Description

A BMP that utilizes bioretention is an engineered, depressed landscape area designed to capture and filter or infiltrate the water quality capture volume (WQCV). BMPs that utilize bioretention are frequently referred to as rain gardens or porous landscape detention areas (PLDs). The term PLD is common in the Denver metropolitan area as this manual first published the BMP by this name in 1999. In an effort to be consistent with terms most prevalent in the stormwater industry, this document generally refers to the treatment process as bioretention and to the BMP as a rain garden.

The design of a rain garden may provide detention for events exceeding that of the WQCV. There are generally two ways to achieve this. The design can provide the flood control volume above the WQCV water surface elevation, with flows bypassing the filter usually by overtopping into an inlet designed to restrict the peak flow for a larger event (or events). Alternatively, the design can provide and slowly release the flood control volume in an area downstream of one or more rain gardens.

This infiltrating BMP requires consultation with a geotechnical engineer when proposed near a structure. A geotechnical engineer can assist with evaluating the suitability of soils, identifying potential impacts, and establishing minimum distances between the BMP and structures.

Terminology

The term bioretention refers to the treatment process although it is also frequently used to describe a BMP that provides biological uptake and retention of the pollutants found in stormwater runoff. This BMP is frequently referred to as a porous landscape detention (PLD) area or rain garden.

<table>
<thead>
<tr>
<th>Bioretention (Rain Garden)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functions</strong></td>
</tr>
<tr>
<td>LID/Volume Red.</td>
</tr>
<tr>
<td>WQCV Capture</td>
</tr>
<tr>
<td>WQCV+Flood Control</td>
</tr>
<tr>
<td>Fact Sheet Includes EURV Guidance</td>
</tr>
<tr>
<td><strong>Typical Effectiveness for Targeted Pollutants</strong></td>
</tr>
<tr>
<td>Sediment/Solids</td>
</tr>
<tr>
<td>Nutrients</td>
</tr>
<tr>
<td>Total Metals</td>
</tr>
<tr>
<td>Bacteria</td>
</tr>
<tr>
<td><strong>Other Considerations</strong></td>
</tr>
<tr>
<td>Life-cycle Costs</td>
</tr>
</tbody>
</table>

$^1$ Not recommended for watersheds with high sediment yields (unless pretreatment is provided).

$^2$ Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

$^3$ Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).
Site Selection

Bioretention can be provided in a variety of areas within new developments, or as a retrofit within an existing site. This BMP allows the WQCV to be treated within areas designated for landscape (see design step 7 for appropriate vegetation). In this way, it is an excellent alternative to extended detention basins for small sites. A typical rain garden serves a tributary area of one impervious acre or less, although they can be designed for larger tributary areas. Multiple installations can be used within larger sites. Rain gardens should not be used when a baseflow is anticipated. They are typically small and installed in locations such as:

- Parking lot islands
- Street medians
- Landscape areas between the road and a detached walk
- Planter boxes that collect roof drains

Bioretention requires a stable watershed. Retrofit applications are typically successful for this reason. When the watershed includes phased construction, sparsely vegetated areas, or steep slopes in sandy soils, consider another BMP or provide pretreatment before runoff from these areas reaches the rain garden. The surface of the rain garden should be flat. For this reason, rain gardens can be more difficult to incorporate into steeply sloping terrain; however, terraced applications of these facilities have been successful in other parts of the country.

When bioretention (and other BMPs used for infiltration) are located adjacent to buildings or pavement areas, protective measures should be implemented to avoid adverse impacts to these structures. Oversaturated subgrade soil underlying a structure can cause the structure to settle or result in moisture-related problems. Wetting of expansive soils or bedrock can cause swelling, resulting in structural movements. A geotechnical engineer should evaluate the potential impact of the BMP on adjacent structures based on an evaluation of the subgrade soil, groundwater, and bedrock conditions at the site. Additional minimum requirements include:

- In locations where subgrade soils do not allow infiltration, the growing medium should be underlain by an underdrain system.
- Where infiltration can adversely impact adjacent structures, the filter layer should be underlain by an underdrain system designed to divert water away from the structure.
- In locations where potentially expansive soils or bedrock exist, placement of a rain garden adjacent to structures and pavement should only be considered if the BMP includes an underdrain designed to divert water away from the structure and is lined with an essentially impermeable geomembrane liner designed to restrict seepage.

Benefits

- Bioretention uses multiple treatment processes to remove pollutants, including sedimentation, filtering, adsorption, evapotranspiration, and biological uptake of constituents.
- Volumetric stormwater treatment is provided within portions of a site that are already reserved for landscaping.
- There is a potential reduction of irrigation requirements by taking advantage of site runoff.

Limitations

- Additional design and construction steps are required for placement of any ponding or infiltration area near or upgradient from a building foundation and/or when expansive (low to high swell) soils exist. This is discussed in the design procedure section.
- In developing or otherwise erosive watersheds, high sediment loads can clog the facility.
Designing for Maintenance

Recommended maintenance practices for all BMPs are in Chapter 6 of this manual. During design, the following should be considered to ensure ease of maintenance over the long-term:

- Do not put a filter sock on the underdrain. This is not necessary and can cause the BMP to clog.

- The best surface cover for a rain garden is full vegetation. Do not use rock mulch within the rain garden because sediment build-up on rock mulch tends to inhibit infiltration and require frequent cleaning or removal and replacement. Wood mulch handles sediment build-up better than rock mulch; however, wood mulch floats and may clog the overflow depending on the configuration of the outlet, settle unevenly, or be transported downstream. Some municipalities may not allow wood mulch for this reason.

- Consider all potential maintenance requirements such as mowing (if applicable) and replacement of the growing medium. Consider the method and equipment for each task required. For example, in a large rain garden where the use of hand tools is not feasible, does the shape and configuration of the rain garden allow for removal of the growing medium using a backhoe?

- Provide pre-treatment when it will reduce the extent and frequency of maintenance necessary to maintain function over the life of the BMP. For example, if the site is larger than 2 impervious acres, prone to debris or the use of sand for ice control, consider a small forebay.

- Make the rain garden as shallow as possible. Increasing the depth unnecessarily can create erosive side slopes and complicate maintenance. Shallow rain gardens are also more attractive.

- Design and adjust the irrigation system (temporary or permanent) to provide appropriate water for the establishment and maintenance of selected vegetation.

Design Procedure and Criteria

The following steps outline the design procedure and criteria, with Figure B-1 providing a corresponding cross-section.

1. **Basin Storage Volume**: Provide a storage volume based on a 12-hour drain time.
   - Find the required WQCV (watershed inches of runoff). Using the imperviousness of the tributary area (or effective imperviousness where LID elements are used upstream), use Figure 3-2 located in Chapter 3 of this manual to determine the WQCV based on a 12-hour drain time.
   - Calculate the design volume as follows:
     \[ V = \left[ \frac{\text{WQCV}}{12} \right] A \]
     \[ V= \text{design volume (ft}^3) \]

   Where:

   - **V** = design volume (ft³)
2. **Basin Geometry:** A maximum WQCV ponding depth of 12 inches is recommended to maintain vegetation properly. Provide an inlet or other means of overflow at this elevation. Depending on the type of vegetation planted, a greater depth may be utilized to detain larger (more infrequent) events. The bottom surface of the rain garden, also referred to here as the filter area, should be flat. Sediment will reside on the filter area of the rain garden; therefore, if the filter area is too small, it may clog prematurely. Increasing the filter area will reduce clogging and decrease the frequency of maintenance. Equation B-2 provides a minimum filter area allowing for some of the volume to be stored beyond the area of the filter (i.e., above the sideslopes of the rain garden).

**Note that the total surcharge volume provided by the design must also equal or exceed the design volume.** Use vertical walls or slope the sides of the basin to achieve the required volume. Use the rain garden growing medium described in design step 3 only on the filter area because this material is more erosive than typical site soils. Sideslopes should be no steeper than 4:1 (horizontal:vertical).

\[ A \geq \left(\frac{2}{3}\right) \frac{V}{1 \text{ foot}} \]

*Equation B-2*

Where:

- \( V \) = design volume (ft³)
- \( A \) = minimum filter area (flat surface area) (ft²)

The one-foot dimension in this equation represents the maximum recommended WQCV depth in the rain garden. The actual design depth may differ; however, it is still appropriate to use a value of one foot when calculating the minimum filter area.

3. **Growing Medium:** For partial and no infiltration sections, provide a minimum of 18 inches of growing medium to enable establishment of the roots of the vegetation (see Figure B-1). Previous versions of this manual recommended a mix of 85% sand and 15% peat (by volume). Peat is a material that typically requires import to Colorado and mining peat has detrimental impacts to the environment (Mazerolle 2002). UDFCD partnered with the University of Colorado to perform a study to find a sustainable material to replace peat. The study was successful in finding a replacement that performed well for filtering ability, clogging characteristics, as well as seed germination. This mixture consists of 85% coarse sand and a 15% compost/shredded paper mixture (by volume). The study used thin (approximately 1/4 inch) strips of loosely packed shredded paper mixed with an equal volume of compost. Based on conversations with local suppliers, compost

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**Benefits of Shredded Paper in Rain Garden Growing Media**

- Shredded paper, similar to other woody materials, captures nutrients from the compost and slowly releases them as the paper decomposes. Compost alone will leach more nutrients than desired.
- As the paper decomposes, nutrients stored in the material are available to the vegetation.
- Paper temporarily slows the infiltration rate of the media and retains moisture, providing additional time for a young root system to benefit from moisture in the growing media.
containing shredded paper is not an uncommon request, although not typically provided in the proportions recommended in this BMP Fact Sheet. Compost suppliers have access to shredded paper through document destruction companies and can provide a mixture of Class 1 compost and shredded paper. The supplier should provide the rain garden compost mixture premixed with coarse sand. On-site mixing is not recommended.

Rain Garden Compost Mixture (by volume)

- 50% Class 1 STA registered compost (approximate bulk density 1000 lbs/CY)
- 50% loosely packed shredded paper (approximate bulk density 50 to 100 lbs/CY)

When using diamond cut shredded paper or tightly packed paper, use the bulk densities provided to mix by weight.

Rain Garden Growing Medium

The supplier should premix the rain garden compost mixture (above) with coarse sand, in the following proportions, prior to delivery to the site:

- 15% rain garden compost mixture described above (by volume)
- 85% coarse sand (either Class C Filter Material per Table B-2 or sand meeting ASTM C-33) (by volume)

Table B-1 provides detailed information on Class 1 compost. Be aware, regular testing is not required to allow a compost supplier to refer to a product as a specific STA class. However, regular testing is required and performed through the United States Compost Council (USCC) Seal of Testing Assurance (STA) Program to be a STA registered compost. To ensure Class 1 characteristics, look for a Class 1 STA registered compost.

Other Rain Garden Growing Medium Amendments

The growing medium described above is designed for filtration ability, clogging characteristics, and vegetative health. It is important to preserve the function provided by the rain garden growing medium when considering additional materials for incorporation into the growing medium or into the standard section shown in Figure B-1. When desired, amendments may be included to improve water quality or to benefit vegetative health as long as they do not add nutrients, pollutants, or modify the infiltration rate. For example, a number of products, including steel wool, capture and retain dissolved phosphorus (Erickson 2009). When phosphorus is a target pollutant, proprietary materials with similar characteristics may be considered. Do not include amendments such as top soil, sandy loam, and additional compost.

Full Infiltration Sections

A full infiltration section retains the WQCV onsite. For this section, it is not necessary to use the prescribed rain garden growing medium. Amend the soils to provide adequate nutrients to establish vegetation. Typically, 3 to 5 cubic yards of soil amendment (compost) per 1,000 square feet, tilled 6 inches into the soil, is required for vegetation to thrive. Additionally, inexpensive soil tests can be conducted to determine required soil amendments. (Some local governments may also require proof of soil amendment in landscaped areas for water conservation reasons.)
# Table B-1. Class 1 Compost

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Stability Indicator (Respirometry)</td>
<td>Stable to Very Stable</td>
</tr>
<tr>
<td>Maturity Indicator Expressed as Ammonia N / Nitrate N Ratio</td>
<td>&lt; 4</td>
</tr>
<tr>
<td>Maturity Indicator Expressed as Carbon to Nitrogen Ratio</td>
<td>&lt; 12</td>
</tr>
<tr>
<td>Maturity Indicator Expressed as Percentage of Germination/Vigor</td>
<td>80+ / 80+</td>
</tr>
<tr>
<td>pH – Acceptable Range</td>
<td>6.0 – 8.4</td>
</tr>
<tr>
<td>Soluble Salts – Acceptable Range (1:5 by weight)</td>
<td>0 – 5 mmhos/cm</td>
</tr>
<tr>
<td>Testing and Test Report Submittal Requirement</td>
<td>Seal of Testing Assurance (STA)/Test Methods for the Examination of Composting and Compost (TMECC)</td>
</tr>
<tr>
<td>Chemical Contaminants</td>
<td>Equal or better than US EPA Class A Standard, 40 CFR 503.13, Tables 1 &amp; 3 levels</td>
</tr>
<tr>
<td>Pathogens</td>
<td>Meet or exceed US EPA Class A standard, 40 CFR 503.32(a) levels</td>
</tr>
</tbody>
</table>
4. **Underdrain System**: Underdrains are often necessary and should be provided if infiltration tests show percolation drawdown rates slower than 2 times the rate needed to drain the WQCV over 12 hours, or where required to divert water away from structures as determined by a professional engineer. Percolation tests should be performed or supervised by a licensed professional engineer and conducted at a minimum depth equal to the bottom of the bioretention facility. Additionally, underdrains are required where impermeable membranes are used. Similar to the terminology used for permeable pavement sections, there are three basic sections for bioretention facilities:

- **No-Infiltration Section**: This section includes an underdrain and an impermeable liner that does not allow for any infiltration of stormwater into the subgrade soils. It is appropriate to use a no-infiltration system when either of the following is true:
  - Land use or activities could contaminate groundwater when stormwater is allowed to infiltrate, or
  - The BMP is located over potentially expansive soils or bedrock and is adjacent (within 10 feet) to structures.

- **Partial Infiltration Section**: This section does not include an impermeable liner and, therefore, allows for some infiltration. Stormwater that does not infiltrate will be collected and removed by an underdrain system.

- **Full Infiltration Section**: This section is designed to infiltrate all of the water stored into the subgrade below. Overflows are managed via perimeter drainage to a downstream conveyance element. UDFCD recommends a minimum infiltration rate of 2 times the rate needed to drain the WQCV over 12 hours.

When using an underdrain system, provide a control orifice sized to drain the design volume in 12 hours or more (see Equation B-3). Use a minimum orifice size of 3/8 inch to avoid clogging. This will provide detention and slow release of the WQCV, providing water quality benefits and reducing impacts to downstream channels. Space underdrain pipes a maximum of 20 feet on center. Provide cleanouts to enable maintenance of the underdrain. Cleanouts can also be used to conduct an inspection (by camera) of the underdrain system to

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**Important Design Considerations**

The potential for impacts to adjacent buildings can be significantly reduced by locating the bioretention area at least 10 feet away from the building, beyond the limits of backfill placed against the building foundation walls, and by providing positive surface drainage away from the building.

The BMP should not restrict surface water from flowing away from the buildings. This can occur if the top of the perimeter wall for the BMP impedes flow away from the building.

**Always adhere to the slope recommendations provided in the geotechnical report.** In the absence of a geotechnical report, the following general recommendations should be followed for the first 10 feet from a building foundation.

1) Where feasible, provide a slope of 10% for a distance of 10 feet away from a building foundation.

2) In locations where non-expansive soil or bedrock conditions exist, the slope for the surface within 10 feet of the building should be at least 5% away from the building for unpaved (landscaped) surfaces.

3) In locations where potentially expansive soil or bedrock conditions exist, the design slope should be at least 10% away from the building for unpaved (landscaped) surfaces.

4) For paved surfaces, a slope of at least 2% away from the building is adequate. Where accessibility requirements or other design constraints do not apply, use an increased minimum design slope for paved areas (2.5% where non-expansive soil or bedrock conditions exist).
Ensure that the pipe was not crushed or disconnected during construction.

Calculate the diameter of the orifice for a 12-hour drain time using Equation B-3 (Use a minimum orifice size of 3/8 inch to avoid clogging):

\[ D_{12\text{ hour drain time}} = \sqrt[3]{\frac{V}{1414 y^{0.41}}} \]  

Equation B-3

Where:

- \( D \) = orifice diameter (in)
- \( y \) = distance from the lowest elevation of the storage volume (i.e., surface of the filter) to the center of the orifice (ft)
- \( V \) = volume (WQCV or the portion of the WQCV in the rain garden) to drain in 12 hours (ft³)

In previous versions of this manual, UDFCD recommended that the underdrain be placed in an aggregate layer and that a geotextile (separator fabric) be placed between this aggregate and the growing medium. This version of the manual replaces that section with materials that, when used together, eliminate the need for a separator fabric.

The underdrain system should be placed within an 6-inch-thick section of CDOT Class C filter material meeting the gradation in Table B-2. Use slotted pipe that meets the slot dimensions provided in Table B-3.

**Table B-2. Gradation Specifications for CDOT Class C Filter Material**
(Source: CDOT Table 703-7)

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Mass Percent Passing Square Mesh Sieves</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0 mm (3/4”)</td>
<td>100</td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td>60 - 100</td>
</tr>
<tr>
<td>300 µm (No. 50)</td>
<td>10 - 30</td>
</tr>
<tr>
<td>150 µm (No. 100)</td>
<td>0 - 10</td>
</tr>
<tr>
<td>75 µm (No. 200)</td>
<td>0 - 3</td>
</tr>
</tbody>
</table>
Table B-3. Dimensions for Slotted Pipe

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Slot Length¹</th>
<th>Maximum Slot Width</th>
<th>Slot Centers¹</th>
<th>Open Area¹ (per foot)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4”</td>
<td>1-1/16”</td>
<td>0.032”</td>
<td>0.413”</td>
<td>1.90 in²</td>
</tr>
<tr>
<td>6”</td>
<td>1-3/8”</td>
<td>0.032”</td>
<td>0.516”</td>
<td>1.98 in²</td>
</tr>
</tbody>
</table>

¹ Some variation in these values is acceptable and is expected from various pipe manufacturers. Be aware that both increased slot length and decreased slot centers will be beneficial to hydraulics but detrimental to the structure of the pipe.

5. **Impermeable Geomembrane Liner and Geotextile Separator Fabric:** For no-infiltration sections, install a 30 mil (minimum) PVC geomembrane liner, per Table B-5, on the bottom and sides of the basin, extending up at least to the top of the underdrain layer. Provide at least 9 inches (12 inches if possible) of cover over the membrane where it is attached to the wall to protect the membrane from UV deterioration. The geomembrane should be field-seamed using a dual track welder, which allows for non-destructive testing of almost all field seams. A small amount of single track and/or adhesive seaming should be allowed in limited areas to seam around pipe perforations, to patch seams removed for destructive seam testing, and for limited repairs. The liner should be installed with slack to prevent tearing due to backfill, compaction, and settling. Place CDOT Class B geotextile separator fabric above the geomembrane to protect it from being punctured during the placement of the filter material above the liner. If the subgrade contains angular rocks or other material that could puncture the geomembrane, smooth-roll the surface to create a suitable surface. If smooth-rolling the surface does not provide a suitable surface, also place the separator fabric between the geomembrane and the underlying subgrade. This should only be done when necessary because fabric placed under the geomembrane can increase seepage losses through pinholes or other geomembrane defects. Connect the geomembrane to perimeter concrete walls around the basin perimeter, creating a watertight seal between the geomembrane and the walls using a continuous batten bar and anchor connection (see Figure B-3). Where the need for the impermeable membrane is not as critical, the membrane can be attached with a nitrile-based vinyl adhesive. Use watertight PVC boots for underdrain pipe penetrations through the liner (see Figure B-2).
### Table B-4. Physical Requirements for Separator Fabric

<table>
<thead>
<tr>
<th>Property</th>
<th>Class B</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elongation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; 50%&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Grab Strength, N (lbs)</td>
<td>800 (180)</td>
<td>ASTM D 4632</td>
</tr>
<tr>
<td>Puncture Resistance, N (lbs)</td>
<td>310 (70)</td>
<td>ASTM D 4833</td>
</tr>
<tr>
<td>Trapezoidal Tear Strength, N (lbs)</td>
<td>310 (70)</td>
<td>ASTM D 4533</td>
</tr>
<tr>
<td>Apparent Opening Size, mm (US Sieve Size)</td>
<td>AOS &lt; 0.3mm (US Sieve Size No. 50)</td>
<td>ASTM D 4751</td>
</tr>
<tr>
<td>Permittivity, sec&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>0.02 default value, must also be greater than that of soil</td>
<td>ASTM D 4491</td>
</tr>
<tr>
<td>Permeability, cm/sec</td>
<td>k fabric &gt; k soil for all classes</td>
<td>ASTM D 4491</td>
</tr>
<tr>
<td>Ultraviolet Degradation at 500 hours</td>
<td>50% strength retained for all classes</td>
<td>ASTM D 4355</td>
</tr>
</tbody>
</table>

<sup>1</sup> Strength values are in the weaker principle direction

<sup>2</sup> As measured in accordance with ASTM D 4632

### Table B-5. Physical Requirements for Geomembrane

<table>
<thead>
<tr>
<th>Property</th>
<th>Thickness 0.76 mm (30 mil)</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness, % Tolerance</td>
<td>±5</td>
<td>ASTM D 1593</td>
</tr>
<tr>
<td>Tensile Strength, kN/m (lbs/in) width</td>
<td>12.25 (70)</td>
<td>ASTM D 882, Method B</td>
</tr>
<tr>
<td>Modulus at 100% Elongation, kN/m (lbs/in)</td>
<td>5.25 (30)</td>
<td>ASTM D 882, Method B</td>
</tr>
<tr>
<td>Ultimate Elongation, %</td>
<td>350</td>
<td>ASTM D 882, Method A</td>
</tr>
<tr>
<td>Tear Resistance, N (lbs)</td>
<td>38 (8.5)</td>
<td>ASTM D 1004</td>
</tr>
<tr>
<td>Low Temperature Impact, °C (°F)</td>
<td>-29 (-20)</td>
<td>ASTM D 1790</td>
</tr>
<tr>
<td>Volatile loss, % max.</td>
<td>0.7</td>
<td>ASTM D 1203, Method A</td>
</tr>
<tr>
<td>Pinholes, No. Per 8 m&lt;sup&gt;2&lt;/sup&gt; (No. per 10 sq. yds.) max.</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>Bonded Seam Strength, % of tensile strength</td>
<td>80</td>
<td>N/A</td>
</tr>
</tbody>
</table>
6. **Inlet/Outlet Control:** In order to provide the proper drain time, the bioretention area can be designed without an underdrain (provided it meets the requirements in step 4) or the outlet can be controlled by an orifice plate. Equation B-3 is a simplified equation for sizing an orifice plate for a 12-hour drain time.

7. How flow enters and exits the BMP is a function of the overall drainage concept for the site. Inlets at each rain garden may or may not be needed. Curb cuts can be designed to both allow stormwater into the rain garden as well as to provide release of stormwater in excess of the WQCV. Roadside rain gardens located on a steep site might pool and overflow into downstream cells with a single curb cut, level spreader, or outlet structure located at the most downstream cell. When selecting the type and location of the outlet structure, ensure that the runoff will not short-circuit the rain garden. This is a frequent problem when using a curb inlet located outside the rain garden for overflow.

For rain gardens with concentrated points of inflow, provide for energy dissipation. When rock is used, provide separator fabric between the rock and growing medium to minimize subsidence.

8. **Vegetation:** UDFCD recommends that the filter area be vegetated with drought tolerant species that thrive in sandy soils. Table B-6 provides a suggested seed mix for sites that will not need to be irrigated after the grass has been established.

All seed must be well mixed and broadcast, followed by hand raking to cover seed and then mulched. Hydromulching can be effective for large areas. Do not place seed when standing water or snow is present or if the ground is frozen. Weed control is critical in the first two to three years, especially when starting with seed.

Do not use conventional sod. Conventional sod is grown in clay soil that will seal the filter area, greatly reducing overall function of the BMP. Several successful local installations have started with seed.

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**Designing for Flood Protection**

Provide the WQCV in rain gardens that direct excess flow into to a landscaped area providing the flood control volume. Design the flood control outlet to meter the major event (100-year event) and slowly release the difference in volume between the EURV and the WQCV. (This assumes that the runoff treated by the rain gardens is routed directly into the outlet or infiltrates.) Providing treatment in this manner will reduce inundation in the landscaped area to a few times per year, resulting in an area better suited for multipurpose uses.
When using an impermeable liner, select plants with diffuse (or fibrous) root systems, not taproots. Taproots can damage the liner and/or underdrain pipe. Avoid trees and large shrubs that may interfere with restorative maintenance. Trees and shrubs can be planted outside of the area of growing medium. Use a cutoff wall to ensure that roots do not grow into the underdrain or place trees and shrubs a conservative distance from the underdrain.

9. **Irrigation:** Provide spray irrigation at or above the WQCV elevation or place temporary irrigation on top of the rain garden surface. Do not place sprinkler heads on the flat surface. Remove temporary irrigation when vegetation is established. If left in place this will become buried over time and will be damaged during maintenance operations.

Irrigation schedules should be adjusted during the growing season to provide the minimum water necessary to maintain plant health and to maintain the available pore space for infiltration.
Table B-6. Native Seed Mix for Rain Gardens

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Variety</th>
<th>PLS* lbs per Acre</th>
<th>Ounces per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand bluestem</td>
<td>Andropogon hallii</td>
<td>Garden</td>
<td>3.5</td>
<td></td>
</tr>
<tr>
<td>Sideoats grama</td>
<td>Bouteloua curtipendula</td>
<td>Butte</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Prairie sandreed</td>
<td>Calamovilfa longifolia</td>
<td>Goshen</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Indian ricegrass</td>
<td>Oryzopsis hymenoides</td>
<td>Paloma</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Switchgrass</td>
<td>Panicum virgatum</td>
<td>Blackwell</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Western wheatgrass</td>
<td>Pascopyrum smithii</td>
<td>Ariba</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Little bluestem</td>
<td>Schizachyrium scoparium</td>
<td>Patura</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Alkali sacaton</td>
<td>Sporobolus airoides</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Sand dropseed</td>
<td>Sporobolus cryptandrus</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Pasture sage</td>
<td>Artemisia frigida</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Blue aster</td>
<td>Aster laevis</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Blanket flower</td>
<td>Gaillardia aristata</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Prairie coneflower</td>
<td>Ratibida columnifera</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Purple prairieclover</td>
<td>Dalea (Petalostemum) purpurea</td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sub-Totals:</td>
<td></td>
<td></td>
<td>27.5</td>
<td>22</td>
</tr>
<tr>
<td><strong>Total lbs per acre:</strong></td>
<td></td>
<td></td>
<td><strong>28.9</strong></td>
<td></td>
</tr>
</tbody>
</table>

* Wildflower seed (optional) for a more diverse and natural look.
* PLS = Pure Live Seed.
Aesthetic Design

In addition to providing effective stormwater quality treatment, rain gardens can be attractively incorporated into a site within one or several landscape areas. Aesthetically designed rain gardens will typically either reflect the character of their surroundings or become distinct features within their surroundings. Guidelines for each approach are provided below.

Reflecting the Surrounding

- Determine design characteristics of the surrounding. This becomes the context for the drainage improvement. Use these characteristics in the structure.

- Create a shape or shapes that "fix" the forms surrounding the improvement. Make the improvement part of the existing surrounding.

- The use of material is essential in making any new improvement an integral part of the whole. Select materials that are as similar as possible to the surrounding architectural/engineering materials. Select materials from the same source if possible. Apply materials in the same quantity, manner, and method as original material.

- Size is an important feature in seamlessly blending the addition into its context. If possible, the overall size of the improvement should look very similar to the overall sizes of other similar objects in the improvement area.

- The use of the word texture in terms of the structure applies predominantly to the selection of plant material. The materials used should as closely as possible, blend with the size and texture of other plant material used in the surrounding. The plants may or may not be the same, but should create a similar feel, either individually or as a mass.

Creating a Distinct Feature

Designing the rain garden as a distinct feature is limited only by budget, functionality, and client preference. There is far more latitude in designing a rain garden that serves as a distinct feature. If this is the intent, the main consideration beyond functionality is that the improvement create an attractive addition to its surroundings. The use of form, materials, color, and so forth focuses on the improvement itself and does not necessarily reflect the surroundings, depending on the choice of the client or designer.
Figure B-1 – Typical Rain Garden Plan and Sections
NO-INfiltration Sections
**T-3 Bioretention**

**SECTION C**

- HEADWALL OR FLARED END SECTION
- TYPE VL OR L RIPRAP
- GEOTEXTILE SEPARATOR FABRIC
- RAIN GARDEN GROWING MEDIA
- CLOTH CLASS C FILTER MATERIAL (FOR UNDERGRAIN)

**SECTION D**

- WQCW WSE
- VEGETATED FILTER AREA
- ORIFICE PLATE TO DRAIN WQCW OVER 12 HOURS
- ADDITIONAL DETENTION VOLUME (OPTIONAL)
- GRATED INLET
- ADDITIONAL DETENTION ORIFICE (OPTIONAL)
- 4" SLOTTED PIPE PER TABLE B-3, SLOPE TO OUTLET

**SECTION E**

1. SLOPE (STRAIGHT GRADE) SUBGRADE (2-10%) TO UNDERGRAIN TO REDUCE SATURATED SOIL CONDITIONS BETWEEN STORM EVENTS (OPTIONAL)
Figure B-2. Geomembrane Liner/Underdrain Penetration Detail

Figure B-3. Geomembrane Liner/Concrete Connection Detail

3/8" x 3" STAINLESS STEEL ANCHOR BOLT, NUT & WASHER Ø 1/2" O.C.

TEMPORARILY ATTACH FABRIC TO WALL DURING BACKFILL PROCESS (DO NOT WRAP AROUND BATTEN BAR)

30 MIL (MIN.) PVC LINER

CONCRETE PERIMETER BARRIER

NOTE:
BACKFILL NOT SHOWN

NOTE:
BACKFILL AND UNDERDRAIN SYSTEM NOT SHOWN

NOTE:
PREPARED SUBGRADE

GEO textile separator fabric
(IF SUBGRADE CONTAINS ANGULAR ROCKS OR OTHER MATERIAL THAT COULD PUNCTURE THE LINER)

GEO textile separator fabric

PROVIDE SLACK IN LINER PLACEMENT TO ENSURE PROPER INSTALLATION AND BACKFILL WITHOUT DAMAGE.

NITRILE POLYMER BASED VINYL MEMBRANE SEAMING ADHESIVE MAY BE USED AS AN ALTERNATIVE TO THE BOLTED BATTEN BAR IN AREAS WHERE THE NEED FOR AN IMPERMEABLE LINER IS LESS CRITICAL.
Construction Considerations

Proper construction of rain gardens involves careful attention to material specifications, final grades, and construction details. For a successful project, implement the following practices:

- Protect area from excessive sediment loading during construction. This is the most common cause of clogging of rain gardens. The portion of the site draining to the rain garden must be stabilized before allowing flow into the rain garden. This includes completion of paving operations.

- Avoid over compaction of the area to preserve infiltration rates (for partial and full infiltration sections).

- Provide construction observation to ensure compliance with design specifications. Improper installation, particularly related to facility dimensions and elevations and underdrain elevations, is a common problem with rain gardens.

- When using an impermeable liner, ensure enough slack in the liner to allow for backfill, compaction, and settling without tearing the liner.

- Provide necessary quality assurance and quality control (QA/QC) when constructing an impermeable geomembrane liner system, including but not limited to fabrication testing, destructive and non-destructive testing of field seams, observation of geomembrane material for tears or other defects, and air lace testing for leaks in all field seams and penetrations. QA/QC should be overseen by a professional engineer. Consider requiring field reports or other documentation from the engineer.

- Provide adequate construction staking to ensure that the site properly drains into the facility, particularly with respect to surface drainage away from adjacent buildings. Photo B-3 and Photo B-4 illustrate a construction error for an otherwise correctly designed series of rain gardens.
Construction Example

Photograph B-5. Rain garden is staked out at the low point of the parking area prior to excavation.

Photograph B-6. Curb and gutter is installed. Flush curbs with wheel stops or a slotted curb could have been used in lieu of the solid raised curb with concentrated inflow.
Photograph B-7. The aggregate layer is covered with a geotextile and growing media. This photo shows installation of the geotextile to separate the growing media from the aggregate layer below. Cleanouts for the underdrain system are also shown. Note: The current design section does not require this geotextile.

Photograph B-8. Shrubs and trees are placed outside of the ponding area and away from geotextiles.

Photograph B-9. This photo was taken during the first growing season of this rain garden. Better weed control in the first two to three years will help the desired vegetation to become established.
Design Example

The UD-BMP workbook, designed as a tool for both designer and reviewing agency is available at www.udfcd.org. This section provides a completed design form from this workbook as an example.
### Basin Storage Volume

1. **Effective Imperviousness of Tributary Area, \( I_a \)**
   
   \[ I_a = 95.0\% \]

2. **Tributary Area's Imperviousness Ratio \( i = I_a / 100 \)**
   
   \[ i = 0.950 \]

3. **Water Quality Capture Volume (WQCV) for a 12-hour Drain Time**
   
   \[ \text{WQCV} = \frac{0.36}{\text{watershed inches}} \]

4. **Contributing Watershed Area (including rain garden area)**
   
   \[ \text{Area} = 32,000 \text{ sq ft} \]

5. **Water Quality Capture Volume (WQCV) Design Volume**
   
   \[ V_{WQCV} = 954 \text{ cu ft} \]

6. **User Input of Water Quality Capture Volume (WQCV) Design Volume**
   
   \[ V_{WQCV\text{ USER}} = \text{cu ft} \]

### Basin Geometry

1. **WQCV Depth (12-inch maximum)**
   
   \[ D_{WQCV} = 12 \text{ in} \]

2. **Rain Garden Side Slopes \( Z = 4\text{ min. horiz. dist per unit vertical} \)**
   
   \[ Z = 0.00 \text{ ft/ft} \]

3. **Minimum Flat Surface Area**
   
   \[ A_{MIN} = 636 \text{ sq ft} \]

4. **Actual Flat Surface Area**
   
   \[ A_{ACTUAL} = 955 \text{ sq ft} \]

5. **Area at Design Depth (Top Surface Area)**
   
   \[ A_{TOP} = 955 \text{ sq ft} \]

6. **Rain Garden Total Volume**
   
   \[ V_T = \frac{(A_{TOP} + A_{ACTUAL})}{2} \times \text{Depth} \]

### Growing Media

**Choose One**

- **18" Rain Garden Growing Media**
- **Other (Explain):**

### Underdrain System

1. **Are underdrains provided?**
   
   \[ \text{Choose One:} \]
   - YES
   - NO

2. **Underdrain system orifice diameter for 12 hour drain time**
   
   \[ y = 2.7 \text{ ft} \]

   \[ V_{ORI} = 954 \text{ cu ft} \]

   \[ D_O = 0.67 \text{ in} \]
5. Impermeable Geomembrane Liner and Geotextile Separator Fabric
   A) Is an impermeable liner provided due to proximity of structures or groundwater contamination?
   [Choose One]

6. Inlet / Outlet Control
   A) Inlet Control
   [Choose One]

7. Vegetation
   [Choose One]

8. Irrigation
   A) Will the rain garden be irrigated?
   [Choose One]

Notes:

References

