WQ-03: BIORETENTION

1.0 Bioretention

1.1 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 temporarily stored and collected by an underdrain system that eventually discharges to a designed storm conveyance system.

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. Applicable sites include:

- Parking lot islands,
- Cul-de-sacs,
- Common areas,
- Individual residential home sites, and
- Small commercial facilities.

Bioretention areas are capable of removing metals, suspended solids, and oil and grease, and phosphorus but may perform poorly in the removal of nitrogen. In areas where nitrogen is a pollutant of concern, the Bioretention area underdrain system can be adapted to provide some denitrification.

1.2 Design

1.2.1 General Design Criteria

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 forty (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 1.

Table 1. General Design Characteristics for Bioretention Areas

Infiltration Rate	Between 1- and 6-inches per hour for Filter Media.
Maximum Water Depth	Range from 6- to 12-inches, with a 9-inch standard.
Surface Area	Varies, but typically 3 to 8% of the contributing watershed, depending on the amount of impervious area.
Water Table	Vertical distance of 3 feet between bottom of Bioretention area and seasonally high ground water table (typically 4- to 6-feet below ground surface of the Bioretention).
Places to Avoid	Areas that regularly flood (at least once a year) and areas adjacent to building foundations.
Mulch	A minimum of 2-inches is required while 3- to 4-inches is preferable. Use hardwood, not pine bark nuggets (float). Double-shredded hardwood works well.
Stone for Gravel Layer	Washed 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.

1.2.2 Surface Area

The Bioretention surface area may be calculated by the following equation from research by the North Carolina Extension Service, 1999:

$$\text{BSA} = \frac{(\text{DA})(Rv)}{D_{avg}}$$

Where:

BSA = Bioretention surface area ($feet^2$)
DA = Contributing drainage area of Bioretention area ($feet^2$)
Rv = Runoff volume (feet) 0.083-feet (1-inch) for Anderson County
Davg = Average ponding water depth above ground (feet)

The Bioretention surface area may also be calculated by the following equation from research by Prince George's County, MD:

$$\text{BSA} = 0.1(Rv)(DA)$$

Where:

BSA = Bioretention surface area ($feet^2$)
0.1 = Empirical conversion factor
Rv = Runoff volume (inches) 1-inch for Anderson County
DA = Contributing drainage area of Bioretention area ($feet^2$)

1.2.3 Water Draw Down Time

Design Bioretention areas to fully de-water within a 24- to 72-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 12 hours. Design for runoff within the filter media to drain to a depth of 2-feet below the Bioretention area surface within 48 hours.

Design the underdrain system to safely pass the peak draw down flow rate of the filter media The general equation used to determine draw down time is Darcy's Equation:

$$Q = 2.3e^{-5}\ K\ A \frac{\Delta H}{\Delta L}$$

Where:

Q = Flow rate through bioretention (cfs)

K = Hydraulic conductivity of the filter media (in/hr) (Value varies based on actual filter media used)

A = Surface area of bioretention ($feet^2$)

ΔH = Maximum ponding depth above bottom of soil mix (feet)

ΔL = Depth of soil mix (feet)

Typical hydraulic conductivity values are given in Table 2.

Table 2. General Hydraulic Conductivity of Soils

Soil Classification	Hydraulic Conductivity (inches/hour)
Sand	6.0
Loamy Sand	2.0
Sandy Loam	0.5-1.0

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

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.

1.3 Materials

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

1.3.1 Underdrain System

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

Provide an underdrain system that consists of continuous closed joint perforated plastic pipe underdrains with a minimum 4-inch diameter, an 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 minimum 4-inch diameter non-perforated PVC clean out wells.

The maximum spacing of pipe underdrains is 10 feet.

Design the under drain system to safely pass the peak draw down rate calculated in Section 1.2.3.

Table 3: Underdrain Material Specifications

Material	Specification
No. 57 Aggregate	Use course aggregate No. 57 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 underdrains with a minimum diameter of 4-inches.
Nonwoven Geotextile Fabric	Use Class 2 Type C non-woven geotextile fabric.

1.3.2 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 (min 12 inches).

Provide a minimum of 12 inches of Filter Media above the max ponding height of the Internal Water Storage Zone.

Install a valve as specified in Section 1.4.2.3 for dewatering the Internal Water Storage Zone if prolonged standing water occurs.

1.3.2 Filter Media

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

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 9-inches to 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 1.0 in/hour and a maximum rate of 6.0 in/hr. The average porosity of the filter media is approximately 0.45.

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 following criteria:

Table 4: 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 in.	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 in.	100
		1 in.	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, Peat Moss or Pinebark Nursery Mix**	5% Min	3/8 in.	85-100
		No. 8	50-80
		No. 30	0-40

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

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 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 5:

Table 5: 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.

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.

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.

The recommended depth of the filter media is shown in Table 6.

Table 6: Filter Media Depth

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

1.3.3 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 9-inch to 12-inch ponding depth above the Bioretention area surface to carry excess runoff to a stormwater conveyance system or stabilized outlet.

1.3.4 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.

Use plant materials that have normal, well developed stems or branches and a vigorous root system. Only use plantings that are healthy, 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 1 in. 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,
- Native Grasses and Perennials,
- Shrubs, and
- Trees.

1.3.4.1 Turf Grass Only

Use turfgrass species with a thick dense cover, slow growing, 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.

1.3.4.2 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.

1.3.4.3 Shrubs

Provide shrubs a minimum of 2-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 10 feet on-center.

1.3.4.4 Trees

Provide trees with a minimum 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.

1.3.4.5 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. Typical plantings are shown in Table 7.

Table 7: Native Plant Species for Bioretention Areas

Perennials/Grasses	Shrubs	Trees
Eastern Bluestar *(Amsonia tabernaemontana)*	Beautyberry *(Callicarpa americanas)*	Red Buckeye *(Aesulus pavia)*
Swamp Milkweed *(Asclepias incarnata)*	Button Bush *(Cephalanthus occidentalis)*	Serviceberry *(Amelanchier canadensis)*
Butterfly Milkweed *(Asclepias tuberosa)*	Sweet Pepperbush *(Clethra ainifolia)*	Ironwood - American Hornbeam (*Carpinus caroliniana*)
White Turtlehead *(Chelone glabra)*	Common Winterberry *(Ilex verticillatta)*	Eastern Redbud (*Cercis candensis*)
Joe Pye Weed *(Eupatorium purpureum)*	Virginia Sweetspire *(Itea virginica)*	Fringe Tree (*Chionanthus virginicus*)
Swamp Sunflower *(Helianthus angustifolius)*	Spicebush *(Lindera benzoin)*	Silky Dogwood *(Cornus amomum)*
Rose / Swamp Mallow *(Hibiscus moscheutos)*	Possumhaw *(Viburnum nudum)*	Mayhaw, May Hawthorn *(Crataugus aestivalis)*
Cardinal Flower *(Lobelia cardinalis)*		*Hawthorn* *(Crataegus marshallii)*
Black-eyed Susan *(Rudbeckia fulgida)*	**Evergreens**	
Goldenrod *(Solidago rugosa)*	Inkberry Holly *(Ilex glabra)*	**Evergreens**
Ironweed *(Vernonia noveboracensis)*	Dwarf Yaupan / Yaupan Holly *(Ilex vomitoria)*	American Holly *(Ilex Opaca)*
Grasses	Wax Myrtle *(Myrica cerifera)*	Sweetbay Magnolia *(Magnolia virginiana)*
Big Bluestem *(Andropogon gerardii)*		
River Oats *(Chasmanthium latifolium)*	**Ferns**	
Virginia Wild Rye *(Elymus virginicus)*	Cinnamon Fern *(Onoclea cinnamomea)*	
Muhly Grass *(Muhlenbergia capillaries)*	Royal Fern (Osmunda regalis)	
Switch Grass *(Panicum virgatum)*		
Little Bluestem *(Schiachyrium scoparium)*		
Indian Grass *(Sorghastrum nutans)*		
Note: Prior to selection, review detailed Bioretention plant lists for more detailed information regarding inundation, drought and salt tolerance for each species.		

Botanical Name	Common Name	Height	Zone[1]	Light	Description
Small Trees Under 30-fet 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.
Ilex opaca (evergreen)	American Holly	15-30 ft.	1,2	Sun/ shade	Medium drought tolerance; Bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand); Sun to shade evergreen, slow growing, white flowers, red berries.
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	Very flood tolerant intermediate drought resistance; Bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand). White flowers with red berries retained in winter; sun to part shade; 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. Well suited for Piedmont. Prefers moist soils.
Lindera benzoin	Spicebush	8 ft.	3	Part shade/ shade	Very early chartreuse flowers, fragrant leaves, pale yellow fall color. Suitable for Coast.
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.
Ilex glabra (evergreen)	Inkberry Holly	6-8 ft.	3	Sun/ shade	Very flood tolerant. Salt resistant; Hi anaerobic tolerance. White flowers with black berries.
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.

Botanical Name	Common Name	Height	Zone[1]	Light	Description
Perennials					
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 Piedmont.
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 or 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 rugosa	Goldenrod	1-4 ft.	3	Sun	Thin sprays of arching flowering stems occur at the top of sturdy stems.; Other species & cultivars
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	Part shade/ 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.
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/ 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
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[2]	**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.				

1.3.5 Mulch Layer

Provide a uniform 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 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 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 ENGINEER. 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.

1.3.6 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 pretreatment 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 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.
- **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 2 to 4 inch elevation drop from a hard-edged surface into the Bioretention area.
- **Manufactured Stormwater Devices (MTDs):** An approved MTD may be used to provide pre-treatment.

1.4 Construction Requirements

Do not construct Bioretention areas until all contributing drainage areas are stabilized as directed by the ENGINEER. 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 4 feet between the bottom of the Bioretention area and the seasonally high ground water table.

1.4.1 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.

1.4.2 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.

1.4.2.1 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.

1.4.2.2 Underdrain System

Prior to placing the underdrain system, alleviated 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 12 inches. Substitute methods must be approved by the ENGINEER. 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 3-foot wide, and minimum of 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 1000 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 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 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 9-inch to 12-inch ponding depth of the Bioretention area to carry excess runoff from the Bioretention area to a stormwater conveyance system, or stabilized outlet.

1.4.2.3 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 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.

1.4.2.4 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 12 to 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 ENGINEER. 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 1 to 6 inches per hour.

1.4.2.5 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 1/8th of the ball is above final filter media surface. Ensure the diameter of the planting pit/hole is at least six 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 2-inch by 2-inch stakes only as necessary. Ensure stakes are equally spaced on the outside of the tree ball.

1.4.2.6 Mulch

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

1.5 Inspection and Maintenance of Bioretention

Regular inspection and maintenance is critical to the effective operation of Bioretention areas. Maintenance responsibility of the Bioretention area is vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

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 8: Summary of Maintenance Requirements

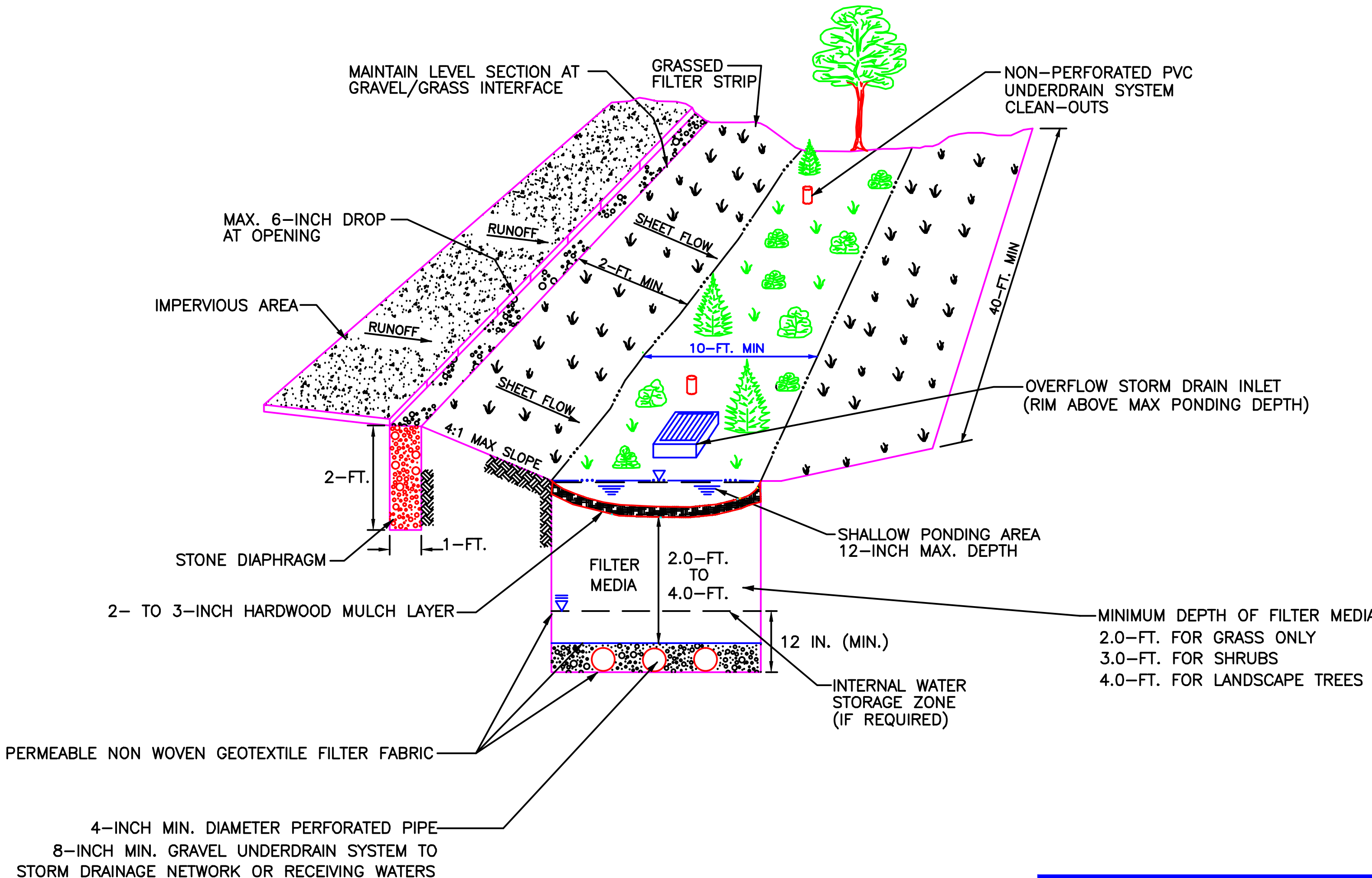
Required Maintenance	Frequency
Pruning and weeding.	As needed
Remove trash and debris.	As needed
Inspect inflow points for clogging. Remove any sediment	Semi-annual (every 6 months)
Repair eroded areas. Re-seed or sod as necessary.	Semi-annual (every 6 months)
Mulch void areas.	Semi-annual (every 6 months)
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)
Removal of evasive 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

1.6 References

Clemson University Public Service Activities Carolina Clear, Rain Gardens, A Rain Garden Manual for South Carolina.

NCDENR Stormwater BMP Manual, Chapter 12 Bioretention, Chapter Revised 07-24-09

Prince George's County, Maryland, Bioretention Design Specifications and Criteria, Section 2.0 - Siting and Design Criteria



SOURCE: ADAPTED FROM PRINCE GEORGE'S COUNTY DESIGN MANUAL FOR THE USE OF BIORETENTION IN STORMWATER MANAGEMENT, 1993

Anderson County, SC

BIORETENTION

STANDARD DRAWING NO. WQ-03 Page 1 of 2

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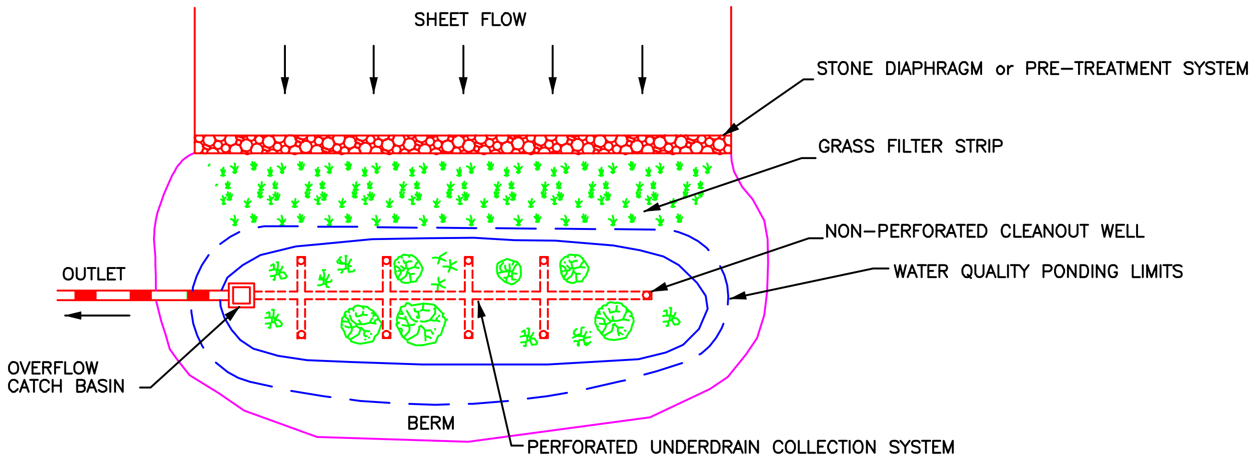
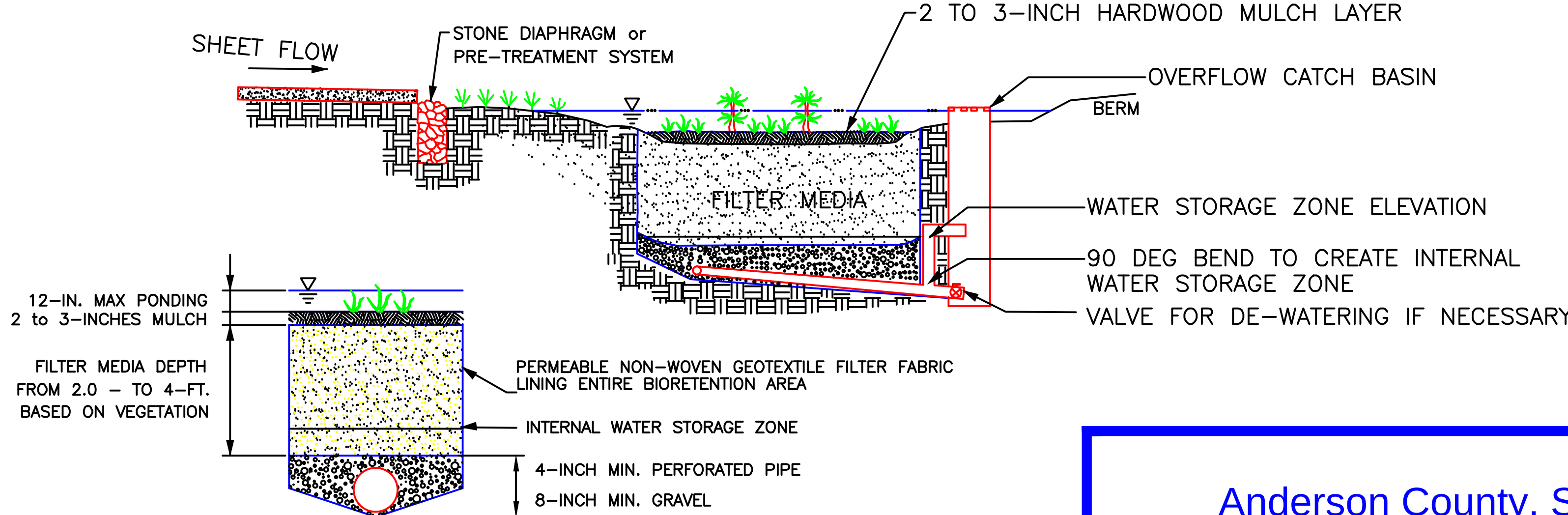


PLAN VIEW



Anderson County, SC

BIORETENTION

STANDARD DRAWING NO. WQ–03 Page 2 of 2

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