C-2. Bioretention Cell

Design Objective

A bioretention cell is an excavation that is filled with a sandy media and plants. It is designed to temporarily hold and filter stormwater. Bioretention cells are one of the most versatile SCMs: They can be installed in a variety of soil types from clay to sand and in a wide variety of sites. They are also one of the most effective SCMs for removing pollutants, because they use many different pollutant removal mechanisms, including infiltration, absorption, adsorption, microbial action, plant uptake, sedimentation, and filtration.

Design Volume

The design volume for a bioretention cell is equivalent to the volume that is contained above the planting surface to the invert of the bypass mechanism for the design storm.

Important Links

[Rule 15A NCAC 2H .1052. MDC for Bioretention Cells]

[SCM Credit Document, C-2. Credit for Bioretention Cells]

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Figure 1: Bioretention Example: Plan View

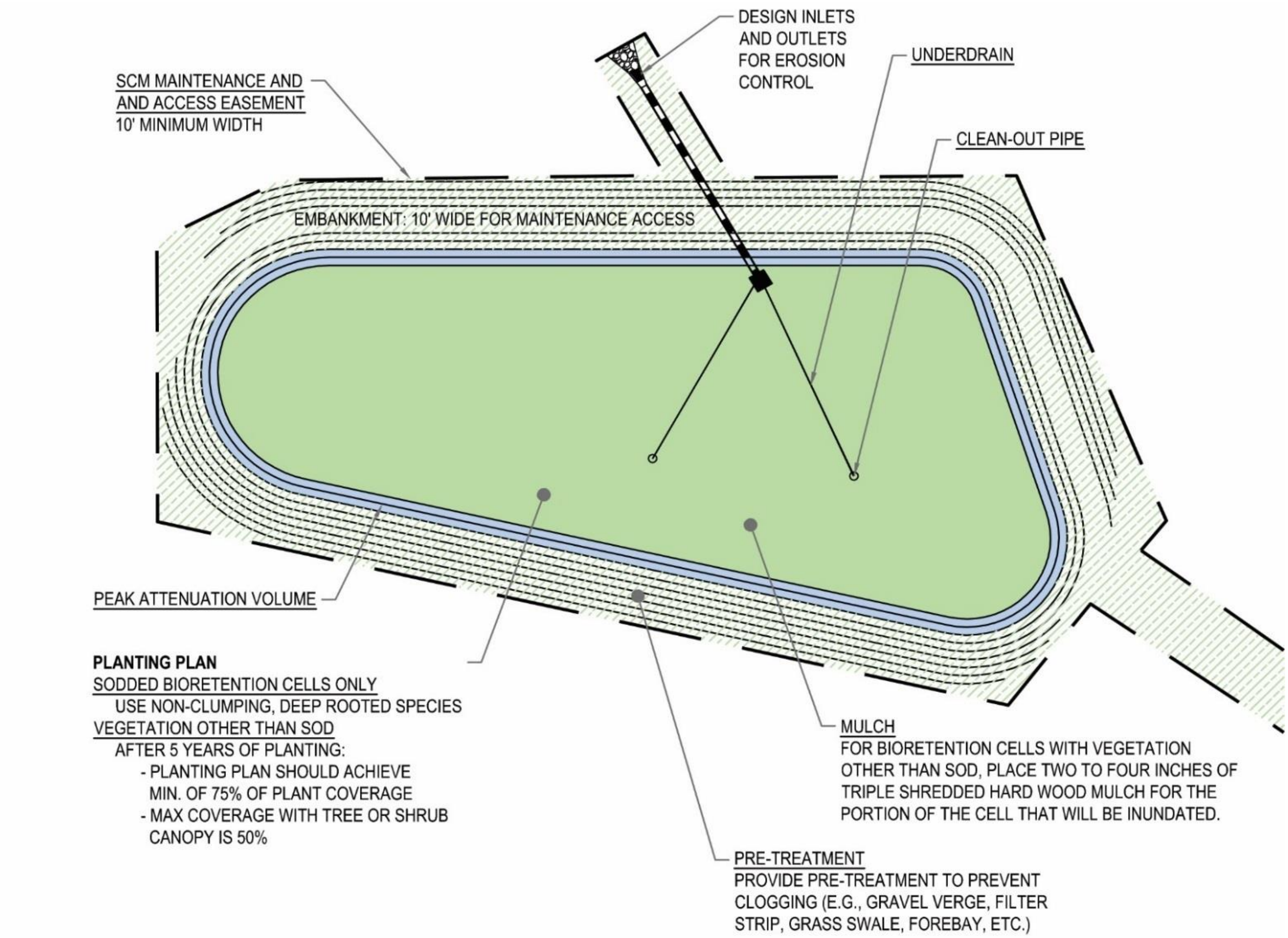
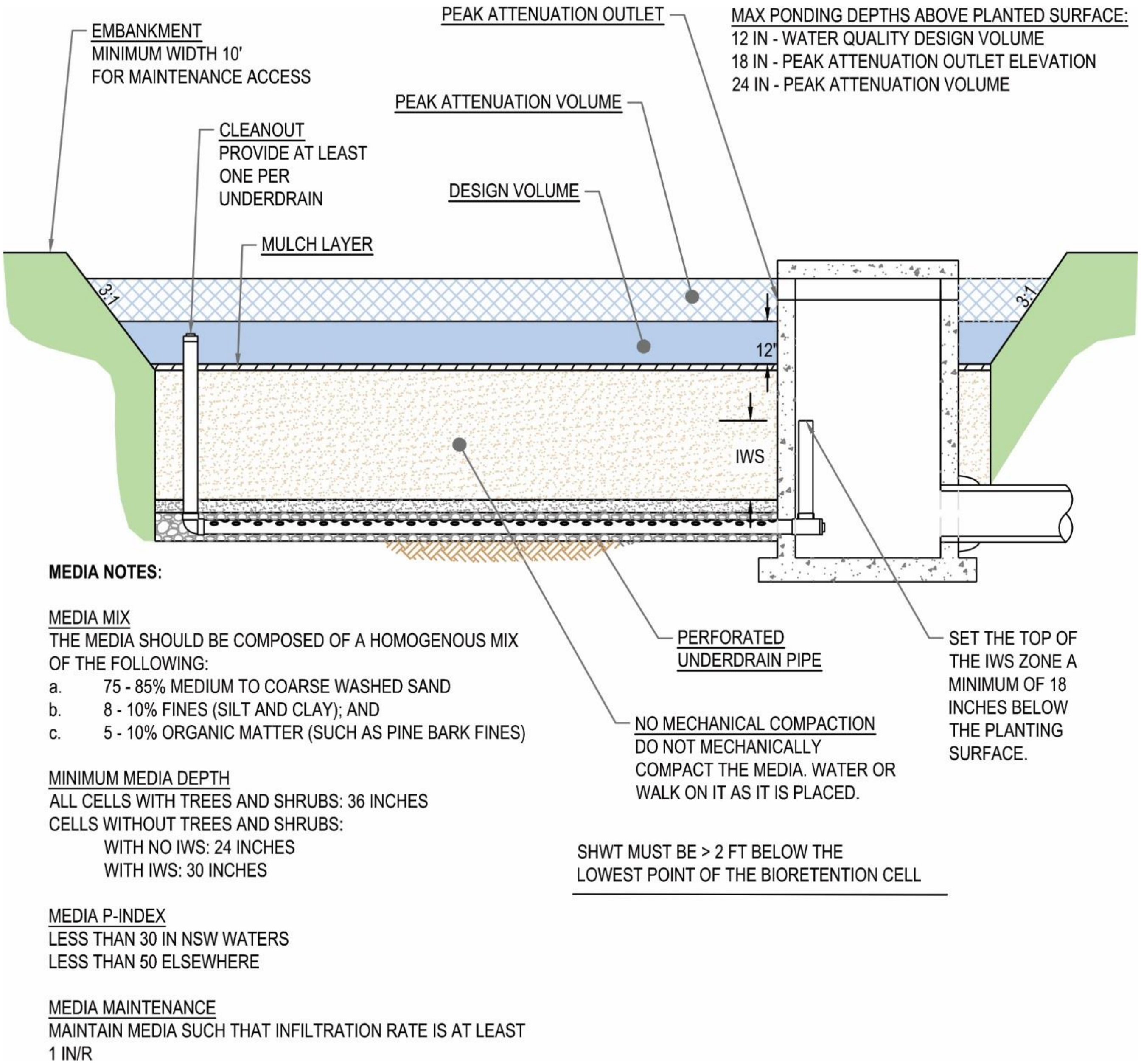


Figure 2: Bioretention Example: Cross-Section



Guidance on the MDC

BIORETENTION MDC 1. SEPARATION FROM THE SHWT.
The lowest point of the bioretention cell shall be a minimum of two feet above the SHWT. However, the separation may be reduced to no less than one foot if the applicant provides a hydrogeologic evaluation prepared by a licensed professional. The calculation of the volume of the main pool under this MDC does not include the volume of the forebay.

The separation from the seasonal high water table is needed to insure that the media does not become saturated and unable to function effectively. See Part A-3 for more information about conducting soil tests for SCMs.

BIORETENTION MDC 2: MAXIMUM PONDING DEPTH FOR DESIGN VOLUME.
The maximum ponding depth for the design volume shall be 12 inches above the planting surface.

This MDC is used to calculate the required surface area of the bioretention cell, which is equal to the required treatment volume divided by the ponding depth. The ponding depth above the media and mulch shall be 12 inches or less (however 9 inches or less is recommended if the site will allow this much space to be devoted to the bioretention cell). The 12-inch limitation on depth is based on the typical inundation tolerance of the vegetation used in bioretention facilities, as well as the ability of the ponded water to drain into the soil within the required time.

BIORETENTION MDC 3: PEAK ATTENUATION VOLUME.
Bioretention cells may store peak attenuation volume at a depth of up to 24 inches above the planting surface. The peak attenuation outlet shall be a maximum of 18 inches above the planting surface.

There is the option to design bioretention cells to attenuate peak flows. If this is an objective of the design, then the overflow structure shall be sized to accommodate storm volumes in excess of the first flush. The first available outlet on the outlet structure should therefore be placed at the height of the first flush, which is the ponded level of the bioretention cell. Use the weir equation to consider the height of the water above the weir during overflow from large storm events. Stormwater is allowed to temporarily pond an additional 12 inches above the maximum ponding level for the design storm of 12 inches; however, the peak attenuation outlet shall not be more than 18 inches above the planting surface. A particular design storm is not specified for overflow structure design; that should be determined by the designer. The designer should also consider potential flooding risks outside of the bioretention cell.

BIORETENTION MDC 4: UNDERDRAIN.
An underdrain with internal water storage shall be installed unless it is demonstrated that the in-situ soil infiltration rate is two inches per hour or greater immediately prior to the initial placement of the media. The top of the internal water storage zone shall be set at a minimum of 18 inches below the planting surface.

Underdrain sizing requirements are discussed in Part A-4.a. If the *in-situ* soil has a permeability of two inches per hour or greater, then an underdrain is not required because the stormwater will naturally infiltrate into the soil. Nearly all bioretention cells in the Piedmont and western portions of NC will have underdrains.

An internal water storage zone (IWS) is created by adding an upturned elbow in the underdrain piping perpendicular to the horizontal underdrain. Including an IWS enhances the bioretention cell's ability to attenuate peak flows, infiltrate stormwater, remove TSS and nitrogen, and cool stormwater. In fact, a bioretention cell with an IWS will only rarely generate outflows in A and B soils. In Piedmont soils, the IWS remains saturated for a longer time, which creates anaerobic conditions that promote denitrification and increased N removal. In addition to their other benefits, bioretention cells cool stormwater because stormwater is stored and discharged from underground.

BIORETENTION MDC 5: MEDIA DEPTH.
The minimum depth of the media depends on the design of the cell as follows:
(a) all cells with trees and shrubs: 36 inches;
(b) cells without trees and shrubs:
(i) with no internal water storage: 24 inches; or
(iii) with internal water storage: 30 inches.

The media depth of bioretention cells that are planted with trees and shrubs shall be a minimum of 36 inches to accommodate the plant roots. Bioretention cells that are not planted with trees and shrubs (i.e., grass or herbaceous plants) may have a shallower media depth, either 30 inches with an underdrain or 24 inches without an underdrain (see MDC 4 for when an underdrain is required).

BIORETENTION MDC 6: MEDIA MIX.
The media shall be a homogeneous soil mix engineered media blend with approximate volumes of:
(a) 75 to 85 percent medium to coarse washed sand (ASTM C33, AASHTO M 6/M 80, ASTM C330, AASHTO M195, or the equivalent);
(b) 8 to 15 percent fines (silt and clay); and
(c) 5 to 10 percent organic matter (such as pine bark fines).

It is very important to ensure that sand meets the specification above; sand particles that are too fine have caused clogging in several bioretention cells across NC. Higher (12-15 percent) fines should be reserved for areas where TN is the target pollutant. In areas where phosphorus is the target pollutant, lower (8 percent) fines should be used. A 'fine' is defined as passing a #200 sieve.

The bioretention media mix is designed to maintain long-term fertility and pollutant processing capability. Research on metal attenuation indicates that metal accumulation should not present a toxicity concern for at least 20 years in bioretention facilities (USEPA 2000). If the media in a bioretention cell needs to be replaced, DEQ recommends having it tested for toxicity for proper disposal, although usually a standard landfill can accept it.

BIORETENTION MDC 7: MEDIA P-INDEX.
The phosphorus index (P-index) for the media shall not exceed 30 in NSW waters as defined in 15A NCAC 02B .0202 and shall not exceed 50 elsewhere.

Soil media should be sent to an NC Department of Agriculture lab or another reputable lab for analysis of the P-index. The P-Index is a crucial design element. Some of the media in NC and many farm soils contains a high level of phosphorus that can increase the P concentration in stormwater by an order or magnitude or more.

BIORETENTION MDC 8: NO MECHANICAL COMPACTION.
The media shall not be mechanically compacted. It is recommended to either water it or walk on it as it is placed.

Inspectors should make allowances for rapid infiltration of water through newly installed media and allow several large storms to infiltrate and consolidate the media before determining infiltration rates in newly installed beds.

BIORETENTION MDC 9: MAINTENANCE OF MEDIA.
The bioretention cell shall be maintained in a manner that results in a drawdown of at least one inch per hour at the planting surface.

See Maintenance section later in this Chapter.

BIORETENTION MDC 10: PLANTING PLAN.
For bioretention cells with vegetation other than sod, the planting plan shall be designed to achieve a minimum of 75 percent plant coverage at five years after planting. The maximum coverage with tree or shrub canopy shall be 50 percent at five years after planting. If sod is used, then it shall be a non-clumping, deep-rooted species.

Plants are integral to bioretention cells because their roots intercept pollutants, improve soil structure, and increase infiltration rates of the media. Each bioretention cell’s planting plan should ideally be customized to the conditions and aesthetic goals of the site. Visually pleasing plant designs encourage community and homeowner acceptance. Bioretention cell plants can be used to meet local landscaping requirements.

Soil moisture conditions within a bioretention cell from saturated (bottom of cell) to relatively dry (rim of cell) as well as over time. Bioretention facilities in the piedmont and mountains tend to become wetter over time; coastal bioretention facilities tend to be very dry. The plant materials used should be facultative species adapted to stresses associated with wet and dry conditions.

Table 1: Planting Plan Recommendations

Planting Plan Topic	Recommendation
Plant community	Should be diverse plant to avoid susceptibility to insects and disease.
Sod media for sod	Sod must *not* be installed that has been grown in soil that has an impermeable layer, such as **clay**.
Standards for plant materials	Plant material should conform to the current edition of [American Standards for Nursery Stock].
Upon delivery of plants, check:	Normal, well-developed branches and vigorous root systems, and be free from physical defects, plant diseases, and insect pests, tagged for identification
Plant size	Plant size should be no less than 2.5” dbh for trees; 3-gallon for shrubs; and 1-quart for herbaceous plants.
Optimal planting time	Fall and winter planting are best (will vary for western Piedmont and mountains). Spring is acceptable but will require more summer watering than fall planting. Summer planting drastically increases plant mortality and requires regular watering immediately following installation.
How the plants should be planted	For best survival, trees should be planted with the top of the root ball partially out of the media. They should be planted to have from 1/3 to 1/2 of the root ball within the media. This would leave from 2/3 to 1/2 of the root ball above the media. If large trees are to be planted in deep fill media, care should be taken to ensure that they would be stable and not fall over.
Local jurisdiction codes	Local jurisdictions often have specific guidelines for the types and location of trees and other landscape plants planted along public streets or rights-of-way. Additionally, local landscape ordinances must be followed. Contact local authorities when making plant selections for your project.

Plants suitable for North Carolina bioretention cells are listed in Tables 2 through 4. Additional plant species may be suitable that are not shown in the table.

Table 2: Trees for Bioretention Cells

Latin Name	Common Name	Comments
Amelanchier arborea	Common serviceberry	Mountains/piedmont/inner coastal plain; (ht: 25-50ft)
Betula nigra	River birch	Entire state. Bioretention soil must be sandy loam. Intolerant to coarse soils (loamy sand); (ht: 50-75ft)
Taxodium distichum	Bald cypress	Piedmont to Coast; wet-moist soils; low drought resistance; not salt tolerant; (ht: 25-50ft)

Table 3: Shrubs for Bioretention Cells

Latin Name	Common Name	Comments
Clethra alnifolia	Summersweet Clethra	Piedmont-Coastal Plain; flood and salt tolerance
Cyrilla racemiflora	Swamp Cyrilla (ti-ti)	Entire state; medium anaerobic tolerance; medium drought tolerance, some salt tolerance
Hypericum densiflorum	Dense Hypericum	Entire state; flood & salt tolerant
Hypericum prolificum	Shrubby St. Johnswort	Entire state; flood & salt tolerant
Ilex glabra	Inkberry	Piedmont; high anaerobic tolerance
Ilex verticillata	Winterberry	Piedmont; bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand)
Ilex vomitoria	Yaupon Holly	Coastal plain; High drought tolerance, No anaerobic tolerance
Itea virginica	Virginia Sweetspire	Piedmont-coast; high anaerobic tolerance; bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand)
Rhododendron viscosum	Swamp Azalea	Entire state; medium drought tolerance; medium anaerobic tolerance; pH 4-7
Viburnum dentatum	Arrowwood Viburnum	Entire state; flood tolerant & drought tolerant; salt resistant
Viburnum nudum	Possumhaw Viburnum	Entire state; flood tolerant & drought tolerant; salt resistant

Table 4: Herbaceous Plants for Bioretention Cells

Latin Name	Common Name	Comments
Amsonia ciliata (A. tabernaemontana is better)	Fringed blue star (Eastern blue Star)	Entire state; drought resistant; pale blue flowers
Baptisia alba	White wild indigo	Coast. White flowers.
Carex spp.	Sedge	Entire state. Tolerates a wide variety of conditions; many different cultivars
Chasmanthium latifolium	River Oats	Entire state; medium drought and anaerobic tolerance
Coreopsis spp.	Tickseed	Entire state; tolerates a wide variety of conditions; many different cultivars
Eupatorium perfoliatum	Boneset	Entire state; low drought tolerance; high anaerobic tolerance; high toxicity
Eupatorium fistulosum	Joe Pye Weed	Piedmont-mountains, infrequent coast; bioretention soil must be sandy loam - intolerant to coarse soils (loamy sand)
Gaillardia spp.	Blanket Flower	Entire state; some drought tolerance; variety of species and hybrids
Hemerocallis fulva	Daylily	Entire state; drought resistant
Heuchera americana	Coral bells	Entire state; many different cultivars
Juncus effusus	Soft rush	Entire state; medium drought and anaerobic tolerance
Monarda sp.	Bee Balm	Piedmont-mtns most species; many cultivars
Panicum virgatum	Switchgrass	Entire state, few mtns; drought resistant
Pennisetum sp.	Fountain grass	Piedmont-coast; many cultivars
Solidago canadensis	Goldenrod	Entire state; medium drought and anaerobic tolerance
Solidago sempervirens	Seaside goldenrod	Coast; salt tolerant; drought tolerant
Sorghastrum nutans	Indiangrass	Entire state; drought tolerant
Spiraea tomentosa	Steeplebush	Entire state; drought tolerant; pink flowers
Verbena sp.	Verbena	Variable locations; cultivar tolerances vary

Table 5: Grass Specification for Bioretention Cells

In grassed bioretention cells, use perennial grasses such as hybrid Bermuda or centipede in the CP and Piedmont, use cool season turf grass such as fescue or bluegrass in the Mountains. Grass should never be seeded, use sod instead. When using sod, avoid sod that is grown in soil that has an impermeable layer (such as clay).

BIORETENTION MDC 11: MULCH.
For bioretention cells with vegetation other than sod, triple shredded hardwood mulch shall be used for the portion of the cell that will be inundated. Mulch shall be uniformly placed two to four inches deep.

Triple-shredded hardwood mulch has been found less likely to wash away than other forms of mulch (such as pine). The mulch layer functions to reduce weeds; regulate soil temperatures and moisture; reduce soil compaction and prevent erosion, and prevent soil and fungi from splashing on the foliage. Mulch serves as a pretreatment layer by trapping the finer sediments that remain suspended after the primary pretreatment.

Applying more than four inches of mulch can cause plants to grow in the mulch and not the soil, which weakens them, particularly during drought. Mulch should be free of weed seeds, soil, roots, and other material that is not bole or branch wood or bark.

Mulch needs to be periodically renewed to maintain a two to four-inch depth. The ideal time to reapply mulch is in the late spring after the soil has warmed. Every few years, mulch should be removed and replaced.

BIORETENTION MDC 12: CLEAN-OUT PIPES.
A minimum of one clean-out pipe shall be provided on each underdrain line. Clean out pipes shall be capped.

DEQ recommends providing a minimum of one clean-out pipe one per every 1,000 square feet of surface area. Clean out pipes should be in an accessible location for observation and maintenance. Clean out pipes are particularly prone to failure in sodded beds as large mowers break them off. Specify PVC pipes with glued clean-out fittings with screw type caps that extend at least 2 feet above the surface of the bed. NO flexible pipe allowed.

In Figure 3, the clean-out pipe on the left shows a properly installed clean-out pipe. The clean-out pipe on the right is a poor design, it is easy to break and when it does, the stormwater will leave the bioretention cell via the pipe rather than passing through the plants and media as intended.

Figure 3: Bioretention Clean-Out Pipes

YES

NO

Recommendations

BIORETENTION RECOMMENDATION 1: DISPERSE FLOW OR ENERGY DISSIPATION. Flow should enter the bioretention cell via disperse flow or an energy dissipater.

Inflow should enter a bioretention cell via disperse flow with a velocity less than 1.0 foot per second for mulched cells or 3.0 feet per second for grassed cells to prevent erosion. Disperse flow can be provided via a gently sloping parking lot that drains toward a bioretention cell. If inflow is concentrated in a pipe or swale, then a rip rap lined entrance, a forebay, or other energy-dissipating device should be used. If a forebay is used, it can both dissipate energy and provide pre-treatment.

BIORETENTION RECOMMENDATION 2: PRETREATMENT. Pretreatment should be provided.

A bioretention cell should have a pretreatment area. The most commonly used pretreatment devices are:

- ***A grass and gravel combination:*** This should consist of 8 inches of gravel followed by 3 to 5 feet of sod. In eastern and central North Carolina, hybrid Bermuda and centipede have been used successfully. In the mountains, fescue and bluegrass are appropriate.

- ***A forebay:*** The forebay should be 18-30 inches deep and used only in areas where standing water is not considered a safety concern. The forebay should be deepest where water enters, and more shallow where water exits in order to dissipate hydraulic energy of the water flowing to the forebay. The forebay should be lined to ensure that water will not flow direction into the underdrain without first flowing through the treatment area of the bioretention cell. Lining material should allow for removal of sediment and debris with a shovel of vac-truck.

Figure 4: Example of Concrete-Lined Bioretention Forebay

Maintenance

Bioretention maintenance requirements are typical landscape care procedures and include:

- ***Watering:*** Plants should be selected to be tolerant of the bioretention facility's particular conditions. Watering should not be required after establishment (about 2 to 3 years). However, watering may be required during prolonged dry periods after plants are established.

- ***Erosion Control:*** Inspect flow entrances, ponding area, and surface overflow areas periodically. Replace soil, plant material, and/or mulch in areas where erosion has occurred. Erosion problems should not occur with proper design except during extreme weather events. If erosion problems do occur, the following issues should be re-assessed: flow volumes from the contributing drainage area and bioretention size; flow velocities and gradients within the bioretention facility; flow dissipation and erosion protection methods in the pretreatment and in-flow areas. If sediment is deposited in the bioretention facility, immediately determine the source, remove excess deposits, and correct the problem.

- ***Plant Material:*** Depending on plants selected and aesthetic requirements, occasional pruning and removal of dead plant material may be necessary. Be careful to prune trees and shrubs to maintain lines of sight in parking lots and along roadways. NCDOT states: “Shrubs must be kept low, and trees and large shrubs under-trimmed sufficiently to permit clear sight in the area between 2 feet and 6 feet above roadway elevations. ”Replace all dead plants. However, if specific plants consistently have a high mortality rate, assess the cause and replace with appropriate species. Periodic weeding is necessary until groundcover plants are established. Weeding should become less frequent if an appropriate plant density has been used.

- ***Nutrients and Pesticides:*** The soil media and plant material should have been selected for optimum fertility, plant establishment, and growth within the particular conditions of each bioretention facility. Nutrient and pesticide inputs should NOT be required and will degrade the pollutant processing capability of the bioretention facility, as well as contribute to additional pollutant loading to receiving waters. By design, bioretention facilities are typically specified in watersheds where phosphorous and nitrogen levels are often elevated. Therefore, these should not be limiting nutrients with regard to plant health. If in question, have the soil analyzed for fertility. Addition of commercial fertilizer or compost to bioretention will likely result in nutrient export from the bed.

- ***Mulch:*** Replace mulch annually in bioretention facilities where heavy metal deposition is likely (e.g., drainage areas that include commercial/industrial uses, parking lots, or roads). Metal ‘hot spots’ occur where water enters the bed. In residential or other settings where metal deposition is not a concern, replace or add mulch as needed to maintain a 2 to 4-inch depth at least once every two years.

- ***Filtering Capacity:*** When the filtering capacity diminishes substantially (e.g., when water ponds on the surface for more than 12 hours), remedial actions must be taken. If the water still ponds for more than 12 hours, the top few inches of material should be removed and replaced with fresh material. The removed sediments should be disposed of in an acceptable manner (e.g., landfill) or land application. If that does not solve the problem, more extensive rebuilding is required. If the bed has filter fabric installed under the media above the washed rock the filter fabric may be clogged with sediment. If clogged filter fabric is present, the bed will need to be rebuilt.

Figure 5: Soil Probe Showing a Profile of Bioretention Cell Media

Figure 6: Examples of When to Perform Maintenance

Replace gravel when it has become clogged with sediment

Replace mulch when it becomes thin or is taken over by grass.

Sample Operation and Maintenance Provisions

Important operation and maintenance procedures:

- Immediately after the bioretention cell is established, the plants will be watered twice weekly if needed until the plants become established (commonly six weeks).

- Snow, mulch or any other material will NEVER be piled on the surface of the bioretention cell.
- Heavy equipment will NEVER be driven over the bioretention cell.
- Special care will be taken to prevent sediment from entering the bioretention cell.
- Once a year, a soil test of the soil media will be conducted.
- After the bioretention cell is established, I will inspect it **once a quarter.** Records of operation and maintenance will be kept in a known set location and will be available upon request.
- Inspection activities shall be performed as follows. Any problems that are found shall be repaired immediately.
- Remove top layer of fill media when the pool does not drain quickly. The pool is designed to drain within 12 hours.

Table 6: Sample Operation and Maintenance Provisions for Bioretention Cells

SCM element:	Potential problems:	How to remediate the problem:
The entire bioretention cell	Trash/debris is present.	Remove the trash/debris.
The perimeter of the bioretention cell	Areas of bare soil and/or erosive gullies have formed.	Regrade the soil if necessary to remove the gully, and then plant a ground cover and water until it is established. Provide lime and a one-time fertilizer application.
The inlet	Unclog the pipe. Dispose of the sediment off-site.	Unclog the pipe. Dispose of the sediment off-site.
	The pipe is cracked or otherwise damaged (if applicable).	Replace the pipe.
	Erosion is occurring in the swale (if applicable).	Regrade the swale if necessary to smooth it over and provide erosion control devices such as reinforced turf matting or riprap to avoid future problems with erosion.
	Stone verge is clogged or covered in sediment (if applicable).	Remove sediment and clogged stone and replace with clean stone.

The pretreatment system	Flow is bypassing pretreatment area and/or gullies have formed.	Regrade if necessary to route all flow to the pretreatment area. Restabilize the area after grading.
	Sediment has accumulated to a depth greater than three inches.	Search for the source of the sediment and remedy the problem if possible. Remove the sediment and restabilize the pretreatment area.
	Erosion has occurred.	Provide additional erosion protection such as reinforced turf matting or riprap if needed to prevent future erosion problems.
	Weeds are present.	Remove the weeds, preferably by hand.
Plant material	Best professional practices show that pruning is needed to maintain optimal plant health.	Prune according to best professional practices Maintain lines of sight
	Plants are dead, diseased or dying.	Determine the source of the problem: soils, hydrology, disease, etc. Remedy the problem and replace plants. Provide a one-time fertilizer or lime application to establish the ground cover if a soil test indicates it is necessary.
	Weeds are present.	Remove the weeds, preferably by hand. If a herbicide is used, wipe it on the plants rather than spraying.
Bioretention cell vegetation	Best professional practices show that pruning is needed to maintain optimal plant health.	Prune according to best professional practices. Maintain lines of sight
	Plants are dead, diseased or dying.	Determine the source of the problem: soils, hydrology, disease, etc. Remedy the problem and replace plants. Provide a one-time fertilizer application to establish the ground cover if a soil test indicates it is necessary. If sod was used, check to see that it was not grown on clay or impermeable soils. Replace sod if necessary.

	Tree stakes/wires are present six months after planting.	Remove tree stake/wires (which can kill the tree if not removed).
Bioretention cell mulch and media	Mulch is breaking down or has floated away.	Spot mulch if there are only random void areas. Replace whole mulch layer if necessary. Remove the remaining much and replace with triple shredded hard wood mulch at a maximum depth of three inches.
	Soils and/or mulch are clogged with sediment.	Determine the extent of the clogging - remove and replace either just the top layers or the entire media as needed. Dispose of the spoil in an appropriate off-site location. Use triple shredded hard wood mulch at a maximum depth of three inches. Search for the source of the sediment and remedy the problem if possible.
	An annual soil test shows that pH has dropped or heavy metals have accumulated in the soil media.	Dolomitic lime shall be applied as recommended per the soil test and toxic soils shall be removed, disposed of properly and replaced with new planting media.
The underdrain, filter fabric element, and outlet system	Clogging has occurred.	Wash out the underdrain system.
	Clogging has occurred.	Clean out the drop inlet. Dispose of the sediment off-site.
	The drop inlet is damaged	Repair or replace the drop inlet.
The receiving water	Erosion or other signs of damage have occurred at the outlet.	Contact the NC Division of Water Resources.

Old Versus New Design Standards

The following is a summary of some of the changes in bioretention design standards between the archived version of the BMP Manual and the current MDC for bioretention cells. It is intended to capture the highlights only; any bioretention MDC that are not captured in this table are still required per 15A NCAC 02H .1052.

	Old manual requirements	New MDC
Internal water storage	Optional	Required unless the in-situ soil infiltration rate is equal to or greater than two inches/hour
Maximum P-Index of media	30	30 for NSW, 50 elsewhere
Sand specification	A homogenous soil mix of: 85-88% by volume sand (USDA Soil Textural Classification), 8-12% fines (silt and clay), and 3-5% organic matter (such as peat moss)	A homogeneous soil mix engineered media blend with approximate volumes of: (a) 75-85% medium to coarse washed sand (ASTM C33, AASHTO M 6/M 80, ASTM C330, AASHTO M195, or the equivalent); (b) 8-15% fines (silt and clay); and (c) 5-10% organic matter (such as pine bark fines).
Maximum media drawdown rate	6 inches	Not specified; compliance with the media specification will result in an appropriate drawdown rate upon installation
Mechanical compaction prohibition	Not provided	Media may not be compacted mechanically
Minimum infiltration rate that must maintained	Not provided	1 in/hr
Planting plan for bioretention cells with trees and shrubs	Based on density of plantings	Based on providing a maximum of 50% canopy cover after five years of growth

Photo Gallery

Street Side Project (Courtesy of Stuart Patton Echols, Pennsylvania State University)

Courtyard Project (Courtesy of Stuart Patton Echols, Pennsylvania State University)