5.3.4 Bioretention

Description

Bioretention areas are vegetated, shallow surface depressions that use the interaction of plants, soil, and microorganisms to store, treat, and reduce runoff volume, and to reduce the flow rate of stormwater runoff. Small bioretention areas are often referred to as rain gardens. Bioretention areas designed for infiltration can also be referred to as bioinfiltration areas, while those that cannot infiltrate and must discharge via an underdrain are sometimes referred to as biofiltration areas.

Bioretention areas are generally flat and include engineered or modified soils that allow drainage of stormwater through soils. Plants are a critical component of bioretention and improve the soil structure and porosity through the establishment of root systems and microbial communities.

Bioretention provides stormwater management by capturing runoff in the shallow surface depression. Water then drains through the bioretention soils during small, frequent rainfall events. A bioretention area may include a stone storage bed beneath the soils. Bioretention systems **always** include a positive drainage overflow structure to safely convey large rainfall events from the bioretention area.

Water that has drained through a bioretention area may infiltrate into the subsoil or discharge at a controlled flow rate through an underdrain system (or a combination of both).

Figures 5.3.4-1a and b. Bioretention area immediately following construction and after three years of establishment.

BMP Functions Table

BMP	Applicability*	Volume Reduction*	Water Quality (TSS)	Peak Rate Reduction	Recharge*	Runoff Temperature Mitigation	Heat Island	Habitat Creation	Maintenance Burden*	Cost*
Bioretention	U/S/R	L/H	H	M	L/H	H	M	H	L/M/H	L/M/H

KEY: U = Urban; S = Suburban; R = Rural; H = High; M = Medium; L = Low

*Rating varies based on design considerations.

Key Design Features

- Shallow ponding of water (surface storage) is limited in depth and duration. Standing water does not remain visible for more than a few hours after rainfall has ceased.
- Captures the runoff from small (1.6 inches and less) rainfalls events, and the first portion of larger rainfall events.
- Always includes an overflow control structure or design to allow large storm events to bypass or discharge at a controlled flow rate without passing through the soils.
- The surface area and size are directly correlated to the contributing drainage area size and land use, especially impervious surfaces.
- Are generally small (less than 1,000 square feet) or comprised of several interconnected bioretention areas.
- Are generally level at the water surface. Constructed on a level uncompacted subgrade.
- May include an underlying aggregate drainage bed.
- Should not be placed on compacted fill if infiltration is required.
- When possible, bioretention should be placed on upland soils.
- Biofiltration areas that cannot infiltrate must include a low-flow slow-release system. Lined and slow-release systems may be constructed on compacted fill material.

Applications

- Road shoulders, medians, and cul-de-sacs
- Parking islands and edges
- Individual home lots
- Shared facilities in common areas for individual lots
- Common areas in multifamily housing and commercial office areas

- Institutions, such as schools, libraries, and public facilities
- In parks and along open space edges

Advantages

- Integrates stormwater into the landscape
- Improves aesthetics
- Flexible dimensions to fit conditions
- Creates habitat
- Excellent retrofit capability
- Cost-effective

Disadvantages

- Built on areas that are generally level (or graded level).
- Steep slopes may require larger footprint to create level grading.
- Vegetation and soils must be protected from damage and compaction.
- Infiltration requires suitable site conditions.
- Salt use may impact vegetation and soils.
- Maintenance is required to maintain both performance and aesthetics.

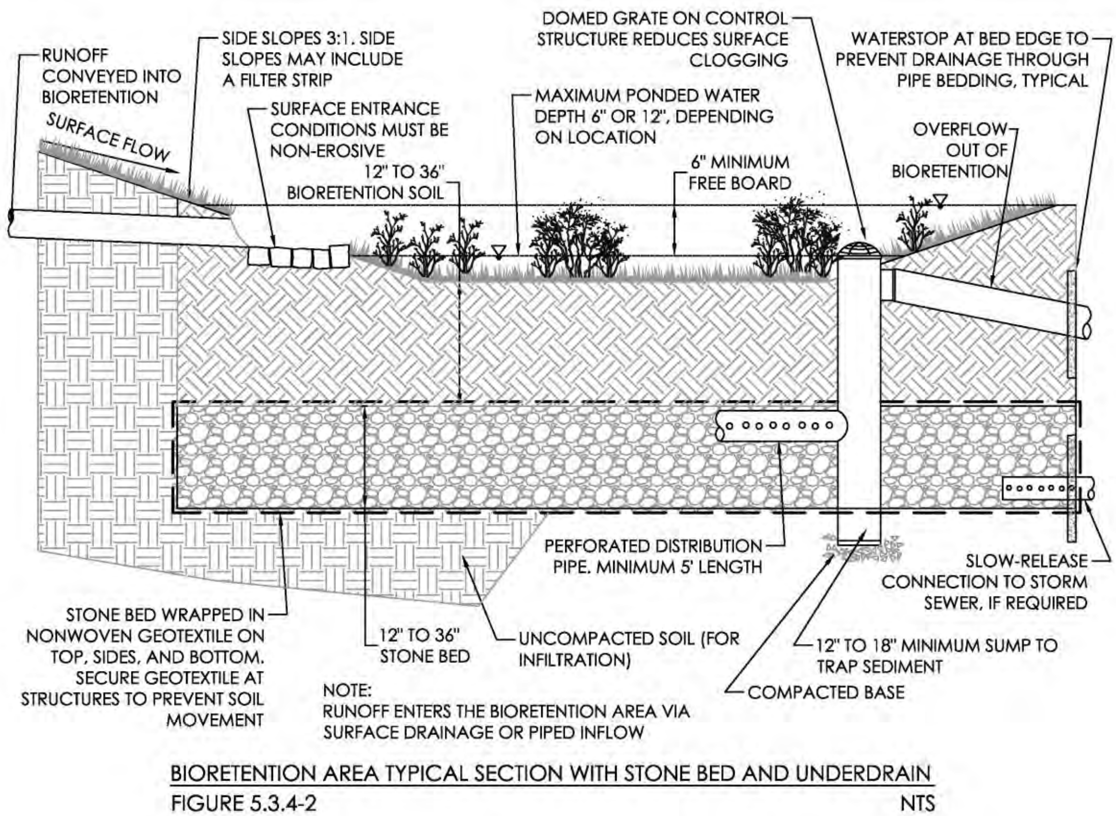

Figure 5.3.4-2. Typical bioretention detail (infiltration).

Applications

Bioretention basins are versatile, effective, and aesthetically pleasing stormwater management devices that are applicable to a variety of site characteristics.

Residential Bioretention Area

Figure 5.3.4-3. Residential bioretention that manages runoff from a single home. Roof leaders are directly connected to the bed.

Roadside Bioretention Area

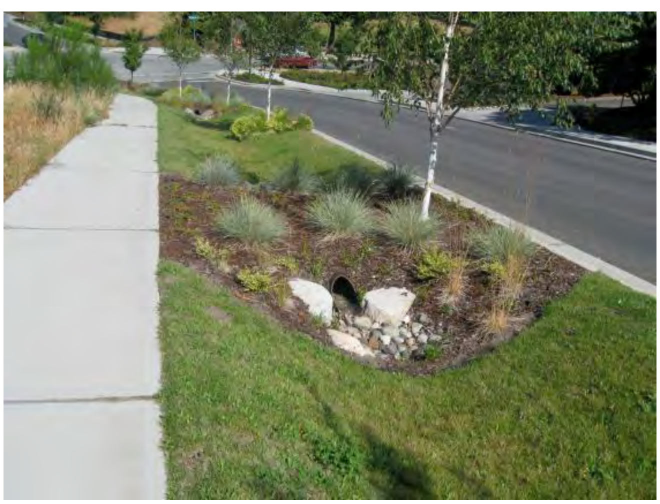

Figure 5.3.4-4. Roadside bioretention in a residential neighborhood that manages street runoff (located in public right-of-way).

Institutional Bioretention Area

Figure 5.3.4-5. Institutional bioretention area at an urban schoolyard (adjacent to porous rubber play surface).

Commercial Bioretention Area

Figure 5.3.4-6. Commercial bioretention (rain garden) in parking lot.

Applicable Protocols and Specifications

The following Protocols and Specifications (see Appendices A through F) are applicable to bioretention and must be addressed:

- Protocol 1 Setbacks from Structures
- Protocol 2 Coordination with Other Utilities
- Protocol 3 Site Evaluation and Infiltration Testing
- Protocol 4 Infiltration System Design and Construction Guidelines
- Protocol 5 Planting Guidelines
  - Bioretention Soil Specifications
  - Stormwater System Specifications
  - Aggregates and Drainage Layers
  - Pipes
  - Control Structures
  - Geotextiles
  - Impervious Liners and Waterproofing

Bioretention Design Criteria

ITEM	RECOMMENDATION	REFERENCE SECTION
Maximum Drainage Area (Recommended)	Generally 10,000 square feet or less of impervious area per bioretention area. Several bioretention areas may be interconnected or placed in series to create larger systems.	5.3.4.1
Concept Phase Loading Ratio (LR) (Recommended)	1:8 for South Chickamauga Watershed	5.3.4.5
	1:10 for all other Watersheds	
Concept Phase Surface Area Size (ft^2) (Recommended)	Impervious Drainage Area Managed (ft^2) / Loading Ratio	5.3.4.5
Entrance/Flow conditions	Surface Dispersed: Grading must prevent concentrated flow paths	5.3.4.2
	Surface Concentrated: Provide erosion control at entrance	
	Direct Connection (into stone bed): Recommended only for "clean" runoff such as roofs	
Pretreatment/Management of Sediment Trash and Debris	Required for high sediment drainage areas (i.e. parking lots). See Filter Strip (BMP 5.3.6)	5.3.4.3
SOV Volume or Water Quality Volume Credit	Static Storage provided by: Surface Ponding, Soil Storage, Stone Storage (if applicable), Other structures (pipes, rain storage units, etc.)	5.3.4.4
Surface Ponding Depths	Maximum 6 inches for high use areas (near pedestrians and public) Maximum 12 inches for less used areas (limited access)	5.3.4.5
Soil Storage Coefficient and Volume	0.2 Storage Volume (ft^3) = Soil Depth (ft) x Soil Area(ft^2) x 0.2	5.3.4.4
Bioretention Soil Layer Depths	Minimum 12 inches Maximum 36 inches	5.3.4.5
Stone Storage Coefficient and Volume	0.4 Storage Volume = Stone Depth (ft) x Stone Area (ft^2) x 0.4	5.3.4.4
Stone Depths	Minimum 12 inches	5.3.4.5
	Maximum 36 inches	
Pipe sizes for Overflow and Peak Rate	Minimum size 6 inch diameter. See Stormwater System Specifications	5.3.4.6
Freeboard	6 inches	5.3.4.7
Conveyance Capacity	Peak rate 10-year, 24-hour rainfall event	5.3.4.6
Underdrain	Required if Infiltration Rate < 0.1 inches per hour	5.3.4.8
Setback from Structures	Required. See Stormwater Specification for Impervious Liner	Protocol 1
Coordination with Other Utilities	Required	Protocol 2
Infiltration Testing	Required	Protocol 3
Infiltration System Setbacks	Required	Protocol 4
Vegetation and Mulch	Required	Protocol 5
Inspection and Longterm Maintenance	Required	Chapter 8

Design Considerations for Bioretention

Designed appropriately, bioretention can be implemented on a myriad of development sites. The key design components for bioretention discussed below allow design flexibility to ensure maximum performance from this multi-purpose BMP.

Figure 5.3.4-7. Bioretention in a supermarket parking lot takes advantage of typically underutilized space between parked vehicles.

1. Location and Capture Area

Human activity influences the location of bioretention areas. The following site-specific conditions should be considered:

- Select location to prevent vegetation damage and soil compaction from pedestrian traffic or unintended vehicle compaction. Ideal locations are often located to the side or downhill of high vehicle or pedestrian traffic areas. Consider locating bioretention areas in places that are generally “not used” such as traffic islands; between parked cars in parking lots; along edges of public playgrounds, school yards, and plazas; in courtyards; and in place of traditional landscape planting areas.
- If necessary, provide for pedestrian passage and maintenance access. This will prevent unintended damage to soils and vegetation.
- Use structures, barriers, and plantings to limit access and prevent damage to soils and vegetation. Low fences, curbs, and woody vegetation are examples.
- Locate bioretention area to prevent future conflicts for space, and provide public access if necessary. Long-term maintenance is more likely if bioretention area is readily visible.

Figure 5.3.4-8. Cobbles in the bioretention area allow for easy and safe pedestrian crossing without disturbing soils and vegetation.

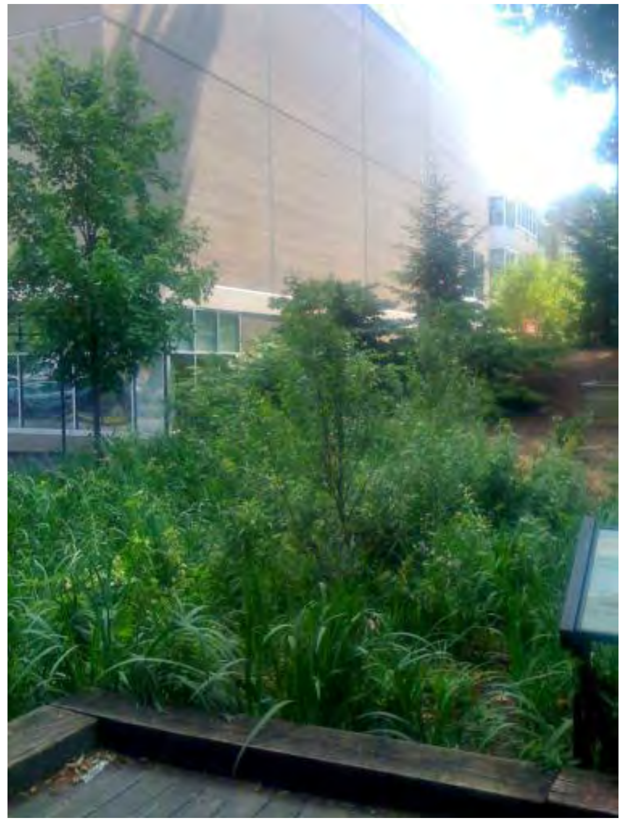

Figure 5.3.4-9. A low wood curb along a bioretention area protects the vegetation.

Locate bioretention areas:

- Close to the source of runoff. Bioretention areas should not receive excessive amounts of drainage from undisturbed areas.
- To capture runoff from impervious areas and highly compacted pervious areas such as athletic fields and lawns.
- To capture smaller drainage areas. If necessary, use several connected bioretention areas to address larger areas.

Figure 5.3.4-10. A bioretention area in the public right-of-way avoids homeowner conflicts such as decks, pools, and swing sets and also allows for public access and visibility.

2. Entrance/Flow Conditions

Captured runoff may enter a bioretention area in one of three ways:

a. Through dispersed surface flow such as along a depressed curb, lawn area, or edge of pavement. Careful grading is essential to prevent concentrated flow points and potential erosion. For bioretention adjacent to existing impervious pavement, such as in a retrofit installation or modification to an existing site, it is recommended that the adjacent pavement be milled and repaved/replaced to provide a uniform edge and dispersed sheet flow into the bioretention area.
b. Through a concentrated discharge location such as a trench drain, outlet pipe, or curb cut. Bioretention soils and mulch are highly erosive. Entrance velocities should not exceed 1 foot per second unless designed with entrance measures to prevent erosion. Cobble splash blocks, small level spreaders, and turf reinforcement materials are options. Supporting entrance velocity calculations are required for all concentrated surface discharges into bioretention areas.

c. Via a direct connection (such as a pipe) into the underlying stone storage bed. This is a good option for "clean" runoff discharging at high velocities. For example, a roof leader may be connected directly to a stone storage bed (see Figure 5.3.4-14).

Figure 5.3.4-11. Edge conditions at a school allow for direct surface flow from the play area to the adjacent bioretention area.

Figure 5.3.4-12. Edge conditions in a commercial parking lot allow for direct and unconcentrated surface flow into the adjacent bioretention area.

3. Management of Sediment, Trash, and Debris

In areas of high sediment load, bioretention areas should include measures to prevent the movement of material into the bioretention area. Sediment can clog a bioretention area and limit its functional lifespan.

For surface runoff into a bioretention area, a vegetated filter strip (BMP 5.3.6) can reduce sediment. For aesthetic purposes in manicured landscapes, the filter strip should be incorporated along the edges and within the bioretention landscape area.

For piped runoff into the surface of a bioretention area, a small sump within a cobble splash block or similar measure will provide for ease of maintenance in sediment removal.

Storm sewer pipes are not recommended for conveyance of stormwater with high levels of trash, debris, leaf litter, or other materials that may cause clogging unless regular maintenance and cleaning of pipes are ensured. Trench drains, curb cuts, and visible surface entrances require maintenance. Maintenance is more likely to occur if clogging conditions are visible.

In areas of high trash or with specific concerns such as plastic shopping bags (a common concern in commercial areas), entrance conditions may include a screen to prevent material from entering the bioretention area. Plant selection should consider the amount and type of trash that may enter the bioretention area. Items such as windblown plastic shopping bags that adhere to vegetation should be considered when selecting plants. Relatively deep (greater than 6 inches) bioretention areas in commercial shopping areas and along busy roadways tend to inadvertently collect shopping carts and debris. The designer must consider the site-specific conditions and adjacent land uses in each application.

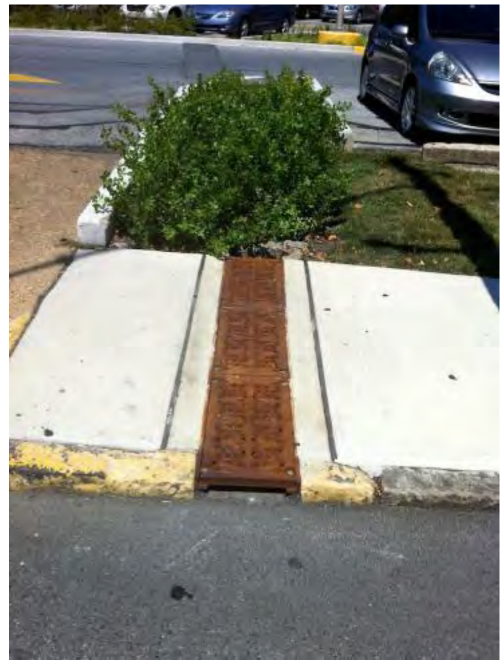

Figure 5.3.4-13. A trench drain collects and directly conveys street runoff into the bioretention area.

Figure 5.3.4-14. Roof leaders convey runoff below the walkway directly into an adjacent bioretention area. The walk is graded so that runoff sheet flows into the bioretention area. A small filter strip captures any coarse sediment from the walk.

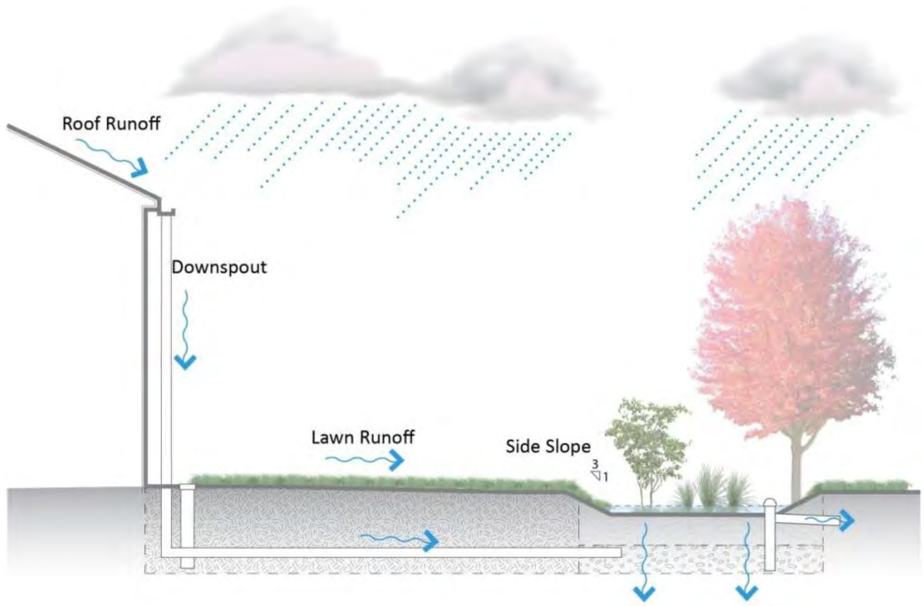

Figure 5.3.4-15. Roof leaders can convey high-velocity flows from the roof directly into the stone bed to prevent erosive conditions.

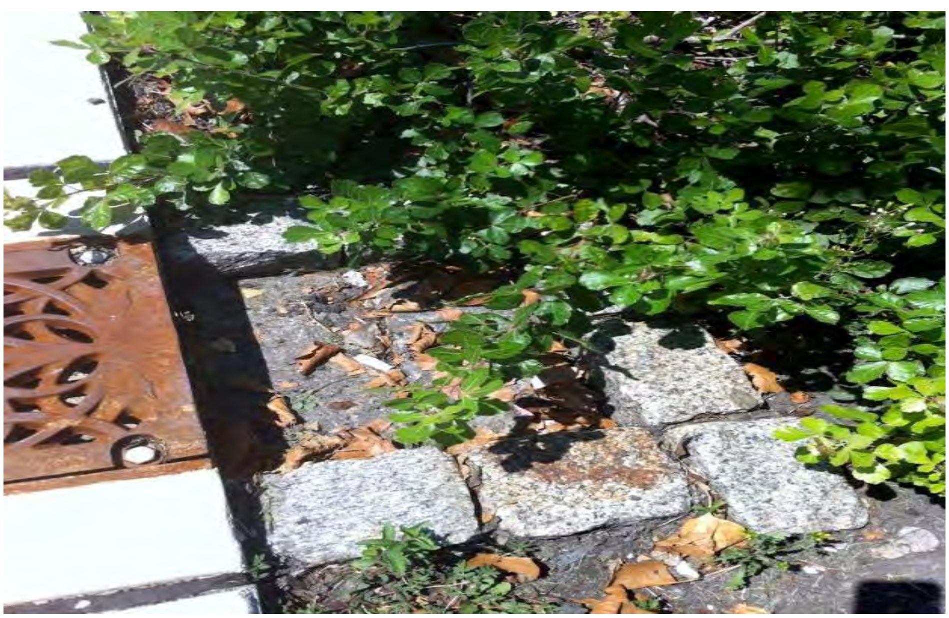

Figure 5.3.4-16. A cobble splash block prevents the movement of sediment into the bioretention area and also allows for routine cleaning and maintenance.

4. Storage and Stay-on-Volume

A bioretention system provides volume management within the surface ponding area, the bioretention soil area, and the stone storage bed (if applicable). Because water must move **through** the bioretention soils, the storage volume is **not** defined by the discharge pipe invert. This is different than non-vegetated BMPs.

The **SOV** is a function of the storage volume available for the 1-inch or 1.6-inch storm.

Storage Volume (ft^3) =

Surface Water Volume + Soil Storage Volume + Stone Storage Volume

<u>Surface Water Volume:</u> Available surface water storage between soil surface and overflow structure (always equal to or less than 12 inches). The designer should consider the bed side slopes when estimating volume.

<u>Soil Storage Volume:</u> This is the bioretention soil volume x 0.20 void space ratio.

Soil Storage Volume (ft^3) = Soil Area (ft^2) x Soil Depth (ft) Below Overflow x Void Ratio

<u>Stone Storage Volume:</u> This is the stone storage volume x 0.40 void space ratio.

Stone Storage Volume (ft^3) = Stone Area (ft^2) x Stone Depth (ft) Below overflow x Void Ratio

Void ratios are generally:

- 0.20 for bioretention soils
- 0.40 for clean-washed aggregate such as AASHTO No. 3
- 0.85 to 0.95 for manufactured storage units depending on manufacturer

5. Surface Area and Dimensions

The size and surface area of a bioretention system may be a function of the drainage area that will discharge to the bioretention system. It is important not to concentrate too much flow in one location. A basic rule-of-thumb is to design a bioretention system with a surface area that is a ratio of the impervious and compacted pervious areas draining to it. The amount of rainfall volume must also be considered. The following ratios based on design rainfall depth can be used to estimate a bioretention area:

1-inch Rainfall

1:10 ratio of surface area to impervious drainage area

1.6-inch Rainfall

1:8 ratio of surface area to impervious drainage area

One of the benefits of bioretention is that the dimensions of the system may be adjusted to fit into an available location. A bioretention area may be long and linear when located in a parking lot, circular when located within a cul-de-sac, or varied in dimensions to support a landscape design. As long as the runoff can disperse through the bioretention system and sufficient surface area is provided, dimensions can be flexible.

With an estimate of the required bioretention area and SOV, the designer can estimate the depth of water, soil, and if necessary, stone storage using the Sizing Calculations Worksheet.

The recommended depths for surface water storage, soil storage, and stone storage are:

Surface Water Storage Depth:

- **6 inches maximum in high-use areas** (along streets, at schools, in public landscapes, etc.)
- **12 inches in less used areas** (away from frequent public access)

Bioretention Soil Depth: Between 12 and 36 inches

Stone Storage Depth: Between 12 and 36 inches

6. Overflow and Peak Rate

Bioretention designs must provide a safe way for water to exit the system when large storms generate more stormwater runoff than the depression can hold. The inclusion of a positive overflow route ensures that flooding risks and related property damage are minimized.

The positive overflow route is often in the form of a domed riser, with an invert at the maximum allowable surface ponding level. The overflow must discharge to the storm sewer or to another approved discharge point. **The minimum allowable diameter of an overflow pipe is 6 inches for bioretention areas.**

A structure (i.e., outlet or weir) or vegetated swale that discharges to an approved discharge point may also be used. An inlet with an internal weir maximizes volume storage when the outlet pipe and inlet pipe cannot be placed to ensure sufficient storage (i.e., the bed is shallow, or slopes do not permit), as shown on Figure 5.3.4-17.

All overflows must safely convey the 10-year/24-hour storm.

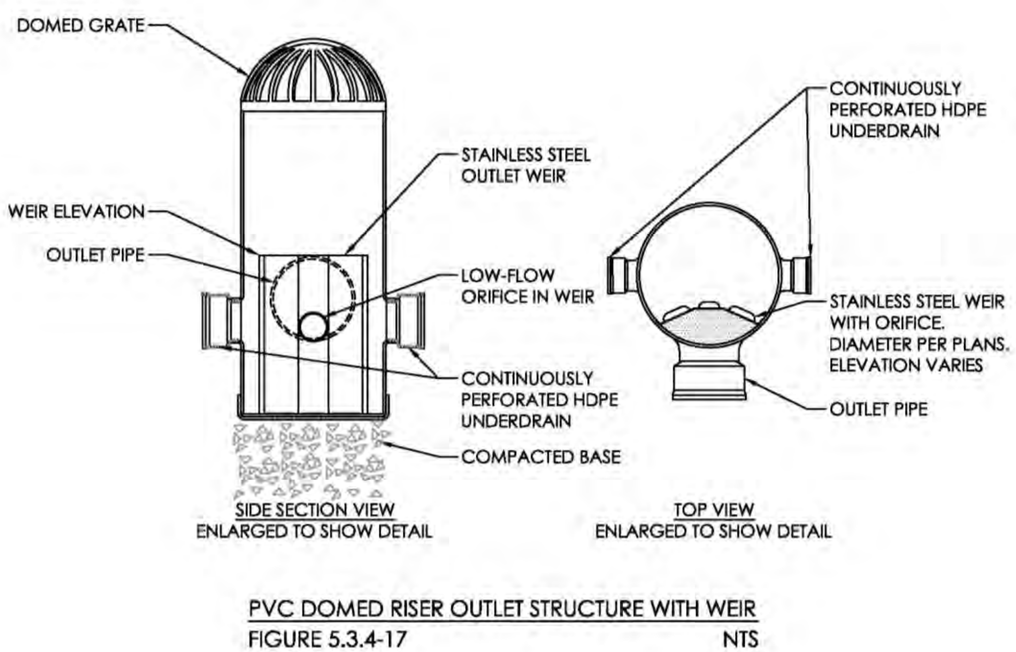

Figure 5.3.4-17. An inlet with an internal weir can also provide maximum volume storage within a bioretention or other area while allowing for safe conveyance. A number of manufactured products are available for this purpose.

The overflow structure should be easily visible from outside the bioretention area. Bioretention control structures can become clogged with vegetation at the inlet grate if maintenance is neglected. A domed inlet will reduce the likelihood of this problem occurring. A visible structure will facilitate ease of maintenance and ensure awareness of clogged inlet grates.

Peak Rate Control and Infiltration Credit

For the purposes of site peak rate control, the designer may adjust the Curve Number value based on the volume managed by both the SOV and the infiltration volume that occurs during a portion of a 24-hour storm event. This allows the designer to account for runoff that was captured by applying LID, and to develop a representative lower Curve Number. This procedure is described in Chapter 7.

When adjusting the Curve Number, the infiltration volume can be estimated as the infiltration that occurs during 12 hours of a 24-hour design storm. This will ensure that estimated infiltration volumes are not greater than the actual volume captured within the BMP.

Infiltration Volume (ft^3) = Bioretention Bottom Area (ft^2) x Infiltration Rate (in/hr) x 1/12 x 12 hours

7. Freeboard

It is recommended that bioretention areas include a minimum of 6 inches of freeboard above the overflow route.

8. Underdrain

The underdrain system is used to ensure that water moves through the system when the native soil infiltration rate is not high enough to empty the basin of water**. Underdrain systems must be included in the design if the native soil infiltration is less than 0.1 inch per hour or if the system is lined with an impervious liner** and intended for slow release only. Underdrains must be located at the intended bottom of the bioretention system (i.e., below soils and stone if applicable). See Protocol 3 for the infiltration testing procedure and Protocol 4 for infiltration system guidelines.

Bioretention systems may require very low discharge rates to achieve water quality discharge between 48 and 72 hours. Constructing a very small orifice will often achieve this, but a small orifice is easily subject to clogging.

One method for achieving a low discharge rate is to install a perforated pipe at the bottom elevation of the bioretention area. If the pipe is located in the bioretention soils, it must be set in clean-washed gravel and wrapped in non-woven geotextile to prevent soil movement. A perforated low-flow pipe can be set directly in a stone stormwater bed. The perforated pipe connects to a stormwater structure (such as a catch basin) with a transition coupling for a very small orifice. Various products are available for this purpose.

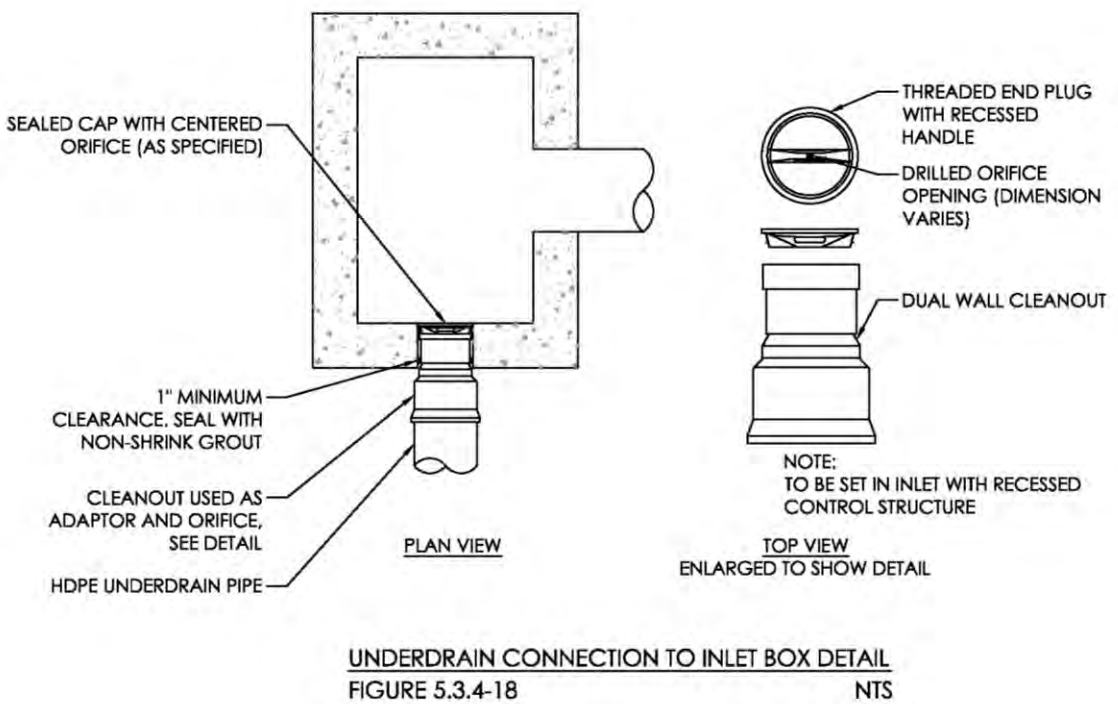

Figure 5.3.4-18. This coupling device can allow an "orifice" connection to a storm structure, providing an extended low discharge rate for underdrained systems.

9. Waterproofing

In some instances, bioretention areas may be designed to infiltrate, but there may be concerns about impacts on adjacent structures, such as basements, or on the subbase of adjacent paved surfaces. The system may be designed with an underdrain for slow release of flows rather than infiltration, but there may be concerns regarding lateral movement of water from the sides of the bioretention area. For all bioretention areas, the designer must evaluate the impact of the system on adjacent structures and utilities as defined in Protocol 1, Setbacks from Structures and Protocol 2, Coordination with Other Utilities. The liner, if applied, must meet the guidelines provided in the Stormwater Specification. In many situations, a partial liner (i.e., one side of a trench) will adequately protect structures.

10. Bioretention Soils

The soils used in the bioretention basin are a crucial factor in determining its performance. If an inadequate soil specification is used, or if the specification is prepared, installed, or maintained poorly, the runoff may infiltrate either too quickly or not quickly enough. If the soil infiltration rate is too low, the result is that runoff short-circuits the system and exits via the overflow without treatment or detention. If the soil infiltration rate is too high, the runoff will not have enough contact with the soil media to provide adequate water quality treatment, and it may be difficult to maintain healthy vegetation.

The Bioretention Soil Specification detailed in Appendix F of this document is required for use in all bioretention designs.

To provide adequate water quality treatment, the bioretention soil layer must be a minimum of 12 inches deep; however, greater depths of up to 36 inches are preferred.

Bioretention soils must never be placed when wet or during wet weather. Soils should be protected from saturation until plant installation, and from sediment deposition into the bioretention area. If necessary, the bioretention area can be protected by installing erosion and sediment control measures immediately upslope. Compost socks works very well for this purpose.

11. Bioretention Mulch

The type and application of mulch used in bioretention systems are important, and all systems must use mulch that meets the requirements of the Planting and Mulching Guidelines in Protocol 5 (Appendix E). The use of woodchips, which may "float," is directly prohibited.

12. Vegetation

The type of plant and planting plan for bioretention systems must comply with Protocol 5 (Appendix E) of this manual.

Zone 1: Soils subject to both flooding and periodic drought.

Zone 2: Soils periodically moist or saturated during heavier storms.

Zone 3: Frequently saturated soils and occasional standing water (not for periods beyond 72 hours). An area of periodic or frequent standing or flowing water. Plants must tolerate periods of drought.

13. Water Quality/Total Suspended Solids

Bioretention systems that can capture and manage the required SOV through infiltration are considered to meet all water quality requirements. Bioretention systems that are underdrained must be sized to provide water quality treatment. See Chapter 7 for additional discussion.

Sizing Calculations Worksheet for Bioretention

(Digital link to worksheet or reference on where to find worksheet on City web page)

Bioretention Project Example

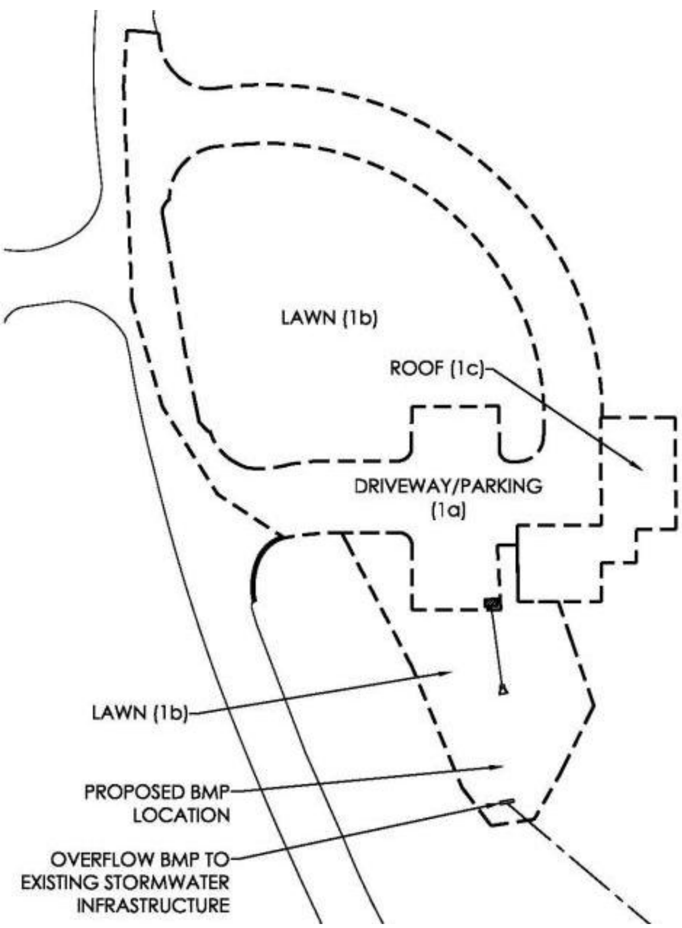

Figure 5.3.4-19. Bioretention project example.

Construction Considerations

For the best success, bioretention areas should not be installed and planted until site construction is complete and site stabilization has occurred. Bioretention areas completed before site stabilization **must** be protected from receiving sediment-laden runoff. Runoff should be directed around completed bioretention areas until site stabilization has occurred. Sediment-laden water should not be allowed to enter bioretention soils or infiltration beds.

The excavated capacity of an infiltration bioretention area may be used as temporary sediment trap areas during construction as long as the temporary grade is not within 2 feet of the final infiltration bottom elevation. Underdrained bioretention areas may be used as sediment traps during construction to the final bed bottom elevation.

Figure 5.3.4-20. A trench drain outlet is closed to prevent sediment-laden water from entering the bioretention area until site stabilization occurs.

Construction Sequence Example

Step 1 Excavate and Prepare Subgrade

a. Do **not** compact or subject bioretention system locations to excessive construction equipment traffic during construction. Protect areas from vehicle traffic during construction with construction fence, silt fence, or compost sock.

b. Initial excavation of bioretention areas can be performed during rough site grading. When performing initial excavation, do not grade beyond 2 feet above the final bioretention bottom elevation. Complete final excavation only after all disturbed areas in the drainage area have been stabilized.
c. Remove fine materials and/or surface ponding in the graded bottom, caused by erosion, with light equipment and scarify underlying soils to a minimum depth of 6 inches with a York rake or equivalent by light tractor.
d. Bring subgrade of bioretention area to line, grade, and elevations indicated on the plans. Fill and lightly regrade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas shall be level grade on the bottom.
e. Halt excavation and notify engineer immediately if evidence of sinkhole activity, unanticipated bedrock or groundwater conditions, or other site conditions that may affect infiltration trench design or performance are encountered. Unanticipated utility crossings may be encountered in urban bioretention areas along roadways.

Figure 5.3.4-21. An underdrained bioretention area is used as a sediment trap during construction.

Step 2 Install Overflow Structure and Other Stormwater Structures

a. Place the stormwater overflow structure on suitable subgrade to prevent settling. Install overflow structure, inlet pipes, curbs, and other stormwater structures as appropriate before placement of stone storage bed and bioretention soils.
b. Close and secure all inlets, pipes, trench drains, and other structures to prevent runoff from entering infiltration trench before completion and site stabilization.
c. Maintain drainage overflow paths during construction, while bioretention area is closed, to provide for drainage during storm events.
d. Bioretention conditions must be observed by the design engineer following excavation and grading, and prior to placement of material, to confirm that construction requirements have been met. Documentation must be provided to the City (see Appendix I).

Figure 5.3.4-22. Installation of distribution pipes in bioretention area.

Figure 5.3.4-23. A curb cut is closed to prevent sediment-laden water from entering the bioretention area until site stabilization occurs.

Step 3 Install Bioretention Area

a. For bioretention areas with a subsurface storage/infiltration bed, place geotextile on the bottom and sides of excavated area immediately after approval of subgrade preparation and installation of structures. Place geotextile in accordance with manufacturer's standards and recommendations. Overlap adjacent strips of geotextile a minimum of 16 inches.
b. Place clean-washed, uniformly graded aggregate (AASHTO No. 3, No. 57 or approved substitute with at least 40 percent void space) or other storage media in the trench in maximum 6-inch lifts. Lightly compact each layer with a hand roller or tamp while keeping construction equipment off the trench bottom as much as possible.
c. Following placement of storage media, place geotextile over the top of the trench to prevent soil movement into the trench. Place and secure geotextile to prevent soil movement.
d. Place planting soil immediately after approval of subgrade preparation/stone bed installation. Remove any accumulation of debris or sediment that takes place after approval of subgrade and prior to installation of planting soil at no extra cost to the owner.
e. Install planting soil (exceeding all criteria) in 8-inch maximum lifts and lightly compact (tamp with backhoe bucket). Keep equipment movement over planting soil to a minimum – do not over compact. Install planting soil to grades indicated on the drawings.
f. Plant trees and shrubs according to the supplier's recommendations and only from early April through the end of June or from early September through late October.
g. Install 2 to 3 inches of shredded hardwood mulch (minimum age of 6 months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.

h. Protect bioretention areas from sediment at all times during construction. Hay bales, diversion berms, and/or other appropriate measures shall be used at the toe of slopes adjacent to bioretention areas to prevent sediment from washing into these areas during site development.
i. Notify engineer when the site is fully vegetated and the soil mantle is stabilized. The engineer shall inspect the bioretention basin drainage area at his/her discretion before the area is brought online and sediment control devices are removed.

The contractor shall provide a one-year 80 percent care and replacement warranty for all planting beginning after installation and inspection of plants.

Figure 5.3.4-24. Planting soil is carefully placed in 8-inch lifts to avoid over compaction.

Figure 5.3.4-25. Inlet protection is placed over a domed riser to prevent sediment from entering the system.

Operations and Maintenance

All properly designed and installed bioretention systems require regular annual maintenance:

- While vegetation is being established, pruning and weeding may be required.
- Detritus may need to be removed approximately twice per year. Perennial grasses can also be cut down or mowed at the end of the growing season.
- Mulch should be replaced when erosion is evident. Once every two to three years, the entire area may require mulch replacement (remove old mulch first).
- Bioretention systems should be inspected annually for sediment buildup, erosion, vegetative conditions, etc.
- During periods of extended drought, bioretention systems may require watering approximately every 10 days.
- Bioretention systems should not be mowed on a regular basis, but mowed according to the maintenance schedule if indicated.
- Trees and shrubs should be inspected twice per year to evaluate health.
- Vegetation should be controlled and maintained as needed.
    - To avoid soil compaction, weeds should be removed by hand.
- Debris and sediment should be removed as needed.
- Mulch or soil should be replaced when evidence of erosion is encountered.