Chapter 7.2 - Bioretention Filters

A bioretention cell is a type of underdrained soil filter that collects, filters, and treats moderate amounts of stormwater runoff using conditioned planting soil beds, gravel underdrained beds, and vegetation within shallow depressions. The filter basin captures and retains runoff and passes it through a soil filter media that contains a mixture of silty sand and organic matter to remove a wide range of pollutants, including suspended solids, phosphorus, nitrogen, metals, hydrocarbons, and some dissolved pollutants. Once through the soil media, the runoff is collected in a perforated underdrain pipe system and discharged downstream. Bioretention basins are usually located in close proximity to the origin of the stormwater runoff and should be scattered throughout a residential area or along the downhill edge of smaller parking areas with a maximum drainage area of 0.75 to 1.0 acre to each individual filter.

The major difference between an underdrained grassed soil filter and a bioretention cell is the vegetation. A typical grassed underdrained soil filter may be planted with grass, whereas a bioretention cell is planted with a variety of shrubs and perennials whose roots assist with the passing of water and uptake of pollutants.

Basin Siting: The following criteria apply to all bioretention filters:

- *Drainage Area:* Size of the underdrained soil filter and storage capacity over the filter is based on the land use composition of the area draining into the structure. Upgradient areas not intended to be treated should be directed around the filter basin.
- *Subsurface Investigation:* Subsurface explorations (test pits or borings) should be made within the basin area to identify depths to seasonal high groundwater and bedrock. Explorations should extend to below the proposed basin bottom elevation.
- *Separation from Seasonal High Watertable:* The bottom of the underdrained soil filter should be at a minimum one (1) foot above the seasonal high groundwater table, unless an impermeable liner (not clay) or other design elements are employed.
- *Separation from Bedrock:* The bedrock surface may be no closer than 1 foot from the bottom of the basin, unless an impermeable liner (not clay) or other design elements are employed.
- *Permeable Soils:* Vegetated soil filters can be designed to infiltrate water into the groundwater below. In soil group A and B, an underdrained filter basin should be designed as an infiltration basin provided that the design and siting criteria for infiltration can be met. Otherwise, an impermeable liner (not clay) may be required if the basin does not have 3 feet of undisturbed overburden soil over the seasonal high water table. The bioretention basin will not need a liner and will not need to be designed as an infiltration system if it receives stormwater from a developed area that:
  - Contains less than one acre of imperious area.
  - Consists only of roof.
  - Is a single family residential subdivision, or
  - Is not a facility that has a high turnover parking, that stocks hazardous products or that provides industrial or vehicle services and maintenance.

Basin Plan: When used to meet Chapter 500 Phosphorus Standard, underdrain filter structures need to be sized in accordance with Volume II of this BMP manual.

- *Treatment Volume:* An underdrained soil filter must detain and filter a runoff volume equal to 1.0 inch times the subcatchment's impervious area plus 0.4 inch times the subcatchment's landscaped developed area. Other upgradient areas should be directed away from the filter basin.
- *Storage:* Storage within the bioretention cell is provided with a 6-inch pooling depth and 6 inches of storage within the filter (1/3 of the volume of 18 inches of filter media).
- *Filter Area*: The surface area of the filter must be no less than 7% from the impervious area and 3% from the landscaped area draining to the filter.
- *Basin Size:* The size of a bioretention bed should not exceed 2000 sq. ft. in basin bottom area or have more than one acre of subwatershed draining to the structure. Larger sizes are difficult to construct and maintain.
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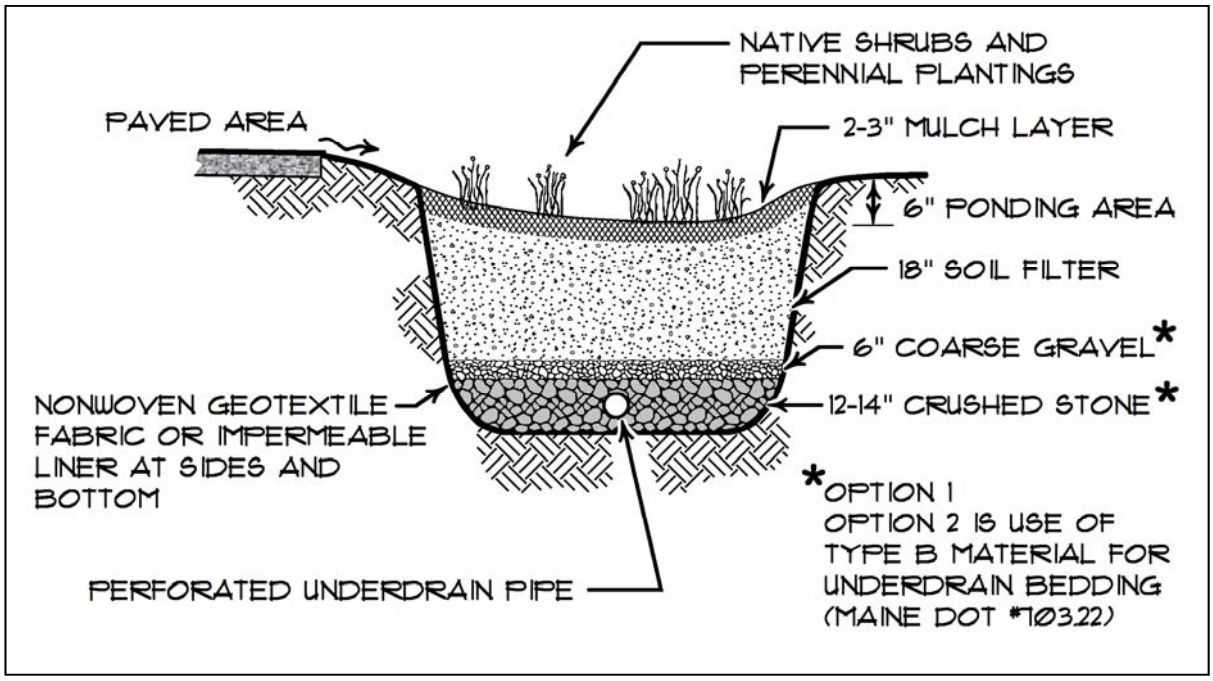

Figure 7.2.1 – Bioretention Filter Cell

- *Drain Time:* A filter basin must drain dry within 24 and 48 hours.
- *Impoundment Depth*: The peak water quality storage depth should not exceed 6 inches over a bioretention basin filter. Due to the deeper root zones of the plants and increased evapotranspiration potential, one third of the soil filter volume (6 inches) may be included as storage volume when designing bioretention cells. Plants that can sustain frequent draught and inundation should be selected. Storage over the treatment volume to control peak flows for the flooding standards cannot be provided because of potential damage to the vegetation; and an independent structure must be provided. The overflow outlet can be no more than 6 inches above the filter surface.
- *Pretreatment:* Pretreatment devices such as a grassed swale, grass or meadow filter strip and sediment trap should be provided to minimize the discharge of sediment to the bioretention filter basin. Pretreatment structures should be sized to hold an annual sediment load calculated using a sand application rate of 50 cubic feet per acre per year for sanding of the pavement surface within the basin's subcatchment area.
- *Access:* Where needed, a maintenance access should be provided and maintained that is at least 10 feet wide with a maximum slope of 15% and a maximum cross slope of 3%. This access should never cross the emergency spillway, unless the spillway has been designed for that purpose. An easement for long-term access may be needed.
- *Rock Forebay:* A rock forebay is recommended to reduce flow velocity into the basin. All sediment should be removed after construction and the upgradient tributary area is fully stabilized.
- *Plant Species:* The soil filter surface should be planted with plants that are tolerant of well drained soils and frequent inundation. Native plants should be chosen for their tolerance to urban runoff, moisture fluctuation, pollutant loading, light amount, temperature and ph. Based upon the expected full grown size of the plant, the plants' spacing should be no more than 18 inches to 3 feet on center. A landscape designer or architect should be involved to select the appropriate plants for site conditions. Beware of invasives. Full plant cover should be achieved within the first year from construction.
- *Mulch:* Upon planting, the soil filter should be mulched with 2-3 inches of cover. Acceptable mulch is a well-aged, uniform in color, and free of foreign material including plant root material.

Outlet: The channel protection volume must be discharged solely through a network of underdrain pipe having a single outlet with a diameter that is no greater than eight inches. A manually adjustable valve may be installed to control the outflow rate from the underdrain pipe to obtain the required 24 to 48 hour release time.

- *Discharge Elevation*: The overflow from the basin must be placed no more than 6 inches above the filter media to prevent over-inundation of the plantings.
- *Downgradient Discharge Area:* Each underdrain system must discharge to an area capable of withstanding concentrated flows and saturated conditions without eroding.
- *Underdrain Pipe:* A proper layout of the pipe underdrain system is necessary to effectively drain the entire filter area. The pipes should be placed no further apart than 15 feet and should have a positive gradient. The underdrain piping should be 4" to 6" slotted, rigid schedule 40 PVC or SDR35. Structure joints should be sealed and watertight.
- *Outlet Discharge*: Outflow of the filter basin underdrain can be controlled by a constrictive orifice or a valve (2" plastic ball valve, type 346, with a ball valve handle extension, type 615, with a three-piece valve box installed over the valve). Upon completion of the installation of the soil filter media and the establishment of 90% of grass cover over the filter media, the contractor should flood the vegetated basin to the design elevation with clean water and adjust the outflow to obtain a 24 to 48 hours release time.

Pipe Bedding: The perforated underdrain pipe(s) must be bedded in 12 inches of underdrain material with at least 4 inches of material beneath the pipe and 4 inches above. Two options for pipe bedding are provided below (Option 1 is preferred):

- *OPTION 1 - Drainage Layer*: The underdrain material consists of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain Type B for Underdrain Backfill (See Table 7.2.1). The material must contain less than 5% fines passing the #200 sieve. No transition zone is necessary since the drainage pipe is bedded in less pervious gravel and this design is acceptable for areas where the head or depth to seasonal high groundwater is close to the bottom of the drainage layer.
- *OPTION 2 – Drainage Layer with Transition Layer:* The underdrain material consists of 12 inches of crushed stone meeting the MEDOT specification 703.22 Underdrain Type C for Underdrain Backfill Material (Table 7.2.1). As a transition zone, a 6 inch layer of well graded, clean, coarse gravel meeting the MEDOT specification 703.22 Underdrain Type B for Underdrain Backfill (Table 7.2.1) is needed above the bedding. The amount of fines passing the #200 sieve in the gravel should be preferably less than 5%.

Table 7.2.1 - Maine DOT Specifications for Underdrains (MEDOT #703.22)

Sieve #	% by Weight
UNDERDRAIN - TYPE B	
1"	90-100
½"	75-100
#4	50-100
#20	15-80
#50	0-15
#200	0-5
UNDERDRAIN - TYPE C	
1"	100
¾"	90-100
3/8"	0-75
#4	0-25
#10	0-5

Soil Filter Bed: The soil filter over the gravel underdrain pipe bedding must be at least 18 inches deep and must extend across the entire filter area. This soil mixture should be a uniform mix, free of stones, stumps, roots, or other similar objects larger than two inches. No materials or substances that may be harmful to plant growth can be mixed within the filter. Most organic sources other than agricultural may be acceptable for the organic component of the media. Two options are provided for the treatment portion of the basin.

- *OPTION 1- Soil Filter Media:* Soil media consists of a silty sand soil or soil mixture combined with 20% to 25% by volume (no less than 10% by dry weight) of a moderately fine shredded bark or wood fiber mulch. The resulting mixture should have more than 8% passing the 200 sieve and a clay content of less than 2%. *As an example, the mixture may contain the following (by volume):*
  - *50% of sand (MEDOT #703.01 is close but contains insufficient fine for the media)*
  - *20% of sandy loam to fine sandy loam (Table 7.1.2).*
  - *30 % of composted woody fibers and fine shredded bark, superhumus or equivalent (adjusted for mineral soil content)*

- *OPTION 2 – Layered System with Topsoil:* A filter media mixed from different sources may lack nutrients, may be unable to retain moisture (because of its coarseness), and may be devoid of micro-organisms (such as fungus, bacteria and nematodes) which are found in a natural soil and which benefit the germination and establishment of vegetation. Natural soils contain these important organisms and provide superior filtration. Option 2 provides for a layered system that takes advantage of the characteristics of natural soils. The different layers from the bottom up are:
  - *Optional Hay Layer:* A layer of hay can be placed to separate the drainage layer from the filter layer above to prevent subsidence or plugging of the sand/gravel/stone layer and/or pipe.
  - *Filter Layer:* A 12 inches layer of loamy coarse sand which is loosely installed and meets the grain size specifications as provided. See Table 7.2.3.
  - *Topsoil:* The surface of the basin should be covered with 6 inches of non-clayey, loamy topsoil such as USDA loamy sand topsoil with 5-8% humified organic matter and meeting the specifications as provided. Topsoil from the development site may be appropriate but should be tested for organic content and clay content (hydrometer test). The soil must be screened, loose, friable, and shall be free from admixtures of subsoil, refuse, stones (greater than 2 inches in diameter), clogs, root and other undesirable foreign matter. The topsoil should be gently mixed within the filter layer to provide continuity for deep root penetration. The teeth of a backhoe, a hand rake, a shovel or rototilling 2-3 inches may be used to create a loosened transition.

Table 7.2.2 - Sandy Loam to Fine Sandy Loam Specifications

Sieve #	% by Weight
4	75-95
10	60-90
40	35-85
200	20-70
200 (clay size)	< 2.0

Table 7.2.3 - Loamy Coarse Sand Specifications

Sieve #	% by Weight
10	85-100
20	70-100
60	15-40
200	8-15
200 (clay size)	<2.0

- *Clay Content:* The media mixture should have very little or no clay content as tested via hydrometer test. Soils with more than 2 % clay content could cause failure of the system.
- *Filter Permeability:* The filter must be permeable enough to insure drainage within 24-48 hours, yet have sufficient fines to insure the filtration of fine particles and the removal of dissolved pollutants. The design may either rely on the soil permeability, if known, to provide the slow release of the water treatment volume over a minimum of 24 hours, or may insure this rate by installing a constrictive orifice or valve on the underdrain outlet. In determining the permeability of the media, the amount of fines of the mixture and the level of compaction should be considered.
- *Gradation testing:* Gradation tests, including hydrometer testing for clay content, and permeability testing of the soil filter material, should be performed by a qualified soil testing laboratory and submitted to the project engineer for review before placement.

Geotextile Fabric: A geotextile fabric may be placed between the sides of the filter layer and adjacent soil to prevent the surrounding soil from migrating into and clogging the filter or clogging the outlet. Overlap seams should be a minimum of 12 inches. Do not wrap fabric over the pipe bedding as it may clog and prevent flows out of the filter. The geotextile fabric should be Mirafi 170N or equivalent.

Construction: All material intended for the filter basin must be approved by the design engineer after tests by a certified laboratory show that the material conform to the DEP specifications. The soil filter media should not be installed until the drainage area has been permanently stabilized or the runoff is diverted around the filter until stabilization is completed. Erosion and sedimentation from unstable subcatchments is the most common reason for filter failure.

- *Construction Components:* Bioretention filters consist of (from bottom up):
  - A geotextile fabric to separate the filter basin from the natural soils. An impermeable membrane may be required if groundwater contamination is a concern or it may influence the effectiveness of the basin. A 12-inch base of coarse clean stone or coarse gravel in which a 4 to 6 inch perforated underdrain pipe system is bedded.
  - A gravel transition layer, if necessary.

  - 18-inch layers of soil filter media.
  - A selection of plants and 2-3 inches of wood mulch.
- *Basin Excavation:* The basin area excavated for underdrain installation can be used as a sediment trap during construction. After excavation of the basin, the outlet structure and piping system may be installed if protected with a sediment barrier. If the basin is to be used as a sediment trap, the sides of the embankments must be stabilized and maintained to prevent erosion.
- *Compaction of Soil Filter:* Filter soil media and underdrain bedding material should be compacted to between 90 and 92% standard proctor. The filter should be installed in at least 2 lifts of 9 inches to prevent pockets of loose media.
- *Remedial Loam Cover:* If vegetation is not established within the first year, a 2-3 inch layer of sandy loam topsoil (with less than 2% clay) may be installed on the surface of the filter. It will need to be removed at the end of construction, seeded and mulched.
- *Construction Oversight:* Inspection of the filter basin must be provided for each phase of construction by the design engineer with required reporting to the DEP. At a minimum, inspections will occur after:
  - The preliminary construction of the filter grades and once the underdrain pipes are installed (not backfilled),
  - The drainage layer is constructed and prior to the installation of the filter media,
  - The filter media has been installed, seeded and mulched,
  - The first year of operation, to inspect vegetation and make corrections.
  - All material intended for the filter basin must be approved by the design engineer after tests by a certified laboratory show that they are passing all DEP specifications.

Testing and Submittals: The contractor needs to identify the location of the source of each component of the filter media. All results of field and laboratory testing must be submitted to the project engineer for confirmation.

- *Media Source:* Samples of each type of material should be blended for the mixed filter media and underdrain bedding material. Samples must be a composite of three different locations (grabs) from the stockpile or pit face. Sample size required will be determined by the testing laboratory.
- *Sieve Analysis:* A sieve analysis conforming to ASTM C136 (Standard test method for sieve analysis of fine and coarse aggregates; 1996a) should be performed on each type of the sample material. The resulting soil filter media mixture must have 8% to 12% by weight passing the #200 sieve, a clay content of less than 2% (determined hydrometer grain size analysis) and have 10% dry weight of organic matter.
- *Permeability Testing:* Permeability of the soil filter media mixture should be tested and should be conforming to ASTM D2434 with the mixture compacted to 90-92% of maximum dry density based on ASTM D698.

Maintenance: The bioretention basin should be inspected semi-annually and following major storm events. Debris and sediment buildup should be removed from the forebay and basin as needed. Any bare area or erosion rills should be repaired with new filter media, seeded and mulched.

- *Maintenance Agreement:* A legal entity should be established with responsibility for inspecting and maintaining any filter basin. The legal agreement establishing the entity should list specific maintenance responsibilities (including timetables) and provide for the funding to cover long-term inspection and maintenance.
- *Drainage:* The filter should be draining within 48 hours following a one-inch storm or greater. If the system drains too fast, an orifice may need to be added on the underdrain outlet or may need to be modified if already present.
- *Sediment Removal:* Sediment and plant debris should be removed from the pretreatment structure at least annually.
- *Remedial Cover:* The organic mulch should be removed and replaced with a 2-3 inch layer of fresh mulch annually or as needed.
- *Soil Filter Replacement:* The mulch shall be replaced with fresh material on a yearly basis.
- *Fertilization:* Fertilization of the filter area should be avoided unless absolutely necessary to establish vegetation.
- *Harvesting and Weeding:* Harvesting and pruning of excessive growth should be done occasionally.

Weeding to control unwanted or invasive plants may also be necessary.

- *Planting:* Maintaining a healthy vegetative cover will minimize clogging with fine sediments. If ponding exceeds 48 hours, the top of the filter bed should be rototilled to reestablish the soil's filtration capacity.
- *Soil Filter Replacement:* The top several inches of the filter can be replaced with fresh material if water is ponding for more than 72 hours.