2.0 Bioretention

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

- 2-A Traditional Bioretention
- 2-B In-Situ Bioretention (including Rain Gardens)
- 2-C Streetscape Bioretention
- 2-D Engineered Tree Boxes
- 2-E Stormwater Planters
- 2-F Advanced Bioretention Systems

Bioretention systems are typically designed to manage stormwater runoff from frequent, small magnitude storm events, but may provide stormwater detention of larger storms (e.g., 10-yr) in some circumstances. Bioretention practices shall generally be designed such that larger storm events bypass the system into a separate facility where site conditions allow.

For each of the design variants above, there are two basic configurations:

- *Underdrain Designs*: Practices with a positive discharge using perforated pipe; pollutant reduction occurs through a combination of runoff reduction and treatment by the filtering media. Addition of an infiltration sump is required to maximize runoff reduction performance. Advanced systems may provide greater pollutant removal capabilities through the use of improved media components and/or internal modifications that encourage partial anaerobic conditions.
- *Infiltration Designs:* Practices with no underdrains that can infiltrate the design storm volume within 48 hours; pollutant reduction is based solely on the load reduction provided by the design retention storage volume.

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 discussed in more detail below.

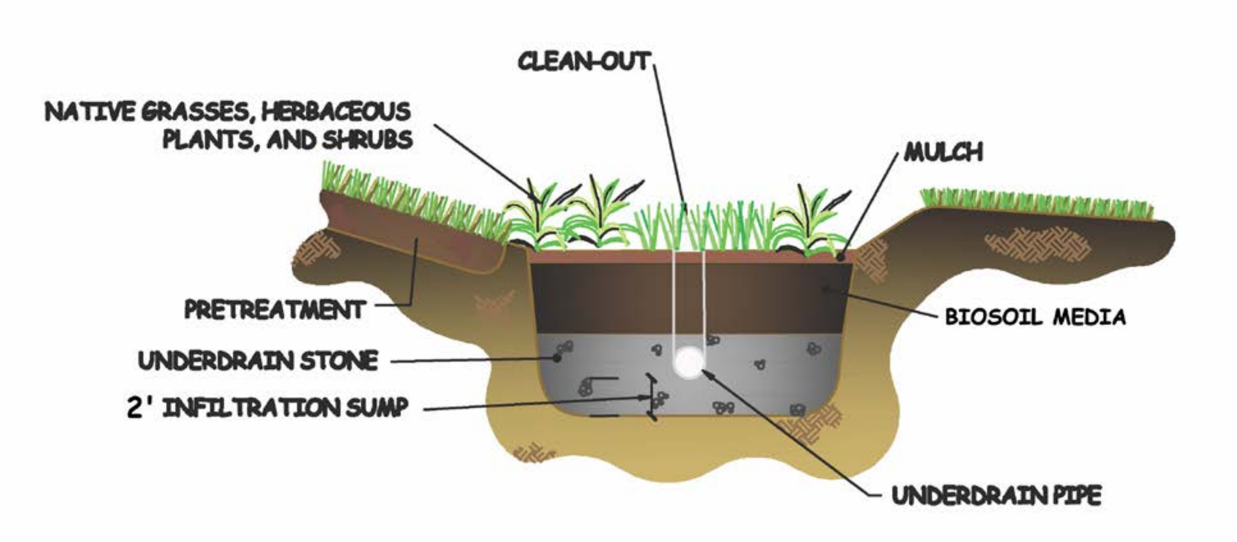

Figure 2.1. Traditional Bioretention Underdrain Design

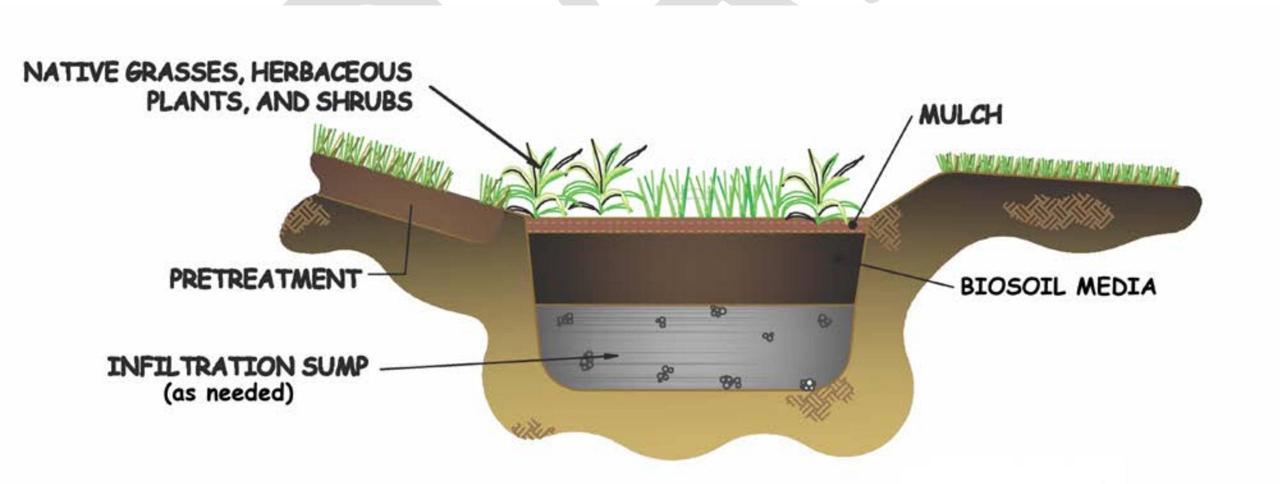

Figure 2.2. Traditional Bioretention Infiltration Design

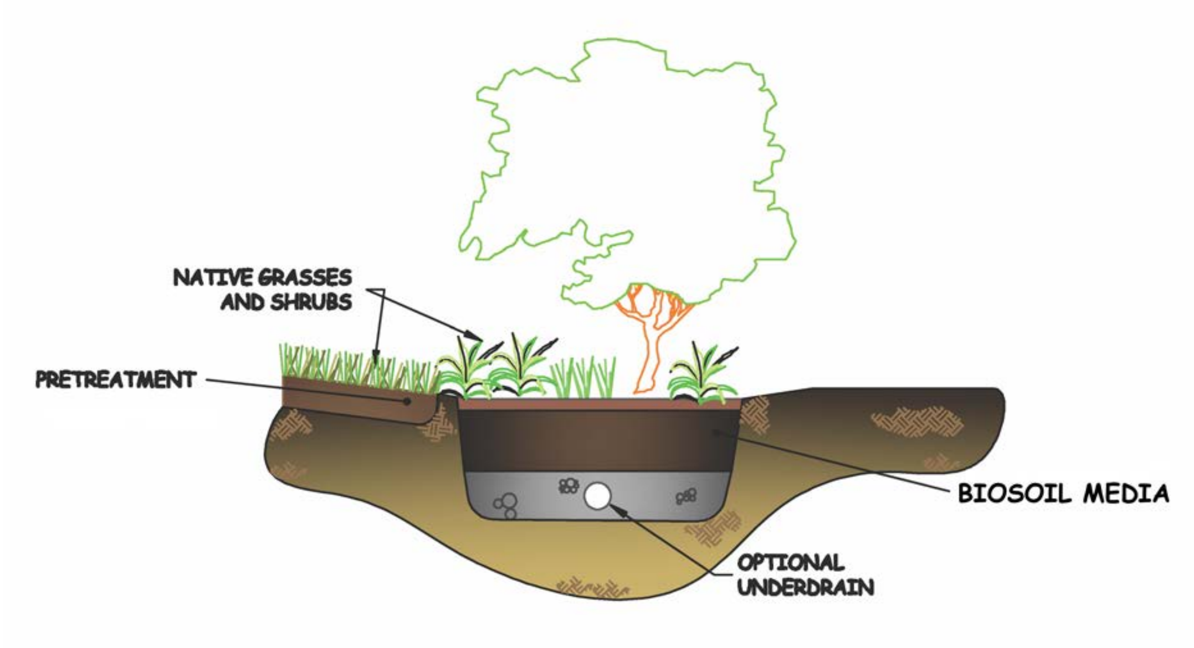

Figure 2.3. Rain Garden

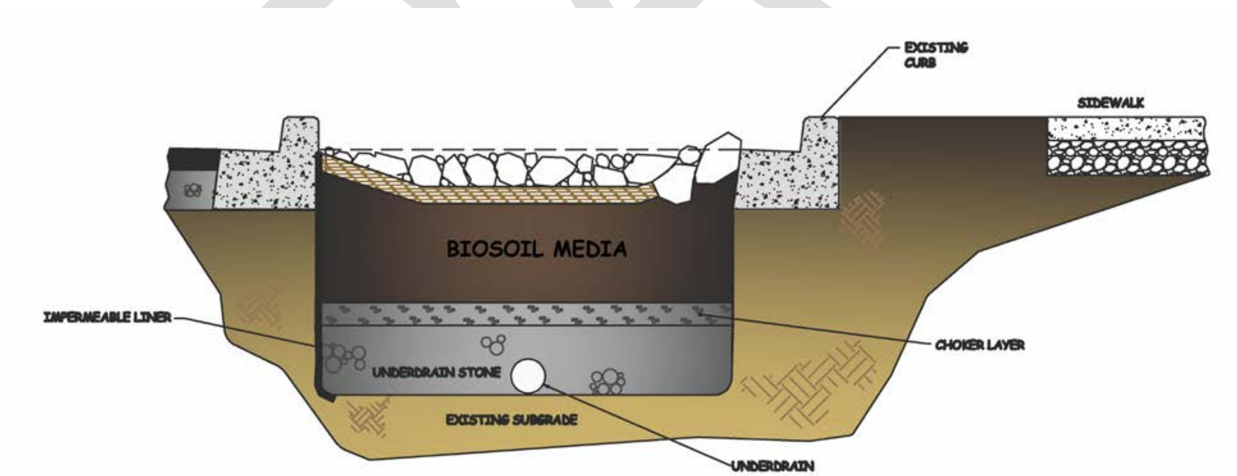

Figure 2.4. Streetscape Bioretention

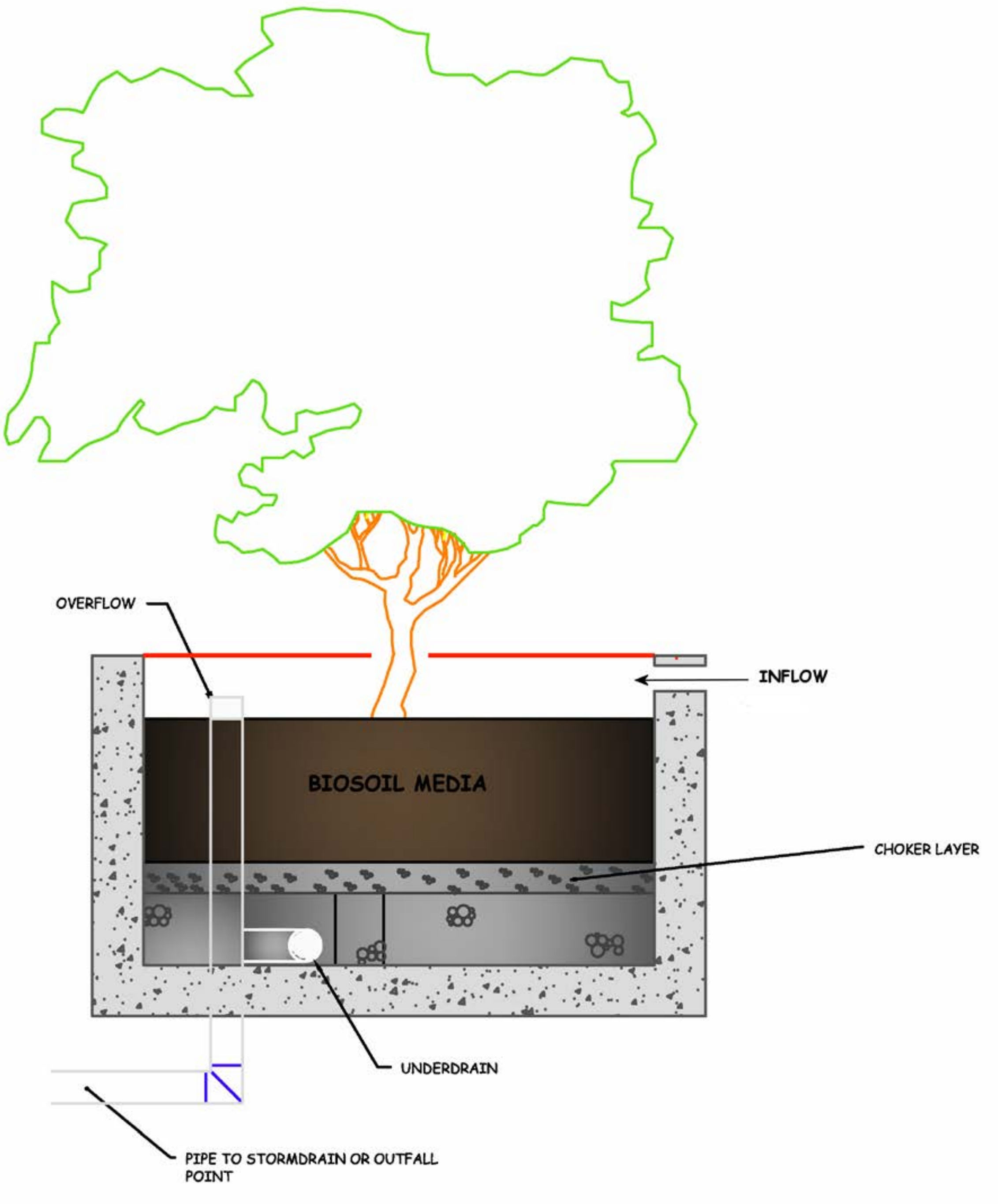

Figure 2.5. Engineered Tree Box

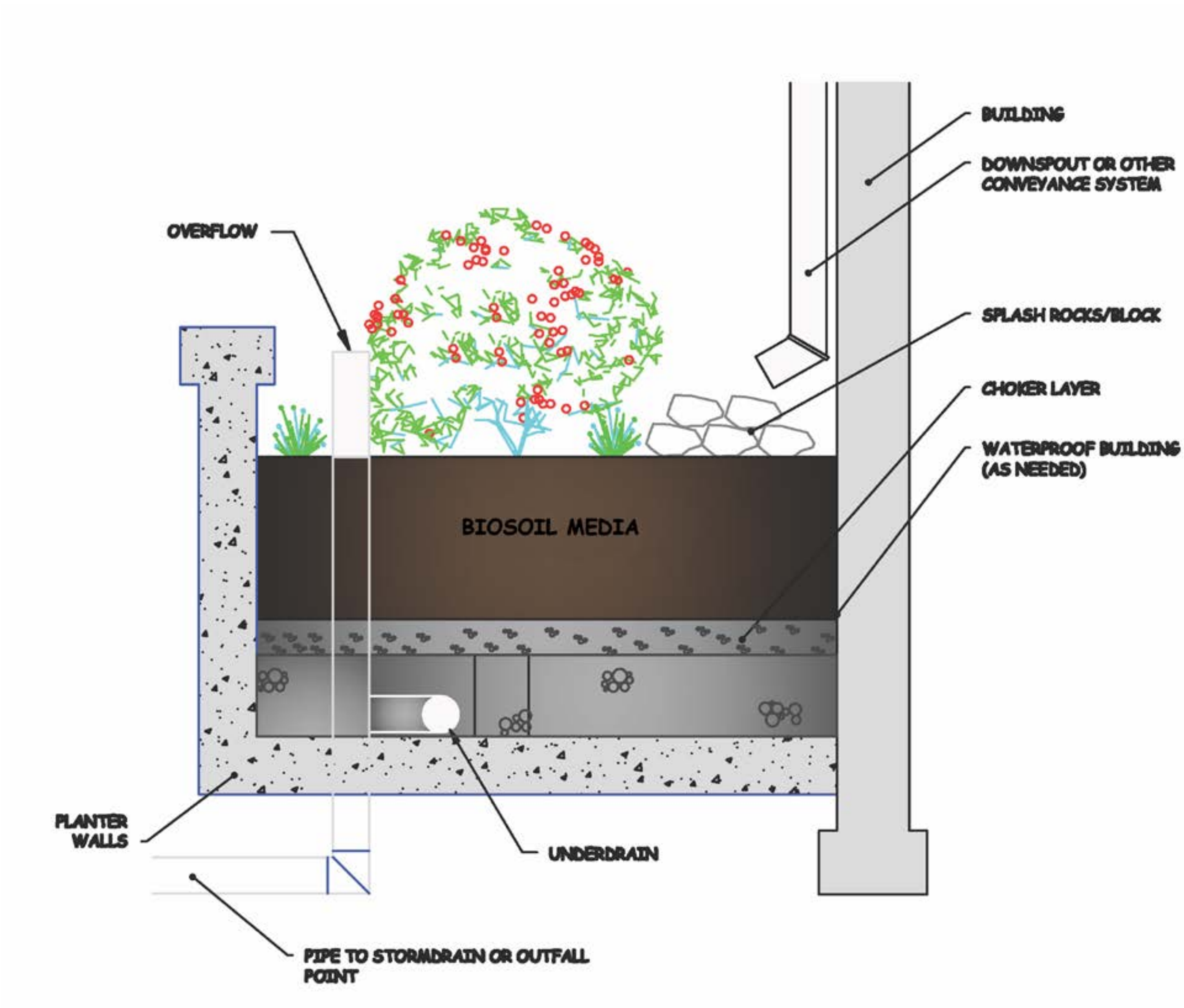

Figure 2.6. Stormwater Planter

2.1 Bioretention Stormwater Credit Calculations

The retention volume credit for Bioretention practices depends on the volume of runoff that is infiltrated from this practice (Table 2.1a & b). In addition, Bioretention systems using an underdrain receive a removal efficiency credit for filtering pollutants as they pass through the soil media.

2.1(a) Bioretention With Underdrain Performance Credits

Runoff Reduction	
Retention Allowance	50%
RPv -A/B Soil	50% of Retention Storage
RPv - C/D Soil	50% of Retention Storage
Cv	5% of Retention Storage
Fv	1% of Retention Storage
Pollutant Reduction*	
TN Reduction	100% of Load Reduction + 30% Removal Efficiency
TP Reduction	100% of Load Reduction + 40% Removal Efficiency
TSS Reduction	100% of Load Reduction + 80% Removal Efficiency

*Advanced systems may provide higher removal efficiencies

2.1(b) Bioretention With Infiltration Performance Credits

Runoff Reduction	
Retention Allowance	100%
RPv -A/B Soil	100% of Retention Storage
RPv - C/D Soil	100% of Retention Storage
Cv	100% of Retention Storage
Fv	100% of Retention Storage
Pollutant Reduction	
TN Reduction	100% of Load Reduction
TP Reduction	100% of Load Reduction
TSS Reduction	100% of Load Reduction

2.2 Bioretention Design Summary

Table 2.2 summarizes design criteria for bioretention practices, and Table 2.3 summarizes the materials specifications for these practices. For more detail, consult the appropriate sections referenced in column 1.

Table 2.2 Bioretention Design Summary

	Standard Underdrain Designs	Infiltration Designs
Feasibility (Section 2.3)	• Can treat hotspots if designed with an impermeable liner, but cannot treat high sediment loads or dry weather flows • Invert of underdrain must not intersect seasonal high groundwater table • Minimum 3-4 feet of head (unless designed for internal water storage)	• Minimum soil infiltration rate IAW Appendix 1 • Restrictions for treating hotspots, high loads, or dry weather flows • 2 foot separation from seasonal high groundwater
	• Small CDA, varying based on practice type (Table 2.4) • Setbacks from wells, buildings and utilities (Table 2.5)	
Conveyance (Section 2.4)	• Can be designed off-line or on-line • Must safely convey the 10-year storm event (Cv) and 100-year storm event (Fv) unless designed to bypass these larger storm events	
Pretreatment (Section 2.5)	• All runoff directed to a bioretention practice must receive pretreatment	
Sizing (Total Storage) (Section 2.6)	$Sv = SA_{filter} \times \left[\left(d_{media} \times \eta_{media} \right) + \left(d_{gravel} \times \eta_{gravel} \right) \right] + (SA_{p-1} + SA_{p-2}) / 2 \times d_{ponding} + Sv_{pretreatment}$	
Sizing (Min. Surface Area) (Section 2.6)	$SA_{filter} \geq \dfrac{Sv \times d_{media}}{k \times t_f \times \left(d_{ponding}/2 + d_{media} \right)}$	
Sizing (Ponding Volume)	$V_{ponding} = (SA_{p-1} + SA_{p-2}) / 2 \times d_{ponding} + Sv_{pretreatment}$	
Variables:	d_{media} = depth of the filter media (typically 2 ft) η_{media} = effective porosity of the filter media (typically 0.4) d_{gravel} = depth of the underdrain and underground storage gravel layer(ft) η_{gravel} = effective porosity of the gravel layer (typically 0.4) SA_{p-1} = surface area at the lowest elevation of the ponding area (sq. ft.) [Note SA_{p-1} may be no greater than 2X SA_{filter}] SA_{p-2} = surface area at the depth of ponding $d_{ponding}$ = the maximum ponding depth of the practice (ft). $Sv_{pretreatment}$ = volume stored in pretreatment practices k = filtering media permeability (ft/day; typically assume 5.7) t_d = drawdown time within the filter (2 days maximum)	
Geometry and Dimensions (Section 2.6)	Ponding Depth: RPv: 12"; Cv: 18", Fv: 24" Media Depth: Minimum 24" (varies for small-scale practices); may require gravel layer to extend into more permeable soil profile Side Slopes: 3:1 side slopes in ponding area; for "curb drop" designs (e.g., streetscape bioretention), maximum drop of 12"	
Landscaping (Section 2.7)	Plant in zones based on elevation within the filter (see Appendix A-2) Maintain vegetation in the drainage area to limit sediment loads to the practice.	

Table 2.3. Bioretention Material Specifications

Material	Specification	Notes
Filter Media (Biosoil-14)	Biosoil-14 Media to contain (by volume): • 60% concrete sand; fineness modulus > 2.75 • 30% triple-shredded hardwood mulch • 10% aged, STA certified compost	• Minimum depth of 24" (may be less for *in-situ* Bioretention practices) • The volume of filter media used should be based on 110% of the calculated design volume, to account for settling
Filter Media Testing	Between 7 and 23 mg/kg of P in the soil media; CECs greater than 10	The media must be procured from approved biosoil media vendors
Mulch Layer	Use aged, shredded hardwood bark mulch	3" layer on the surface of the biosoil media bed
Alternative Surface Cover	Use of river stone or pea gravel, coir and jute matting, or turf cover may be acceptable with prior approval	3" layer 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
Underdrain stone (as needed)	Rice Gravel (1/4" stone) shall be double-washed and free of all fines	Min. 3" cover on underdrain; min. 2' sump below invert of 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)	Use a 30 mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile. (NOTE: THIS IS USED ONLY FOR HOTSPOTS AND SMALL PRACTICES NEAR BUILDING FOUNDATIONS, OR IN FILL SOILS AS DETERMINTED BY A GEOTECHNICAL INVESTIGATION)	
Underdrains, Cleanouts, and Observation Wells	• 4- or 6-inch perforated corrugated polyethylene pipe (CPP) for underdrains • 4- or 6-inch SDR 35 (min.) PVC for cleanouts and observation wells	• Under-drains shall be laid flat, be no more than 20-ft apart and daylight to point of adequate conveyance. • Clean-outs shall be provided at all terminal ends and every 100-ft. • An observation well shall be provided for every 500-sq.ft. of filter media surface area.
Plant Materials	See Appendix 2, Stormwater BMP Landscaping Criteria	Establish plant materials as specified in the landscaping plan and the recommended plant list

2.3 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:

EPA Requirements for Class V Injection Wells. Certain types of practices in this category may be classified as Class V Injection Wells, which are subject to regulations under the Federal Underground Injection Control (UIC) program. In general, if the facility allows stormwater runoff to come in direct contact with groundwater it would meet this criterion. Facilities with a minimum 2' vadose zone separation from the groundwater table would not meet the criterion. Designers are advised to contact the DNREC Groundwater Discharges Section for additional information regarding UIC regulations and possible permitting requirements.

Required Space. Designers can assess the feasibility of using bioretention facilities based on a simple relationship between the contributing drainage area and the corresponding required surface area. The bioretention surface area will usually be between 3% to 6% of the contributing drainage area (CDA), depending on the imperviousness of the CDA and the desired bioretention ponding depth. When a bioretention facility is installed on a private residential lot, its existence and purpose should be noted on the deed of record. A sample Record Plan note is as follows: "This lot contains practices that are intended to meet State regulations related to the management of stormwater runoff. It is the responsibility of the owner to maintain these practices in proper working condition in order fulfill this requirement".

Site Topography. Bioretention is best applied when the grade of contributing slopes is greater than 1% and less than 5%.

Available Hydraulic Head. Bioretention is fundamentally constrained by the invert elevation of the existing conveyance system to which the practice. In general, 4 to 5 feet of elevation above this invert is needed to accommodate the required ponding and filter media depths. If an inverted or elevated underdrain design is used to accommodate an internal water storage (IWS) design, less hydraulic head may be adequate.

Water Table. Bioretention should always be separated from the water table to ensure that groundwater does not intersect the filter bed. This could otherwise 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 facility and the seasonally high ground water table for infiltration designs.

Soils and Underdrains. Soil conditions do not typically constrain the use of Bioretention, although they do determine whether an underdrain is needed. Underdrains are required if the measured permeability of the underlying soils does not meet the requirements for infiltration practices in accordance with ***Appendix 1, Soil Investigation Procedures for Stormwater BMPs***.

A stone sump can be used to extend an infiltrating facility to a more permeable layer, as needed. When designing a Bioretention practice, designers should verify soil permeability by using the methods provided in ***Appendix 1, Soil Investigation Procedures for Stormwater BMPs***.

In fill soil locations, geotechnical investigations are required to determine if the use of an impermeable liner and underdrain are necessary.

Contributing Drainage Area. Bioretention facilities work best with smaller contributing drainage areas, where it is easier to achieve flow distribution over the filter bed. Typical drainage area size for traditional Bioretention facilities (2-A) can range from 0.1 to 5 acres and consist of up to 100% impervious cover. Drainage areas to smaller Bioretention practices (2-B, 2-C, 2-D, and 2-E) typically range from 0.5 acre to 1.0. The maximum recommended impervious area to a single bioretention basin or single cell of a Bioretention facility is 2.5 acres due to limitations in the ability of bioretention to effectively manage large volumes and peak rates of runoff. 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, forebays, etc.), there may be case-by-case instances where these recommended maximums can be adjusted.

Table 2.4. Maximum Recommended CDA to Bioretention

	Traditional Bioretention	**Small-scale and Urban Bioretention**
Design Variants	2-A, 2-F	2-B, 2-C, 2-D, and 2-E
Maximum CDA	10.0 acres (2.5 ac. impervious)	1.0 acres (0.25 ac. impervious)

Hotspot Land Uses. An impermeable bottom liner and an underdrain system must be employed when a Bioretention facility will receive untreated hotspot runoff. However, Bioretention can still be used to treat "non-hotspot" parts of the site. For a list of potential stormwater hotspots, see ***Appendix 4, Stormwater Hotspots Guidance***.

Floodplains. Bioretention facilites should be constructed outside the limits of the 100-year floodplain.

No Irrigation or Baseflow. The Bioretention facility should not receive baseflow, irrigation water, chlorinated wash-water or other non-stormwater flows.

Setbacks. To avoid the risk of seepage, Bioretention facilities should not be hydraulically connected to structure foundations. The designer should check to ensure footings and foundations of adjacent buildings do not encroach within an assumed 4:1 phreatic zone drawn from the maximum design water elevation in the Bioretention facility. The setback for buildings from Table 2.5 can be used in lieu of a phreatic zone analysis.

Table 2.5. Setbacks for Bioretention Practices

Contributing Drainage Area/ Design Variant	Buildings		Wells	Septic Systems
	Facility Up-Gradient	Facility Down-gradient		
0 to 0.5 Acre CDA	50’	10’		
0.5 to 5 Acre CDA	100’	25’		
Any Practice With a Liner			100’	50’
Any Practice Without a Liner			150’	100’

Proximity to Utilities. Interference with underground utilities should also be avoided, particularly water and sewer lines. Approval from the applicable utility company or agency is required if utility lines will run below or through the bioretention area. Conflicts with water and sewer laterals (e.g., house connections) may be unavoidable, and the construction sequence must be altered, as necessary, to avoid impacts to existing service.

Additionally, designers should ensure that future tree canopy growth in the Bioretention facility will not interfere with existing overhead utility lines.

Minimizing External Impacts. Urban Bioretention practices may be subject to higher public visibility, greater trash loads, pedestrian traffic, vandalism, and 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 plant growth. 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 or other measures to prevent damage from pedestrian short-cutting across the practices.

2.4 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 runoff from the design storm enters the Bioretention area. Larger flows by-pass the Bioretention facility.

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.

Off-line Bioretention: Optional overflow 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.
- Utilize a low-flow diversion or flow splitter at the inlet to allow only the design storm volume (e.g., the RP_v or a fraction of the RP_v) to enter the facility. This may be achieved with a weir or curb opening sized for the target flow, in combination with a bypass channel. Using a weir or curb opening helps minimize clogging and reduces the maintenance frequency. Determining the peak flow rate will be necessary in order to ensure proper design of the diversion structure.

On-line Bioretention : An overflow structure should always be incorporated into on-line designs to safely convey larger storms through the Bioretention facility. The following criteria apply to overflow structures:
- An overflow shall be provided within the practice to pass flows not treated by the practice to an adequate conveyance system. Larger events (e.g., the C_v or F_v) may be partially or fully managed by the Bioretention facility as long as the maximum depth of ponding in the bioretention cell does not exceed 18" for the C_v and 24" for F_v .
- Common overflow systems within bioretention practices consist of an outlet structure, where the top of the structure is set so as to control the maximum ponding depth within the bioretention facility. The crest of the outlet structure is therefore typically set at 6 to 18 inches above the surface of the filter bed.
- The overflow capture 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.
- The maximum design discharge should be checked for a non-erosive condition at the outlet point. Outlet protection should be provided as necessary.

2.5 Bioretention Pretreatment Criteria

Pre-treatment of runoff entering Bioretention facilities is necessary to trap coarse sediment particles before they reach and prematurely clog the filter bed. Ideally, pre-treatment measures should be designed to evenly spread runoff across the entire width of the bioretention area. Several pre-treatment 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:

For Traditional Bioretention (2-A, 2-F):
- **Pre-treatment Cells** (channel flow): Similar to a forebay, this cell is located at piped inlets or curb cuts leading to the bioretention area and may include an energy dissipater sized for the expected rates of discharge. It has a storage volume equivalent to at least 15% 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 berm. Pretreatment cells do not need underlying engineered soil media, in contrast to the main bioretention cell.
- **Grass Filter Strips** (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 facility has sides slopes that are 3:1 or flatter, a 5 foot grass filter strip at a maximum 5% (20:1) slope can be used.

- **Gravel or Stone Diaphragms** (sheet flow). A gravel diaphragm located at the edge of the pavement should be oriented perpendicular to the flow path to pre-treat 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** (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 should extend the entire width of the opening and create a level stone weir at the bottom or treatment elevation of the basin.
- **Proprietary Practices:** Structures that meet the pre-treatment requirements of ***Specification 15.0, Proprietary Practices*** may be used for pre-treatment.

For Small-Scale Bioretention (2-B, 2-C, 2-D, 2-E):

- **Leaf Screens** as part of the gutter system serve to keep the heavy loading of organic debris from accumulating in the bioretention cell.
- **Grass Filter Strips** (for sheet flow), applied on residential lots, where the lawn area can serve as a grass filter strip adjacent to a rain garden.
- **Gravel or Stone Diaphragm** (for either sheet flow or concentrated flow); this is a gravel diaphragm at the end of a downspout or other concentrated inflow point that should run perpendicular to the flow path to promote settling.
- **Trash Racks** (for either sheet flow or concentrated flow) between the pre-treatment cell and the main filter bed or across curb cuts. These will allow trash to collect in specific locations and create easier maintenance.
- **Pre-treatment Cell** (see below) located above ground or covered by a manhole or grate. This type of pretreatment is not recommended for residential rain gardens (B-5).

2.6 Bioretention Design Criteria

Design Geometry: Bioretention facilities must be designed with an internal flow path geometry such that the treatment mechanisms provided by the bioretention are not bypassed or short-circuited during the Resource Protection Event (RPv). In order for these Bioretention facilities 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 (2-C), Engineered Tree Boxes (2-D) and Stormwater Planters (2-E) should be stabilized using DE No. 3 stone, splash block, river stone or other acceptable energy dissipation measures. Iinlet protection practices that could be considered include:

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

Ponding Depth: The maximum surface ponding depth is 12" for the RPv. Ponding depths can be increased to a maximum of 18" for management of the Cv and a maximum of 24" for the Fv. However, if these greater ponding depths are used, the design must carefully consider issues such as safety, aesthetics, the viability and survival of plants, and erosion and scour of side slopes. The depth of ponding in the bioretention area should never exceed 24". Shallower ponding depths (typically 6 to 12 inches) are recommended for Streetscape Bioretention (2-C), Engineered Tree Boxes (2-D), and Stormwater Planters (2-E).

Side Slopes: Traditional Bioretention facilities (2-A, 2-F) and Rain Gardens (2-B) 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 stable, vertical side walls. For safety purposes, drop curb designs should not exceed a vertical drop of more than 12 inches.

Biosoil Media and Surface Cover: The filter media and surface cover are the two most important elements of a Bioretention facility in terms of long-term performance. The following are key factors to consider in determining an acceptable soil media mixture.

- **General Biosoil Media Composition.** The Biosoil-14 soil mixture has the following volumetric composition:
  - 60% coarse concrete sand (Fineness Modulus > 2.75)
  - 30% triple shredded hardwood mulch
  - 10% aged, STA certified compost

  For systems intended to meet regulatory requirements, biosoil media must be obtained from an approved vendor that can certify conformance with the media composition and standards in this specification.

  Phosphorus Content. The recommended range for phosphorus content for the soil component is between 7 mg/kg and 23 mg/kg.

- **Compost.** Compost used for Bioretention facilities shall meet the requirements ***Appendix 3, Compost Material Properties***.

- **Cation Exchange Capacity (CEC).** The CEC of a soil refers to the total amount of positively charged elements that a soil can hold; it is expressed in milliequivalents per 100 grams (meq/100g) of soil. For agricultural purposes, these elements are the basic cations of calcium (Ca^{+2}), magnesium (Mg^{+2}), potassium (K^{+1}) and sodium (Na^{+1}) and the acidic cations of hydrogen (H^{+1}) and aluminum (Al^{+3}). The CEC of the soil is determined in part by the amount of clay and/or humus or organic matter present. Soils with CECs exceeding 10 are preferred for pollutant removal. Increasing the organic matter content of any soil will help to increase the CEC.

- **Biosoil Infiltration Rate.** The biosoil media must meet the minimum infiltration rate established in the Department's testing protocol for Bioretention soil.

- **Biosoil Depth.** The biosoil media bed depth should be a minimum of 24 inches although this can be reduced for small-scale bioretention practices (practices 2-B, 2-C, 2-D and 2-E) as noted elsewhere in this specification. A rice gravel layer may be added below the filter media if a greater depth is required to reach a more permeable layer in the soil profile. If trees are included in the bioretention planting plan, tree planting holes in the filter should be deep enough to provide enough soil volume for the root structure of the selected mature trees. Trees are not recommended for underdrain systems. Native grasses, perennials or shrubs should be used instead of trees to landscape shallower filter beds and underdrain systems.

- **Mulch.** A 2 to 3 inch layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth, and pre-treats runoff before it reaches the filter media. 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, river rock, or pea gravel. Use of such alternative covers require prior approval from the appropriate approval authority.

Underdrains: For Bioretention designs that require an underdrain (see **Section 2.3**), the underdrain shall be a 4- or 6-inch perforated corrugated polyethylene pipe (CPP). The underdrain must be sized so that the bioretention practice fully drains within 48 hours. The underdrain shall be encased in a layer of clean, washed "rice gravel" (nominal 1/4" bank-run gravel) with a minimum of 3" of cover. The gravel layer should be extended a minimum of 2' below the invert of the underdrain to enhance the infiltration capabilities of the system. This may also serve as an aerobic/anaerobic zone for situations in which the water table fluctuates below the invert.

Each underdrain should be located no more than 20 feet from the next pipe.

All traditional Bioretention practices should include at least one observation well and/or cleanout pipe. The observation wells/cleanouts should be appropriately sized PVC tied into any T's or Y's in the underdrain system, and should extend slightly above the surface, with a screw-on or locking cap.

Underground Storage Layer (optional): For Bioretention facilities 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 to increase storage for larger storm events. The depth and volume of the storage layer will depend on the target treatment and storage volumes needed to meet water quality, channel protection, and/or flood protection criteria.

Impermeable Liner: This material should be used only for appropriate hotspot designs, small scale practices (i.e., B-4) that do not meet the necessary separation requirements from buildings, or in fill applications where deemed necessary by a geotechnical investigation. Designers should use a thirty mil (minimum) PVC Geomembrane liner covered by 8 to 12 oz./sq. yd. non-woven geotextile.

Material Specifications: Recommended material specifications for Bioretention facilities are shown in Table 2.3.

Signage: Bioretention facilities in highly urbanized areas may be stenciled or permanently marked to designate them as a stormwater management facility in order to avoid potential complaints about an otherwise properly functioning system. 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 In-Situ Bioretention, including Rain Gardens (2-B):
In some cases, the native soil profile may be adequate to support infiltration of the RPv without the need for a more elaborate traditional-type system. Certified yard waste compost may also be mixed with the native soils instead of biosoil media. It is generally recommended that this approach be used for projects with small CDAs and/or outlying areas within larger projects that cannot be easily captured by a primary facility. For some residential applications, front, side, and/or rear yard bioretention may be an acceptable option. This form of bioretention captures roof, lawn, and driveway runoff from low- to medium- density residential lots in a depressed area (6 to 12 inches) between the home and the primary stormwater conveyance system (roadside ditch or pipe system).

The planting media must be deep enough to extend below the topsoil and into the more permeable subsoil. If the permeable soil layer is relatively close to the surface, it may be possible to simply excavate to provide the necessary design storage volume and incorporate 3”-4” of certified yard waste compost into the native soil. Although this type of system is particularly conducive to the inclusion of trees in the planting plan, tree planting holes should be deep enough to provide enough soil volume for the root structure of the selected mature trees. Shredded hardwood mulch is added as a top dressing to complete the installation.

It is preferred that this category of bioretention be designed as an infiltration practice. However, if an underdrain is required to ensure adequate function or to retro-fit a failing system, it may be connected to a storm drain or open channel conveyance system.

Specific Design Issues for Streetscape Bioretention (2-C): 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 expanded 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 facility to keep water from saturating the road's sub-base.

Specific Design Issues for Engineered Tree Boxes (2-D): 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 box 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 should 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 Box 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 box bed and serve as a protective barrier if there is a dropoff 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 of 400 cubic feet of root space.

Specific Design Issues for Stormwater Planters (2-E): 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 Stormwater Planter and the filter Stormwater Planter.

An **infiltration** Stormwater Planter filters rooftop runoff through soil in the planter followed by infiltration into soils below the planter. The recommended minimum depth is 30 inches, with the shape and length determined by architectural considerations. The planter should be sized to treat at least 1/2-inch of runoff from the contributing rooftop area. Infiltration planters should be placed at least 10 feet away from a building to prevent possible flooding or basement seepage damage.

A **filter** Stormwater 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 Stormwater Planter is self-contained and does not infiltrate into the ground, it can be installed right next to a building. The minimum planter 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. In addition, an underdrain is used to carry runoff to the storm sewer system.

All planters should be placed at or above finished grade elevation. Plant materials should be capable of withstanding moist and seasonally dry conditions. Planting media should have an infiltration rate of at least 2 inches per hour. 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.

Specific Design Issues for Advanced Systems (2-F): Recent research on Bioretention has led to more advanced systems that are capable of greater reductions of certain targeted pollutants. One promising technology for reducing phosphorus levels in stormwater runoff involves the use of *water treatment residuals (WTR)* in the media mix. Other media supplements such as activated charcoal, sawdust and even shredded paper have also been shown to improve removal of certain constituents from stormwater runoff. Another approach employs modifications to the configuration of the bioretention system to retain a portion of the accumulated stormwater. This so-called *internal water storage (IWS)* design has been shown to reduce soluble nitrogen levels by inducing an anaerobic condition within the Bioretention facility itself. While this research looks promising, design specifications have not been developed to date. However, the Department recognizes that the technology in this field is evolving rapidly and encourages the use of the latest advances in science. Advanced systems will be evaluated on a case-by-case basis and assigned performance credits as deemed appropriate by the Department until formally adopted into these Standards and Specifications.

Practice Sizing: Bioretention will typically be sized to treat all or a portion of the RP_v, and can also partially meet the C_v through volume contained in the surface ponding area, soil media, and gravel reservoir layers of the practice. The following equations are provided to assist designers in determining an optimal sizing for the facility. However traditional sizing approaches using design volume, void ratio of the stone and biosoil media, etc. are also acceptable.

First, designers should calculate the total storage volume of the practice using **Equation 2.1**

Equation 2.1

$$Sv = SA_{filter} \times \left[\left(d_{media} \times \eta_{media} \right) + \left(d_{gravel} \times \eta_{gravel} \right) \right] + (SA_{p-1} + SA_{p-2}) / 2 \times d_{ponding} + Sv_{pretreatment}$$

Where:

Sv	=	total storage volume of practice (cu. ft.)
SA_{filter}	=	surface area of the top of the filter media (sq. ft.)
d_{media}	=	depth of the filter media (typically 2 ft)
η_{media}	=	effective porosity of the filter media (typically 0.4)
d_{gravel}	=	depth of the underdrain and underground storage gravel layer(ft)
η_{gravel}	=	effective porosity of the gravel layer (typically 0.4)
SA_{p-1}	=	surface area at the lowest elevation of the ponding area (sq. ft.) [Note SA_{p-1} may be no greater than 2X SA_{filter}]
SA_{p-2}	=	surface area at the depth of ponding
$d_{ponding}$	=	the maximum ponding depth of the practice (ft).
$Sv_{pretreatment}$	=	volume stored in pretreatment practices

Equation 2.1 can be modified if the storage depths of the biosoil 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 facility should not exceed 24 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 ***Specification 10.0, Detention Practices***

Minimum Filter Surface Area

The filter should be designed with sufficient surface area to dewater within 48 hours (Equation 2.2). If the surface area used in Equation 2.1 is insufficient to allow for this drawdown time, the designer should increase the surface area of the practice, or adjust the value of Sv to reflect a volume that can be drawn down in this time.

Equation 2.2

$$SA_{filter} \geq \frac{\mathrm{Sv} \times d_{media}}{k \times t_d \times \left(d_{ponding}/2 + d_{media} \right)}$$

Where:

k	=	filtering media permeability (ft/day; typically assume 5.7)
t_d	=	drawdown time within the filter (2 days maximum)

<u>Infiltration Volume</u>:

The amount of stormwater that enters the stormwater practice can either be filtered and discharge through an underdrain, or be infiltrated. The volume infiltrated depends on the design variation and is calculated using Equations 2.3 or 2.4.

Infiltration Designs with an Underdrain and Sump

For designs with an underdrain, Bioretention practices must include a sump (i.e., storage below the underdrain, see figure 2.2). The volume stored in the sump is assumed to infiltrate within 48 hours for the purposes of Equation 2.3.

Equation 2.3

$$Sv_{infiltration} = SA_{filter} \times \min\left[\left(d_{sump} \times \eta_{gravel}\right), 2i\right]$$

Where:

$Sv_{infiltration}$	=	volume infiltrated through from the practice (cu. ft.)
d_{sump}	=	depth of underground storage gravel layer below the underdrain(ft)
i	=	field-measured infiltration rate for the native soils (ft./day)

Infiltration Designs

For practices without an underdrain, the volume infiltrated is equal to the entire storage volume, provided that the soil's infiltration rate is sufficient to infiltrate this volume within 48 hours (equation 2.4).

Equation 2.4

$$Sv_{infiltration} = \min\left(Sv, 2i\right)$$

<u>Filtering Volume:</u>

The volume treated by filtration (i.e., filtered through the practice medium and discharged through an underdrain), is defined as $Sv_{filtering}$, and is calculated using equation 2.5. Filtering alone is only acceptable for small-scale bioretention variants. For such designs, the filtering volume is equal to the total storage volume. However, the filter must be sized to achieve the minimum treatment volume.

Equation 2.5

$$Sv_{filtering} = Sv - Sv_{infiltration}$$

Ponding Volume:
During high intensity storm events, the bioretention practice will fill up faster than the collected stormwater is able to filter through the soil media. Consequently, it is critical to ensure that sufficient volume is ponded, or stored prior to the filter. The ponding volume is calculated in equation 2.6.

Equation 2.6

$$V_{ponding} = (SA_{p-1} + SA_{p-2}) / 2 \times d_{ponding} + Sv_{pretreatment}$$

Bioretention can be designed to address, in whole or in part, the detention storage needed to comply with conveyance and/or flood control requirements. The *Sv* can be discounted from the 10-yr or 100-yr runoff volumes to satisfy stormwater quantity control requirements.

2.7 Bioretention Landscaping Criteria

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

Minimum plan elements should include the proposed bioretention template to be used, delineation of planting areas, the planting plan, including the size, the list of planting stock, sources of plant species, and the planting sequence, including post-nursery care and initial maintenance requirements. Planting plans must be prepared by a qualified professional.

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 ***Appendix 2, Stormwater BMP Landscaping Criteria***.

The degree of landscape maintenance that will be provided will also 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

2.8 Bioretention Construction Sequence

Erosion and Sediment Controls. Bioretention facilities should be fully protected by silt fence or construction fencing. Ideally, Bioretention facilities should remain undisturbed during construction to prevent soil compaction by heavy equipment. Large Bioretention facilities may be used as small sediment traps or basins during construction. However, these must be accompanied by notes and graphic details on the Sediment & Stormwater 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 bottom of the facility shall be ripped, tilled or otherwise scarified upon final excavation. If the facility is designed for infiltration, the original field-measured infiltration rate must be verified through retesting. The plan must also show the proper procedures for converting the temporary sediment control practice to a permanent Bioretention facility, including dewatering, cleanout and stabilization.

Bioretention Installation. The following is a typical construction sequence to properly install a Bioretention facility (also see **Figure 2.3**). The construction sequence for small-scale Bioretention is more simplified. These steps may be modified to reflect different Bioretention applications or expected site conditions:

Step 1. Construction of the Bioretention facility 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. The designer and the installer should 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 facility. The designer should clearly communicate, in writing, any project changes determined during the preconstruction meeting to the installer and the plan review/inspection authority.

Step 3. Temporary erosion and sediment controls (e.g., diversion dikes, reinforced silt fence) are needed during construction of the Bioretention facility to divert stormwater away from the Bioretention facility 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. Any pre-treatment cells should be excavated first.

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

Step 6. It may be necessary to rip or till the bottom soils to a depth of 6 to 12 inches to promote greater infiltration if a bucket without teeth is used for excavation.

Step 7. If a stone storage layer will be used for an underdrain design, place the appropriate depth of rice gravel on the bottom, install the perforated underdrain pipe, pack rice gravel to 3 inches above the underdrain pipe. A layer of rice gravel may also be necessary for an infiltrating design if the 24" biosoil media does not reach a permeable layer in the soil profile.

Step 8. The biosoil media must come from an approved supplier. If not used upon delivery, store it on an adjacent impervious area or plastic sheeting. Apply the media in 12-inch lifts until the desired top elevation of the Bioretention facility is achieved. Wait a few days to check for settlement, and add additional media, as needed, to achieve the design elevation. Sprinkling with water between lifts may reduce the amount of settling that occurs.

Step 9. Prepare planting holes for any shrubs and plants, install the vegetation, and water accordingly. Install any temporary irrigation.

Step 10**.** Place the surface cover in both cells (mulch, river rock, etc.), depending on the design. If stabilization matting will be used in areas that will be planted, the matting will need to be installed prior to planting (**Step 9**), and holes or slits will have to be cut in the matting to install the plants.

Step 11. Install the plant materials as shown in the landscaping plan, and water them during weeks of no rain for the first two months.

Step 12. 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**.** Conduct the final construction inspection (see **below**), then log the GPS coordinates for each bioretention facility and submit them for entry into the local maintenance tracking database.

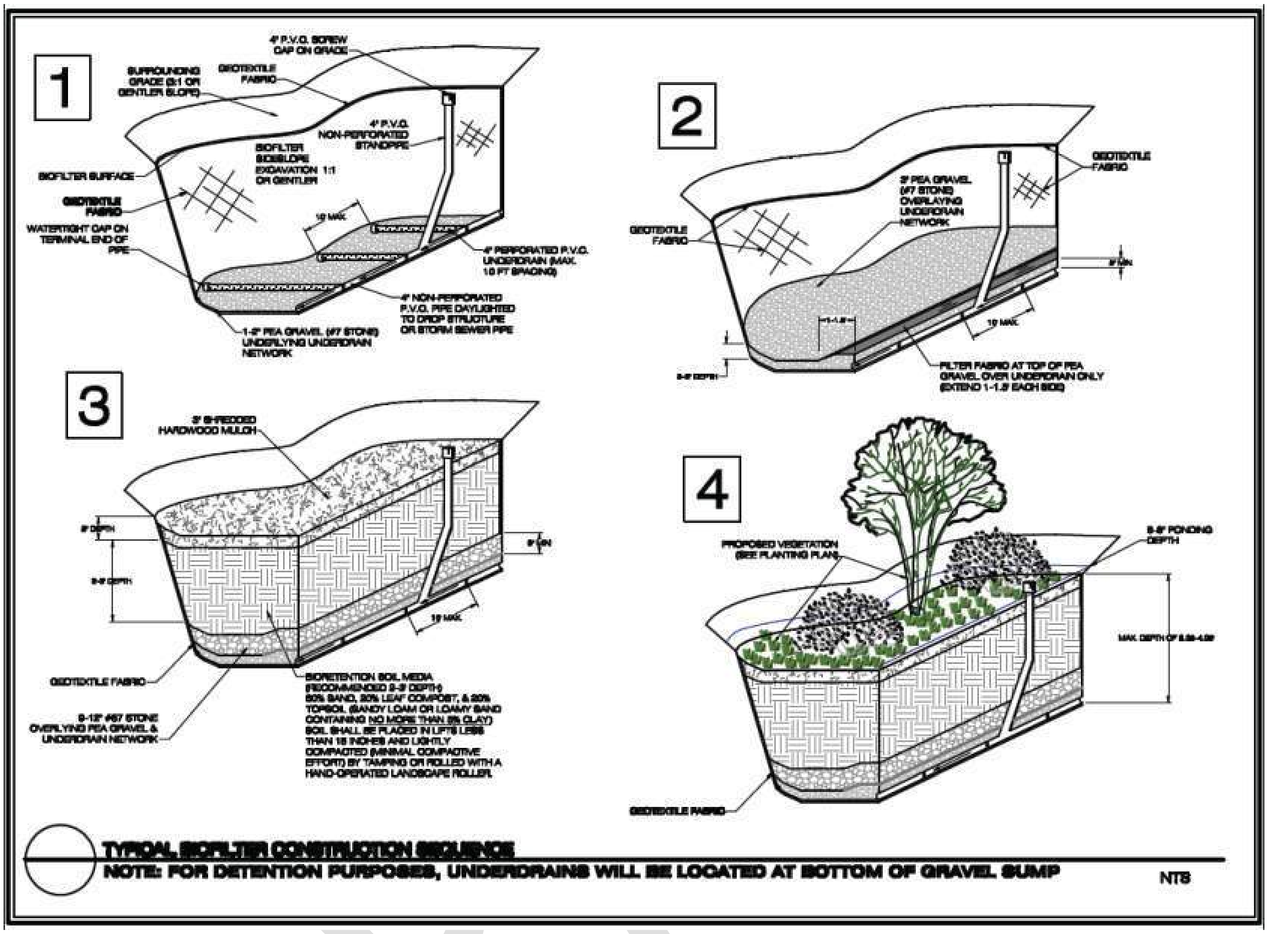

Figure 2.3. Typical Bioretention Construction Sequence

Construction Inspection. An example construction phase inspection checklist is available in the appropriate section of the Technical Document.

Post Construction Verification Documentation. The following items shall be included in the Post Construction Verification Documentation for Bioretention Practices:

- Surface dimensions of biosoil bed.
- Depth of biosoil media.
- Volume dimensions of any pre-treatment component.
- Elevations of any structural components, including inverts of pipes, weirs, etc.

2.9 Bioretention Maintenance Criteria

An Operation and Maintenance Plan for the project will be approved by the Department or the Delegated Agency prior to project closeout. The Operation and Maintenance Plan will specify the property owner's primary maintenance responsibilities and authorize the Department or

Delegated Agency staff to access the property for maintenance review or corrective action in the event that proper maintenance is not performed. Bioretention Practices that are, or will be, owned and maintained by a joint ownership such as a homeowner's association must be located in common areas, community open space, community-owned property, jointly owned property, or within a recorded easement dedicated to public use.

Operation and Maintenance Plans should clearly outline how vegetation in the Bioretention Practice will be managed or harvested in the future. The Operation and Maintenance Plan should schedule a cleanup at least once a year to remove trash and debris.

Maintenance of Bioretention Practices is driven by annual maintenance reviews that evaluate the condition and performance of the practice. Based on maintenance review results, specific maintenance tasks may be required.

Table 2.6. Typical Bioretention Maintenance Items and Frequency

Frequency	Maintenance Items
During establishment, as needed (first year)	• Inspect the site after storm event that exceeds 0.5 inches of rainfall. • Stabilize any bare or eroding areas in the contributing drainage area including the Bioretention perimeter area • Water trees and shrubs planted in the Bioretention planting bed during the first growing season. In general, water every 3 days for first month, and then weekly during the remainder of the first growing season (April - October), depending on rainfall.
Quarterly or after major storms (>1 inch of rainfall)	• Remove debris and blockages • Repair undercut, eroded, and bare soil areas
Twice a year	• Mowing of the Bioretention vegetated perimeter area and banks (as directed in approved O&M plan)
Annually	• Cleanup to remove trash, debris and floatables • A full maintenance review • Check condition of outlet structure • Repair broken mechanical components, if needed
One time –during the second year following construction	• Bioretention planting bed replacement/reinforcement plantings
Every 5 to 7 years	• Forebay sediment removal (as applicable) • Flush underdrain system (as applicable)
From 5 to 25 years	• Repair pipes, outlet structure and spillway, as needed • Remove any accumulated sediment within facility, as needed

2.10 References

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