Bioretention (Rain Gardens)

Practice Description

A bioretention cell consists of a depression in the ground filled with a soil media mixture that supports various types of water-tolerant vegetation. The surface of the BMP is depressed in bioretention facilities to allow for ponding of runoff that filters through the BMP media. Water exits the bioretention area via exfiltration into the surrounding soil, flow out an underdrain, and evapotranspiration. The surface of the cell is protected from weeds, mechanical erosion, and desiccation by a layer of mulch. Bioretention is an efficient method for removing a wide variety of pollutants, such as suspended solids, heavy metals, nutrients, and pathogens (North Carolina Cooperative Extension (NCCE), 2007). Bioretention areas provide some nutrient uptake in addition to physical filtration. If located at a site with appropriate soil conditions to provide infiltration, bioretention can also be effective in reducing peak runoff rates, reducing runoff volumes, and recharging groundwater.

Planning Considerations

Many development projects present a challenge to the designer of conventional stormwater BMPs because of physical site constraints. Bioretention areas are intended to address the spatial constraints that can be found in densely developed urban areas where the drainage areas are highly impervious. They can be used on small urban sites that would not normally support the hydrology of a wet detention pond and where the soils would not allow for an infiltration device. Median strips, ramp loops, traffic circles, and parking lot islands are good examples of typical locations for bioretention areas.

Bioretention units are ideal for distributing several units throughout a site to provide treatment of larger areas. Developments that incorporate this decentralized approach to stormwater management can achieve savings by eliminating stormwater-management ponds; reducing pipes, inlet structures, curbs and gutters; and having less grading and clearing. Depending on the type of development and site constraints, the costs for using decentralized bioretention stormwater-management methods can be reduced by 10 to 25 percent compared to stormwater and site development using other BMPs (Coffman, 1993).

Figure 1 Bioretention in Parking Lot Island

Bioretention facilities are generally most effective if they receive runoff as close as possible to the source. Reasons for this include: minimizing the concentration of flow to reduce entry velocity; reducing the need for inlets, pipes, and downstream controls; and allowing for blending of the facilities with the site (e.g., parking median facilities). For sites where infiltration is being utilized, it also avoids excessive groundwater mounding. Where bioretention takes the place of required green space, the landscaping expenses that would be required in the absence of bioretention should be subtracted when determining the actual cost (LID Center, 2003). Bioretention cells may also address landscaping/green space requirements of some local governments (Wossink and Hunt 2003).

Design Criteria

Design is an eight-step process:

1. Understand basic layout concepts.
2. Determine the volume of water to treat.
3. Determine the surface area required.
4. Select the soil media type.
5. Decide the depth of soil media.
6. Size the underdrain pipes (if necessary).
7. Select the appropriate overflow or bypass method.
8. Select plants and mulch.

Step 1: Understand Basic Layout Concepts

The layout of bioretention areas varies according to individual sites and to specific site constraints such as underlying soils, existing vegetation, drainage, location of utilities, sight distances for traffic, aesthetics, and ease of maintenance. Figure 2 illustrates a concept for a bioretention traffic island. These types of bioretention facilities typically take up no more space than what is required by typical zoning rules, and they provide stormwater treatment as well as site aesthetics. The following photographs are examples of existing bioretention cells that have been designed using these techniques. These cells blend into the landscape and appear to be typical flowerbeds or medians. Often, bioretention cells can be designed with flowering plants to enhance the landscape.

Examples of Previously Installed Bioretention Cells

Figure 2 shows an 8-inch gravel strip followed by 5 feet of grass for pretreatment along the side that receives water from the jogging trail. This is an example of both gravel strip pretreatment design as well as when to maintain the gravel strip. This strip has become overgrown with grass and has been clogged with sediment. The mulch has also become thin, and should be replaced.

Figure 2 Bioretention Cell with Pretreatment: Gravel and Grass (Needs Maintenance)

Figure 3 shows a bioretention cell with a pretreatment forebay. Notice the sediment that has settled onto the rocks. Without the forebay, this sediment would have collected on the top of the bioretention cell, clogged the soil media, and would have become a maintenance burden. Forebays that are located inside a cell should be lined in order to ensure that the treatment volume drains through the media.

Figure 3 Bioretention Cell with Pretreatment Forebay

Examples of Additional Design Options

Use of Flow Splitters

Bioretention units can be designed using a flow splitter so that only the treatment volume is directed into the cell. An example of this design is provided as Figure 4. This example shows a filter strip, though it is not required for every design.

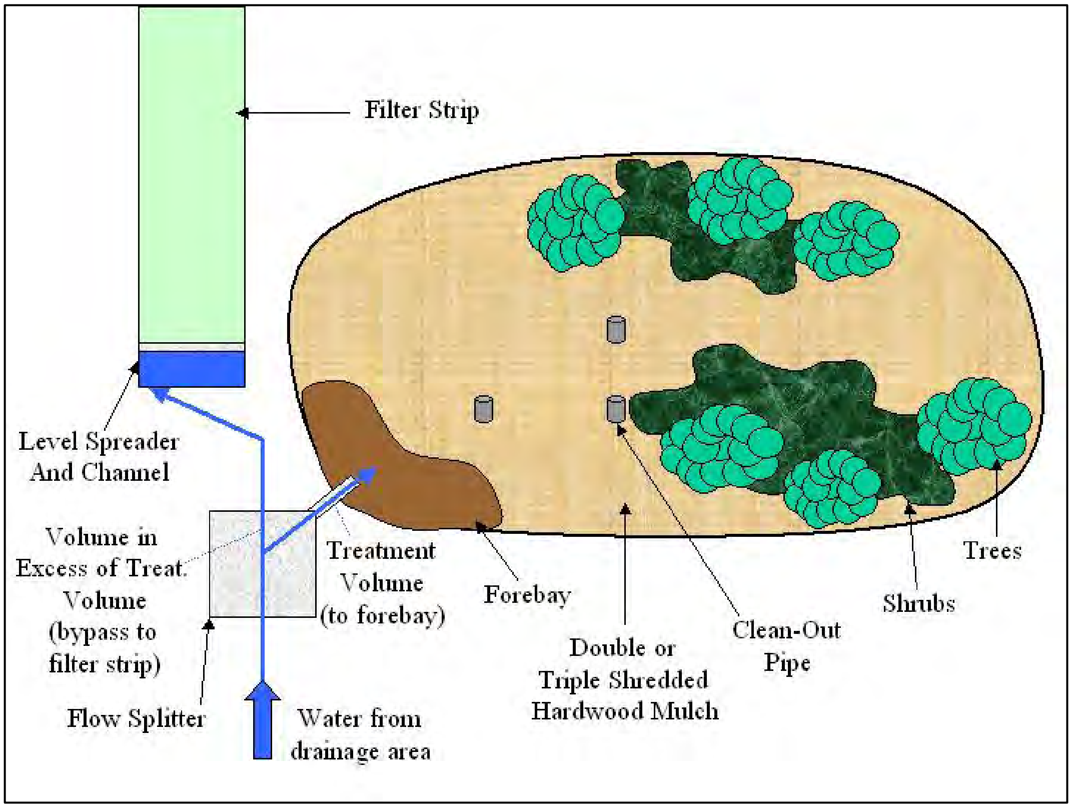

Figure 4 Typical Bioretention Cell Using a Flow Splitting Device (Source: North Carolina Department of Environment and Natural Resources (NCDENR)

Use of Overflow Devices

Bioretention units can be designed using an overflow device so that water in excess of the treatment volume overflows to a filter strip. An example of this design is provided in Figure 5. This example shows a filter strip, though it is not required for every design.

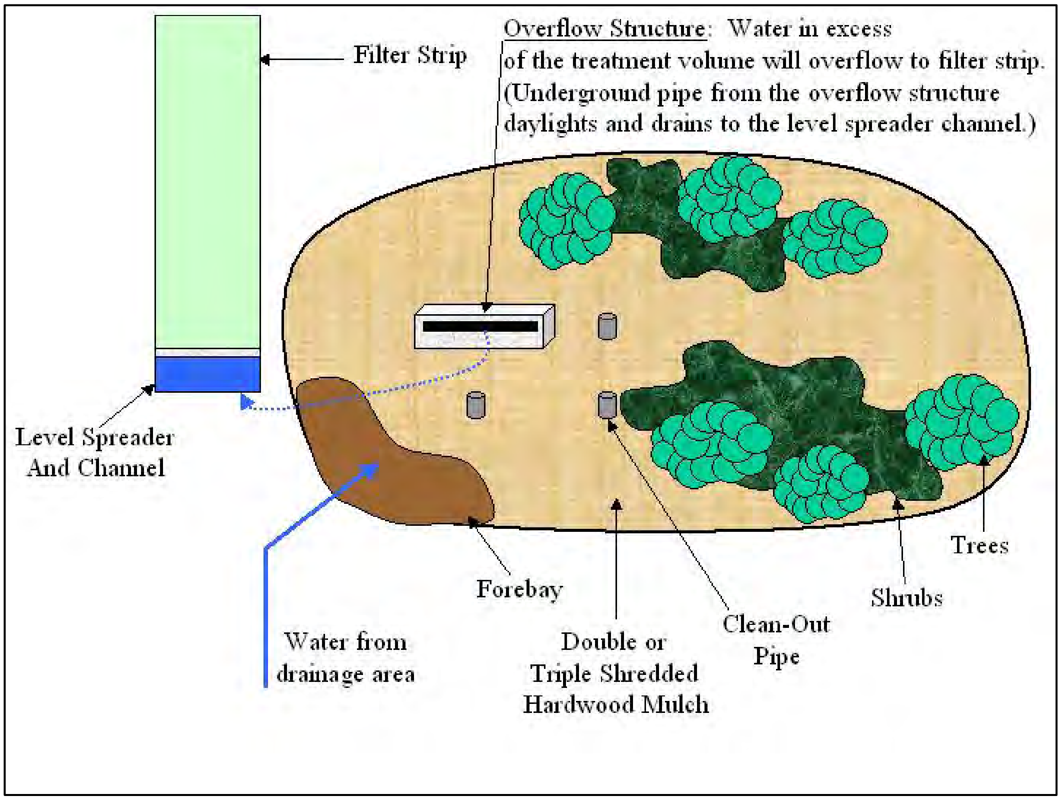

Figure 5 Typical Bioretention Cell Using an Overflow Device (Source: NCDENR)

Internal Water Storage Zones (IWS)

An internal water storage zone (IWS) can be created by the addition of an elbow in the underdrain piping at a 90-deg angle vertically perpendicular to the horizontal underdrain, either in retrofit conditions or in new installations. This upturned elbow on underdrains can force water to remain longer in the bottom of the cell, creating a saturated IWS. If this zone remains saturated long enough, anaerobic conditions are created, promoting denitrification and increased nitrogen removal (Passeport et al., 2009).

There are several benefits to using the upturned elbow and IWS. The IWS works for both pollutant and peak flow reduction as anaerobic conditions can be created to increase nitrogen removal. It also allows more water to infiltrate into the surrounding soils. If an upturned elbow is installed correctly in sufficiently permeable soils, it may only rarely generate outflows.

The use of upturned elbows and IWS can be especially beneficial in areas where surrounding sandy soils can be ideal for infiltration, reducing outflows and surface water runoff. Additionally, there is often a cost benefit for using upturned elbows, both for new installations and retrofits. In new installations, a cost-savings is associated with installation since the invert of the outlet is not as deep. Often with IWS, there can be less trenching and fewer materials associated with using it. In retrofits, upturned elbows can be cheaply added to existing bioretention cells where increased nitrogen and phosphorus removal rates are needed. Additionally, cells with IWS can be added as retrofits even in areas with restricted outlet depth.

For an internal water storage zone to work correctly, the underlying soils must have some permeability. In general, if the underlying soils are Group A or B soils with a low clay content, the IWS will be effective. If soils are too compacted, water will not infiltrate and may stagnate in the lower portion, causing problems for the BMP. Media depth above the bottom gravel and underdrain layer must be at least 3 feet. The top of IWS should be separated from the outlet and bowl surface by at least 12 inches (ideally 18 inches). See Figure 6.

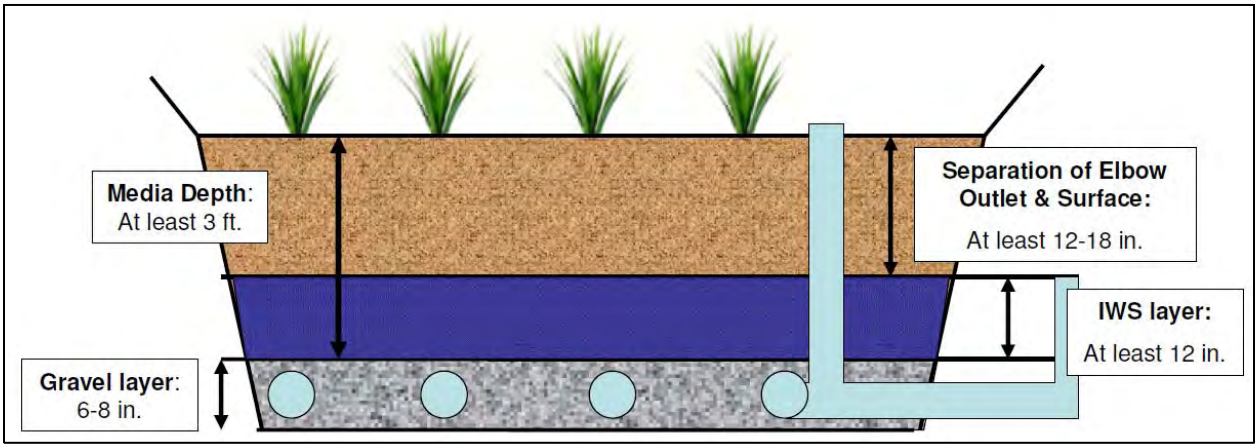

Figure 6 Bioretention Cell showing IWS Zones (Source: NCDENR)

Parking Lot Diversion Method

A bioretention area that can be installed along the perimeter of a parking lot is shown in Figure 7. The water is diverted to the bioretention area through the use of a curb diversion structure. A 2-foot buffer between the curb and the bioretention area serves as pretreatment and reduces the possibility of drainage seeping under the pavement section and creating “frost heave” during winter months. Flow diversion by curb diversion structures may not meet the volume attainment requirements.

A berm one foot in height separates the swale from the bioretention area. The bioretention area should be at an elevation such that, when the design ponding depth is reached, additional flow continues down the swale and is diverted from the bioretention cell.

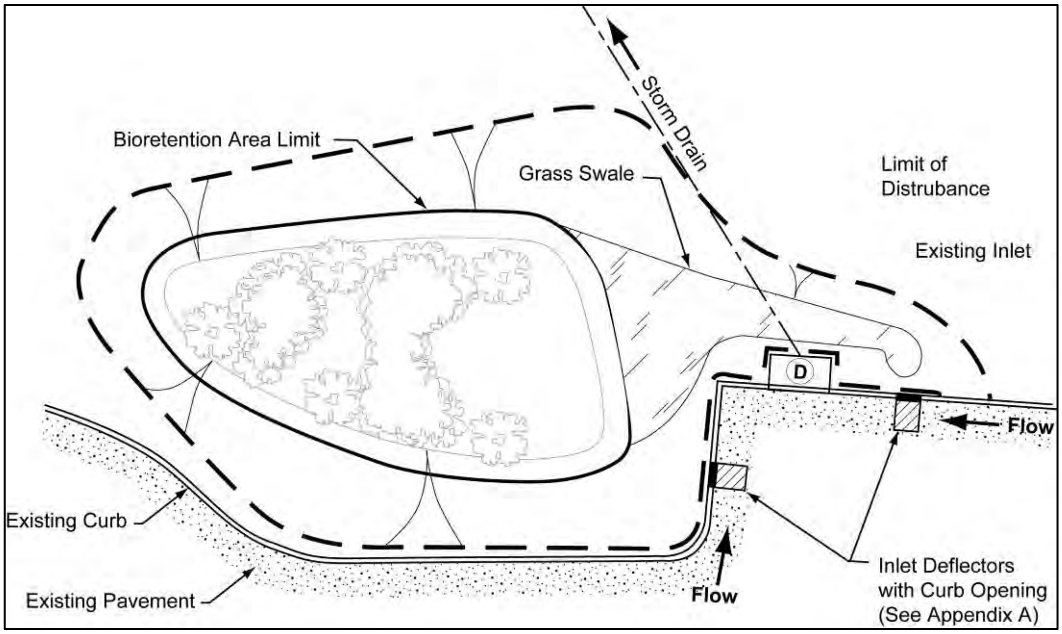

Figure 7 Parking Edge and Perimeter with Curb (Source: Prince George's County, 2000)

Bioretention Cells on Steep Slopes

Figure 8 depicts a bioretention terrace that can be used in sloping terrain (for 10-20% slopes). An impermeable or very low-permeability geomembrane must be used against the gabions or similar retaining structure to prevent flow from leaving the treatment unit through that surface. An underdrain could be placed at the low point of the filter if the native soil against which the unit is built will not provide adequate infiltration capacity.

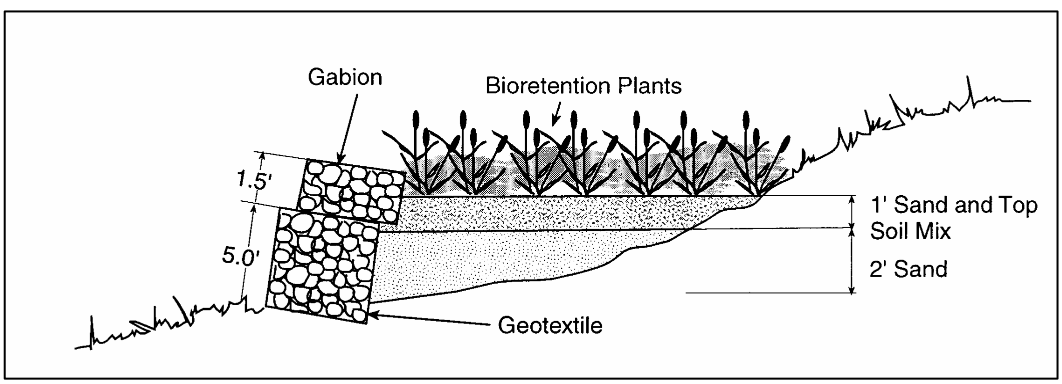

Figure 8 Bioretention Terrace Suitable for Use on Slopes 10-20%

Pretreatment Options

Inflow must enter a bioretention cell via sheet flow (1ft/sec for cells with mulch, or 3.0 ft/sec for grassed cells) or alternative energy-dissipating devices must be used. Sheet flow provides for the most even distribution of flow and the least energy (minimizing erosion). Sheet flow can be naturally provided, as in the case of a gently sloping parking lot with no curb and gutter or a vegetated buffer/filter strip, or it can be designed into the device by the use of a level spreader. In some instances sheet flow is not attainable and the inflow will enter from concentrated sources such as curb diversion structures, drainage pipes, grassy swales, etc. In these cases, a riprap-lined entrance, a forebay, or other energy-dissipating device must be used.

The water treatment volume shall be calculated as specified in Appendix A. The cell must be designed to have a pretreatment area. The most commonly used pretreatment devices are these:

1) A grass and gravel combination: This should consist of 8 inches of gravel followed by 3 to 5 feet of sod. See the *Sodding Practice* in Volume 1 for more information on sod installation.

2) A grassed water quality swale: A water quality swale shall be designed as specified in the *Grass Swale Practice*.

3) 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. If there is a risk that water in the forebay could flow into the underdrain without first flowing to the cell, the forebay should also be lined.

Maintenance Considerations

When performing the following remaining steps of designing a bioretention cell, consider how landscape professionals will later access the site for maintenance. Because the soil must be able to accommodate fast water infiltration, it cannot be compacted by heavy equipment. Is the forebay accessible for heavy equipment to remove sediment from it without driving onto the cell? Are the clean-out pipes accessible? All aspects of design should consider future maintenance.

Construction Sequencing

The drainage area to the cell should be stabilized before cell construction begins in order to prevent clogging. For roadways draining to the cell, the subbase course (crusher run) and the base course layer of asphalt need to be in place prior to cell construction. If fines get washed into the excavated cell, they must be removed before building the cell, in order to restore the permeability of the in situ soils. It is recommended that the cell media be covered with impermeable plastic during construction.

Step 2: Determine the Volume of Water to Treat

Water Volume

An individual bioretention cell is intended to treat the first flush. *Appendix A: Erosion and Stormwater Runoff Calculations* details the volumetric calculation.

Siting Issues

Bioretention facilities shall not be used in areas with the following characteristics:

- The seasonal high water table is less than 2 feet below the bottom of the cell.

- Slopes are 20 percent or greater, unless bioretention terraces are planned.
- Further construction is planned on either the immediately surrounding site or in outparcels that may drain to the bioretention site. (The upstream contributing drainage area must be completely and permanently stabilized, e.g., gravel base course driving surface (preferably paved), or a dense and vigorous vegetative cover. The heavy sediment load from a bare-earth construction site will cause premature failure of a bioretention BMP.)
- The cell is inaccessible for maintenance.
- The cell will not comply with local landscape ordinances.

Contributing Drainage Basin

Consider the effect of large storms on potential erosion within the cell as well as potential overflow and downhill erosion upon water leaving the cell. The contributing area to an individual bioretention cell will typically be 5 acres or less, because many large watersheds will not have an area that is large enough to serve the treatment volume while also being high enough above the water table.

Step 3: Determine the Surface Area and Depth Required

The cell can be designed to hold the first inch of rainfall from the entire drainage area. The required surface area of the bioretention cell is equal to the required treatment volume (as calculated using the Simple Method outlined in *Appendix A*) divided by the ponding depth. No dimension (width, length, or radius) can be less than 10 feet. This is to provide sufficient space for plants.

Step 4: Select the Soil Media Type

The soil mix should be uniform and free of stones, stumps, roots, or other similar material greater than 2 inches. It should be a homogenous soil mix of 85-88 percent by volume sand (USDA Soil Textural Classification), 8 to 12 percent fines (silt and clay), and 3 to 5 percent organic matter (such as peat moss). The higher (12 percent) fines content should be reserved for areas where total nitrogen is the target pollutant. In areas where phosphorus is the target pollutant, lower (8 percent) fines should be used. Additionally, the phosphorus (P) content of the soil mix should be low. The P-Index for bioretention soil media should always range between 10 and 30, regardless of the target pollutant (Hunt and Lord, 2006). The P-Index is an extremely important design element. Cells that are constructed of high P-Index soils can export phosphorus.

The media should be tested to determine an actual drainage rate after placement. The permeability should fall between 1 and 6 inches per hour, and 1-2 inches per hour is preferred. As a rule of thumb, using the above-specified media, the infiltration rates should be approximately 2 in./hr and 1 in./hr for 8% and 12% fines, respectively, depending on the target pollutant. An estimated drainage rate for percent fines between 8 and 12 can be approximated during design by linear interpolation. If total suspended solids (TSS) or pathogens are the target pollutant, the higher permeability can be used because these two pollutants are removed on the surface of the bioretention cell rather than within the cell.

Step 5: Determine the Soil Media Depth

Different pollutants are removed in various zones of the bioretention cell using several mechanisms. The TSS are removed both in pretreatment and on the surface of the cell itself. For that reason, TSS removal is not a major factor in depth of the cell design. Depth is, however, an issue for other pollutants. Metals are removed in the top layer of mulch and the soil, as they are often bound to sediment. Additionally, two thirds of phosphorus entering the cell is attached to soil particles. As a result, this portion is removed on the surface. The remaining third is soluble and is removed 12 inches or more below the surface. Bacterial, viral, and protozoan pathogens can be killed on the surface and removed throughout the cell by several mechanisms: sun-exposure, drying, sedimentation, and filtration (Hathaway and Hunt, 2008). Temperature is reduced at approximately 48 inches below the surface. Nitrogen is removed 30 inches below the surface. Initial research at North Carolina State University shows that using an upturned underdrain pipe may increase nitrogen removal. The upturned piped creates an anaerobic zone that may facilitate nitrogen removal. (See the *Internal Water Storage Zones* section of this practice for more information.) Consider the types of pollutants to be removed, and select an appropriate media depth.

The ponding depth above the media and mulch shall be 12 inches or less (9 inches or less is preferred). This is based on both 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.

The depth of the media in a bioretention cell should be between 2 and 4 feet. This range reflects the fact that most of the pollutant removal occurs within the first 2 feet of soil, and excavations deeper than 4 feet become more expensive. The depth should accommodate the vegetation (shrubs or trees). If the minimum depth of 2 feet is used, only shallow-rooted plants can be planted. Grassed bioretention cells with no IWS can be as shallow as 2 feet. However, if nitrogen is the target pollutant, the cell should have at least 30 inches of media because, as previously discussed, nitrogen is removed 30 inches below the surface. Bioretention facilities where shrubs or trees are planted can be as shallow as 3 feet. 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. As stated above, if IWS is used, cells must have a minimum depth of 3 feet.

If underdrain piping is used (which is only for cases in which the infiltration rate is less than 2 in./hr), the media is as shown in Figure 9. This figure shows a cross-sectional design. No. 57 stone shall be installed around the underdrain. Crusher run shall not be used around the underdrain, as it can form an impermeable layer (Amerson et al., 1991). For pretreatment, the gravel and grass option is presented in this figure because it is one of the most common pretreatment options. The design shown here is for a bioretention cell in a non-developing area. Bioretention cells should be used only in non-developing areas. If there is any concern that the surrounding area may be developed in the future, consider using an alternate BMP or protecting the BMP from sediment. If this is only a nominal concern, use 2 inches of either No. 8 or No. 89 washed choking stone in place of the filter fabric shown in Figure 9.

If an underdrain system is not used, the cross-sectional design of the cell will be the same although the underdrain will be omitted. Figure 9 is shown using the gravel and grass pretreatment option, though it could be modified to use any of the pretreatment methods.

This figure also shows an overflow structure. Typically, an overflow structure is adapted from an existing drainage culvert inlet.

In Figure 9, the vertical sides of the bioretention cell do not have to be at a specified angle. However, the surface area of the bottom of the cell should be maximized.

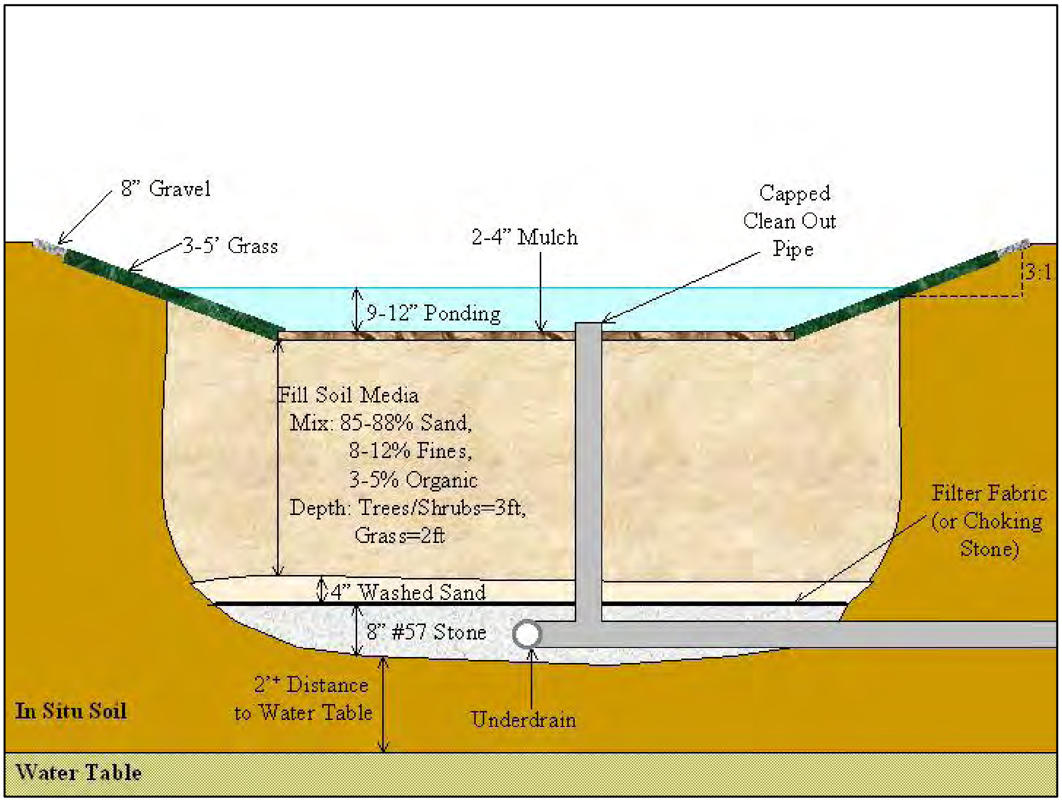

Figure 9: Bioretention Conceptual Layout: Cross-Section (Source: NCDENR)

Sediment Accumulation

There should be very little, if any, sediment accumulation in a bioretention cell, since the upstream drainage basin must be stabilized prior to bringing the bioretention cell into service, and since pretreatment is required prior to the BMP.

Drainage Considerations

Water shall pond above the cell for a maximum of 12 hours. Water must then drain to a level 24 inches below the surface of the cell within 48 hours (maximum) to allow the appropriate contact time for pollutant removal. This requirement is demonstrated in Figure 10. The time to drain the ponded volume is simply the depth of the ponding in inches, divided by the limiting drainage rate. If the cell has an underdrain, the length of time that it takes to drain the ponding volume of a bioretention cell is controlled by the infiltration rate of the media. If the cell does not have an underdrain and is an infiltration type system, it will be controlled by the lesser of the infiltration rate of the media or the infiltration rate of the native soil.

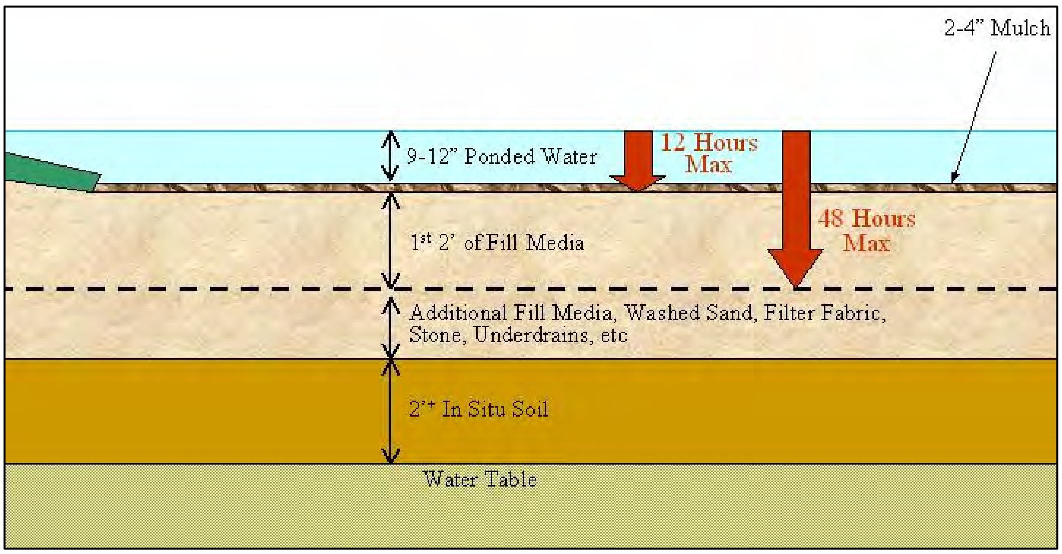

Figure 10: Bioretention Drain Time (Source: NCDENR)

Step 6: Size the Underdrains (if required)

The need for an underdrain is driven by the permeability of the in situ soil. If the in situ soil has a high permeability, the system can be designed as an infiltration type bioretention facility with no underdrains. If in situ soil permeability is less than 2 inches/hour, the bioretention facility will likely have an underdrain system. If the in situ soil drains more slowly than the planting media, the designer should include an explanation of how water will drain from the media. The underdrain system will connect to another BMP or to the conveyance system. Due to the risk of underdrain clogging, designers are encouraged to install more than one underdrain of smaller diameter in order to facilitate drainage. The minimum diameter of pipe for underdrain systems is four inches. As previously discussed, an upturned elbow may be used.

Clean-out pipes must be provided (minimum one per every 1,000 square feet of surface area). Clean-out pipes must be capped.

Step 7: Select the Appropriate Overflow Structure

The overflow structure should 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. Typically, water can rise about 2 inches above the ponded water level. But, this height can be higher, about 4″-6″ above the ponded water level, if required by design restraints. A particular design storm is not specified for overflow structure design. Professional judgment should be used when considering potential flooding risks outside the bioretention cell.

Step 8: Select Plants and Mulch

Plants are an integral element of the bioretention system's pollutant removal and water filtration process. Plant roots aid in the physical and chemical bonding of soil particles necessary to form stable aggregates, improve soil structure, and increase infiltration capacity. Vegetated soils are more capable of more effective degradation, removal, and mineralization of total petroleum hydrocarbons, polycyclic aromatic hydrocarbons, pesticides, chlorinated solvents, and surfactants than are nonvegetated soils (USEPA, 2000).

The primary design considerations for plant selection include the following:

1. Soil moisture conditions: Soil moisture conditions will vary widely within the bioretention facility from saturated (bottom of cell) to relatively dry (rim of cell), as well as over time. Therefore, the predominant plant material utilized should be facultative species adapted to stresses associated with both wet and dry conditions (MDER, 2002). In some cases, the in situ soil can be ripped and amended so that vegetation can grow.
2. Pollutant loadings: Since bioretention is often specified for use in impaired and/or nutrient-sensitive watersheds, strategic use of particular plants for phytoremediation purposes is crucial. Plants should tolerate typical pollutants and loadings from the surrounding land uses.
3. Above- and below-ground infrastructure in and near the bioretention facility: Plant selection should consider the surrounding conditions, including light pollution tolerance, wind, and above- and below-ground utilities. Slotted or perforated pipes should be more than 5 feet away from tree locations. Plants with taproots should not be used.
4. Adjacent plant communities and potential invasive species control.
5. Site distances and setbacks for roadway applications.
6. Visual buffering: Plants can be used to buffer structures from roads, enhance privacy among residences, and provide an aesthetic amenity for the site.
7. Aesthetics: Visually pleasing plant designs add to the property and encourage community and homeowner acceptance. Public education and participation in the plant selection and design should be encouraged to promote greater involvement in long-term care.
8. Grass may be used; however, grassed cells must be sodded (not seeded), and the sod must not be grown in soil that has an impermeable layer, such as clay.

Planting design will vary with the surrounding landscape context and design objectives. For example, the use of plants in bioretention areas could replicate a variety of native terrestrial ecosystems, including forests, ornamental gardens, meadows, hedgerows, and wetlands, as well as wildlife habitats.

A minimum of one tree, three shrubs, and three herbaceous species should be incorporated in the bioretention planting plan unless it is a grassed cell. A diverse plant community is necessary to avoid susceptibility to insects and disease. A recommended minimum planting density is 400 stems/acre. Bacteria die-off occurs at the surface where stormwater is exposed to sunlight and the soil can dry out. Therefore, it is best for bioretention cells to not be too densely vegetated in order to allow greater exposure to sunlight and consequent die-off of bacteria (NCCE 2007).

The plants selected should be able to tolerate typical stormwater pollutant loads, variable (often very dry) soil moisture, temporary submergence, and extended wet conditions. Consult a design profession for the selection of plants.

To increase survival rates and ensure quality of plant materials, the following general guidelines for plantings within bioretention facilities are recommended:

- All plant material should conform to the standards of the current edition of American Standards for Nursery Stock as approved by the American Standards Institute, Inc. All plant grades shall be those established by the current edition of American Standards for Nursery Stock [http://www.anla.org/applications/Documents/Docs/ANLAStandard2004.pdf].
- All plant materials should have normal, well-developed branches and vigorous root systems, and be free from physical defects, plant diseases, and insect pests.
- All plant materials should be tagged for identification when delivered.
- Optimum planting time is fall. Winter planting is acceptable. Spring is acceptable but will require more summer watering than fall planting. Summer planting is the least desirable, as it drastically increases plant mortality and requires regular watering immediately following installation.
- Plant size should be no less than 2.5″ diameter at breast height for trees; 3-gallon for shrubs; and 1-quart for herbaceous plants.
- Woody vegetation should not be planted at inflow locations.
- 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.

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 to determine if there are guidelines or restrictions to consider when making plant selections for your project.

The mulch layer plays an important function in the performance of the bioretention system by reducing weed establishment; regulating soil temperatures and moisture; reducing soil compaction from rainfall; preventing erosion; and promoting an environment suitable for soil microorganisms at the mulch/soil interface (important for filtering nutrients and other pollutants). Mulches prevent soil and possible fungi from splashing on the foliage, reducing the likelihood of soil-borne diseases (Evans, 2000). Mulch serves as a pretreatment layer by trapping the finer sediments that remain suspended after the primary pretreatment. Additionally, most attenuation of heavy metals in bioretention facilities occurs in the first 1-2 inches of the mulch layer (Hinman, 2005). Other considerations related to mulch are these:

- Mulch should be free of weed seeds, soil, roots, and other material that is not bole or branch wood or bark.
- Use commercially available double- or triple-shredded hardwood mulch. This mulch has been found to be less likely to wash away than other forms of mulch (such as pine).
- Mulch depth depends on the type of material used and the drainage and moisture-holding capacity of the soil. A 2-4 inch layer (after settling) is adequate for most applications. Excessive application of mulch can result in a situation where the plants are growing in the mulch and not the soil. Over-mulched plants are easily damaged during periods of drought stress. Mulching in an area that is poorly drained can aggravate the condition (Evans, 2000).
- Mulch can be applied any time of year; however, the best time to mulch is late spring after the soil has warmed.
- Mulch should be at least 6 months old (12 months is ideal).
- It should be placed uniformly, about 3 inches deep.
- Mulch should be renewed as needed to maintain a 2-4″ depth; on previously mulched areas, apply a one-inch layer of new material. It should be added 1-2 times per year and completely removed/replaced once every two years.

Siting Considerations

Some considerations for selecting a stormwater-management practice are the drainage area the practice will need to treat, the slopes both at the location of the practice and the drainage area, soil and subsurface conditions, and the depth of the seasonably high groundwater table. Bioretention can be applied on many sites, with its primary restriction being the need to apply the practice on small sites.

Drainage Area

Bioretention areas should, in general, be used on small sites (i.e., 5 acres or less). When used to treat larger areas, they tend to clog. In addition, it is difficult to convey flow from a large area to a bioretention area.

Slope

Bioretention areas are best applied to relatively shallow slopes (usually about 5 percent). However, sufficient slope is needed at the site to ensure that water that enters the bioretention area can be connected with the storm drain system. These stormwater-management practices are most often applied to parking lots or residential landscaped areas, which generally have shallow slopes.

Soils/Topography

Bioretention areas can be applied in almost any soils or topography, since runoff percolates through a man-made soil bed and is returned to the stormwater system.

Groundwater

Bioretention should be separated somewhat from the groundwater to ensure that the groundwater table never intersects with the bed of the bioretention facility. This design consideration prevents possible groundwater contamination.

Design Variations

One design alternative to the traditional bioretention practice is the use of a “partial exfiltration” system, used to promote groundwater recharge. Other design modifications may make this practice more effective in arid or cold climates.

Partial Exfiltration

In one design variation of the bioretention system, the underdrain is installed on only part of the bottom of the system. This design alternative allows for some infiltration, with the underdrain acting as more of an overflow. This system can be applied only when the soils and other characteristics are appropriate for infiltration (see *Infiltration Trench* and *Infiltration Basin*).

Common Problems

Bioretention areas have a few limitations. Bioretention areas cannot be used to treat a large drainage area, limiting their usefulness for some sites. In addition, although the practice does not consume a large amount of space, incorporating bioretention into a parking lot design may reduce the number of parking spaces available if islands were not previously included in the design.

Maintenance

Common maintenance activities include re-mulching, treating diseased trees and shrubs, and mowing turf areas.

Newly planted vegetation should be watered regularly until properly established.

Erosion issues should be addressed immediately.