

3.6 Bioretention

Definition. Practices that capture and store stormwater runoff and pass it through a filter bed of engineered soil media composed of sand, soil, and organic matter. Filtered runoff may be collected and returned to the conveyance system, or allowed to infiltrate into the soil. Design variants include:

- B-1 Traditional bioretention
- B-2 Streetscape bioretention
- B-3 Engineered tree pits
- B-4 Stormwater planters
- B-5 Residential rain gardens

Bioretention systems are typically not designed to provide stormwater detention of larger storms (e.g., 2-year, 15-year), but they may be in some circumstances. Bioretention practices shall generally be combined with a separate facility to provide those controls.

There are two different types of bioretention design configurations:

- **Standard Designs.** Practices with a standard underdrain design and less than 24 inches of filter media depth (see Figure 3.17). If trees are planted using this design, the filter media depth must be at least 24 inches to support the trees.
- **Enhanced Designs.** Practices with underdrains that contain at least 24 inches of filter media depth and an infiltration sump/storage layer (see Figure 3.18) or practices that can infiltrate the design storm volume in 72 hours (see Figure 3.19).

The particular design configuration to be implemented on a site is typically dependent on specific site conditions and the characteristics of the underlying soils. These criteria are further discussed in this chapter.

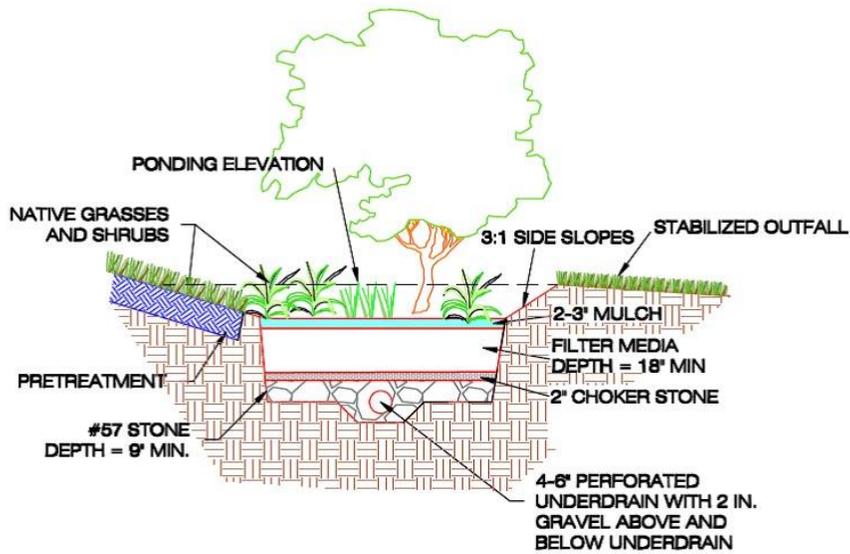
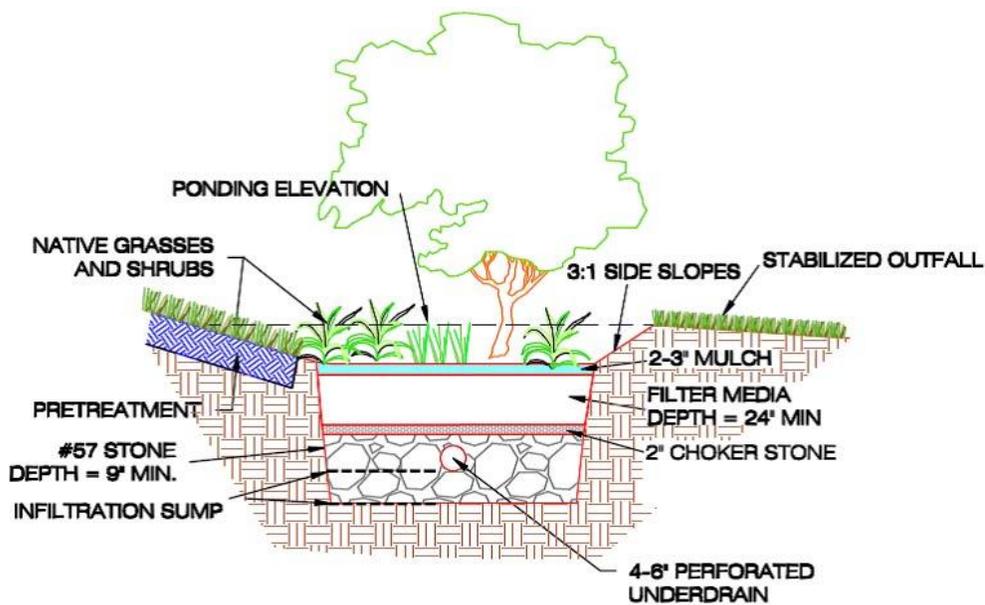


Figure 3.17 Example of standard bioretention design.



NOTE: If underlying soil infiltration rate < 0.5 "/hr, the underdrain and infiltration sump option may be used. The infiltration sump option must be designed to infiltrate the design storm volume in less than 72 hours.

Figure 3.18 Example of an enhanced bioretention design with an underdrain and infiltration sump/storage layer.

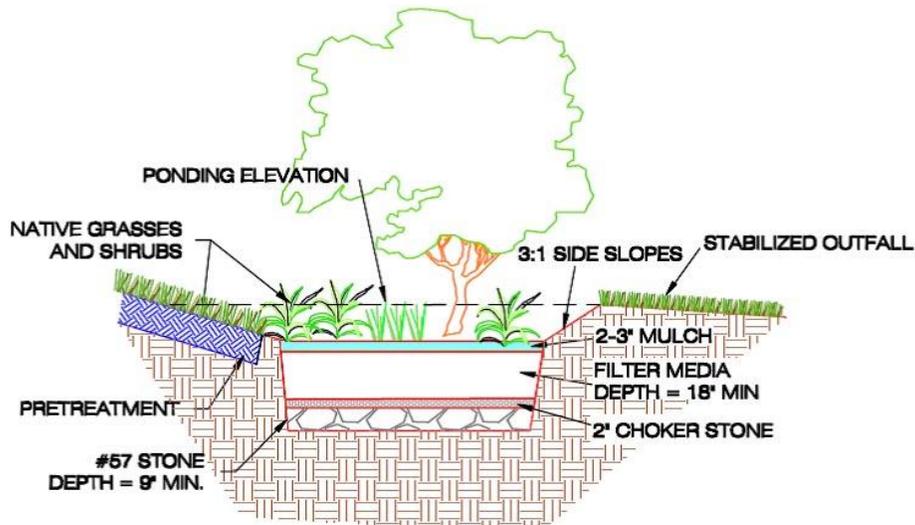


Figure 3.19 Example of enhanced bioretention design without an underdrain.

3.6.1 Bioretention Feasibility Criteria

Bioretention can be applied in most soils or topography, since runoff simply percolates through an engineered soil bed and is infiltrated or returned to the stormwater system via an underdrain. Key constraints with bioretention include the following:

Required Space. Planners and designers can assess the feasibility of using bioretention facilities based on a simple relationship between the contributing drainage area (CDA), and the corresponding bioretention surface area. The surface area is recommended to be approximately 3 to 6 percent of CDA, depending on the imperviousness of the CDA and the desired bioretention ponding depth.

Available Hydraulic Head. Bioretention is fundamentally constrained by the invert elevation of the existing conveyance system to which the practice discharges (i.e., the bottom elevation needed to tie the underdrain from the bioretention area into the storm drain system). In general, 4 to 5 feet of elevation above this invert is needed to accommodate the required ponding and filter media depths. If the practice does not include an underdrain or if an inverted or elevated underdrain design is used, less hydraulic head may be adequate.

Water Table. Bioretention must be separated from the water table to ensure that groundwater does not intersect the filter bed. Mixing can lead to possible groundwater contamination or failure of the bioretention facility. A separation distance of 2 feet is required between the bottom of the excavated bioretention area and the seasonally high ground water table.

Soils and Underdrains. Soil conditions do not typically constrain the use of bioretention, although they do determine whether an underdrain is needed. Underdrains may be required if the measured permeability of the underlying soils is less than 0.5 in./hr. When designing a

bioretention practice, designers must verify soil permeability by using the on-site soil investigation methods provided in Appendix O. Impermeable soils will require an underdrain.

For fill soil locations, geotechnical investigations are required to determine if it is necessary to use an impermeable liner and underdrain.

Contributing Drainage Area. Bioretention cells work best with smaller CDAs, where it is easier to achieve flow distribution over the filter bed. The maximum drainage area to a traditional bioretention area (B-1) is 2.5 acres and can consist of up to 100 percent impervious cover. The drainage area for smaller bioretention practices (B-2, B-3, B-4, and B-5) is a maximum of 1 acre. However, if hydraulic considerations are adequately addressed to manage the potentially large peak inflow of larger drainage areas, such as off-line or low-flow diversions, or forebays, there may be case-by-case instances where the maximum drainage areas can be adjusted. Table 3.18 summarizes typical recommendations for bioretention CDAs.

Table 3.18 Maximum Contributing Drainage Area to Bioretention

Bioretention Type	Design Variants	Maximum Contributing Drainage Area (acres of impervious cover)
Traditional	B-1	2.5
Small-scale and urban bioretention	B-2, B-3, B-4, and B-5	1.0

Hotspot Land Uses. An impermeable bottom liner and an underdrain system must be employed when a bioretention area will receive untreated hotspot runoff, and the Enhanced Design configuration cannot be used. However, bioretention can still be used to treat parts of the site that are outside of the hotspot area. For instance, roof runoff can go to bioretention while vehicular maintenance areas would be treated by a more appropriate hotspot practice.

For a list of potential stormwater hotspots, please consult Appendix P.

On sites with existing contaminated soils, as indicated in Appendix P, infiltration is not allowed. Bioretention areas must include an impermeable liner, and the Enhanced Design configuration cannot be used.

No Irrigation or Baseflow. The planned bioretention area should not receive baseflow, irrigation water, chlorinated wash-water or any other flows not related to stormwater. However, irrigation is allowed during the establishment period of the bioretention area to ensure plant survival.

Setbacks. To avoid the risk of seepage, bioretention areas must not be hydraulically connected to structure foundations. Setbacks to structures must be at least 10 feet and adequate water-proofing protection must be provided for foundations and basements. Where the 10-foot setback is not possible, an impermeable liner may be used along the sides of the bioretention area (extending from the surface to the bottom of the practice).

Proximity to Utilities. Designers should ensure that future tree canopy growth in the bioretention area will not interfere with existing overhead utility lines. Interference with underground utilities should be avoided, if possible. When large site development is undertaken the expectation of achieving avoidance will be high. Conflicts may be commonplace on smaller sites and in the public right-of-way. Consult with each utility company on recommended offsets, which will allow utility maintenance work with minimal disturbance to the bioretention system. For bioretention in the public right-of-way a consolidated presentation of the various utility offset recommendations can be found in Chapter 33.14.5 of the District of Columbia Department of Transportation Design and Engineering Manual, latest edition. Consult the District of Columbia Water and Sewer Authority (DC Water) Green Infrastructure Utility Protection Guidelines, latest edition, for water and sewer line recommendations. Where conflicts cannot be avoided, follow these guidelines:

- Consider altering the location or sizing of the bioretention to avoid or minimize the utility conflict. Consider an alternate BMP type to avoid conflict.
- Use design features to mitigate the impacts of conflicts that may arise by allowing the bioretention and the utility to coexist. The bioretention design may need to incorporate impervious areas, through geotextiles or compaction, to protect utility crossings. Other a key design feature may need to be moved or added or deleted
- Work with the utility to evaluate the relocation of the existing utility and install the optimum placement and sizing of the bioretention.
- If utility functionality, longevity and vehicular access to manholes can be assured accept the bioretention design and location with the existing utility. Incorporate into the bioretention design sufficient soil coverage over the utility or general clearances or other features such as an impermeable linear to assure all entities the conflict is limited to maintenance.

Note: When accepting utility conflict into the bioretention location and design, it is understood the bioretention will be temporarily impacted during utility work but the utility will replace the bioretention or, alternatively, install a functionally comparable bioretention according to the specifications in the current version of this Stormwater Management Guidebook. If the bioretention is located in the public right-of-way the bioretention restoration will also conform with the District of Columbia Department of Transportation Design and Engineering Manual with special attention to Chapter 33, Chapter 47, and the Design and Engineering Manual supplements for Low Impact Development and Green Infrastructure Standards and Specifications.

Minimizing External Impacts. Urban bioretention practices may be subject to higher public visibility, greater trash loads, pedestrian traffic, vandalism, and even vehicular loads. Designers should design these practices in ways that prevent, or at least minimize, such impacts. In addition, designers should clearly recognize the need to perform frequent landscaping maintenance to remove trash, check for clogging, and maintain vigorous vegetation. The urban landscape context may feature naturalized landscaping or a more formal design. When urban bioretention is used in sidewalk areas of high foot traffic, designers should not impede pedestrian movement or create a safety hazard. Designers may also install low fences, grates, or other measures to prevent damage from pedestrian short-cutting across the practices.

When bioretention will be included in public rights-of-way or spaces, design manuals and guidance developed by agencies or organizations other than DDOE may also apply (e.g., District Department of Transportation, Office of Planning, and National Capital Planning Commission).

3.6.2 Bioretention Conveyance Criteria

There are two basic design approaches for conveying runoff into, through, and around bioretention practices:

1. **Off-line:** Flow is split or diverted so that only the design storm or design flow enters the bioretention area. Larger flows bypass the bioretention treatment.
2. **On-line:** All runoff from the drainage area flows into the practice. Flows that exceed the design capacity exit the practice via an overflow structure or weir.

If runoff is delivered by a storm drain pipe or is along the main conveyance system, the bioretention area shall be designed off-line so that flows do not overwhelm or damage the practice.

Off-line Bioretention. Overflows are diverted from entering the bioretention cell. Optional diversion methods include the following:

- Create an alternate flow path at the inflow point into the structure such that when the maximum ponding depth is reached, the incoming flow is diverted past the facility. In this case, the higher flows do not pass over the filter bed and through the facility, and additional flow is able to enter as the ponding water filters through the soil media. With this design configuration, an overflow structure in the bioretention area is not required.
- Utilize a low-flow diversion or flow splitter at the inlet to allow only the design storm volume (i.e., the Stormwater Retention Volume (SWR_v)) to enter the facility (calculations must be made to determine the peak flow from the 1.2-inch, 24-hour storm). This may be achieved with a weir, curb opening, or orifice for the target flow, in combination with a bypass channel or pipe. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency. With this design configuration, an overflow structure in the bioretention area is required (see on-line bioretention below).

On-line Bioretention. An overflow structure must be incorporated into on-line designs to safely convey larger storms through the bioretention area. The following criteria apply to overflow structures:

- An overflow shall be provided within the practice to pass storms greater than the design storm storage to a stabilized water course. A portion of larger events may be managed by the bioretention area so long as the maximum depth of ponding in the bioretention cell does not exceed 18 inches.
- The overflow device must convey runoff to a storm sewer, stream, or the existing stormwater conveyance infrastructure, such as curb and gutter or an existing channel.

- Common overflow systems within bioretention practices consist of an inlet structure, where the top of the structure is placed at the maximum ponding depth of the bioretention area, which is typically 6 to 18 inches above the surface of the filter bed.
- The overflow device should be scaled to the application. This may be a landscape grate or yard inlet for small practices or a commercial-type structure for larger installations.
- At least 3–6 inches of freeboard must be provided between the top of the overflow device and the top of the bioretention area to ensure that nuisance flooding will not occur.
- The overflow associated with the 2-year and 15-year design storms must be controlled so that velocities are non-erosive at the outlet point, to prevent downstream erosion.

3.6.3 Bioretention Pretreatment Criteria

Pretreatment of runoff entering bioretention areas is necessary to trap coarse sediment particles before they reach and prematurely clog the filter bed. Pretreatment measures must be designed to evenly spread runoff across the entire width of the bioretention area. Several pretreatment measures are feasible, depending on the type of the bioretention practice and whether it receives sheet flow, shallow concentrated flow, or deeper concentrated flows. The following are appropriate pretreatment options:

Small-Scale Bioretention (B-2, B-3, B-4, and B-5)

- **Leaf Screens.** A leaf screen serves as part of the gutter system to keep the heavy loading of organic debris from accumulating in the bioretention cell.
- **Pretreatment Cells** (for channel flow). Pretreatment cells are located above ground or covered by a manhole or grate. Pretreatment cells are atypical in small-scale bioretention and are not recommended for residential rain gardens (B-5).
- **Grass Filter Strips** (for sheet flow). Grass filter strips are applied on residential lots, where the lawn area can serve as a grass filter strip adjacent to a rain garden.
- **Stone Diaphragm** (for either sheet flow or concentrated flow). The stone diaphragm at the end of a downspout or other concentrated inflow point should run perpendicular to the flow path to promote settling.

Note: stone diaphragms are not recommended for school settings.

- **Trash Racks** (for either sheet flow or concentrated flow). Trash racks are located between the pretreatment cell and the main filter bed or across curb cuts to allow trash to collect in specific locations and make maintenance easier.

Traditional Bioretention (B-1)

- **Pretreatment Cells** (for channel flow). Similar to a forebay, this cell is located at piped inlets or curb cuts leading to the bioretention area and consists of an energy dissipater sized for the expected rates of discharge. It has a storage volume equivalent to at least 15 percent of the total storage volume (inclusive) with a recommended 2:1 length-to-width ratio. The cell may be formed by a wooden or stone check dam or an earthen or rock berm. Pretreatment cells do not need underlying engineered soil media, in contrast to the main

bioretention cell. However, if the volume of the pretreatment cell will be included as part of the bioretention storage volume, the pretreatment cell must de-water between storm events. It cannot have a permanent ponded volume.

- **Grass Filter Strips** (for sheet flow). Grass filter strips that are perpendicular to incoming sheet flow extend from the edge of pavement, with a slight drop at the pavement edge, to the bottom of the bioretention basin at a 5:1 slope or flatter. Alternatively, if the bioretention basin has side slopes that are 3:1 or flatter, a 5-foot grass filter strip can be used at a maximum 5 percent (20:1) slope.
- **Stone Diaphragms** (for sheet flow). A stone diaphragm located at the edge of the pavement should be oriented perpendicular to the flow path to pretreat lateral runoff, with a 2 to 4 inch drop from the pavement edge to the top of the stone. The stone must be sized according to the expected rate of discharge.
- **Gravel or Stone Flow Spreaders** (for concentrated flow). The gravel flow spreader is located at curb cuts, downspouts, or other concentrated inflow points, and should have a 2 to 4 inch elevation drop from a hard-edged surface into a gravel or stone diaphragm. The gravel must extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the basin.
- **Filter System** (see Section 3.7 Stormwater Filtering Systems). If using a filter system as a pretreatment facility, the filter will not require a separate pretreatment facility.
- **Innovative or Proprietary Structure**. An approved proprietary structure with demonstrated capability of reducing sediment and hydrocarbons may be used to provide pretreatment. Refer to Section 3.13 Proprietary Practices for information on approved proprietary structures.

Other pretreatment options may be appropriate as long as they trap coarse sediment particles and evenly spread runoff across the entire width of the bioretention area.

3.6.4 Bioretention Design Criteria

Design Geometry. Bioretention basins must be designed with an internal flow path geometry such that the treatment mechanisms provided by the bioretention are not bypassed or short-circuited. In order for the bioretention area to have an acceptable internal geometry, the travel time from each inlet to the outlet should be maximized by locating the inlets and outlets as far apart as possible. In addition, incoming flow must be distributed as evenly as possible across the entire filter surface area.

Inlets and Energy Dissipation. Where appropriate, the inlet(s) to streetscape bioretention (B-2), engineered tree boxes (B-3), and stormwater planters (B-4) should be stabilized using No. 3 stone, splash block, river stone, or other acceptable energy dissipation measures. The following types of inlets are recommended:

- Downspouts to stone energy dissipaters.
- Sheet flow over a depressed curb with a 3-inch drop.
- Curb cuts allowing runoff into the bioretention area.

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- Covered drains that convey flows across sidewalks from the curb or downspouts.
 - Grates or trench drains that capture runoff from a sidewalk or plaza area.
 - Drop structures that appropriately dissipate water energy.

Ponding Depth. The recommended surface ponding depth is 6–12 inches. Minimum surface ponding depth is 3 inches (averaged over the surface area of the BMP). Ponding depths can be increased to a maximum of 18 inches. However, when higher ponding depths are utilized, the design must consider carefully issues such as safety, fencing requirements, aesthetics, the viability and survival of plants, and erosion and scour of side slopes. This is especially true where bioretention areas are built next to sidewalks or other areas where pedestrians or bicyclists travel. Shallower ponding depths (typically 6–12 inches) are recommended for streetscape bioretention (B-2), engineered tree boxes (B-3), and stormwater planters (B-4).

Side Slopes. Traditional bioretention areas (B-1) and residential rain gardens (B-5) should be constructed with side slopes of 3:1 or flatter. In highly urbanized or space constrained areas, a drop curb design or a precast structure can be used to create a stable, vertical side wall. These drop curb designs should not exceed a vertical drop of more than 12 inches, unless safety precautions, such as railings, walls, grates, etc. are included.

Filter Media. The filter media and surface cover are the two most important elements of a bioretention facility in terms of long-term performance.

- **Particle Size Composition.** The bioretention soil mixture shall be classified as a loamy sand on the USDA Texture Triangle, with the following particle size composition:
 - ◆ 80–90 percent sand (at least 75 percent of which must be classified as coarse or very coarse sand)
 - ◆ 10–20 percent soil fines (silt and clay)
 - ◆ Maximum 10 percent clay
 - ◆ The particle size analysis must be conducted on the mineral fraction only or following appropriate treatments to remove organic matter before particle size analysis.
- **Organic Matter.** The filter media must contain 3 to 5 percent organic matter by the conventional Walkley-Black soil organic matter determination method or similar analysis. Soil organic matter is expressed on a dry weight basis and does not include coarse particulate (visible) components.
- **Available Soil Phosphorus (P).** The filter media should contain sufficient available P to support initial plant establishment and growth, but not serve as a significant source of P for long-term leaching. Plant-available soil P should be within the range of Low+ (L+) to Medium (M) as defined in Table 2.2 of Virginia Nutrient Management Standards and Criteria (2005). For the Mehlich I extraction procedure this equates to a range of 5 to 15 mg/kg P or 18 to 40 mg/kg P for the Mehlich III procedure.
- **Cation Exchange Capacity (CEC).** The relative ability of soils to hold and retain nutrient cations like Ca and K is referred to as cation exchange capacity (CEC) and is measured as the total amount of positively charged cations that a soil can hold per unit dry mass. CEC is also

used as an index of overall soil reactivity and is commonly expressed in milliequivalents per 100 grams (meq/100g) of soil or cmol+/kg (equal values). A soil with a moderate to high CEC indicates a greater ability to capture and retain positively charged contaminants, which encourages conditions to remove phosphorus, assuming that soil fines (particularly fine silts and clays) are at least partially responsible for CEC. The minimum CEC of the filter media is 5.0 (meq/100 g or cmol+/kg). The filter media CEC should be determined by the Unbuffered Salt, Ammonium Acetate, Summation of Cations or Effective CEC techniques (Sumner and Miller, 1996) or similar methods that do not utilize strongly acidic extracting solutions.

The goal of the filter media mixture described in this section is to create a soil media that maintains long-term permeability while also providing enough nutrients to support plant growth. The initial permeability of the mixture will exceed the desired long-term permeability of 1 to 2 in./hr. The limited amount of topsoil and organic matter is considered adequate to help support initial plant growth, and it is anticipated that the gradual increase of organic material through natural processes will continue to support growth while gradually decreasing the permeability. Finally, the root structure of maturing plants and the biological activity of a self-sustaining organic content will maintain sufficient long-term permeability as well as support plant growth without the need to add fertilizer.

The following is the recommended composition of the three media ingredients:

- **Sand.** Sand shall consist of silica-based coarse aggregate, angular or round in shape and meet the mixture grain size distribution specified in Table 3.19. No substitutions of alternate materials (such as diabase, calcium carbonate, rock dust, or dolomitic sands) are accepted. In particular, mica can make up no more than 5 percent of the total sand fraction. The sand fraction may also contain a limited amount of particles greater than 2.0 mm and less than 9.5 mm per the table below, but the overall sand fraction must meet the specification containing greater than 75 percent coarse or very coarse sand. Consult Table 3.19 for recommended sand sizing criteria.

Table 3.19 Sand Sizing Criteria

Sieve Type	Particle Size (mm)	Percent Passing (%)
3/8 in.	9.50	100
No. 4	4.75	95– 100
No. 8	2.36	80– 100
No. 16	1.18	45– 85
No. 30	0.60	15– 60
No. 50	0.30	3– 15
No. 100	0.15	0– 4

Note: Effective particle size (D10) > 0.3mm. Uniformity coefficient (D60/D10) < 4.0.

- **Topsoil.** Topsoil is generally defined as the combination of the ingredients referenced in the bioretention filter media: sand, fines (silt and clay), and any associated soil organic matter. Since the objective of the specification is to carefully establish the proper blend of these ingredients, the designer (or contractor or materials supplier) must carefully select the topsoil source material in order to not exceed the amount of any one ingredient.

Generally, the use of a topsoil defined as a loamy sand, sandy loam, or loam (per the USDA Textural Triangle) will be an acceptable ingredient and in combination with the other ingredients meet the overall performance goal of the soil media.

- **Organic Matter.** Organic materials used in the soil media mix should consist of well-decomposed natural C-containing organic materials such as peat moss, humus, compost (consistent with the material specifications found in Appendix J), pine bark fines or other organic soil conditioning material. However, per above, the combined filter media should contain 3 to 5 percent soil organic matter on dry weight basis (grams organic matter per 100 grams dry soil) by the Walkley-Black method or other similar analytical technique.

In creating the filter media, it is recommended to start with an open-graded coarse sand material and proportionately mix in the topsoil materials to achieve the desired ratio of sand and fines. Sufficient suitable organic amendments can then be added to achieve the 3 to 5 percent soil organic matter target. The exact composition of organic matter and topsoil material will vary, making the exact particle size distribution of the final total soil media mixture difficult to define in advance of evaluating available materials. Table 3.20 summarizes the filter media requirements.

Table 3.20 Filter Media Criteria for Bioretention

Soil Media Criterion	Description	Standard(s)		
General Composition	Soil media must have the proper proportions of sand, fines, and organic matter to promote plant growth, drain at the proper rate, and filter pollutants	80% to 90% sand (75% of which is coarse or very coarse); 10% to 20% soil fines; maximum of 10% clay; and 3% to 5% organic matter		
Sand	Silica based coarse aggregate ¹	Sieve Type	Particle Size (mm)	Percent Passing (%)
		3/8 in. No. 4 No. 8 No. 16 No. 30 No. 50 No. 100	9.50 4.75 2.36 1.18 0.6 0.3 0.15	100 95–100 80–100 45–85 15–60 3–15 0–4
		Effective Particle size (D10) > 0.3mm Uniformity Coefficient (D60/D10) < 4.0		
Top Soil	Loamy sand or sandy loam	USDA Textural Triangle		
Organic Matter	Well-aged, clean compost	Appendix J		
P-Index or Phosphorus (P) Content	Soil media with high P levels will export P through the media and potentially to downstream conveyances or receiving waters	P content = 5 to 15 mg/kg (Mehlich I) or 18 to 40 mg/kg (Mehlich III)		
Cation Exchange Capacity (CEC)	The CEC is determined by the amount of soil fines and organic matter. Higher CEC will promote pollutant removal	CEC > 5 milliequivalents per 100 grams		

¹Many specifications for sand refer to ASTM C-33. The ASTM C-33 specification allows a particle size distribution that contains a large fraction of fines (silt and clay sized particles < 0.05 mm). The smaller fines fill the voids between the larger sand sized particles, resulting in smaller and more convoluted pore spaces. While this condition provides a high degree of treatment, it also encourages clogging of the remaining void spaces with suspended solids and biological growth, resulting in a greater chance of a restrictive biomat forming. By limiting the fine particles allowed in the sand component, the combined media recipe of sand and the fines associated with the soil and organic material will be less prone to clogging, while also providing an adequate level of filtration and retention.

In cases where greater removal of specific pollutants is desired, additives with documented pollutant removal benefits, such as water treatment residuals, alum, iron, or other materials may be included in the filter media if accepted by DDOE.

- **Filter Media Depth.** The filter media bed depth must be a minimum of 18 inches for the Standard Design. The media depth must be 24 inches or greater to qualify for the Enhanced Design, unless an infiltration-based design is used. The media depth must not exceed 6 feet. Turf, perennials, or shrubs should be used instead of trees to landscape shallower filter beds. See Table 3.23 and Table 3.24 for a list of recommended native plants.

During high intensity storm events, it is possible for the bioretention to fill up faster than the collected stormwater is able to filter through the soil media. This is dependent upon the surface area of the BMP (SA) relative to the contributing drainage area (CDA) and the runoff coefficient (R_v) from the CDA . To ensure that the design runoff volume is captured and filtered appropriately, a maximum filter media depth must not be exceeded (see Table 3.24). The maximum filter media depth is based on the runoff coefficient of the CDA to the BMP (R_{vCDA}) and the bioretention ratio of BMP surface area to the BMP CDA ($SA:CDA$) (in percent). The applicable filter media depth from Table 3.21 should be used as d_{media} in Equation 3.5.

Table 3.21 Determining Maximum Filter Media Depth (feet)

SA:CDA (%)	R _v CDA								
	0.25	0.3	0.40	0.50	0.60	0.70	0.80	0.90	0.95
0.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1.0	5.0	5.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0
1.5	3.5	4.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0
2.0	2.5	3.0	4.0	5.0	5.5	6.0	6.0	6.0	6.0
2.5	2.0	2.5	3.5	4.0	4.5	5.0	5.5	6.0	6.0
3.0	1.5	2.0	3.0	3.5	4.0	4.5	5.0	5.5	5.5
3.5	1.5	1.5	2.5	3.0	3.5	4.0	4.5	5.0	5.0
4.0	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	4.5
4.5	1.5	1.5	2.0	2.5	3.0	3.5	3.5	4.0	4.5
5.0	1.5	1.5	1.5	2.0	2.5	3.0	3.5	4.0	4.0
5.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0	3.5	3.5
6.0	1.5	1.5	1.5	1.5	2.0	2.5	3.0	3.0	3.5
6.5	1.5	1.5	1.5	1.5	2.0	2.5	2.5	3.0	3.0
7.0	1.5	1.5	1.5	1.5	1.5	2.0	2.5	3.0	3.0
7.5	1.5	1.5	1.5	1.5	1.5	2.0	2.5	2.5	2.5
8.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.5	2.5
8.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.5
9.0	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0
9.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0
10.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	2.0	2.0

Surface Cover. Mulch is the recommended surface cover material, but other materials may be substituted, as described below:

- **Mulch.** A 2- to 3-inch layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth, pretreats runoff before it reaches the filter media, and prevents rapid evaporation of rainwater. Shredded hardwood bark mulch, aged for at least 6 months, makes a very good surface cover, as it retains a significant amount of pollutants and typically will not float away.

- **Alternative to Mulch Cover.** In some situations, designers may consider alternative surface covers, such as turf, native groundcover, erosion control matting (e.g., coir or jute matting), river stone, or pea gravel. The decision regarding the type of surface cover to use should be based on function, expected pedestrian traffic, cost, and maintenance. When alternative surface covers are used, methods to discourage pedestrian traffic should be considered. Stone or gravel are not recommended in parking lot applications, since they increase soil temperature and have low water-holding capacity.
- **Media for Turf Cover.** One adaptation suggested for use with turf cover is to design the filter media primarily as a sand filter with organic content only at the top. Compost, as specified in Appendix J, tilled into the top layers will provide organic content for the vegetative cover. If grass is the only vegetation, the ratio of organic matter in the filter media composition may be reduced.

Choking Layer. A 2 to 4 inch layer of choker stone (e.g., typically ASTM D448 No. 8 or No. 89 washed gravel) should be placed beneath the soil media and over the underdrain stone.

Geotextile. If the available head is limited, or the depth of the practice is a concern, geotextile fabric may be used in place of the choking layer. An appropriate geotextile fabric that complies with AASHTO M-288 Class 2, latest edition, requirements, and has a permeability of at least an order of magnitude higher (10x) than the soil subgrade permeability must be used. Geotextile fabric may be used on the sides of bioretention areas, as well.

Underdrains. Many bioretention designs will require an underdrain (see Section 3.6.1 Bioretention Feasibility Criteria). The underdrain should be a 4- or 6-inch perforated schedule 40 PVC pipe, or equivalent corrugated HDPE for small bioretention BMPs, with 3/8-inch perforations at 6 inches on center. The underdrain must be encased in a layer of clean, double washed ASTM D448 No.57 or smaller (No. 68, 8, or 89) stone. The underdrain must be sized so that the bioretention BMP fully drains within 72 hours or less.

Multiple underdrains are necessary for bioretention areas wider than 40 feet, and each underdrain must be located no more than 20 feet from the next pipe or the edge of the bioretention. (For long and narrow applications, a single underdrain running the length of the bioretention is sufficient.)

All traditional bioretention practices must include at least one observation well and/or cleanout pipe (minimum 4 inches in diameter). The observation wells should be tied into any of the Ts or Ys in the underdrain system and must extend upward above the surface of the bioretention area.

Underground Storage Layer (optional). For bioretention systems with an underdrain, an underground storage layer consisting of chambers, perforated pipe, stone, or other acceptable material can be incorporated below the filter media layer and underdrain to increase the infiltration sump volume or the storage for larger storm events. To qualify for the Enhanced Design, this storage layer must be designed to infiltrate in 72 hours, at ½ the measured infiltration rate. The may also be designed to provide detention for the 2-year, 15-year, or 100-year storms, as needed. The depth and volume of the storage layer will then depend on the target storage volumes needed to meet the applicable detention criteria.

Impermeable Liner. An impermeable liner is not typically required, although it may be utilized in fill applications where deemed necessary by a geotechnical investigation, on sites with contaminated soils, or on the sides of the practice to protect adjacent structures from seepage. Use a 30-mililiter (minimum) PVC geomembrane liner. (Follow manufacturer’s instructions for installation.) Field seams must be sealed according to the liner manufacturer’s specifications. A minimum 6-inch overlap of material is required at all seams.

Material Specifications. Recommended material specifications for bioretention areas are shown in Table 3.22.

Table 3.22 Bioretention Material Specifications

Material	Specification	Notes
Filter Media	<ul style="list-style-type: none"> ▪ See Table 3.20 	Minimum depth of 24 inches (18 inches for small-scale practices) To account for settling/compaction, it is recommended that 110% of the plan volume be utilized.
Mulch Layer	Use aged, shredded hardwood bark mulch	Lay a 2 to 3-inch layer on the surface of the filter bed.
Alternative Surface Cover	Use river stone or pea gravel, coir and jute matting, or turf cover.	Lay a 2 to 3-inch layer of to suppress weed growth.
Top Soil For Turf Cover	Loamy sand or sandy loam texture, with less than 5% clay content, pH corrected to between 6 and 7, and an organic matter content of at least 2%.	3-inch tilled into surface layer.
Geotextile or Choking Layer	An appropriate geotextile fabric that complies with AASHTO M-288 Class 2, latest edition, requirements and has a permeability of at least an order of magnitude higher (10x) than the soil subgrade permeability must be used	Can use in place of the choking layer where the depth of the practice is limited. Geotextile fabric may be used on the sides of bioretention areas, as well.
	Lay a 2 to 4 inch layer of choker stone (e.g., typically No.8 or No.89 washed gravel) over the underdrain stone.	
Underdrain stone	1-inch diameter stone must be double-washed and clean and free of all fines (e.g., ASTM D448 No. 57 or smaller stone).	At least 2 inches above and below the underdrain.
Storage Layer (optional)	To increase storage for larger storm events, chambers, perforated pipe, stone, or other acceptable material can be incorporated below the filter media layer	
Impermeable Liner (optional)	Where appropriate, use a thirty mil (minimum) PVC Geomembrane liner	
Underdrains, Cleanouts, and Observation Wells	Use 4- or 6-inch rigid schedule 40 PVC pipe, or equivalent corrugated HDPE for small bioretention BMPs, with 3/8-inch perforations at 6 inches on center. Multiple underdrains are necessary for bioretention areas wider than 40 feet, and each underdrain must be located no more than 20 feet from the next pipe or the edge of the bioretention.	Lay the perforated pipe under the length of the bioretention cell, and install non-perforated pipe as needed to connect with the storm drain system or to daylight in a stabilized conveyance. Install T’s and Y’s as needed, depending on the underdrain configuration. Extend cleanout pipes to the surface.

Material	Specification	Notes
Plant Materials	See Section 3.6.5 Bioretention Landscaping Criteria	Establish plant materials as specified in the landscaping plan and the recommended plant list.

Signage. Bioretention units in highly urbanized areas should be stenciled or otherwise permanently marked to designate it as a structural BMP. The stencil or plaque should indicate (1) its water quality purpose, (2) that it may pond briefly after a storm, and (3) that it is not to be disturbed except for required maintenance.

Specific Design Issues for Streetscape Bioretention (B-2). Streetscape bioretention is installed in the road right-of way either in the sidewalk area or in the road itself. In many cases, streetscape bioretention areas can also serve as a traffic calming or street parking control devices. The basic design adaptation is to move the raised concrete curb closer to the street or in the street, and then create inlets or curb cuts that divert street runoff into depressed vegetated areas within the right-of-way. Roadway stability can be a design issue where streetscape bioretention practices are installed. Designers should consult design standards pertaining to roadway drainage. It may be necessary to provide an impermeable liner on the road side of the bioretention area to keep water from saturating the road's sub-base.

Specific Design Issues for Engineered Tree Boxes (B-3). Engineered tree boxes are installed in the sidewalk zone near the street where urban street trees are normally installed. The soil volume for the tree pit is increased and used to capture and treat stormwater. Treatment is increased by using a series of connected tree planting areas together in a row. The surface of the enlarged planting area may be mulch, grates, permeable pavers, or conventional pavement. The large and shared rooting space and a reliable water supply increase the growth and survival rates in this otherwise harsh planting environment.

When designing engineered tree boxes, the following criteria must be considered:

- The bottom of the soil layer must be a minimum of 4 inches below the root ball of plants to be installed.
- Engineered tree box designs sometimes cover portions of the filter media with pervious pavers or cantilevered sidewalks. In these situations, it is important that the filter media is connected beneath the surface so that stormwater and tree roots can share this space.
- Installing an engineered tree pit grate over filter bed media is one possible solution to prevent pedestrian traffic and trash accumulation.
- Low, wrought iron fences can help restrict pedestrian traffic across the tree pit bed and serve as a protective barrier if there is a drop-off from the pavement to the micro-bioretention cell.
- A removable grate may be used to allow the tree to grow through it.
- Each tree needs a minimum rootable soil volume as described in Section 3.14.

Specific Design Issues for Stormwater Planters (B-4). Stormwater planters are a useful option to disconnect and treat rooftop runoff, particularly in ultra-urban areas. They consist of confined planters that store and/or infiltrate runoff in a soil bed to reduce runoff volumes and pollutant loads. Stormwater planters combine an aesthetic landscaping feature with a functional form of stormwater treatment. Stormwater planters generally receive runoff from adjacent rooftop downspouts and are landscaped with plants that are tolerant to periods of both drought and inundation. The two basic design variations for stormwater planters are the infiltration planter and the filter planter. A filter planter is illustrated in Figure 3.2 below.

An infiltration planter filters rooftop runoff through soil in the planter followed by infiltration into soils below the planter. The minimum filter media depth is 18 inches, with the shape and length determined by architectural considerations. Infiltration planters should be placed at least 10 feet away from a building to prevent possible flooding or basement seepage damage.

A filter planter does not allow for infiltration and is constructed with a watertight concrete shell or an impermeable liner on the bottom to prevent seepage. Since a filter planter is self-contained and does not infiltrate into the ground, it can be installed right next to a building. The minimum filter media depth is 18 inches, with the shape and length determined by architectural considerations. Runoff is captured and temporarily ponded above the planter bed. Overflow pipes are installed to discharge runoff when maximum ponding depths are exceeded, to avoid water spilling over the side of the planter. In addition, an underdrain is used to carry runoff to the storm sewer system.

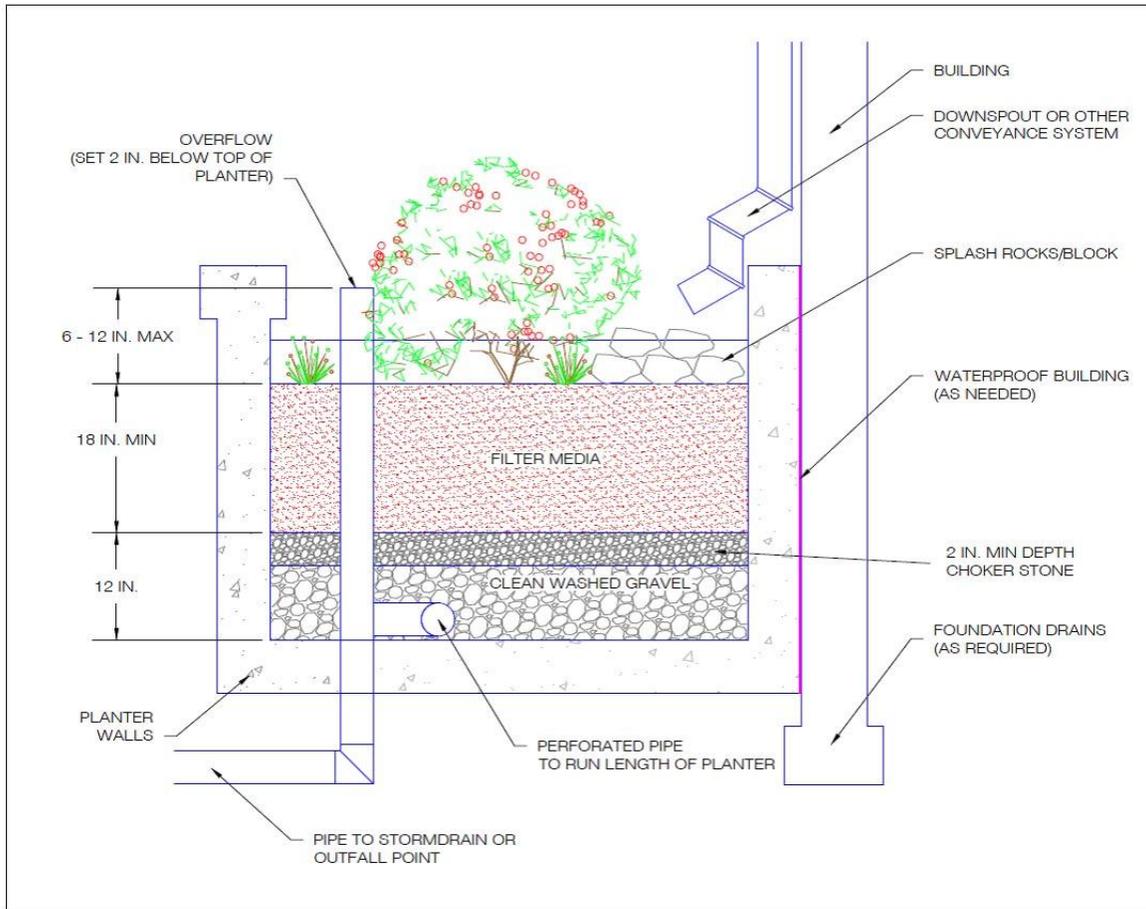


Figure 3.20 Example of a stormwater planter (B-4).

All planters should be placed at grade level or above ground. Plant materials must be capable of withstanding moist and seasonally dry conditions. The sand and gravel on the bottom of the planter should have a minimum infiltration rate of 5 inches per hour. The planter can be constructed of stone, concrete, brick, wood, or other durable material. If treated wood is used, care should be taken so that trace metals and creosote do not leach out of the planter.

Specific Design Issues for Residential Rain Gardens (B-5). For some residential applications, front, side, and/or rear yard bioretention may be an attractive option. This form of bioretention captures roof, lawn, and driveway runoff from low- to medium- density residential lots in a depressed area (i.e., 6 to 12 inches) between the home and the primary stormwater conveyance system (i.e., roadside ditch or pipe system). The bioretention area connects to the drainage system with an underdrain.

The bioretention filter media must be at least 18 inches deep. The underdrain is directly connected into the storm drain pipe running underneath the street or in the street right-of-way. A trench needs to be excavated during construction to connect the underdrain to the street storm drain system.

Construction of the remainder of the bioretention system is deferred until after the lot has been stabilized. Residential rain gardens require regular maintenance to perform effectively.

BMP Sizing. Bioretention is typically sized to capture the SWR_v or larger design storm volumes in the surface ponding area, soil media, and gravel reservoir layers of the BMP.

Total storage volume of the BMP is calculated using Equation 3.5.

Equation 3.5 Bioretention Storage Volume

$$S_v = SA_{bottom} \times [(d_{media} \times \eta_{media}) + (d_{gravel} \times \eta_{gravel})] + (SA_{average} \times d_{ponding})$$

where:

S_v	=	total storage volume of bioretention (ft ³)
SA_{bottom}	=	bottom surface area of bioretention (ft ²)
d_{media}	=	depth of the filter media (ft)
η_{media}	=	effective porosity of the filter media (typically 0.25)
d_{gravel}	=	depth of the underdrain and underground storage gravel layer (ft)
η_{gravel}	=	effective porosity of the gravel layer (typically 0.4)
$SA_{average}$	=	average surface area of bioretention (ft ²) typically, where SA_{top} is the top surface area of bioretention, $SA_{average} = \frac{SA_{bottom} + SA_{top}}{2}$
$d_{ponding}$	=	maximum ponding depth of bioretention (ft)

Equation 3.5 can be modified if the storage depths of the filter media, gravel layer, or ponded water vary in the actual design or with the addition of any surface or subsurface storage components (e.g., additional area of surface ponding, subsurface storage chambers, etc.). The maximum depth of ponding in the bioretention must not exceed 18 inches. If storage practices will be provided off-line or in series with the bioretention area, the storage practices should be sized using the guidance in Section 3.12.

Bioretention can be designed to address, in whole or in part, the detention storage needed to comply with channel protection and/or flood control requirements. The S_v can be counted as part of the 2-year or 15-year runoff volumes to satisfy stormwater quantity control requirements. At least 3–6 inches of freeboard are required between the top of the overflow device and the top of the bioretention area when bioretention is used as detention storage for 2-year and 15-year storms.

Note: In order to increase the storage volume of a bioretention area, the ponding surface area may be increased beyond the filter media surface area. However, the top surface area of the practice (i.e., at the top of the ponding elevation) may not be more than twice the size of the surface area of the filter media (SA_{bottom}).

3.6.5 Bioretention Landscaping Criteria

Landscaping is critical to the performance and function of bioretention areas. Therefore, a landscaping plan shall be provided for bioretention areas.

Minimum plan elements include the proposed bioretention template to be used, delineation of planting areas, and the planting plan including the following:

- Common and botanical names of the plants used
- Size of planted materials
- Mature size of the plants
- Light requirements
- Maintenance requirements
- Source of planting stock
- Any other specifications
- Planting sequence

It is recommended that the planting plan be prepared by a qualified landscape architect professional (e.g. licensed professional landscape architect, certified horticulturalist) in order to tailor the planting plan to the site-specific conditions.

Native plant species are preferred over non-native species, but some ornamental species may be used for landscaping effect if they are not aggressive or invasive. Some popular native species that work well in bioretention areas and are commercially available can be found in Table 3.23 and Table 3.24. Internet links to more detailed bioretention plant lists developed in the Chesapeake Bay region are provided below:

- Prince Georges County, MD
http://www.aacounty.org/DPW/Highways/Resources/Raingarden/RG_Bioretention_PG%20CO.pdf
- Delaware Green Technology Standards and Specifications
http://www.dnrec.state.de.us/DNREC2000/Divisions/Soil/Stormwater/New/GT_Std%20&%20Specs_06-05.pdf

The degree of landscape maintenance that can be provided will determine some of the planting choices for urban bioretention areas. Plant selection differs if the area will be frequently mowed, pruned, and weeded, in contrast to a site which will receive minimum annual maintenance. In areas where less maintenance will be provided and where trash accumulation in shrubbery or herbaceous plants is a concern, consider a “turf and trees” landscaping model where the turf is mowed along with other turf areas on the site. Spaces for herbaceous flowering plants can be included.

Table 3.23 Herbaceous Plants Appropriate for Bioretention Areas in the District

Plant	Light	Wetland Indicator ¹	Plant Form	Inundation Tolerance	Notes
Aster, New York (<i>Aster novi-belgii</i>)	Full Sun- Part Shade	FACW+	Perennial	Yes	Attractive flowers; tolerates poor soils
Aster, New England (<i>Aster novae-angliae</i>)	Full Sun- Part Shade	FACW	Perennial	Yes	Attractive flowers
Aster, Perennial Saltmarsh (<i>Aster tenuifolius</i>)	Full Sun- Part Shade	OBL	Perennial	Yes	Salt tolerant
Coreopsis, Threadleaf (<i>Coreopsis verticillata</i>)	Full Sun- Part Shade	FAC	Perennial	No	Drought tolerant
Beardtongue (<i>Penstemon digitalis</i>)	Full Sun	FAC	Perennial	No	Tolerates poor drainage
Beebalm (<i>Monarda didyma</i>)	Full Sun- Part Shade	FAC+	Perennial	Saturated	Herbal uses; attractive flower
Black-Eyed Susan (<i>Rudbeckia hirta</i>)	Full Sun- Part Shade	FACU	Perennial	No	Common; Maryland state flower
Bluebells, Virginia (<i>Mertensia virginica</i>)	Part Shade- Full Shade	FACW	Perennial	Yes	Attractive flower; dormant in summer
Blueflag, Virginia (<i>Iris virginica</i>)	Full Sun- Part Shade	OBL	Perennial	Yes	Tolerates standing water
Bluestem, Big (<i>Andropogon gerardii</i>)	Full Sun	FAC	Grass	No	Attractive in winter; forms clumps
Bluestem, Little (<i>Schizachyrium scoparium</i>)	Full Sun	FACU	Grass	No	Tolerates poor soil conditions
Broom-Sedge (<i>Andropogon virginicus</i>)	Full Sun	FACU	Grass	No	Drought tolerant; attractive fall color
Cardinal Flower (<i>Lobelia cardinalis</i>)	Full Sun- Part Shade	FACW+	Perennial	Yes	Long boom time
Fern, New York (<i>Thelypteris noveboracensis</i>)	Part Shade- Full Shade	FAC	Fern	Saturated	Drought tolerant; spreads
Fern, Royal (<i>Osmunda regalis</i>)	Full Sun- Full Shade	OBL	Fern	Saturated	Tolerates short term flooding; drought tolerant
Fescue, Red (<i>Festuca rubra</i>)	Full Sun- Full Shade	FACU	Ground- cover	No	Moderate growth; good for erosion control
Iris, Blue Water (<i>Iris versicolor</i>)	Full Sun- Part Shade	OBL	Perennial	0-6"	Spreads
Lobelia, Great Blue (<i>Lobelia siphilitica</i>)	Part Shade- Full Shade	FACW+	Perennial	Yes	Blooms in late summer; bright blue flowers
Phlox, Meadow (<i>Phlox maculata</i>)	Full Sun	FACW	Perennial	Yes	Aromatic; spreads
Sea-Oats (<i>Uniola paniculata</i>)	Full Sun	FACU-	Grass	No	Salt tolerant; attractive seed heads
Swamp Milkweed (<i>Asclepias incarnata</i>)	Full Sun- Part Shade	OBL	Perennial	Saturated	Drought tolerant
Switchgrass (<i>Panicum virgatum</i>)	Full Sun	FAC	Grass	Seasonal	Adaptable; great erosion control

Plant	Light	Wetland Indicator ¹	Plant Form	Inundation Tolerance	Notes
Turtlehead, White (<i>Chelone glabra</i>)	Full Sun- Part Shade	OBL	Perennial	Yes	Excellent growth; herbal uses
Violet, Common Blue (<i>Viola papilionacea</i>)	Full Sun- Full Shade	FAC	Perennial	No	Stemless; spreads
Virginia Wild Rye (<i>Elymus virginicus</i>)	Part Shade- Full Shade	FACW-	Grass	Yes	Adaptable

¹Notes:

FAC = Facultative, equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).

FACU = Facultative Upland, usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).

FACW = FACW Facultative Wetland, usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.

OBL = Obligate Wetland, occurs almost always (estimated probability 99%) under natural conditions in wetlands.

Sources: Prince George's County Maryland Bioretention Manual; Virginia DCR Stormwater Design Specification No. 9: Bioretention.

Table 3.24 Woody Plants Appropriate for Bioretention Areas in the District

Plant	Light	Wetland Indicator ¹	Plant Form	Inundation Tolerance	Notes
Arrow-wood (<i>Viburnum dentatum</i>)	Full Sun- Part Shade	FAC	Shrub	Seasonal	Salt tolerant
River Birch (<i>Betula nigra</i>)	Full Sun- Part Shade	FACW	Tree	Seasonal	Attractive bark
Bayberry, Northern (<i>Myrica pennsylvanica</i>)	Full Sun- Part Shade	FAC	Shrub	Seasonal	Salt tolerant
Black Gum (<i>Nyssa sylvatica</i>)	Full Sun- Part Shade	FACW+	Tree	Seasonal	Excellent fall color
Dwarf Azalea (<i>Rhododendron atlanticum</i>)	Part Shade	FAC	Shrub	Yes	Long lived
Black-Haw (<i>Viburnum prunifolium</i>)	Part Shade- Full Shade	FACU+	Shrub	Yes	Edible Fruit
Choke Cherry (<i>Prunus virginiana</i>)	Full Sun	FACU+	Shrub	Yes	Tolerates some salt; can be maintained as hedge
Cedar, Eastern Red (<i>Juniperus virginiana</i>)	Full Sun	FACU	Tree	No	Pollution tolerant
Cotton-wood, Eastern (<i>Populus deltoides</i>)	Full Sun	FAC	Tree	Seasonal	Pollutant tolerant; salt tolerant
Silky Dogwood (<i>Cornus amomum</i>)	Full Sun- Part Shade	FACW	Shrub	Seasonal	High wildlife value
Hackberry, Common (<i>Celtis occidentalis</i>)	Full Sun- Full Shade	FACU	Tree	Seasonal	Pollution Tolerant
Hazelnut, American (<i>Corylus americana</i>)	Part Shade	FACU	Shrub	No	Forms thickets; edible nut
Holly, Winterberry (<i>Ilex laevigata</i>)	Full Sun- Part Shade	OBL	Shrub	Yes	Winter food source for birds

Plant	Light	Wetland Indicator ¹	Plant Form	Inundation Tolerance	Notes
Holly, American (<i>Ilex opaca</i>)	Full Sun- Full Shade	FACU	Shrub- Tree	Limited	Pollution Tolerant
Maple, Red (<i>Acer rubrum</i>)	Full Sun- Part Shade	FAC	Tree	Seasonal	Very adaptable; early spring flowers
Ninebark, Eastern (<i>Physocarpus opulifolius</i>)	Full Sun- Part Shade	FACW-	Shrub	Yes	Drought tolerant; attractive bark
Oak, Pin (<i>Quercus palustris</i>)	Full Sun	FACW	Tree	Yes	Pollution Tolerant
Pepperbush, Sweet (<i>Clethra alnifolia</i>)	Part Shade- Full Shade	FAC+	Shrub	Seasonal	Salt tolerant
Winterberry, Common (<i>Ilex verticillata</i>)	Full Sun- Full Shade	FACW+	Shrub	Seasonal	Winter food source for birds
Witch-Hazel, American (<i>Hamamelia virginiana</i>)	Part Shade- Full Shade	FAC-	Shrub	No	Pollution tolerant

¹Notes:

FAC = Facultative, equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).

FACU = Facultative Upland, usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).

FACW = FACW Facultative Wetland, usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.

OBL = Obligate Wetland, occurs almost always (estimated probability 99%) under natural conditions in wetlands.

Sources: Prince George's County Maryland Bioretention Manual; Virginia DCR Stormwater Design Specification No. 9: Bioretention

Planting recommendations for bioretention facilities are as follows:

- The primary objective of the planting plan is to cover as much of the surface areas of the filter bed as quickly as possible. Herbaceous or ground cover layers are as or more important than more widely spaced trees and shrubs.
- Native plant species should be specified over non-native species.
- Plants should be selected based on a specified zone of hydric tolerance and must be capable of surviving both wet and dry conditions ("Wet footed" species should be planted near the center, whereas upland species do better planted near the edge).
- Woody vegetation should not be located at points of inflow; trees should not be planted directly above underdrains but should be located closer to the perimeter.
- Shrubs and herbaceous vegetation should generally be planted in clusters and at higher densities (i.e., 10 feet on-center and 1 to 1.5 feet on-center, respectively).
- If trees are part of the planting plan, a tree density of approximately one tree per 250 square feet (i.e., 15 feet on-center) is recommended.
- Designers should also remember that planting holes for trees must be at least 3 feet deep to provide enough soil volume for the root structure of mature trees. This applies even if the remaining soil media layer is shallower than 3 feet.

- Tree species should be those that are known to survive well in the compacted soils and the polluted air and water of an urban landscape.
- If trees are used, plant shade-tolerant ground covers within the drip line.
- If the bioretention area is to be used for snow storage or is to accept snowmelt runoff, it should be planted with salt-tolerant, herbaceous perennials.

3.6.6 Bioretention Construction Sequence

Soil Erosion and Sediment Controls. The following soil erosion and sediment control guidelines must be followed during construction:

- All Bioretention areas must be fully protected by silt fence or construction fencing.
- Bioretention areas intended to infiltrate runoff must remain outside the limit of disturbance during construction to prevent soil compaction by heavy equipment and loss of design infiltration rate.
 - ◆ Where it is infeasible keep the proposed bioretention areas outside of the limits of disturbance, there are several possible outcomes for the impacted area. If excavation in the proposed bioretention area can be restricted then the remediation can be achieved with deep tilling practices. This is only possible if in-situ soils are not disturbed any deeper than 2 feet above the final design elevation of the bottom of the bioretention. In this case, when heavy equipment activity has ceased, the area is excavated to grade, and the impacted area must be tilled to a depth of 12 inches below the bottom of the bioretention.
 - ◆ Alternatively, if it is infeasible to keep the proposed permeable pavement areas outside of the limits of disturbance, and excavation of the area cannot be restricted, then infiltration tests will be required prior to installation of the bioretention to ensure that the design infiltration rate is still present. If tests reveal the loss of design infiltration rates then deep tilling practices may be used in an effort to restore those rates. In this case further testing must be done to establish design rates exist before the permeable pavement can be installed.
 - ◆ Finally, if it is infeasible to keep the proposed bioretention areas outside of the limits of disturbance, and excavation of the area cannot be restricted, and infiltration tests reveal design rates cannot be restored, then a resubmission of the SWMP will be required.
- Bioretention areas must be clearly marked on all construction documents and grading plans.
- Large bioretention applications may be used as small sediment traps or basins during construction. However, these must be accompanied by notes and graphic details on the soil erosion and sediment control plan specifying that (1) the maximum excavation depth of the trap or basin at the construction stage must be at least 1 foot higher than the post-construction (final) invert (bottom of the facility), and (2) the facility must contain an underdrain. The plan must also show the proper procedures for converting the temporary sediment control practice to a permanent bioretention BMP, including dewatering, cleanout, and stabilization.

Bioretention Installation. The following is a typical construction sequence to properly install a bioretention basin. The construction sequence for micro-bioretention is more simplified. These steps may be modified to reflect different bioretention applications or expected site conditions:

Step 1: Stabilize Drainage Area. Construction of the bioretention area may only begin after the entire contributing drainage area has been stabilized with vegetation. It may be necessary to block certain curb or other inlets while the bioretention area is being constructed. The proposed site should be checked for existing utilities prior to any excavation.

Step 2: Preconstruction Meeting. The designer, the installer, and DDOE inspector must have a preconstruction meeting, checking the boundaries of the contributing drainage area and the actual inlet elevations to ensure they conform to original design. Since other contractors may be responsible for constructing portions of the site, it is quite common to find subtle differences in site grading, drainage and paving elevations that can produce hydraulically important differences for the proposed bioretention area. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the inspector. Material certifications for aggregate, soil media and any geotextiles must be submitted for approval to the inspector at the preconstruction meeting.

Step 3: Install Soil Erosion and Sediment Control Measures to Protect the Bioretention. Temporary soil erosion and sediment controls (e.g., diversion dikes, reinforced silt fences) are needed during construction of the bioretention area to divert stormwater away from the bioretention area until it is completed. Special protection measures, such as erosion control fabrics, may be needed to protect vulnerable side slopes from erosion during the construction process.

Step 4: Install Pretreatment Cells. Any pretreatment cells should be excavated first and then sealed to trap sediment.

Step 5: Avoid Impact of Heavy Installation Equipment. Excavators or backhoes should work from the sides to excavate the bioretention area to its appropriate design depth and dimensions. Excavating equipment should have scoops with adequate reach so they do not have to sit inside the footprint of the bioretention area. Contractors should use a cell construction approach in larger bioretention basins, whereby the basin is split into 500- to 1,000-square foot temporary cells with a 10- to 15-foot earth bridge in between, so that cells can be excavated from the side.

Step 6: Promote Infiltration Rate. It may be necessary to rip the bottom soils to a depth of 6 to 12 inches to promote greater infiltration.

Step 7: Order of Materials. If using a geotextile fabric, place the fabric on the sides of the bioretention area with a 6-inch overlap on the sides. If a stone storage layer will be used, place the appropriate depth of No. 57 stone (clean double washed) on the bottom, install the perforated underdrain pipe, pack No. 57 stone to 3 inches above the underdrain pipe, and add the choking layer or appropriate geotextile layer as a filter between the underdrain and the soil media layer. If no stone storage layer is used, start with 6 inches of No. 57 stone on the bottom and proceed with the layering as described above.

Step 8: Layered Installation of Media. Apply the media in 12-inch lifts until the desired top elevation of the bioretention area is achieved. Wait a few days to check for settlement and add additional media, as needed, to achieve the design elevation.

Note: The batch receipt confirming the source of the soil media must be submitted to the DDOE inspector.

Step 9: Prepare Filter Media for Plants. Prepare planting holes for any trees and shrubs, install the vegetation, and water accordingly. Install any temporary irrigation.

Step 10: Planting. Install the plant materials as shown in the landscaping plan, and water them as needed.

Step 11: Secure Surface Area. Place the surface cover (i.e., mulch, river stone, or turf) in both cells, depending on the design. If coir or jute matting will be used in lieu of mulch, the matting will need to be installed prior to planting (Step 10), and holes or slits will have to be cut in the matting to install the plants.

Step 12: Inflows. If curb cuts or inlets are blocked during bioretention installation, unblock these after the drainage area and side slopes have good vegetative cover. It is recommended that unblocking curb cuts and inlets take place after two to three storm events if the drainage area includes newly installed asphalt, since new asphalt tends to produce a lot of fines and grit during the first several storms.

Step 13: Final Inspection. Conduct the final construction inspection using a qualified professional, providing DDOE with an as-built, then log the GPS coordinates for each bioretention facility, and submit them for entry into the maintenance tracking database.

Construction Supervision. Supervision during construction is recommended to ensure that the bioretention area is built in accordance with the approved design and this specification. Qualified individuals should use detailed inspection checklists that include sign-offs at critical stages of construction, to ensure that the contractor's interpretation of the plan is consistent with the designer's intentions.

DDOE's construction phase inspection checklist can be found in Appendix K.

3.6.7 Bioretention Maintenance Criteria

When bioretention practices are installed, it is the owner's responsibility to ensure they, or those managing the practice, (1) be educated about their routine maintenance needs, (2) understand the long-term maintenance plan, and (3) be subject to a maintenance covenant or agreement, as described below.

Maintenance of bioretention areas should be integrated into routine landscape maintenance tasks. If landscaping contractors will be expected to perform maintenance, their contracts should contain specifics on unique bioretention landscaping needs, such as maintaining elevation differences needed for ponding, proper mulching, sediment and trash removal, and limited use of fertilizers and pesticides.

Maintenance tasks and frequency will vary depending on the size and location of the bioretention, the landscaping template chosen, and the type of surface cover in the practice. A generalized summary of common maintenance tasks and their frequency is provided in Table 3.25.

Table 3.25 Typical Maintenance Tasks for Bioretention Practices

Frequency	Maintenance Tasks
Upon establishment	<ul style="list-style-type: none"> ▪ For the first 6 months following construction, the practice and CDA should be inspected at least twice after storm events that exceed 1/2 inch of rainfall. Conduct any needed repairs or stabilization. ▪ Inspectors should look for bare or eroding areas in the contributing drainage area or around the bioretention area, and make sure they are immediately stabilized with grass cover. ▪ One-time, spot fertilization may be needed for initial plantings. ▪ Watering is needed once a week during the first 2 months, and then as needed during first growing season (April-October), depending on rainfall. ▪ Remove and replace dead plants. Up to 10% of the plant stock may die off in the first year, so construction contracts should include a care and replacement warranty to ensure that vegetation is properly established and survives during the first growing season following construction.
At least 4 times per year	<ul style="list-style-type: none"> ▪ Mow grass filter strips and bioretention with turf cover ▪ Check curb cuts and inlets for accumulated grit, leaves, and debris that may block inflow
Twice during growing season	<ul style="list-style-type: none"> ▪ Spot weed, remove trash, and rake the mulch
Annually	<ul style="list-style-type: none"> ▪ Conduct a maintenance inspection ▪ Supplement mulch in devoid areas to maintain a 3 inch layer ▪ Prune trees and shrubs ▪ Remove sediment in pretreatment cells and inflow points
Once every 2–3 years	<ul style="list-style-type: none"> ▪ Remove sediment in pretreatment cells and inflow points ▪ Remove and replace the mulch layer
As needed	<ul style="list-style-type: none"> ▪ Add reinforcement planting to maintain desired vegetation density ▪ Remove invasive plants using recommended control methods ▪ Remove any dead or diseased plants ▪ Stabilize the contributing drainage area to prevent erosion

Standing water is the most common problem outside of routine maintenance. If water remains on the surface for more than 72 hours after a storm, adjustments to the grading may be needed or underdrain repairs may be needed. The surface of the filter bed should also be checked for accumulated sediment or a fine crust that builds up after the first several storm events. There are several methods that can be used to rehabilitate the filter. These are listed below, starting with the simplest approach and ranging to more involved procedures (i.e., if the simpler actions do not solve the problem):

- Open the underdrain observation well or cleanout and pour in water to verify that the underdrains are functioning and not clogged or otherwise in need of repair. The purpose of this check is to see if there is standing water all the way down through the soil. If there is standing water on top, but not in the underdrain, then there is a clogged soil layer. If the underdrain and stand pipe indicates standing water, then the underdrain must be clogged and will need to be cleaned out.
- Remove accumulated sediment and till 2 to 3 inches of sand into the upper 6 to 12 inches of soil.

- Install sand wicks from 3 inches below the surface to the underdrain layer. This reduces the average concentration of fines in the media bed and promotes quicker drawdown times. Sand wicks can be installed by excavating or auguring (i.e., using a tree auger or similar tool) down to the top of the underdrain layer to create vertical columns which are then filled with a clean open-graded coarse sand material (e.g., ASTM C-33 concrete sand or similar approved sand mix for bioretention media). A sufficient number of wick drains of sufficient dimension should be installed to meet the design dewatering time for the facility.
- Remove and replace some or all of the soil media.

Maintenance Inspections. It is recommended that a qualified professional conduct a spring maintenance inspection and cleanup at each bioretention area. Maintenance inspections should include information about the inlets, the actual bioretention facility (sediment buildup, outlet conditions, etc.), and the state of vegetation (water stressed, dead, etc.) and are intended to highlight any issues that need or may need attention to maintain stormwater management functionality.

DDOE's maintenance inspection checklists for bioretention areas and the Maintenance Service Completion Inspection form can be found in Appendix L.

Declaration of Covenants. A declaration of covenants that includes all maintenance responsibilities to ensure the continued stormwater performance for the BMP is required. The declaration of covenants specifies the property owner's primary maintenance responsibilities, and authorizes DDOE staff to access the property for inspection or corrective action in the event the proper maintenance is not performed. The declaration of covenants is attached to the deed of the property. A template form is provided at the end of Chapter 5 (see Figure 5.4), although variations will exist for scenarios where stormwater crosses property lines. The covenant is between the property and the Government of the District of Columbia. It is submitted through the Office of the Attorney General. All SWMPs have a maintenance agreement stamp that must be signed for a building permit to proceed. A maintenance schedule must appear on the SWMP. Additionally, a maintenance schedule is required in Exhibit C of the declaration of covenants.

Covenants are not required on government properties, but maintenance responsibilities must be defined through a partnership agreement or a memorandum of understanding.

Waste Material. Waste material from the repair, maintenance, or removal of a BMP or land cover shall be removed and disposed of in compliance with applicable federal and District law.

3.6.8 Bioretention Stormwater Compliance Calculations

Bioretention performance varies depending on the design configuration of the system.

Enhanced Designs. These designs are bioretention applications with no underdrain or at least 24 inches of filter media and an infiltration sump. Enhanced designs receive 100 percent retention value for the amount of storage volume (S_v) provided by the practice (Table 3.26), and, therefore, are not considered an accepted total suspended solids (TSS) treatment practice.

Table 3.26 Enhanced Bioretention Retention Value and Pollutant Removal

Retention Value	= S_v
Accepted TSS Treatment Practice	N/A

Standard Designs. These designs are bioretention applications with an underdrain and less than 24 inches of filter media. Standard designs receive 60 percent retention value and are an accepted TSS removal practice for the amount of storage volume (S_v) provided by the practice (Table 3.27).

Table 3.27 Standard Bioretention Design Retention Value and Pollutant Removal

Retention Value	= $0.6 \times S_v$
Accepted TSS Treatment Practice	Yes

The practice must be sized using the guidance detailed in Section 3.6.4.

Note: Additional retention value can be achieved if trees are utilized as part of a bioretention area (see Section 3.2.3 Green Roof Pretreatment Criteria).

Bioretention also contributes to peak flow reduction. This contribution can be determined in several ways. One method is to subtract the S_v or R_v from the total runoff volume for the 2-year, 15-year, and 100-year storms. The resulting reduced runoff volumes can then be used to calculate a Reduced Natural Resource Conservation Service (NRCS) Curve Number for the site or drainage area. The Reduced Curve Number can then be used to calculate peak flow rates for the various storm events. Other hydrologic modeling tools that employ different procedures may be used as well.

3.6.9 References

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