time of discharge from the haul vehicle and at the paver, shall be between 275^{o} and 325^{o} Fahrenheit, within 10^{o} F of the compaction temperature for the approved mix design. The porous asphalt shall be placed within a single application at a minimum two (2) inches thick or in two lifts. If more than one lift is used, measures must be taken to ensure that the porous asphalt layers join completely. Time between layer placements must be kept minimal and the first layer clear from dust and moisture. Traffic should be kept at a minimum on the first layer. Protect all exposed surfaces that are not to be treated from damage during all phases of the pavement operation

The asphalt mixture shall be spread and finished with the appropriate equipment. The mixture shall be struck off in a uniform layer to the full width required and of such depth that each course, when compacted, has the required thickness and conforms to the grade and elevation specified. Pavers shall be used to distribute the mixture over the entire width or over such partial width as practical. On areas where irregularities or unavoidable obstacles make the use of mechanical spreading and finishing equipment impractical, the mixture shall be spread and raked by hand tools.

No material shall be produced so late in the day as to prohibit the completion of spreading and compaction of the mixture during daylight hours, unless night paving has been approved for the project. No traffic will be permitted on material placed until the material has been thoroughly compacted and has been permitted to cool to below 100^{o} F. The use of water to cool the pavement is not permitted. The Engineer reserves the right to require that all work adjacent to the pavement, such as guardrail, cleanup and turf establishment, is completed prior to placing the wearing course when this work could cause damage to the pavement. On projects where traffic is to be maintained, the Contractor shall schedule daily pavement operations so that at the end of each working day all travel lanes of the roadway on which work is being performed are paved to the same limits. Suitable aprons to transition approaches, where required, shall be placed at side road intersections and driveways as directed by the Engineer.

Maintenance

The overall maintenance goal for porous pavement is to prevent clogging of the void spaces within the surface material. Fine particles that can clog the pores are deposited on the surface from vehicles, the atmosphere, and runoff from adjacent land surfaces. Occasional sweeping or vacuuming of debris will be required to ensure the surface does not clog. The surface of porous pavements must not be sealed or repaved with non-porous materials if it is to continue to function.

Vegetated Filter Strip

Design Criteria

A vegetated filter strip is an area of grasses or other generally low growing, dense vegetation designed to remove sediment and other pollutants from stormwater runoff flowing through it. Pollutants suspended in the runoff or attached to suspended soil particles are removed by filtration and sedimentation. A vegetated filter strip is intended to remove pollutants from runoff flowing through it as sheet flow. Filter strips can be effective in reducing sediments and associated pollutants such as hydrocarbons, metals and nutrients though sedimentation and filtration. Soluble pollutants may also be removed through uptake vegetation. While vegetated filter strips address water quality, they do not address water quantity.

Vegetated filter strips are designed to be a post-construction best management practice (BMP). Post-construction design is required for all vegetated filter strip installations.

Periodic maintenance is primarily focused on ensuring healthy plant growth and removal of debris and litter. Keeping the grasses at an acceptable level will minimize the growth of successional vegetation. It is important to avoid the use of herbicides and fertilizers on grassed portions of the filter strip. These applications can directly contribute pollutants.

A design standard has been created for Charleston County which specifies the slope percentage and recommended minimum width of the filter strip based on road width. These criteria are based on a sandy loam soil using a mixed type grass with regular maintenance. Vegetated filter strips must be installed above the flow line of the ditch to ensure the trapping of sediment and pollutants. A stone trench or other flow separating device should be utilized in order to reduce the velocity of water before entering the vegetated filter strip. These standards are meant for a general guideline and may not apply in situations that do not fall under these criteria. Table 2 shows the vegetated filter strip standards approved by Charleston County. Figure 1 provides a detail drawing as guidance for the design of vegetated filter strips.

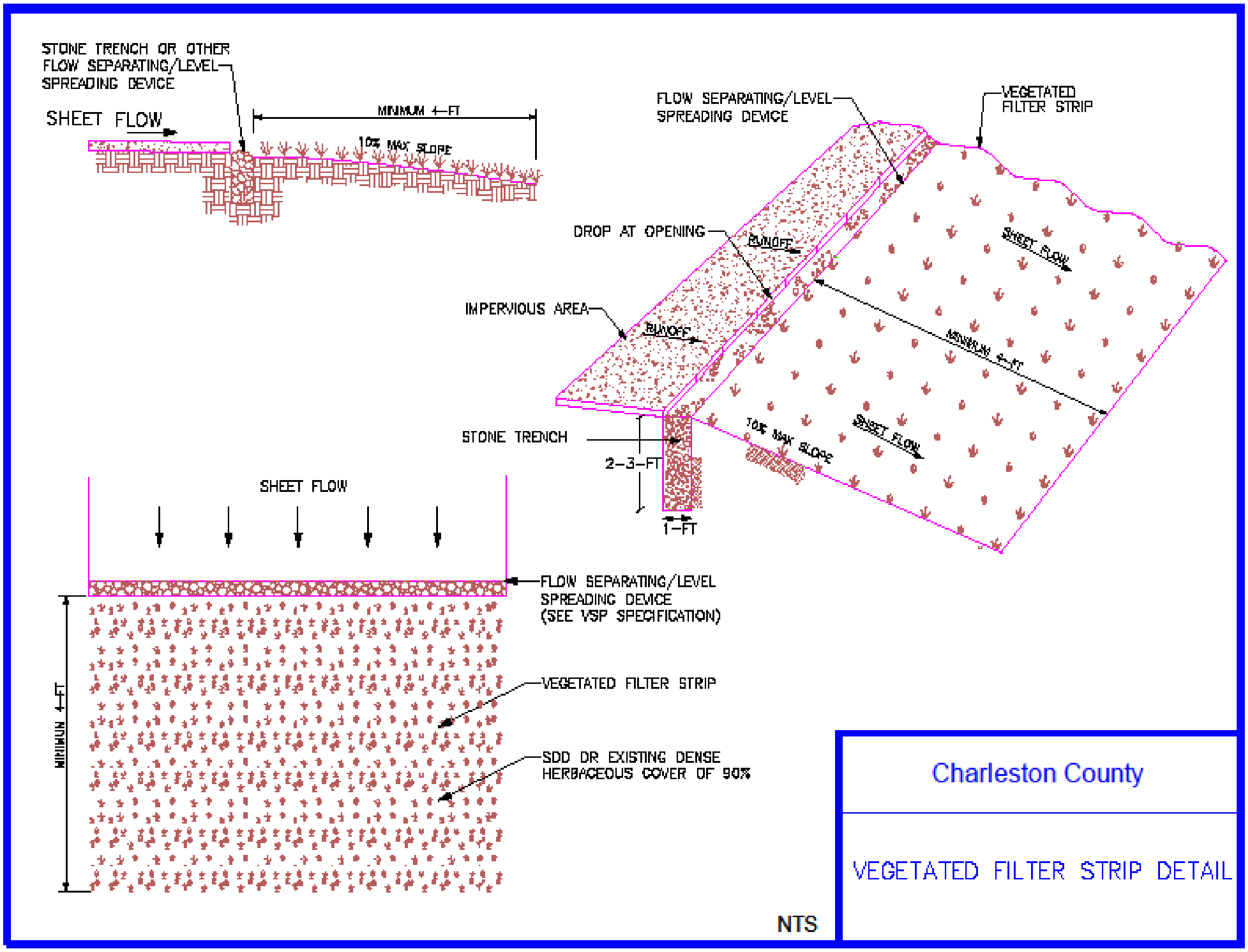
Table 2: Vegetated Filter Strip for 80% Annual TSS Trapping

Width of Road (ft)	Slope of VFS	Minimum Width of VFS (ft)
up to 24	2-10%	4

Site Constraints

The presence of a shallow water table may hinder the infiltration function of the strip. The lowest elevation of the filter strip should be a minimum of six (6) inches above the local seasonally high water table. If site restrictions do not allow for the installation of a vegetated filter strip meeting the specified sizing criteria other BMP solutions will need to be considered.

Figure 1: Vegetated Filter Strip



Infiltration Trenches

Description

Infiltration trenches are excavations filled with stone to create an underground reservoir to manage stormwater runoff. The stormwater runoff volume enters the infiltration trench, is temporarily stored, and gradually exfiltrates through the bottom and sides of the trench into the subsoil. Infiltration Trenches fully de-water within a 24- to 72-hour period depending on trench dimensions, soil type, and underdrain system.

Use Infiltration Trenches to capture sheet flow from a drainage area or function as an off-line device. Due to the relatively narrow shape, Infiltration trenches can be adapted to many different types of sites and can be utilized in retrofit situations. Because infiltration trenches are sensitive to fine sediments, do not install them on sites where the contributing area is not completely stabilized or is periodically being disturbed.

Infiltration trenches are limited to areas with highly porous soils where the water table is located well below the trench bottom. Infiltration trenches:

1. Are only for applicable soils, or soils that have a minimum infiltration rate of 0.3 inches per hour as determined from site specific soil boring samples. Suggested classifications may include hydrological group A, gravels, or sandy soils in accordance with AASHTO or USCS soil classifications.

2. Are located to avoid ground water contamination.

3. Are not intended to trap sediment during construction activities.

4. Have a sediment forebay or other pre-treatment measure to prevent clogging in the gravel.

5. Have an overflow system to provide non-erosive flow velocity along the length and at the outfall.

6. Are applicable for impervious areas where there are low levels of fine particulates in the runoff and the site is completely stabilized and the potential for possible sediment loads are very low.

Pretreatment Criteria

Infiltration trenches must have pretreatment measures in place to ensure the long term longevity of the designed infiltration rate. One of the following techniques must be installed to pretreat 100 percent of the inflow:

1. Grass Channel
2. Grass Filter Strip. A minimum twenty (20) feet and only if sheet flow is established and maintained.
3. Forebay. Should accommodate a minimum fifteen (15) percent of the design storm volume; if the infiltration rate for the underlying soils is greater than two (2) inches per hour, the forebay volume should be increased to a minimum of fifty (50) percent of the design storm volume.
4. Gravel Diaphragm. Minimum one (1) foot deep and two (2) feet wide and only if sheet flow is established and maintained.
5. Filter System.
6. Proprietary Structure. Must demonstrate capability of reducing sediment and hydrocarbons.

Pretreatment structures at the edge of pavement must have a two (2) to four (4) inch drop from the edge of pavement to the top of the grass or stone in the pretreatment structure to prevent accumulation of debris and subsequent clogging at the point where runoff is designed to enter the pretreatment structure.

Design Requirements

To achieve 80% removal efficiency of the average annual post-development total suspended solids (TSS), infiltration trenches are designed to have a water quality volume equal to:

1. One (1) inch of runoff from impervious areas located on the project site, or

2. 1.5 inches of runoff from built-upon portions of the project if located within 1,000 feet of shellfish beds.

Table 3 outlines the accepted design criteria which were derived using models for the most common underlying soil textures in Charleston County. Certain factors were used to determine the extents of these models and any variation from these assumed factors will need to be designed for accordingly. The assumed factors were as follows:

- 300 feet of road length was used to model for design. The length of trench must be scaled up by the same factor as road length for longer road sections.
- Rock fill must be at least 35% porous. If 35% porosity cannot be achieved, trench length must be increased to match the design pore volume.
- Infiltration trenches may include an underdrain or outlet structure.

Figure 2 provides a detail drawing as guidance for the design of infiltration trenches.

Figure 2: Infiltration Trench

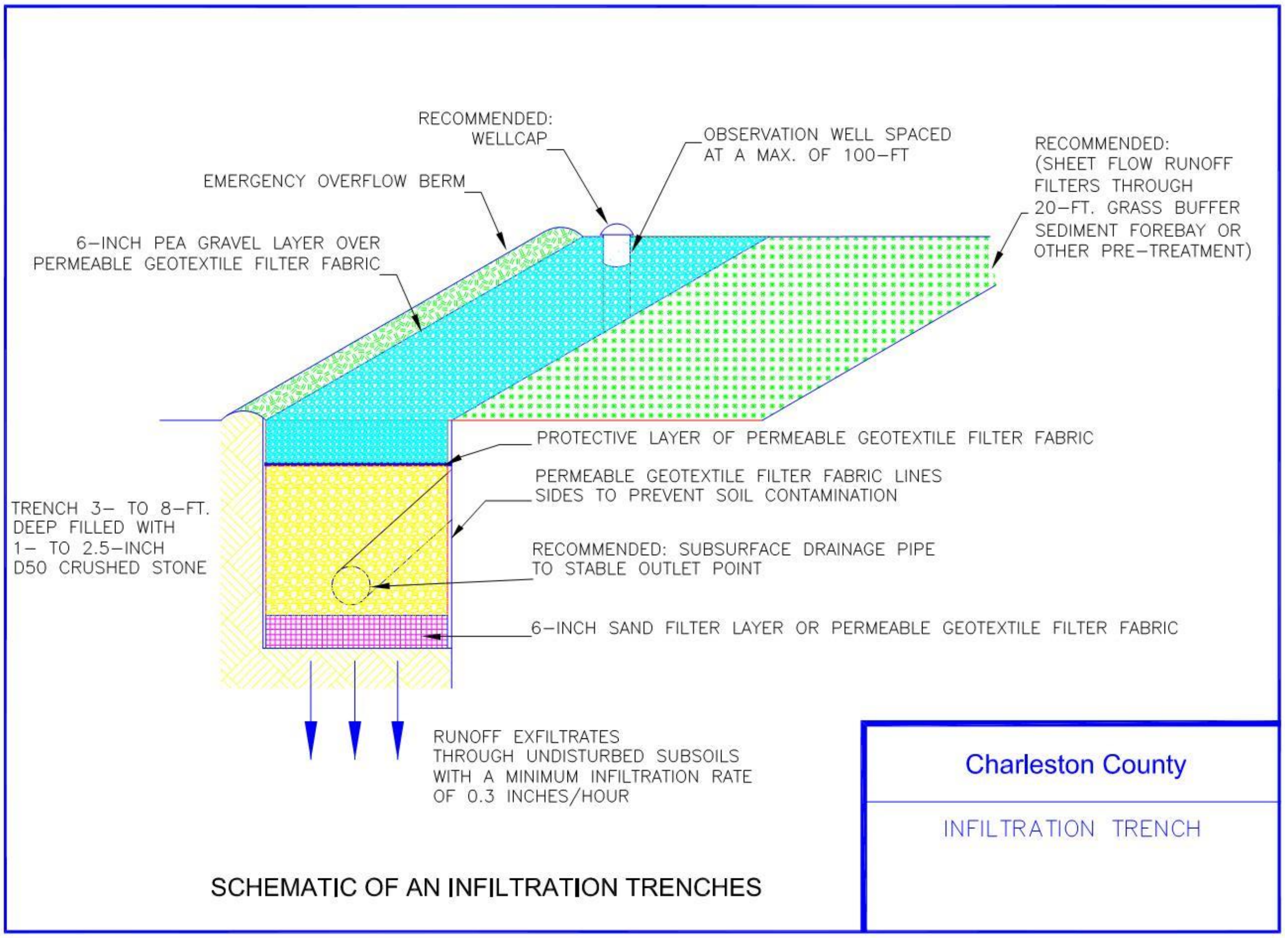


Table 3: Infiltration Design Criteria

Underlying Soil Texture: Clay			
Road Width (ft)	Depth of Trench (ft)	Width of Trench (ft)	Minimum Length of Trench per 300' road (ft)
10	2	3-4	80
		4-6	60
		6+	45
	3	3-4	55
		4-6	45
		6+	30
	4	3-4	45
		4-6	35
		6+	25
12	2	3-4	95
		4-6	75
		6+	50
	3	3-4	65
		4-6	50
		6+	35
	4	3-4	50
		4-6	40
		6+	30
18	2	3-4	145
		4-6	110
		6+	75
	3	3-4	100
		4-6	75
		6+	50
	4	3-4	75
		4-6	60
		6+	40
24	2	3-4	190
		4-6	145
		6+	100
	3	3-4	130
		4-6	100
		6+	70
	4	3-4	100
		4-6	80
		6+	55

Underlying Soil Texture: Sandy Loam			
Road Width (ft)	Depth of Trench (ft)	Width of Trench (ft)	Minimum Length of Trench per 300' road (ft)
10	2	3-4	35
		4-6	30
		6+	20
	3	3-4	25
		4-6	20
		6+	15
	4	3-4	20
		4-6	15
		6+	15
12	2	3-4	40
		4-6	35
		6+	25
	3	3-4	30
		4-6	25
		6+	20
	4	3-4	25
		4-6	20
		6+	15
18	2	3-4	60
		4-6	50
		6+	35
	3	3-4	45
		4-6	35
		6+	25
	4	3-4	35
		4-6	30
		6+	20
24	2	3-4	80
		4-6	65
		6+	45
	3	3-4	60
		4-6	45
		6+	35
	4	3-4	50
		4-6	40
		6+	25

Underlying Soil Texture: Sandy Clay Loam			
Road Width (ft)	Depth of Trench (ft)	Width of Trench (ft)	Minimum Length of Trench per 300' road (ft)
10	2	3	60
		4	45
		6+	30
	3	3	45
		4	35
		6+	25
	4	3	35
		4	25
		6+	20
12	2	3	70
		4	55
		6+	40
	3	3	50
		4	40
		6+	30
	4	3	40
		4	30
		6+	20
18	2	3	110
		4	80
		6+	60
	3	3	75
		4	60
		6+	40
	4	3	60
		4	45
		6+	30

Materials

Stone Fill

The stone fill media consists of a No. 5 clean crushed stone with six (6) inches of No. 6 clean crushed stone located on top separated by a Class 2 Type C permeable nonwoven geotextile filter fabric.

Permeable Nonwoven Geotextile Fabric

Place a permeable nonwoven geotextile filter fabric between the pea gravel and stone fill and the stone fill and adjacent soil. The filter fabric prevents sediment from passing into the stone media and is easily separated from the nonwoven geotextile fabric that protects the sides of the excavated trench.

Sand Filter

Place a six (6) inch sand filter or Class 2 Type C permeable nonwoven filter fabric on the bottom of the trench.

Observation Well

Install observation wells spaced a maximum of 100 feet in every infiltration trench. The well is made of four (4) to six (6) inch PVC pipe. Extend the observation well to the bottom of the trench. The observation well shows the rate of de-watering after a storm event and predicts when maintenance is required for the infiltration trench. Install the observation well along the centerline of the trench, flush with the ground elevation of the trench. Cap the top of the well to discourage vandalism and tampering.

Table 4: Infiltration Trench Material Specifications

Material	Specification
No. 57 Aggregate	Use course aggregate No. 57 consisting of crushed slag or gravel
1.0- to 2.5-inch D_{50} Crushed Stone	Coarse Aggregate Size No.: 2, 24 or 3
Pea Gravel	ASTM D 448; Stone Size No. 6 or 1/8” to 3/8”
Sand Filter Material	AASHTO Std. M-43, Size No. 9 or No. 10) (SCDOT FA-10 Size No. 8)
Pipe Underdrains	Use perforated pipe underdrains with a minimum diameter of 4 inches
Observation Well and Outlet Pipe	Use non-perforated pipe underdrains with a minimum diameter of 4 inches
Class 2 Type C Permeable Non-Woven Geotextile Fabric	Use Class 2 Type C non-woven geotextile fabric

Construction Requirements

Ensure stormwater runoff from areas draining to infiltration trenches passes through stabilized vegetated filter at least twenty (20) feet in length, a sediment Forebay, or other pre-treatment measure before discharging to the infiltration trench. Do not install infiltration trenches in fill material because piping along the fill and natural ground interface may cause slope failure.

Site Preparation

Ensure a vertical distance of six (6) inches between the infiltration trench bottom and the elevation of the seasonally high water table, whether perched or regional. The water table is determined by direct piezometer measurements and on-site soil borings.

Locate infiltration trenches greater than three (3) feet deep a minimum of ten (10) feet from basement walls. Locate infiltration trenches a minimum of 150 feet from any public or private water supply well. Construct infiltration trenches with a maximum width of twenty-five (25) feet.

<u>Installation</u>

Perform the following for all infiltration trench installations:

1. Construct an excavated trench with a minimum depth of three (3) feet and a maximum depth of eight (8) feet. The maximum slope bottom of the infiltration practice is five (5) percent.
2. Do not install infiltration trenches in fill material as piping along the fill/natural ground interface may cause slope failure.
3. Do not install an infiltration trench on or atop a slope whose natural angle of incline exceeds 20 percent.
4. Line the excavated trench with a permeable nonwoven geotextile filter fabric.
5. Place a six (6) inch sand filter on the bottom of the trench and place a permeable geotextile filter fabric over the sand filter.
6. Install observation wells spaced a maximum of 100 feet apart. Extend the well to the bottom of the trench.
7. Install the observation well along the centerline of the trench, and flush with the ground elevation of the trench. Cap the top of the well to discourage vandalism and tampering.
8. Place the crushed stone fill media to a depth of six (6) inches below the top ground surface and place a permeable geotextile filter fabric over the crushed stone. Install this permeable filter fabric so it is easily separated from the geotextile filter fabric that protects the sides of the excavated trench.
9. Place six (6) inches of No. 6 clean crushed stone on top of the No. 5 clean crushed stone.

4.0.6 Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of infiltration trenches. Typical maintenance responsibilities include:

1. Keeping a record of the average de-watering time of the infiltration trench to determine if maintenance is required.
2. Replacing the top six (6) inch layer of pea gravel and the permeable nonwoven geotextile filter fabric separating the pea gravel from the stone media when they become full of sediment.
3. Clearing debris and trash from all inlet and outlet structures monthly.
4. Checking the observation wells after three (3) consecutive days of dry weather after a rainfall event. If complete de-watering is not observed within this period, there may be clogging within the trench and proper maintenance is required.
5. Removing trees, shrubs, or invasive vegetation semi-annually.

6. If complete failure is observed, performing total rehabilitation of the trench by excavating the trench walls to expose clean soil, and replacing the gravel, geotextile filter fabric, and topsoil.

Table 5: Infiltration Trench Maintenance Requirements

Required Maintenance	Frequency
Ensure that the contributing area is stabilized with no active erosion.	Monthly
Mow grass filter strips and remove grass clippings.	Monthly
Check observation wells after 72 hours of rainfall. Ensure Wells are empty after this time period. If wells have standing water, the underdrain system or outlet may be clogged.	Semi-annual (every 6 months)
Remove invasive vegetation.	Semi-annual (every 6 months)
Inspect pretreatment structures for deposited sediment.	Semi-annual (every 6 months)
Replace pea gravel, topsoil and top surface geotextile filter fabric.	When clogging or surface standing water is observed
Perform total rehabilitation of infiltration trench.	Upon observed failure

Bioretention Areas

Description

Bioretention areas are stormwater basins intended to provide water quality management by filtering stormwater runoff before release into a stormwater conveyance system or stabilized outfall. Use individual bioretention areas for drainage areas up to two (2) acres in size.

Stormwater runoff enters bioretention areas and is temporarily stored in a shallow pond on top of a filter media layer. The ponded water then slowly filters down through the filter media and is absorbed by the plantings. As the excess water filters through the system, it is stored and/or collected. An optional underdrain system that eventually discharges to a designed storm conveyance system may be installed.

Design Requirements

General Design Criteria

To achieve 80% removal efficiency of the average annual post-development TSS, bioretention areas are designed to have a water quality volume equal to:

- One (1) inch of runoff from impervious areas located on the Project site, or
- 1.5 inches of runoff from built-upon portions of the Project if located within 1,000 feet of shellfish beds.

Design bioretention areas to treat the water quality volume of runoff from the entire drainage basin. Bioretention areas work best when constructed off-line, capturing only the water quality volume. Divert excess runoff away from the bioretention area or collect it with an overflow catch basin.

Design bioretention areas to fit around natural topography and complement the surrounding landscape. Bioretention areas can be of any reasonable shape and can be fit around sensitive areas, natural vegetation, roads, driveways, and parking lots.

Typical bioretention areas have a minimum width of ten (10) feet and a minimum flow length of 40 feet to establish a strong healthy stand of vegetation.

Where nitrogen or phosphorus is a concern, create a 90 degree elbow in the underdrain system from the bottom of the Bioretention area to create an Internal Water Storage Zone to encourage the denitrification process.

A summary of the design characteristics for bioretention areas is shown in Table 6.

Table 6: Design Characteristics for Bioretention Areas

Drainage Area	0.5 to 2 acres
Surface Area	Varies, but typically 3% to 8% of the contributing watershed depending on the amount of impervious area
Surface Side Slope	4:1 preferred, 3.5:1 maximum
Infiltration Rate	Between 1 and 6 inches per hour for filter media
Water Depth	Range from 6 to 12 inches with a 9-inch standard above the filter media
Water Table	Vertical distance of 3 feet between bottom of Bioretention area and seasonally high groundwater table (typically 4 to 6 feet below ground surface of the Bioretention)
Places to Avoid	Areas that regularly flood (at least once a year), areas adjacent to building foundations, and locations with continuous flow
Mulches	A minimum of 2 inches is required while 3 to 4 inches is preferable. Mulch should be hardwood, not pine bark nuggets (float). Double-shredded hardwood works well. Pine straw may be used in some areas.
Underdrain Stone	Aggregate No. 57 or No. 5 stone is preferred. Separate the gravel from the filter media with a permeable geotextile

Source: *Urban Waterways / Urban Storm Water Structural Best Management Practices (BMPs), North Carolina Extension Service, June, 1999*

The components of a well-designed bioretention area include a pre-treatment area, treatment area consisting of a ponding area, surface mulch layer and planting bed, and a gravel underdrain system separated from the planting bed by a geotextile filter.

Table 7 outlines the design criteria accepted by Charleston County. Refer to Appendix A for recommended surface area calculations. Additional criteria must be met in order for the values in Table 7 to meet the drainage requirements:

- Bioretention areas which have an underdrain sized to handle peak flow, underlying soil texture does not matter.
- Each area will have one layer of uncompacted loamy sand to a depth of twenty-four (24) inches.
- The invert of an eighteen (18) inch circular riser will be one (1) foot above the top of media
- The EMS crest should be two (2) feet above the media and at least ten (10) feet wide.

Table 7: Bioretention Area (BRA) Design Criteria

Road Length	Road Width (ft)	Area of BRA	Area of BRA as Percent of Road Drainage Area
1/2 mile	10	1200	5%
	12	1400	5%
	18	1950	5%
	24	2700	5%

Water Draw Down Time

Design bioretention areas to fully de-water within a 24- to 48-hour period depending on the dimensions, filter media, and underdrain system. In order to allow for proper pollutant removal, design for the ponded runoff above the bioretention area surface to drain in a maximum of twelve (12) hours. Design for runoff within the filter media to drain within forty-eight 48 hours. Refer to Appendix A for the general equation used to determine the draw down time.Determining the total draw down time is a three-step process:

1. Determine the time it takes to drain the ponded water.
   - Utilize Darcy's Equation to calculate the flow rate (cfs).
   - Calculate the total ponded water volume (feet^3) by multiplying the bioretention area (feet^2) by the ponded water depth (feet).
   - Divide the total ponded water volume (feet^3) by the flow rate (cfs) to calculate the time to drain the ponded water (seconds).
2. Determine the time it takes to drain the saturated filter media.
   - Calculate the total volume of water contained in the filter media (feet^3) by multiplying the bioretention area (feet^2) by the filter media depth (feet) by the porosity (dimensionless) of the filter media.
   - Divide the filter media water volume (feet^3) by the flow rate from Darcy's Equation (cfs) to calculate the time to drain the ponded water (seconds).
3. Add up the time to drain the ponded water with the time that it takes to drain the filter media to calculate the total bioretention area draw down time.

Materials

Bioretention areas consist of an underdrain system, an internal water storage zone/ denitrification zone (if required), a filter media, an overflow system, plantings, a mulch layer, and a pre-treatment system.

Underdrain System

Place an underdrain system beneath the filter media for all bioretention areas as many of the native soils found in South Carolina do not allow for adequate infiltration.

Provide an underdrain system that consists of continuous closed joint perforated plastic pipe underdrains with a minimum four (4) inch diameter, an eight (8) inch minimum gravel filter layer, a nonwoven geotextile filter fabric to separate the gravel from the native soils and the gravel from the filter media, and a minimum four (4) inch diameter non-perforated PVC clean out wells.

The maximum spacing of pipe underdrains is ten (10) feet.

Design the underdrain system to safely pass the peak draw down rate calculated in the Water Draw Down Section.

Table 8: Underdrain Material Specifications

Material	Specification
Aggregate	Use course aggregate No. 57 or No. 5 consisting of crushed slag or gravel.
Pipe Underdrains	Use PVC perforated pipe (AASHTO M 252) underdrains with a minimum diameter of 4 inches.
Clean Out and Outlet Pipe	Use non-perforated pipe with a minimum diameter of 4 inches.
Nonwoven Geotextile Fabric	Use Class 2 Type C non-woven geotextile fabric.

Internal Water Storage Zone (Denitrification Zone)

If required for enhanced nitrogen and phosphorus removal, provide an internal water storage zone sized to hold the water quality volume below the outlet of the underdrain system. A nonwoven geotextile fabric is not required between this zone and the underdrain system. Provide a nonwoven geotextile fabric between the internal water storage zone and the underlying native soil. The internal water storage zone consists of the filter media and the stone used in the underdrain system. Adding a suitable carbon source like wood chips to the gravel in the internal water storage zone provides a nutrition source for anaerobic microbes and can enhance the denitrification process.

Design the Internal water storage zone to treat the water quality volume of runoff from the entire drainage basin. Calculate the surface area of the internal water storage zone area by dividing the water quality volume by the ponding depth (minimum 12 inches).

Provide a minimum of twelve (12) inches of Filter Media above the maximum ponding height of the internal water storage zone. Install a valve for dewatering the internal water storage zone if prolonged standing water occurs.

Filter Media

The filter media provides a medium for physical filtration for the stormwater runoff with enough organic matter content to support plant life by providing water and nutrients.

Ensure the filter media of the bioretention area is level to allow uniform ponding over the entire area. The maximum ponding depth above the filter media is nine (9) to twelve (12) inches to allow the bioretention area to drain within a reasonable time and to prevent long periods of plant submergence. Provide a filter media with a minimum infiltration rate of one (1) inch/hour and a maximum rate of six (6) inches/hour. The average porosity of the filter media is approximately 0.45H

The USDA textural classification of the filter media is Loamy Sand or Sandy Loam. The filter media is furnished, and on-site soils are not acceptable. Test the filter media to meet the criteria in Table 9.

Submit the source of the filter media and test results to the Engineer prior to the start of construction of bioretention areas. Do not add material to a stockpile of filter media once a stockpile has been sampled.

Allow sufficient time for testing. Utilize a filter media from a certified source or laboratory to reduce mobilization time and construction delays.

Use a filter media that is uniform, free of stones, stumps, roots, or other similar objects larger than two (2) inches excluding mulch. Do not mix or dump materials or substances within the Bioretention area that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations.

Test the filter media to meet the criteria shown in Table 9.

Should the filter media pH fall outside of the acceptable range, modify with lime (to raise pH) or iron sulfate plus sulfur (to lower pH). Uniformly mix lime or iron sulfate into the filter media prior to use in bioretention areas.

Table 9: Bioretention Filter Media Material Specifications

Item	Percent of Total Filter Media by Weight	ASTM Sieve Size	Percent Passing by Weight
Sand* Clean, Washed, Well Graded, No Organic Material *Aggregate No . FA-10* *ASTM C-33 Concrete Sand* *AASHTO M-6* *AASHTO M-43, No. 9 or No. 10*	80% Max	3/8-inch	100
		No. 4	95-100
		No. 8	80-100
		No. 16	50-85
		No. 30	25-60
		No. 50	10-30
		No. 100	2-10
		No. 200	0-3
Screened Topsoil *Loamy Sand or Sandy Loam* *ASTM D5268* *(imported or manufactured topsoil)* *Max 5% clay content*	15% Max.	2-inch	100
		1-inch	95- 100
		No. 4	75-100
		No. 10	60-100
		No. 200	10-50
		0.002-mm	0-5
Organic Matter in the form of Compost, Leaf Compost,	5% Min	3/8-inch	85-100
		No. 8	50-80

Item	Percent of Total Filter Media by Weight	ASTM Sieve Size	Percent Passing by Weight
Peat Moss or Pine bark Nursery Mix**		No. 30	0-40

Do not use lime stone screenings.
***** Potting grade pine bark with no particles larger than ½ inches.***

Table 10: Filter Media Chemical Analysis

Item	Criteria	Test Method
Corrected pH	6.0 – 7.5	ASTM D4972
Magnesium	Minimum 32 ppm	*
P-Index	0-30	USDA Soil Test
Phosphorus (Phosphate - P_2O_5)	Not to exceed 69 ppm	*
Potassium (K_2O)	Minimum 78 ppm	*
Soluble Salts	Not to exceed 500 ppm	*

**** Use authorized soil test procedures.***

Modify the filter media with magnesium sulfate if the filter media does not meet the minimum requirement for magnesium. Modify the filter media with potash if the filter media does not meet the minimum requirement for potassium. Uniformly mix magnesium sulfate and potash into the filter media prior to use in Bioretention areas.

A filter media that fails to meet the minimum requirements must be replaced. Table 11 shows the recommended depth of the filter media.

Table 11: Bioretention Filter Media Depth

Vegetation	Filter Media Depth (feet)
Turf Grass Only	2.0
Native Grasses or Shrubs	3.0
Small Trees	4.0

Overflow System

Design an overflow system to pass runoff volumes greater than the water quality volume away from the Bioretention area. Place an outflow structure at the elevation of the maximum nine (9) to twelve (12) inch ponding depth above the bioretention area surface to carry excess runoff to a stormwater conveyance system or stabilized outlet.

Plantings

Use plantings that conform to the standards of the current edition of American Standard for Nursery Stock as approved by the American Standards Institute, Inc. For bioretention applications near roadways, consider site distances and other safety concerns when selecting plant heights. Consider human activities which may damage the plantings, cause soil compaction, or otherwise damage the function of the bioretention area when selecting plant species. Table 12 shows plantings suitable for bioretention areas in Charleston County.

Use plant materials that have normal, well-developed stems or branches and a vigorous root system. Only use plantings that are healthy and free from physical defects, plant diseases, and insect pests. Symmetrically balance shade and flowering trees. Ensure major branches do not have V-shaped crotches capable of causing structural weakness. Ensure trunks are free of unhealed branch removal wounds greater than a one (1) inch diameter. Use plant species that are tolerant to wide fluctuations in soil moisture content. Use plantings capable of tolerating saturated soil conditions for the length of time anticipated for the water quality volume, as well as anticipated runoff constituents. Acceptable bioretention area plantings include:

- Turf Grass Only - Use turf grass species that have a thick dense cover, are slow growing, are applicable to the expected moisture conditions (dry or wet), do not require frequent mowing, and have low nutrient requirements. The preferred method of establishing turf grass is sodding. Use temporary erosion control blankets to provide temporary cover when establishing turf grass by seeding.

- Native Grasses and Perennials - Create a low maintenance native grass or wildflower meadow with native grasses and native perennial species. Temporary erosion control blankets may be used in lieu of a hardwood mulch layer. Plant native grasses and perennials of the same species in clusters 1.0 to 1.5 feet on-center.

- Shrubs - Provide shrubs a minimum of two feet in height. Do not plant shrubs near the inflow and outflow points of the Bioretention area. Plant shrubs of the same species in clusters ten (10) feet on-center.

- Trees - Provide trees with a minimum one (1) inch caliper. Plant trees near the perimeter of the Bioretention area. Do not plant trees near the inflow and outflow points of the bioretention area. Do not plant trees directly above underdrains. Plant trees at a density of one tree per 250 square feet.

Table 12: Plantings Suitable for Bioretention

Perennials

Botanical Name	Common Name	Height	Zone[1]	Light	Description
Small Trees Under 30-feet Tall					
Aesculus pavia	Red Buckeye	10-15 ft.	2	Sun /shade	Spring flowers, prefers part shade, may defoliate early in season.
Amalanchier canadensis	Serviceberry	12-20 ft.	2	Sun / part shade	Salt resistant; moist to average soils; Tolerates part shade; Multi-stem grey bark, early spring white flowers, early purple berries, red in fall; high wildlife value, fruits for birds.
Carpinus caroliniana	Ironwood American Hornbeam	30 ft.	1,3	Sun /shade	Shade tolerant, handles inundation of water, unique silver fluted trunk.
Cercis canadensis	Eastern Redbud	20-35 ft.	1,2	Part shade/ shade	Shade tolerant. Moist soils but not too wet; Drought tolerant; many good cultivars.
Chionanthus virginicus	Fringe Tree	20 ft.	2	Sun /shade	Moist soils; excellent small urban tree; Can be shrubby; fragrant pendulous white spring flowers and gold fall color.
Cornus amomum	Silky Dogwood	6-12 ft.	3	Sun	Flood tolerant; intermediate drought & heat resistant; fruit for birds.
Crataugus aestivalis	Mayhaw May Hawthorn	20 ft.	3	Sun	Thorn attractive to nesting birds, red fruit, purple to scarlet in fall.
Crataegus marshallii	Hawthorn	25 ft.	3	Sun /shade	Slender, thorny, or sometimes thorn less, branches. White blossoms followed by bright-red, persistent fruits. Leaves become colorful in fall. Seasonally poor drainage is okay.
Persea borbonia (evergreen)	Redbay	12-25 ft.	3	Sun / part shade	Evergreen small tree or large shrub, some salt tolerance
Magnolia virginiana (evergreen)	Sweetbay Magnolia	15-30 ft.	3	Sun / part shade	Sun to shade semi-evergreen, fragrant flowers, bright red berries, often multi-stem.
Shrubs					
Callicarpa americana	Beautyberry	6 ft.	2	Sun / shade	Average to droughty soils ; no anaerobic tolerance; Striking purple berries on new growth, yellow fall color, sun to part shade; well-suited for mountains.
Cephalanthus occidentalis	Button Bush	8 ft.	3	Part shade / shade	Tolerates flooding, white button flowers persist, attracts hummingbirds; salt-tolerant.
Clethra alnifolia	Sweet Pepperbush	8 ft.	2	Sun/ shade	Extremely fragrant white or pink flowers in summer, yellow in fall; Excellent for coastal gardens due to salt-tolerance.
Ilex verticillata	Common Winterberry	6-10 ft.	3	Sun / part shade	Flood tolerant intermediate drought resistance; Soil must be sandy loam, intolerant to coarse soils (loamy sand). White flowers with red berries retained in winter; well-suited for mountains.
Itea virginica	Virginia Sweetspire	3-6 ft.	3	Sun/ shade	Medium shrub. Fragrant white tassel flowers, deep red or purple fall foliage. Very flood & drought tolerant; salt resistant; Hi anaerobic tolerance. Prefers moist soils.
Lindera benzoin	Spicebush	6-12 ft.	2	Part shade / shade	Very early chartreuse flowers, fragrant leaves, pale yellow fall color. Suitable for Coast.
Virburnum dentatum	Arrowwood	10 ft.	3	Sun/ shade	White flowers, bright blue berry clusters, very tolerant to many soils.
Viburnum nudum	Possumhaw Viburnum	6-12 ft.	3	Sun / part shade	Very flood tolerant & drought tolerant; salt resistant; spring flowers, fruit for birds, fall color, tolerates part shade.
Sabal minor (evergreen)	Dwarf Palmetto	5-8 ft.	3	Sun / shade	Drought tolerant; some salt tolerance; heat resistant. Native palm that slowly spreads with black berries. Suitable for Coast.
Ilex vomitoria (evergreen)	Yaupon Holly	8-15 ft.	1,2	Sun / part shade	High drought tolerance, No anaerobic tolerance. Red fruit in fall & winter. Long lasting translucent berries.
Myrica cerifera (evergreen)	Wax Myrtle	15-20 ft.	1,2	Sun / part shade	Very flood tolerant; excellent salt &resistance; medium drought resistance; medium anaerobic tolerance; medium N fixing. Fragrant leaves, berries for candles, can prune as a hedge.

Wetness Zone[1]	**1** Plants that, once established, withstand drought (3-4 weeks without rainfall); Establishment is 1-2 yrs for trees & shrubs, 1 yr for perennials & grasses **2** Plants that grow best in moist to average soils and only tolerate short periods (1-2 days) of flooding. **3** Plants that tolerate longer periods of flooding (3-5 days), but also grow in moist to average soils.

Amsonia tabernaemontana	Eastern Bluestar	1-3 ft.	3	Sun / part shade	Wetland plant that is Drought resistant; pale blue tubular flowers.
Asclepias incarnata	Swamp Milkweed	2-4 ft.	3	Sun	Pink rose-purple blooms in mid-summer, attracts butterflies. Thrives in mucky clay soils.
Asclepias tuberosa	Butterfly Milkweed	2-3 ft.	1	Sun / part shade	Prefers well-drained sandy soils. Tolerates drought. Striking and rugged plant with orange flowers that attract butterflies. Slow to establish and easy to grow from seed.
Chelone glabra	White Turtlehead	1-4 ft.	3	Sun	Snapdragon type white flowers, often lavender tinged. Attracts butterflies and hummingbirds. Suitable for Coast.
Eupatorium dubium	Joe Pye Weed	3-6 ft.	3	Sun	Rapid grower with large pink to purple flowers that attract butterflies. Has no salt tolerance.
Helianthus angustifolius	Swamp Sunflower	4-7 ft.	3	Sun / part shade	Tall yellow daisy flowers with maroon center. Good seed source for birds. Salt-tolerant.
Hibiscus moscheutos	Rose Mallow Swamp Mallow	3-8 ft.	3	Sun / part shade	Huge white to pink flowers that attract hummingbirds. Salt-tolerant.
Lobelia cardinalis	Cardinal Flower	1-6 ft.	3	Sun/ shade	Drought resistant; Bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand). Brilliant red flower spikes that attract butterflies and hummingbirds.
Rudbeckia fulgida	Black-eyed susan	1-3 ft.	2	Sun	Moist to dry soils; showy flowers; other species & cultivars. Self-sows and produces abundant offsets.
Solidago spp.	Goldenrod	1-4 ft.	3	Sun	Thin sprays of arching flowering stems occur at the top of sturdy stems. *S. sempervirens* (Seaside Goldenrod): salt-tolerant. Most species are suitable.
Vernonia noveboracensis	Ironweed	5-8 ft.	3	Sun	Tall red-purple flower clusters late summer & early fall that attract butterflies. Tolerates inundation.
Grasses					
Andropogon gerardii	Big Bluestem	6-8 ft.	1,2	Sun / part shade	Bunch grass with a blue-green color turning maroon-tan color in fall. Deep roots and drought resistant. Moderately tolerant of acidity and salinity
Chasmanthium latifolium	River Oats	2-4 ft.	1,3	Sun / part shade	Clump forming. Dangling oats are ornamental and copper in fall. Medium drought and anaerobic tolerance; showy seed clusters, spreads by seed.
Elymus virginicus	Virginia Wild Rye	2-4 ft.	1,3	Sun / part shade	Lush green, upright growing grass.
Muhlenbergia capillaris	Muhly Grass	1-3 ft.	1,3	Sun	In the fall, creates a stunning pink to lavender floral display. Functions well in meadow gardens. Salt-tolerant.
Panicum virgatum	Panic Grass Switch grass	3-6 ft.	1,3	Sun / part shade	Clump forming grass very tolerant of flooding and tolerates dry soils and is drought resistant; some salt-tolerance; fuzzy flower heads.
Schizachyrium scoparium	Little Bluestem	2-3 ft.	1,2	Sun / part shade	Clump grass that attracts birds and mammals. Blue-green stems that turn mahogany-red with white seed tufts in the fall. Readily reseeds. Suitable for the Coast.
Sorghastrum nutans	Indiangrass	3-6 ft.	1,2	Sun / part shade	Tall, bunching sod-former, with broad blue-green blades and a large, plume-like, soft, golden-brown seed head. Fall color is deep orange to purple. Drought tolerant.
Spartina patens	Saltmeadow Cordgrass	1-3 ft.	1,3	Sun	Spreads to form mass, fine-textured, salt-tolerant
Ferns					
Osmunda cinnamomea	Cinnamon Fern	3-4 ft.	3	Part shade / shade	Ideal for moist areas of Bioretention area. Non-flowering plant that reproduces by spores.
Osmunda regalis	Royal Fern	2-3 ft.	3	Part shade / shade	Tolerates year-round shallow water.
Wetness Zone[1]	**1** Plants that, once established, withstand drought (3-4 weeks without rainfall); Establishment is 1-2 yrs for trees & shrubs, 1 yr for perennials & grasses **2** Plants that grow best in moist to average soils and only tolerate short periods (1-2 days) of flooding. **3** Plants that tolerate longer periods of flooding (3-5 days), but also grow in moist to average soils.				

Planting Plan

A bioretention area landscape plan includes all planting types, total number of each species, and the location of each species used. The plan includes a description of the contractor's responsibilities including a planting schedule, installation specifications, initial maintenance, a warranty period, and expectations of plant survival. A planting plan includes long-term inspection and maintenance guidelines. Use planting plans prepared by a qualified landscape architect, botanist, or qualified extension agent. Use native plant species over non-native species. Ornamental species may be used for landscaping effect if they are not aggressive or invasive.

Mulch Layer

Provide a uniform three (3) inch layer of mulch on the surface of the bioretention area that provides an environment to enhance plant growth, enhance plant survival, suppresses weed growth, reduce erosion of the filter media, maintain soil moisture, trap fine sediments, promote the decomposition of organic matter, and pre-treat runoff before it reaches the filter media.

Provide shredded hardwood bark that consists of bark from hardwood trees milled and screened to a maximum four (4) inch particle size, uniform in texture, free from sawdust and foreign materials, and free from any artificially introduced chemical compounds detrimental to plant life. Provide mulch that is well aged a minimum of six (6) months.

Do not use pine needle or pine bark mulch due to the ability of floatation.

Use alternative surface covers such as native groundcover, erosion control blankets, river rock, or pea gravel as directed by the RCE. Use alternative surface covers based on function, cost, and maintenance.

Do not provide a mulch layer for bioretention areas that utilize turf grass as the vegetation material.

Pre-treatment System

Provide a pre-treatment system to reduce incoming velocities, evenly spread the flow over the entire bioretention area, and to trap coarse sediment particles before they reach the filter media. Several pre-treatment systems are applicable, depending on whether the bioretention area receives sheet flow, shallow concentrated flow, or deeper concentrated flows. The following are appropriate pre-treatment options:

- Forebay (for channel flow): Located at pipe inlets or curb cuts leading to the bioretention area consisting of energy dissipation and flow dispersion sized for the expected peak discharge rate. The forebay may be formed by a wooden or stone check dam or an earthen or rock berm. Ensure the forebay is protected with the proper erosion prevention measures. The forebay does not require an underlying filter media.

- Grass Filter Strips (for sheet flow): Extend a minimum of ten (10) feet from edge of pavement to the upstream edge of the bioretention area with a maximum slope of 5%.

- Gravel or Stone Diaphragms (for sheet or concentrated flow): Located at the edge of pavement or other inflow point, running perpendicular to the flow path to promote settling. Size the stone according to the expected peak discharge rate.

- Curb stops with cut outs. The cut out height is no greater than one (1) inch with a maximum length of six (6) inches. Space cutouts no less than six (6) feet apart on center.
- Level Spreaders (for sheet flow): Gravel, landscape stone, or concrete level spreader located along the upstream edge of the bioretention area. Level spreaders successfully reduce incoming energy from the runoff and convert concentrated flow to sheet flow that is evenly distributed across the entire Bioretention area.
- This requires a two (2) to four (4) inch elevation drop from a hard-edged surface into the bioretention area.
- Manufactured Treatment Devices (MTDs): An approved MTD may be used to provide pre-treatment.

Construction Requirements

Do not construct bioretention areas until all contributing drainage areas are stabilized as directed by the RCE. Do not use bioretention areas as sediment control facilities for during construction sediment control. Do not operate heavy equipment within the perimeter of bioretention areas during excavation, underdrain placement, backfilling, planting, or mulching.

Separate bioretention areas from the water table to ensure groundwater does not enter the facility leading to groundwater contamination or bioretention failure. Ensure a vertical distance of three (3) feet between the bottom of the bioretention area and the seasonally high ground water table.

Site Preparation

Pre-treat stormwater runoff to reduce the incoming velocities, evenly spread the flow over the entire bioretention area, and provides removal of coarse sediments. Because bioretention areas are sensitive to fine sediments, do not install them on sites where the contributing area is not completely stabilized or is periodically being disturbed.

Installation

Bioretention areas work best when constructed off-line, capturing only the water quality volume. Divert excess runoff away from the bioretention area or collect excess runoff with an overflow system. Install bioretention areas around the natural topography to complement the surrounding landscape by fitting around sensitive areas, natural vegetation, roads, driveways, and parking lots. Bioretention areas have a minimum width of ten (10) feet and a minimum flow length of forty (40) feet to establish a strong healthy stand of vegetation.

Excavation

Excavate the bioretention area to the dimensions, side slopes, and elevations shown on the plans. Excavate bioretention areas to the required depth based on the plantings utilized. Ensure excavation minimizes the compaction of the bottom of the bioretention area. Operate excavators and backhoes on the ground adjacent to the bioretention area or use low ground-contact pressure equipment. Do not operate heavy equipment on the bottom of the bioretention area. Remove excavated materials from the bioretention area and dispose of them properly.

Underdrain System

Prior to placing the underdrain system, alleviate compaction on the bottom of the bioretention area by using a primary tilling operation such as a chisel plow, ripper, or subsoiler to a depth of twelve (12) inches. Substitute methods must be approved by the RCE. Rototillers typically do not till deep enough to reduce the effects of compaction from heavy equipment.

Remove any ponded water from the bottom of the excavated area. Line the excavated area with a Class 2, Type C nonwoven geotextile fabric.

Place a layer of No. 57 aggregate three (3) feet wide and minimum of three (3) inches deep on top of the nonwoven filter fabric. Place the pipe underdrains on top of the underlying aggregate layer. Lay the underdrain pipe at a minimum 0.5 percent longitudinal slope. The perforated underdrain drain pipe may be connected to a stormwater conveyance system or stabilized outlet. Cap the ends of underdrain pipes not terminating in an observation well.

Install observation wells/cleanouts of non-perforated vertically in the bioretention area. Install observation wells and/or clean-out pipes at the ratio of one minimum per every 1,000 square feet of surface area as shown on the plans. Connect the wells/cleanouts to the perforated underdrain with the appropriate manufactured connections as shown on the Plans. Extend the wells/cleanouts six (6) inches above the top elevation of the bioretention area mulch layer and cap with a screw cap.

Place No. 57 aggregate around the pipe underdrain system to a minimum depth of eight (8) inches. Place a Class 2, Type C nonwoven geotextile fabric between the boundary of the gravel and the filter media to prohibit the filter media from filtering down to the perforated pipe underdrain.

Place an outflow structure at the elevation of the maximum nine (9) to twelve (12) inch ponding depth of the bioretention area to carry excess runoff from the bioretention area to a stormwater conveyance system or stabilized outlet.

Internal water storage zone(Denitrification Zone)

Create the internal water storage zone by adding a 90 degree angle (elbow) to the outlet of the underdrain system that is perpendicular (vertical) to the horizontal underdrain. The 90 degree elbow extends to a minimum height of twelve (12) inches above the invert of the underdrain system. The pipe from the elbow will reconnect with the underdrain pipe upstream of the overflow spillway. Install a valve at the 90 degree elbow to allow drainage of the internal water storage zone. Install the 90 degree elbow and valve in the primary outlet structure or in an access well for a means of opening/closing the valve.

Filter Media

Install a permeable, non-woven geotextile filter fabric between the filter media and the on-site soils. Place and grade the filter media using low ground-contact pressure equipment or excavators and/or backhoes operating on the ground adjacent to the bioretention area. Do not use heavy equipment within the perimeter of the bioretention area before, during, or after the placement of the filter media.

Place the filter media in vertical layers with a thickness of twelve (12) to eighteen (18) inches. Compact the filter media by saturating the entire bioretention area after each lift of filter media is placed until water flows from the underdrain system. Apply water for saturation by spraying or sprinkling. Perform saturation of each lift in the presence of the RCE. Do not use equipment to compact the filter media. Use an appropriate sediment control BMP to treat any sediment-laden water discharged from the underdrain during the settling process.

Test the installed filter media to determine the actual infiltration rate after placement. Ensure the infiltration rate is within the range of one (1) to six (6) inches per hour.

Plantings

Plant all bioretention areas grasses, native grasses, perennials, shrubs, trees, and other plant materials specified to applicable landscaping standards.

Ensure all plant materials are kept moist during transport and on-site storage. Plant the root ball so one-eighth ($^1/_8$) of the ball is above final filter media surface. Ensure the diameter of the planting pit/hole is at least six (6) inches larger than the diameter of the planting ball. Set and maintain the plant straight during the entire planting process. Thoroughly water all plantings after installation.

Brace trees using two (2) inch by two (2) inch stakes only as necessary. Ensure stakes are equally spaced on the outside of the tree ball.

Mulch

Immediately mulch the entire bioretention area to a uniform thickness of three (3) inches after all plantings are in place. Do not use mulch for bioretention areas that utilize turf grass as the only vegetation material.

Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of bioretention areas.

The surface of the ponding area may become clogged with fine sediments over time. Perform light core aeration or cultivate unvegetated areas as required to ensure adequate filtration. Other required maintenance includes but is not limited to:

- Perform pruning and weeding to maintain appearance periodically as needed.
- Replace or replenish mulch periodically as needed.
- Remove trash and debris periodically as needed.

Table 13 outlines the maintenance requirements for bioretention areas.

Table 13: Bioretention Maintenance Requirements

Required Maintenance	Frequency
Pruning and weeding	As needed
Remove trash and debris	As needed
Inspect inflow points for clogging and remove any sediment	Semi-annual (every 6 months)
Repair eroded areas and re-seed or sod as necessary	Semi-annual (every 6 months)
Mulch void areas	Semi-annual (every 6 months)
Inspect trees and shrubs to evaluate their health	Semi-annual (every 6 months)
Remove and replace dead or severely diseased vegetation	Semi-annual (every 6 months)
Remove invasive vegetation	Semi-annual (every 6 months)
Nutrient and pesticide management	Annual, or as needed
Water vegetation, shrubs ,and trees	Semi-annual (every 6 months)
Remove mulch, reapply new layer	Annual
Test filter media for pH	Annual
Apply lime if pH < 5.2	As needed
Add iron sulfate + sulfur if pH > 8.0	As needed
Place fresh mulch over entire area	As needed
Replace pea gravel diaphragm	Every 2 to 3 years if needed

Figure 3: Bioretention Area Details

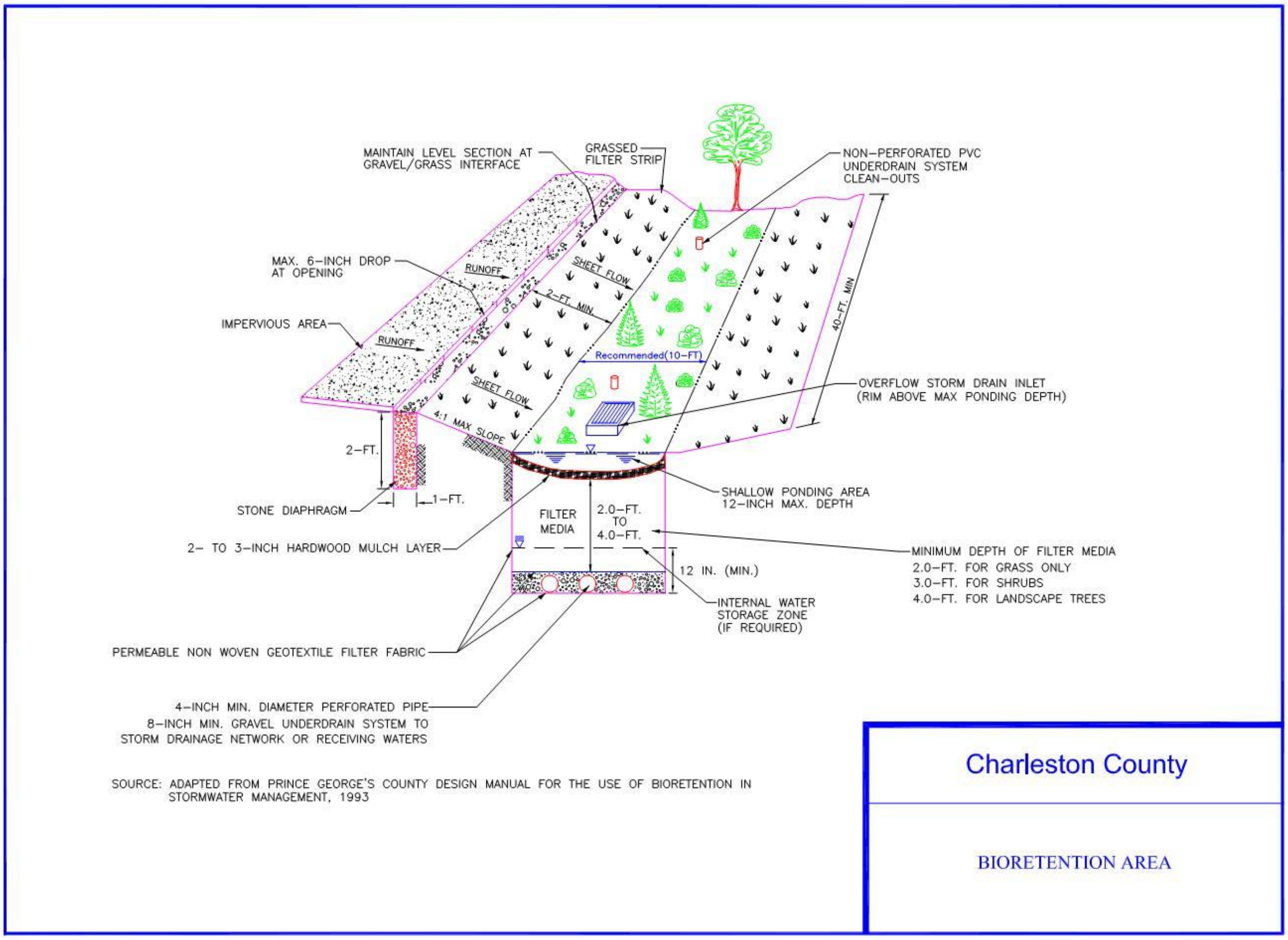
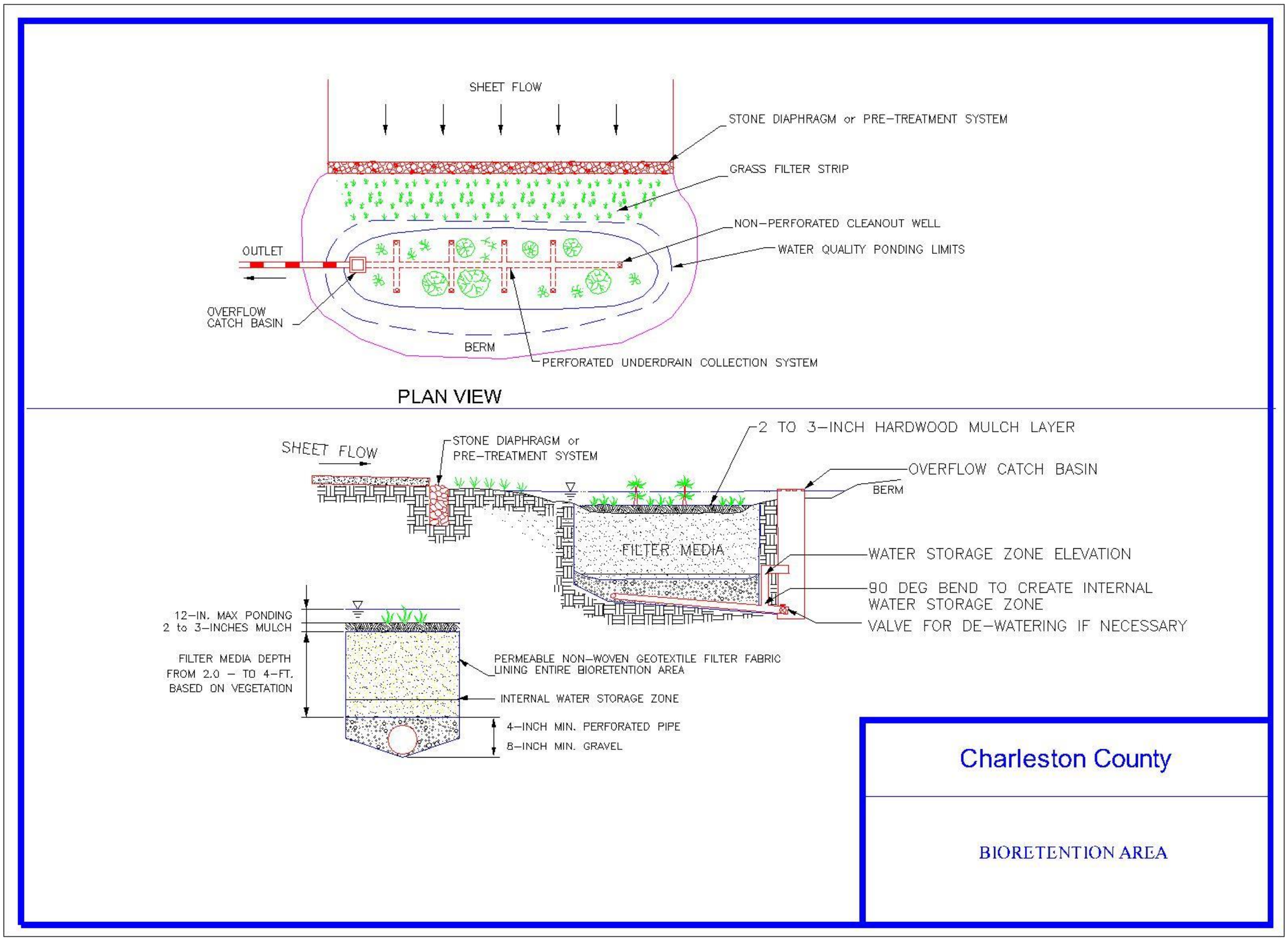


Figure 4: Bioretention Area Cross-section Details



Site Constraints

Bioretention is applicable for small sites where stormwater runoff rates are low and can be received into the bioretention area as sheet flow. Because bioretention areas are sensitive to fine sediments, do not install them on sites where the contributing area is not completely stabilized or is periodically being disturbed.

Enhanced Bioswale

Description

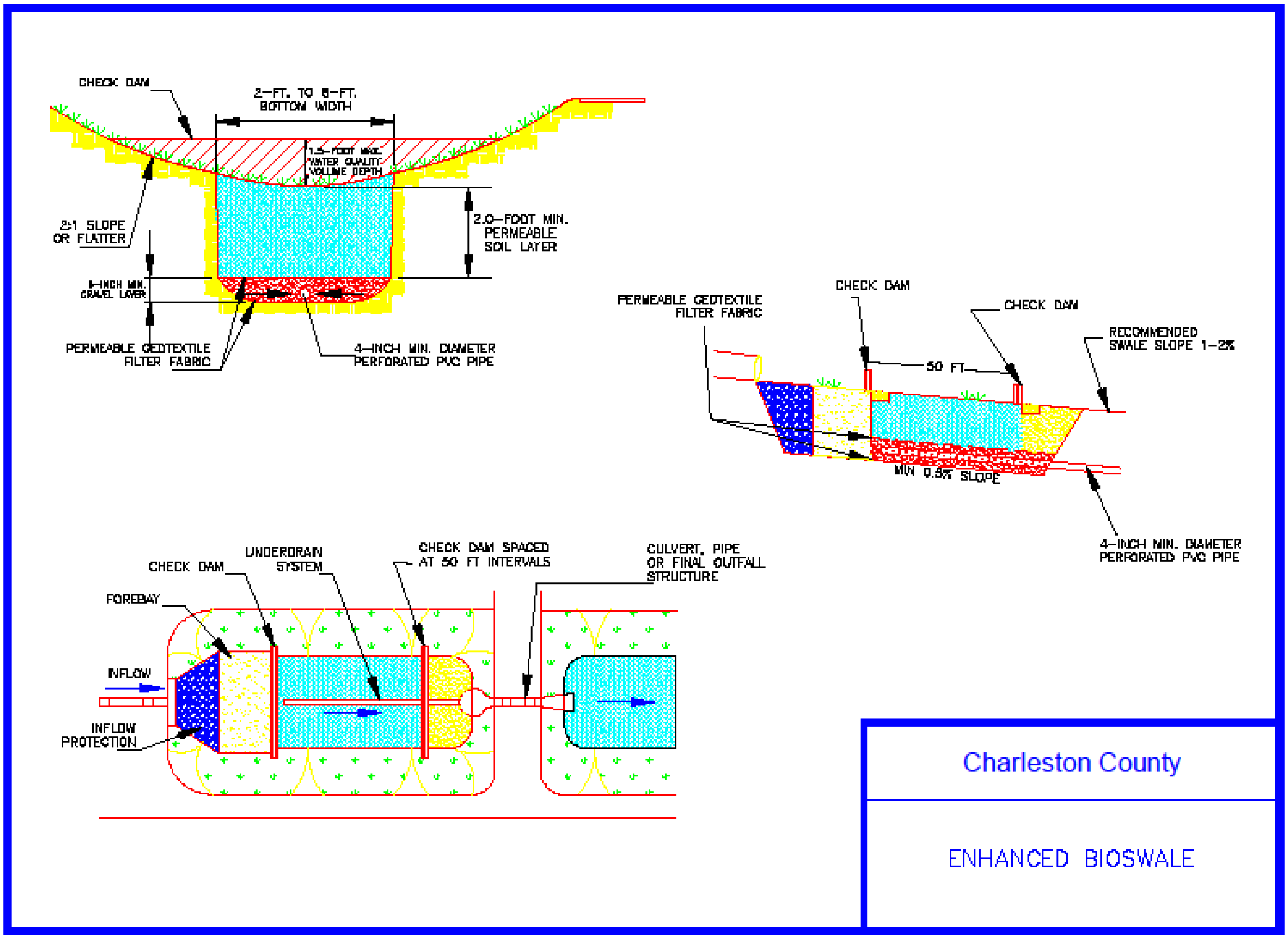
Bioswales are modified vegetated swales that use bioretention media beneath the swale to improve water quality and reduce the runoff volume and peak runoff rate. The bioretention media enhances infiltration, water retention and nutrient and pollutant removal. Infiltration can be enhanced by adding rock check dams at specified intervals along the conveyance.

Table 14 provides the design criteria for enhanced bioswales in Charleston County. Figure 5 provides a detail drawing as guidance for the design of enhanced bioswales.

Table 14: Enhanced Bioswale for 80% Annual TSS Trapping

<table>
<tr><th>Parameters</th><th>Lane Width (ft)</th><th>Longitudinal Slope</th><th>Check Dam spacing (ft)</th></tr>
<tr><td rowspan="2">-Up to 300 ft. of road length to <u>100 ft.</u> of bioswale length</td><td rowspan="5">10</td><td>0.5%</td><td rowspan="3">45</td></tr>
<tr><td>1%</td></tr>
<tr><td rowspan="2">-Enhanced bioswale side slopes 3.5:1 or flatter</td><td>2%</td></tr>
<tr><td>4%</td><td rowspan="2">30</td></tr>
<tr><td rowspan="2">-Enhanced bioswale bottom width must be at least 3 ft.</td><td>6%</td></tr>
<tr><td rowspan="5">12</td><td>0.5%</td><td rowspan="2">45</td></tr>
<tr><td rowspan="2">-Sandy Loam media in enhanced bioswale</td><td>1%</td></tr>
<tr><td>2%</td><td rowspan="3">30</td></tr>
<tr><td>-Check dams at least 1 ft tall</td><td>4%</td></tr>
<tr><td rowspan="4">-Check dam constructed with 2 in. or smaller stones or coir (or similar filtering material) logs</td><td>6%</td></tr>
<tr><td rowspan="5">18</td><td>0.5%</td><td rowspan="2">45</td></tr>
<tr><td>1%</td></tr>
<tr><td>2%</td><td rowspan="2">30</td></tr>
<tr><td rowspan="7"></td><td>4%</td></tr>
<tr><td>6%</td><td>20</td></tr>
<tr><td rowspan="5">24</td><td>0.5%</td><td>45</td></tr>
<tr><td>1%</td><td rowspan="2">30</td></tr>
<tr><td>2%</td></tr>
<tr><td>4%</td><td rowspan="2">20</td></tr>
<tr><td>6%</td></tr>
</table>

Figure 5: Enhanced Bioswale Details



Maintenance

The primary maintenance requirements include periodic mowing, clearing of debris, and sediment removal. It is recommended that the grass should not be cut shorter than the design flow depth. Routine inspections should be performed to ensure the system is functioning properly. The inspector should check for erosion, blockages and evidence of ponding water.