1.6.3 Maintenance and Construction Requirements

C. Major Maintenance Requirements.

1. Sedimentation and Filtration (See Section 1.6.5).

a. Silt should be removed when the accumulation exceeds six (6) inches in sediment basins without sediment traps. In basins with sediment traps, removal of silt shall occur when the accumulation exceeds four (4) inches in the basins, and the sediment traps shall be cleaned when full. Following silt removal the design depth of the filtration media must be verified (see 1.6.3.B.11).

b. Accumulated paper, trash, and debris should be removed every six (6) months or more often as necessary to maintain proper operation.

c. Vegetation within the basin shall not exceed eighteen (18) inches in height at any time, except as called for in the design. The minimum vegetation height shall be three (3) inches. Vegetation that is mowed or cut shall be removed from the basin.

d. The basin shall be inspected annually and repairs shall be made if necessary.

e. Corrective maintenance is required any time a sedimentation <u>or filtration/biofiltration</u> basin does not drain the equivalent of the Water Quality Volume within ~~sixty (60)~~ <u>ninety six (96)</u> hours (i.e., no standing water is allowed).

~~f. Corrective maintenance is required any time the sediment trap in a sedimentation basin does not drain completely within ninety-six (96) hours (i.e., no standing water is allowed).~~

~~g~~f. To limit erosion, no unvegetated area shall exceed 10 square feet.

~~h~~g. Structural integrity of basins shall be maintained at all times.

****

4. Retention-Irrigation Systems (Section 1.6.7.A).

a. Sediment must be removed from the retention basin, splitter box and wet wells, when accumulations exceed six (6) inches in depth.

<u>b To limit erosion in basin, no unvegetated area shall exceed 10 square feet.</u>

<u>c Structural integrity of basins shall be maintained at all times. Woody vegetation should be controlled/removed to prevent basin leakage. The ability of the basin to retain the water quality volume shall be evaluated by the COA.</u>

~~b.~~d. To the greatest extent practicable, irrigation areas are to remain in their natural state. However, vegetation must be maintained in the irrigation area such that it does not impede the spray of water from the irrigation heads. Tree and shrub trimmings and other large debris must be removed from the irrigation area in order to harvest and remove nutrients from the system. See requirements in 1.6.7.~~D.~~A.3.(g) and (h) regarding requirements for soil and vegetation in irrigation areas.

~~c.~~ e. The pumps and irrigation system must be inspected or tested a minimum of six (6) times per year to show all components are operating as intended. In particular, the irrigation system and all of its components and functionality should be inspected to ensure the system performs as designed. This includes controls such as weather stations or rain sensors, delays, valves, alarm system, distribution lines or other components as specified on system design. S~~s~~prinkler heads must be checked to determine if any are broken, clogged, or not spraying properly. All inspection and testing reports must be kept on site and accessible to the City of Austin.

f. The overall system shall be inspected for the ability to retain the water quality volume on site per ECM section 1.6.7.A.

****

5. Vegetative Filter Strips~~, Including Disconnection of Impervious Cover~~ (Section~~s~~ 1.6.7.B ~~and 1.6.7.F~~).

****

6. Biofiltration and Rain Gardens

B. Integrated Pest Management (IPM)

2. Mosquito Management.

Biofiltration ponds shall not become breeding places for mosquitoes. Meet the drainage requirements established per 1.6.7 (C). Once the pond has drained, remaining incidental standing water must not be present for longer than ~~three days (72 hours)~~ four days (96 hours) thereafter.

1.6.5 Design Guidelines for Sedimentation/Filtration Systems

A. Full Sedimentation with Filtration

3. Sedimentation Basin Details

- Sediment Trap (Optional). A sediment trap is a storage area which captures sediment and removes it from the basin flow regime. In so doing, the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. The trap also

maintains adequate volume to hold the water quality volume which would otherwise be partially lost due to sediment storage. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to ten (10) percent of the sedimentation basin volume.

Water collected in the sediment trap shall be conveyed to the filtration basin in order to prevent standing water from occurring. All water collected in the sediment trap shall drain out within ~~sixty (60)~~ ninety six (96) hours. The invert of the drain pipe should be above the surface of the filtration sand bed. The minimum grading of the piping to the filtration basin should be one-quarter (¼) inch per foot (two (2) percent slope). Access for cleaning the sediment trap drain system is necessary.

****

4. Sand Filtration Basin Details

• Sand Bed. The sand bed for city-maintained filtration basins must be built to the "Sand Bed with Gravel Layer" configuration below unless topographic constraints make this design unfeasible. Unfeasible is considered: assuming (for the purposes of this selection process only) a maximum ponding depth of three feet in the sedimentation basin, if it is not feasible to obtain an outlet for the drainage from the filtration basin within one-hundred (100) feet of the crest of the filtration embankment, then the "trench design" may be used. For ponds not maintained by the city, the sand bed may be a choice of one of the two configurations given below.

Note: Sand bed depths are final, compacted depths. Consolidation effects must be taken into account. Pre-soaking of media is recommended to induce consolidation so that the correct amount of makeup material can be determined. To pre-soak apply 5-10 gallons of water per sq. ft. of filtration bed, within 1 hour.

Sand Bed with Gravel Layer (Figures 1-56 and 1-56A in Appendix V of this manual).

The top layer is to be a minimum of eighteen (18) inches of 0.02-0.04 inch diameter sand which corresponds with ASTM C-33 concrete sand (smaller sand size is not acceptable). Under the sand shall be a layer of one-half (0.5) to one and one-half (1.5) inch diameter washed, rounded, river gravel which provides three (3) inches to five (5) inches of cover over the top of the underdrain lateral pipes. Clean, screened, crushed recycled glass no smaller than 3/8 inch is also acceptable. The sand and gravel must be separated by a layer of geotextile fabric meeting the specifications listed in Section 1.4.5.P, Inlet Protection.

Sand Bed - Trench Design (Figures 1-56 and 1-56A in Appendix V of this manual).

The top layer shall be twelve (12) to eighteen (18) inches of 0.02-0.04 inch diameter sand which corresponds with ASTM C-33 concrete sand (smaller sand size is not acceptable). Laterals shall be placed in trenches with a covering of one-half (0.5) to one and one-half (1.5) inch diameter washed, rounded river gravel which provides three (3) inches to five (5) inches of cover over the top of the underdrain lateral pipes and geotextile fabric. The geotextile fabric is needed to prevent the filter media from infiltrating into the lateral piping. The geotextile fabric specifications are listed in Section 1.4.5.P, Inlet Protection.

Biofiltration Medium Bed (Figure 1-56D in Appendix V of this manual)

For Biofiltration Media Bed specifications Refer to Section 1.6.7.C.4.B

1.6.7 Innovative Water Quality Controls

1.6.7.1 Introduction

Innovative, or alternative, water quality controls are eligible for water quality credit pursuant to § 25-8-151 of the Land Development Code (*Innovative Management Practices*). The ~~following~~ innovative practices included in this section have been reviewed and approved by the Watershed Protection ~~and Development Review~~ Department. Acceptance of and the amount of credit allowed for such practices ~~is~~are based on:

- Technical merit
- Compliance with requirements for water quality protection and improvement
- Resource protection and improvement
- Advantages over ~~standard~~ traditional practices
- Anticipated maintenance requirements

Section 1.6.7 includes the following subsections where design criteria and guidance are provided for each practice:

A. Retention/Irrigation Systems

B. Vegetative Filter Strips

C. Biofiltration

D. Rainwater Harvesting

E. Porous Pavement for Pedestrian Use

F. [placeholder]

G. Non-Required Vegetation

H. Rain Garden

Maintenance requirements of the approved innovative water quality controls are provided in section 1.6.3 of the ECM.

~~When considering the use of innovative control the applicant is strongly encouraged to become familiarized with on-going stormwater research, monitoring and modeling concepts and studies, and recognized engineering practices. Some source of information that should be considered include:~~

- ~~International Stormwater BMP database project (http://www.bmpdatabase.org/) including BMP Modeling Concepts and Simulation (http://www.epa.gov/nrmrl/pubs/600r06033/600r06033.htm)~~
- ~~American Society of Civil Engineers and Water Environment Federation manuals of practice:~~
- ~~Urban Runoff Quality Management (WEF Manual of Practice No. 23; ASCE Manual and Report on Engineering Practice No. 87)~~
- ~~Design and Contruction of Urban Stormwater Management Systems (ASCE Manual and Report on Engineering Practice No. 77; WEF Manual of Practice FD-20)~~

~~• University of Texas Center for Research in Water Resources (http://www.crwr.utexas.edu/)~~

~~• North Carolina State Stormwater Engineering Group (http://www.bae.ncsu.edu/stormwater/)~~

~~• University of Maryland Department of Civil and Environmental Engineering (http://www.ence.umd.edu/~apdavis/LID-Publications.htm)~~

~~• Low Impact Development Center (http://www.lowimpactdevelopment.org/)~~

1.6.7.2 Water Quality Credit

The water quality credit system presented in this section sets forth a method for designers to achieve full credit or partial credit for innovative controls that are either undersized or capture runoff from only a portion of the developed site. The objective of the water quality credit system is to provide flexibility for meeting the City's water quality requirements. For example, in many cases full water quality credit can be met through the use of a single control located at the downstream end of the developed site. Alternatively, water quality credit can be achieved through innovative controls distributed throughout a developed site and integrated into the landscape.

~~In urban watersheds, the~~ The amount of credit for the practices described below can be applied as either a reduction in the size of a water quality control or, in Urban Watersheds, a reduction in the fee-in-lieu cost. The basic credit equation is:

$$WQC = IAF * BMPDF \qquad \text{(Equation 1.6.7-1)}$$

Where

- WQC = Water Quality Credit, a value between 0 and 1, with 1 meaning 100% credit;
- ~~Where~~ IAF ~~is the~~= Impervious Area Factor, or the fraction of total impervious area treated by the control; and
- BMPDF ~~is the~~= best management practice (BMP) Design Factor, a measure of the degree of design equivalency with sedimentation-filtration systems. Values are on a scale of 0 to 1, with 1 meaning 100% credit.

For two of the practices, porous pavement for pedestrian use and non-required vegetation, the water quality credit is applied as a deduction in the drainage area for sizing water quality controls~~.~~, as described in the subsections below.

For vegetated pond-type controls the BMPDF factor is based on the following factors:

WQV_{bmp} = water quality capture depth provided by the BMP in inches, and

WQV_{ecm} = ECM required water quality capture depth in inches.

~~water quality volume and design drawdown time, as compared against design criteria in the Environmental Criteria Manual (ECM); the amount of runoff captured and treated decreases as water quality volume decreases or drawdown time increases:~~

Specific drawdown time requirements for vegetated pond-type controls are described below in respective subsections for each control. The BMPDF for vegetated pond-type shall be determined using Figure 1.6.7-1 below.

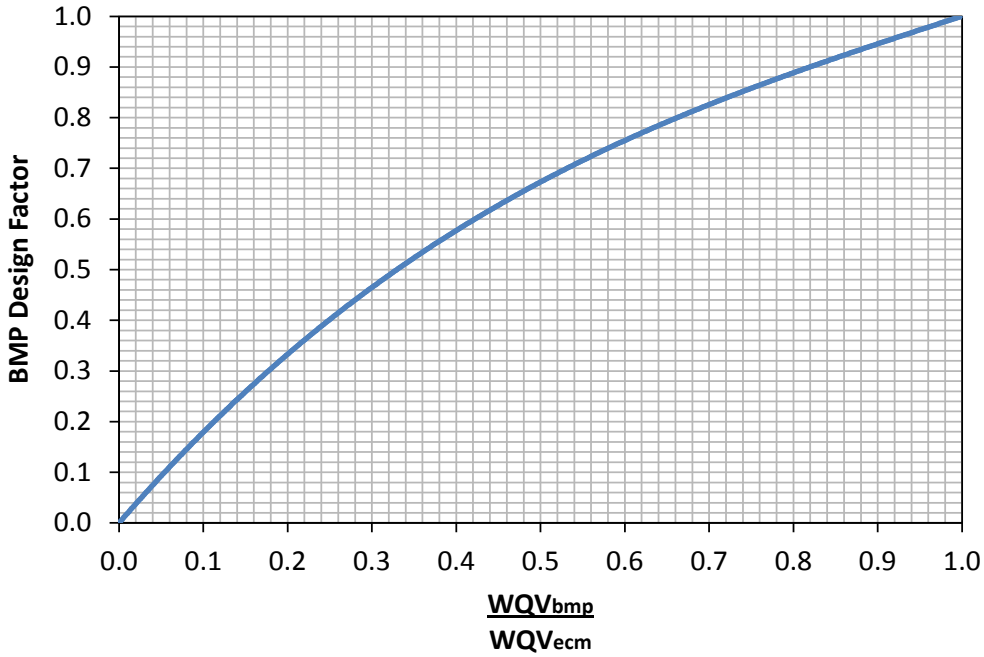

Figure 1.6.7-1. BMP Design Factor for vegetated pond-type controls.

~~BMPDF = (WQV_{bmp} / WQV_{ecm}) * (DDT_{ecm} / DDT_{bmp})~~

- ~~WQV_{bmp} is the water quality capture depth provided by the BMP in inches;~~
- ~~WQV_{ecm} is the ECM required water quality capture depth in inches~~
- ~~DDT_{ecm} is the ECM required drawdown time for sedimentation-filtration system in hours (a minimum 48 hrs.).~~
- ~~DDT_{bmp} is the BMP design drawdown time of the water quality volume in hours (varies with specific control as described below; typically 48 hours with a maximum of 72 hours).~~

~~The scoring system is illustrated below for the Rainwater Harvesting system (1.6.7.D).~~

For Rainwater Harvesting systems, the BMPDF is a function of water quality capture depth and drawdown time as described in 1.6.7.D.

For ~~v~~Vegetative ~~f~~Filter ~~s~~Strips (VFS) ~~that cannot fully meet the design criteria in 1.6.7.B~~ the water quality credit is a function of ~~area~~ percent infiltration and hydraulic loading rate as described in 1.6.7.B.~~, as described below for the Vegetative Filter Strip - Disconnection of Impervious Cover (1.6.7.F)~~.

Credit may be restricted or disallowed in some cases for watersheds in the Barton Springs Contributing and Recharge Zones as described below in the subsections for each control.

1.6.7.3 Guidance for Selecting Controls

The following guidance is provided to assist developers and designers with the process of selecting water quality controls. It is applicable to cases where a developer or designer has control over the drainage area above a point where a central or single control facility might otherwise be used. It is not applicable to cases where some parts of a drainage area are controllable and some are not; in that event, each sub-area that is controllable should be assessed according to this guidance.

For many sites, water quality requirements can be achieved with a single type of control (for example, a sedimentation/filtration system). However, in some cases stormwater can be managed through a suite of

controls that will provide full water quality credit plus added benefits such as reduced runoff volumes, reduction in peak flows, improved site aesthetics and, by distributing control across the watershed, a possible reduction in the need for large, centralized water quality controls at the down gradient end of the site.

Figure 1.6.7-2 outlines the recommended hierarchical approach for selecting on-site water quality controls.

Source Controls: The first step in the process is to consider opportunities for hydrologic source controls based on the project layout. These controls are designed to reduce or eliminate stormwater runoff at the source by promoting either or both direct infiltration to the subsurface or beneficial reuse. Hydrologic source controls promoting infiltration include Porous Pavement for Pedestrian Use and Non-Required Vegetation. Rainwater Harvesting can also function as a source control promoting beneficial reuse if drawdown of the water quality volume occurs within the required timeframe without discharge to landscape areas during precipitation events (e.g., water is pumped to a separate tank for subsequent beneficial reuse) (Note: infiltration or irrigation from Rainwater Harvesting is addressed below). Hydrologic source controls typically achieve partial water quality credit, consequently reducing the size of downstream controls.

Small Scale Distributed Controls: After considering opportunities for reducing runoff at the source, the next step in the water quality control selection process is to consider opportunities for incorporating smaller-scale distributed controls in landscaped areas throughout the site. Distributed controls should be designed to maximize the natural infiltration and storage capacity of the site where feasible. Infiltration is typically not feasible if:

- soils are not conducive for infiltration (low permeability),
- subsurface water storage capacity is limited due to high groundwater levels or shallow bedrock or impermeable layers,
- infiltration would cause or contribute to soil or groundwater contamination, or
- infiltration would cause or contribute to geotechnical issues such as slope or foundation stability.

Distributed controls typically reduce the amount of directly connected impervious area on a site, which will reduce the peak discharge rate by increasing the time of concentration and allow runoff to be managed closer to the source. In addition, distributed controls can also be used to satisfy landscaping requirements described in Section 2 of the ECM. Therefore, both water quality credit and landscape credit can be achieved for the same area. Examples of distributed controls include Vegetated Filter Strips and Rain Gardens. Rainwater Harvesting can also function as a distributed control if the water quality volume is discharged to landscaped areas for infiltration or irrigation. All of these controls can be designed to achieve full or partial water quality credit.

Centralized Controls: If it is not feasible to fully capture and treat the required WQV using hydrologic source controls and distributed controls, then centralized treatment facilities should be selected and sized for the remaining WQV. Centralized facilities typically collect runoff from larger drainage areas and are therefore larger in size. Examples of centralized facilities include Retention/Irrigation Systems, Biofiltration Systems, Sedimentation/Filtration Systems, and Wet Ponds.

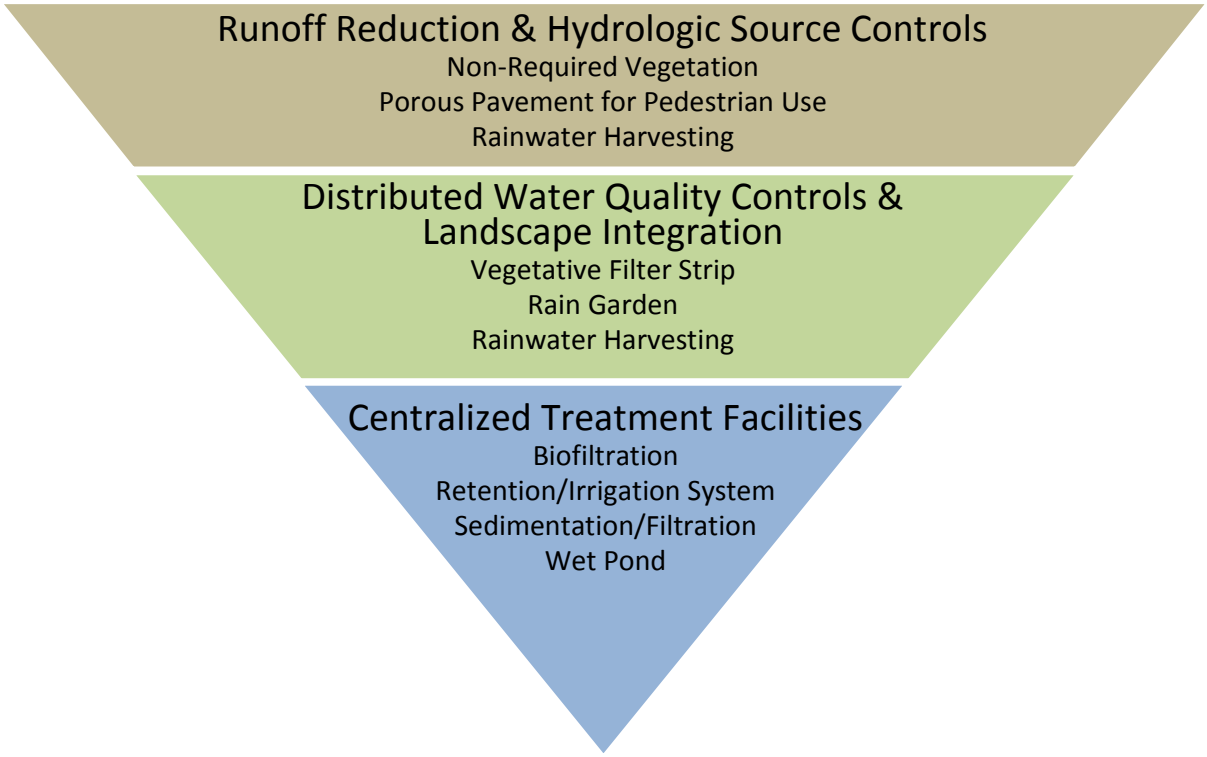

Figure 1.6.7-2. Recommended Hierarchical Approach for Selecting On-site Water Quality Controls

1.6.7.4 Infiltration Rate Evaluation

An evaluation of infiltration rate is necessary to determine if infiltration is feasible and to establish design infiltration rates for several of the innovative water quality controls described in Section 1.6.7.

There are three basic steps for evaluating infiltration rate:

1) Desktop study (i.e., soil survey maps or existing geotechnical information)
2) Field sampling (i.e., soil depth verification and textural analysis)
3) In-situ testing (i.e., more rigorous in-situ infiltration or percolation testing)

The design infiltration rate shall be established by applying a minimum factor of safety of 2 to the estimated or measured infiltration rate. A higher factor of safety may be used at the discretion of the design engineer to take into variability associated with assessment methods, soil texture, soil uniformity, influent sediment loads, and compaction during construction.

Table 1.6.7-1 identifies the minimum required steps for establishing the infiltration rate for each applicable water quality control. Although not required, results from in-situ testing may be used to establish infiltration rate for any applicable control.

Table 1.6.7-1. Minimum required steps for establishing infiltration rate.

	Desktop Study	Field Sampling	In-situ Testing
Retention/Irrigation System	●	●	
Vegetative Filter Strip	●	●	
Rainwater Harvesting[1]	●	●	
Porous Pavement for Pedestrian Use	●		
Rain Garden – Full Infiltration	●	●	●
Rain Garden – Partial Infiltration	●	●	

Note 1: Infiltration evaluation is not required for rainwater harvesting when the system is designed for beneficial reuse (i.e., when capacity for WQV is restored by pumping water to a separate tank).

1) Desktop Study

Desktop resources such as soil survey maps, published reports, or other available data is appropriate for screening to assess the feasibility and desirability of infiltration. The infiltration rate can be derived from the hydraulic conductivity listed in the U.S. Department of Agriculture National Resources Conservation Service Soil Survey for the location and soil type reported for the site. Geotechnical data from previous site studies or nearby representative locations may also be used. If a range of hydraulic conductivity values is available, estimate the infiltration rate as the geometric mean. Porous Pavement for Pedestrian Use may be designed without additional field verification or sampling. Additional field sampling or testing is required for other infiltration-dependent controls.

2) Field Sampling

The purpose of field sampling is to evaluate the depth and texture of soil at the location of the proposed water quality control. Field sampling activities must be conducted under the direction of a qualified professional. Soil depth and texture within the proposed footprint of the control must be evaluated via test pits, probes, borings, or similar means at a minimum frequency of one test location per 500 square feet. The probe or hole must extend to the minimum soil depth required for the proposed control. For example, the depth to an impermeable layer must be at least 2 feet below the bottom of a rain garden. If the bottom of the proposed rain garden is 1.5 feet below existing ground, the probe or hole must extend a minimum depth of 3.5 feet. Soil samples must be collected and evaluated at a depth below the expected bottom of the infiltration BMP (i.e., in the layer of underlying soil where infiltration will occur). Soil texture of representative samples may be classified in the field or by laboratory methods such as sieve and hydrometer analysis. Based on the soil texture determined in the field, a representative infiltration rate can be estimated from desktop resources (as described above). In the event that soil textures in the field differ from published references, additional testing and analysis must be conducted to establish a representative infiltration rate.

3) In-situ Testing

More rigorous in-situ infiltration or percolation testing methods provide the most accurate estimate of infiltration rate. A variety of in-situ tests are available for measuring the infiltration capacity of the soil. Laboratory tests are not recommended because typical laboratory samples are less representative of field conditions.

In-situ testing must be conducted under the direction of a qualified professional. Testing must be conducted within the proposed footprint at a minimum frequency of one test per 2,000 square feet. A higher testing frequency is recommended to more fully characterize the subsurface conditions. When more than one infiltration test is conducted for a single control, a representative infiltration rate may be calculated as the geometric mean of the test results. The infiltration test should be conducted as close as possible to the proposed bottom elevation for the water quality control (i.e., at the bottom of the growing medium layer). Based on observed field conditions, the designer may elect to modify the proposed bottom elevation of the control. Personnel conducting infiltration tests should be prepared to adjust test locations and depths depending on observed conditions.

The City may require verification testing for infiltration facilities serving greater than one acre of contributing area and where the City believes there may be a risk of infiltration system failure. Site conditions that justify infiltration facility verification testing include but are not limited to: low infiltration capacity soils, history of infiltration failure in the project area, high groundwater levels, indications of soil compaction during construction, new information gained during construction with regards to infiltration facility design and performance (e.g., better soils data, groundwater data, etc.).

The designer should keep in mind the difference between percolation tests and infiltration tests when determining the design infiltration rate. A measured infiltration rate can be determined from a single or double ring infiltrometer test. However, a percolation rate determined from the simple open pit percolation test is related to the infiltration rate but tends to overestimate infiltration rates due to both downward (vertical) and horizontal movement of water. Infiltration rates correspond only to the downward movement of water.

An acceptable testing protocol for percolation testing is provided below. Other testing methods that may be used but not discussed in detail in this section include:

- Single Ring Infiltrometer Test (ASTM D5126)
- Double Ring Infiltrometer Test (ASTM D3385)
- Guelph Permeameter
- Constant Head Permeameter (Amoozemeter or USBR Procedure 7300-89)
- Other analysis methods at the discretion of the designer and approval of the Director.

Percolation Test Protocol

The percolation test is geared towards investigating smaller infiltration facilities (i.e., facilities with drainage areas 2 acres or less and maximum ponding depths 12 inches or less). The test can be conducted using simple tools and manual labor, and does not require extensive excavation.

Test Preparation

- The test hole opening shall be between 8 and 12 inches in diameter or between 7 and 11 inches on each side if square.
- The bottom elevation of the test hole shall correspond to the bottom elevation of the proposed control (infiltration surface).

- Place approximately 2 inches of gravel in the bottom of the hole to protect the soil from scouring (optional).
- If horizontal infiltration is to be allowed, scarify the sides of the test hole.
- Pre-soak the hole by carefully filling it with water. If the hole has not drained completely within 24 hours, then an infiltration design is not recommended. Testing may commence after all of the water has percolated or after 15 hours has elapsed since initiating the pre-soak. However, to approximate saturated conditions, testing must commence no later than 26 hours after all pre-soak water has percolated through the test hole.
- Place a bar over the top of the hole or a nail near the top of the hole to serve as a datum from which depth measurements will be made.
- Measure the depth and diameter of the test hole.

Test Procedure

- Carefully fill the hole with water to a level greater than or equal to the maximum ponding depth of the rain garden. Measure this water elevation and the time it was taken.
- Measure the water surface elevation as it drops, and record the time of each measurement. Measurements shall be taken with a precision of 0.25 inches or better. The number of measurements, and thus time required to conduct the testing, will depend on the infiltration rate of the soil and the time available. As a general recommendation for finer grained soils typically found in Austin, plan to take at least 4 measurements over at least 2 hours. Refill the hole as necessary to extend the test to at least 2 hours. The test can be terminated when near steady-state conditions (i.e., when the rate of drop is approximately constant). Alternatively, terminate the test when the test hole is empty (this may require a much longer test period).
- Calculate the percolation rate using representative steady-state data points from the latter stages of test where the rate of drop is approximately constant. The percolation rate is the change in water elevation (in inches) by the corresponding time interval (in hours).
- Convert the steady-state percolation rate (p) to a representative infiltration rate (i) using the reduction factor (R_f) as follows:

  $i = p / R_f$

  The reduction factor (R_f) is given by:

  $R_f = ((2d_1 - \Delta d) / D) + 1$

  Where:

  d_1 = water depth at start of representative time interval (in.)

  Δd = water level drop during representative time interval (in.)

  D = diameter of percolation hole (in.)

  The reduction factor accounts for water losses through the sides of the percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the hole is located in uniform soil. If there are deviations from these assumptions, then other adjustment may be necessary.

1.6.7.5 Additional Resources

Note that while proven, many of the devices described in 1.6.7 are evolving in standard practice. The City should be contacted to determine if any acceptable variations to the controls described herein have been

approved or are pending. When considering the use of innovative control the applicant is strongly encouraged to become familiarized with on-going stormwater research, monitoring and modeling concepts and studies, and recognized engineering practices. Some sources of additional information include:

- International Stormwater BMP database project (http://www.bmpdatabase.org/) including BMP Modeling Concepts and Simulation (http://www.epa.gov/nrmrl/pubs/600r06033/600r06033.htm)
- American Society of Civil Engineers and Water Environment Federation manuals of practice:
  - Urban Runoff Quality Management (WEF Manual of Practice No. 23; ASCE Manual and Report on Engineering Practice No. 87)
  - Design and Construction of Urban Stormwater Management Systems (ASCE Manual and Report on Engineering Practice No. 77; WEF Manual of Practice FD-20)
- University of Texas Center for Research in Water Resources (http://www.crwr.utexas.edu/)
- North Carolina State Stormwater Engineering Group (http://www.bae.ncsu.edu/stormwater/)
- University of Maryland Department of Civil and Environmental Engineering (http://www.ence.umd.edu/~apdavis/LID-Publications.htm)
- Low Impact Development Center (http://www.lowimpactdevelopment.org/)
- TexasLID.org (http://texaslid.org/)

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B. Vegetative Filter Strips.

1. Introduction. Vegetative filter strips (VFS) and disconnection of impervious cover are typically used in areas with relatively low-density development as a passive low maintenance means of protecting nearby receiving waters from marginally increased pollutant loads. They are designed to treat uncontrolled runoff; the procedures described below should not be used when vegetated areas function as a secondary treatment (e.g. vegetated area receiving discharge from a ~~sand~~sedimentation filtration basin). Throughout this division, the acronym VFS and the term filter strip is used when referring to vegetative filter strips. ~~They are referenced in the SOS rules as a method for controlling non-point source pollution in watersheds within the Barton Springs Zone. Vegetative filter strips may also be appropriate for use in other watersheds to provide stormwater treatment equivalent to sedimentation/filtration systems.~~ For filter strips to work effectively sheet flow shall be maintained and maximum ~~velocities~~ hydraulic loading rates (see Design Requirements) in the filter strip shall not be exceeded. This requirement will limit the size and/or impervious cover that is practical for treatment. Vegetated areas that are designed to pond runoff are not considered to be vegetative filter strips and will require different design procedures (not described here). The VFS shall be restricted from development or any use that may negatively affect the function of the VFS~~.~~ (e.g., intensive recreational uses, pet use, etc.). This can be accomplished through the dedication of an easement or dedicated conservation lot for single family construction plans and, for site plans, by clearly labeling the VFS area by shading or cross hatching on the site plan sheet(s). In either case, the site plan must contain provisions to physically restrict access to the easement or conservation lot (e.g., fences, bollards, signage). An approved Integrated Pest Management Plan with a recorded Restrictive covenant is required. It is extremely important that the VFS not be over-irrigated and that fertilizer and chemical use be minimized; otherwise the VFS may become a source of pollution instead of a treatment best management practice (BMP).

2. General Design Guidelines. Filter strips must be sized correctly, have the proper slope, utilize sheet flow ~~that does not exceed a maximum velocity~~, have appropriate soil type and thickness, and have appropriate

vegetation of the proper density. Filter strips are typically designed by grading the site to promote overland flow of runoff to a vegetated area. Level spreaders are required at the upstream end of the filter strip if the length of the contributing drainage area (in the direction of flow) exceeds 72 feet. The maximum length of the contributing drainage area shall not exceed 150 feet. Level spreaders or other measures for preventing flow from becoming concentrated should be spaced throughout the length of the filter strip at intervals of no more than 25 feet. For rooftop impervious cover disconnects the downspouts must be at least 10 feet away from the nearest impervious surface to discourage "re-connections". The VFS shall not receive runoff until after the contributing drainage area has been stabilized to prevent erosion and sedimentation.

Filter strips can be classified as either natural or engineered. In general, natural filter strips utilize existing vegetated areas whereas engineered filter strips are constructed features. Engineered vegetative filter strips differ from natural vegetative filters in that they are specifically designed and constructed to maximize the water quality benefits of this practice, particularly in areas where adequate buffers do not exist naturally or cannot be preserved. Filter strips should have a minimum slope of 1%. Engineered filter strips should be constructed to maintain a constant slope that does not exceed 10%. Where existing vegetated areas are to be used ("natural" VFS) the average slope of the VFS should not exceed 10%, with no portion exceeding 15%.

It should also be noted that vegetative filter strips cannot be used to provide detention of erosive flow (2-year control per ECM 1.6.8) or flood flows.

3. Design Requirements For Full Water Quality Credit ~~Size, Slope and Structure~~. The width (perpendicular to direction of flow) of the VFS should be at least as wide as the contributing drainage area. The hydraulic loading rate (HLR) applied to the VFS for the two-year, three-hour rainfall event shall ~~should~~ not exceed 0.05 cfs/ft width, calculated as the peak flow rate divided by the VFS width.

The length (dimension in direction of flow) of the vegetative filter ~~should~~ shall be at least 25 feet. ~~To facilitate overland flow, level spreaders shall be installed at the upstream and downstream ends of the filter strip, and spaced throughout the length of the filter strip at intervals of no more than 25 feet.~~

To receive full water quality credit, vegetative ~~Vegetative~~ filter strips shall be sized to achieve at least 65% infiltration over the length of the filter strip. The required filter strip area per contributing area to achieve 65% infiltration shall be determined using Figure 1.6.7.B-1 below.~~per the following table.~~

~~**Vegetative Filter Strip (VFS) Sizing**~~ ~~**Acres of VFS per Acre of Contributing Drainage Area**~~		
~~Contributing Area Impervious Cover~~	~~SOS~~	~~Sand Filtration Equivalency~~
~~10%~~	~~0.21~~	~~NA~~
~~15%~~	~~0.28~~	~~NA~~
~~20%~~	~~0.36~~	~~0.32~~
~~25%~~	~~0.45~~	~~0.40~~
~~30%~~	~~0.55~~	~~0.49~~
~~35%~~	~~0.66~~	~~0.58~~
~~40%~~	~~0.78~~	~~0.68~~

~~45%~~	~~0.90~~	~~0.80~~
~~50%~~	~~1.04~~	~~0.91~~
~~55%~~	~~1.18~~	~~1.04~~
~~60%~~	~~1.34~~	~~1.17~~
~~65%~~	~~1.49~~	~~1.31~~
~~70%~~	~~1.67~~	~~1.46~~
~~75%~~	~~1.84~~	~~1.61~~
~~80%~~	~~2.03~~	~~1.77~~
~~85%~~	~~2.22~~	~~1.94~~
~~90%~~	~~2.42~~	~~2.12~~
~~95%~~	~~2.63~~	~~2.30~~
~~100%~~	~~2.85~~	~~2.49~~

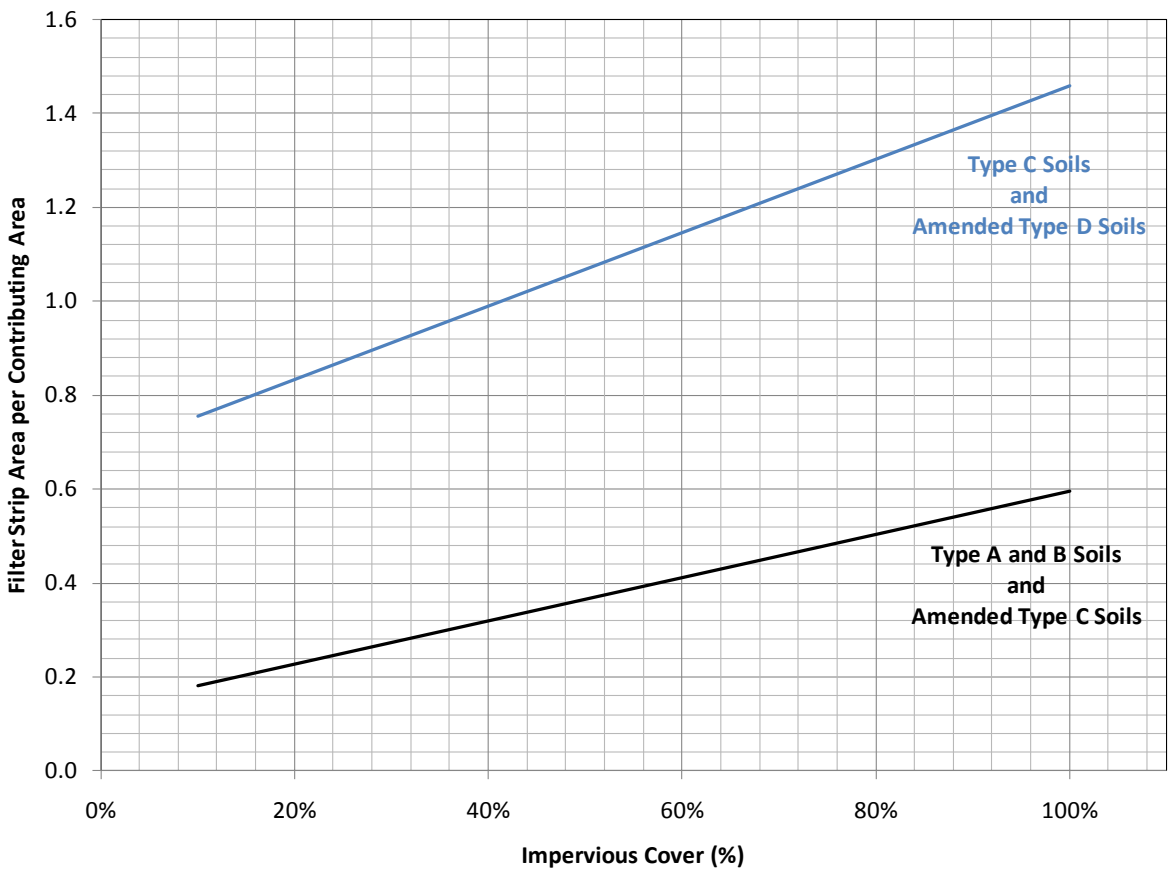


Figure 1.6.7.B-1: Minimum sizing criteria for vegetative filter strips to achieve full water quality credit (i.e., 65% infiltration).

4. Design Requirements For Partial Water Quality Credit. Partial water quality credit is provided for filter strips that do not meet the size and HLR requirements for full credit. The BMP design factor (BMPDF) is one factor that is used to calculate the partial water quality credit (see Equation 1.6.7-1). For filter strips, the BMPDF is calculated as:

If the HLR for the peak flowrate for the 2-year, 3-hour rainfall event is ≤ 0.05 cfs/ft width:

$$BMPDF = I_{VFS}/I_{65} \qquad \text{(Equation B-1)}$$

If the HLR for the peak flowrate for the 2-year, 3-hour rainfall event is > 0.05 cfs/ft width and ≤ 0.15 cfs/ft width:

$$BMPDF = (I_{VFS}/I_{65}) \times (HLR_{0.05}/HLR_{VFS}) \qquad \text{(Equation B-2)}$$

Where:

I_{VFS} = infiltration provided by the proposed filter strip (%),

I_{65} = 65% infiltration criterion for full credit,

HLR_{VFS} = the HLR of the proposed vegetative filter strip (cfs/ft width), and

$HLR_{0.05}$ = 0.05 cfs/ft width HLR criterion for full credit.

Infiltration provided by the proposed filter strip shall be determined using Figure 1.6.7.B-2 below. A maximum value of 1 is allowed for the BMPDF factor, even if the proposed VFS provides more infiltration than 65% or if the HLR is lower than 0.05 cfs/ft width. Additional credit is not provided for filter strips sized larger than 1.5 times the contributing drainage area. For lower permeability soils (Type D or Type C), the soil can be amended to achieve greater infiltration rates. Soil amendment criteria are outlined in the Landscape Elements section below.

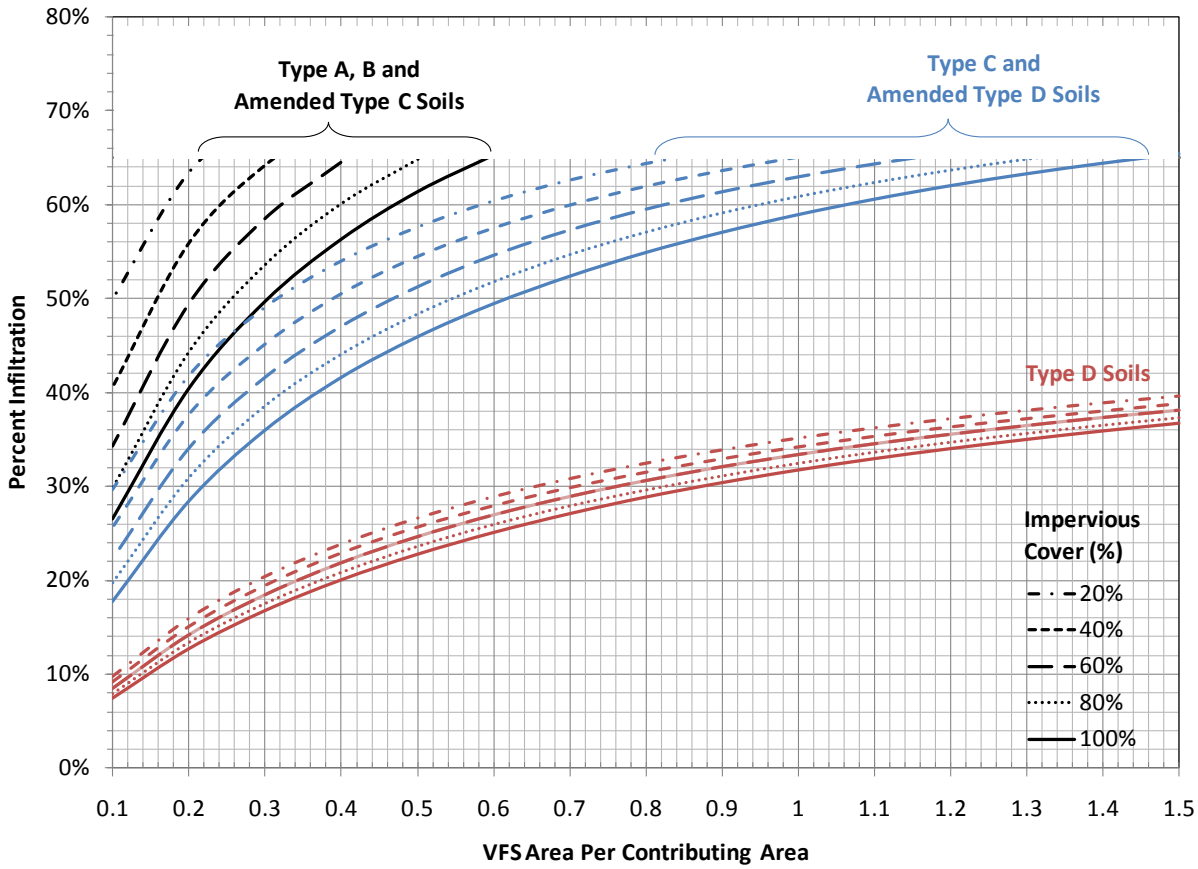


Figure 1.6.7.B-2: For partial water quality credit, use this chart to determine percent infiltration based on the size of the filter strip, size of contributing drainage area, contributing area impervious cover, and soil type.

~~Filter strips should have a minimum slope of 1%. Engineered filter strips should be constructed to maintain a constant slope that does not exceed 10%. Where existing vegetated areas are to be used ("Natural" VFS) the average slope of the VFS should not exceed 10%, with no portion exceeding 15%.~~

5. Level Spreaders. For filter strips that require level spreaders, the following design guidance is provided. To ensure that runoff enters the VFS instead of flowing around it, the elevation of the leading edge of the VFS should be three (3) to six (6) inches lower than the elevation at which flow is discharged from the level spreader. To limit any erosion that could occur as water falls from the top of the level spreader to the filter strip, a layer of filter fabric should be extended a distance of 3 feet from the level spreader lip towards the filter strip. Stone, such as ASTM No. 57 aggregate, should be placed on top of the filter fabric (3 to 4 inches deep) to reduce erosion just downslope of the level spreader. A 3-foot wide strip of erosion control matting can be used in place of the filter fabric and ASTM No. 57 aggregate combination. However, such an area must be stable and have adequate vegetation before receiving stormwater. See Figure 1.6.7.B~~.1~~-3, Recommended Level Spreader Details for Vegetative Filter Strip. For additional guidance on level spreader design see:

http://h2o.enr.state.nc.us/su/documents/LevelSpreaderGuidance_Final_-3.pdf. (note, however, that this North Carolina document is not a substitute for City of Austin criteria).

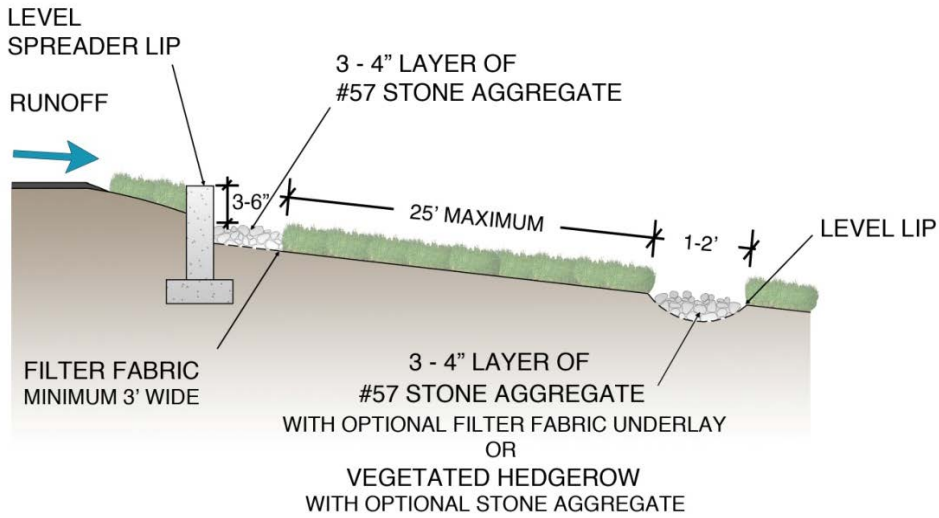


Figure 1.6.7.B-3: Recommended Level Spreader Details for Vegetative Filter Strip.

~~4.~~6. Landscape Elements. Vegetative filter strips shall have a minimum overall soil depth of ~~six (6)~~ twelve (12) inches, ~~but greater depth is preferred~~with at least 6 inches of topsoil at the surface and at least 6 inches of native or fill soil below it. ~~If soil must be added to achieve the minimum depth, the imported soil shall be clean and free of weeds (including seed). Compost-amended soils (25% compost) shall be used when turfgrasses will be used as the vegetation, or if the native soils are classified (per NRCS) as type C or D.~~ Topsoil or amended topsoil (see Figures 1.6.7.B.1 and 1.6.7.B.2 above) must meet the requirements of Standard Specification 601S, Salvaging and Placing Topsoil. If alternative methods of amending soil (such as mechanical aeration with sand medium backfill) can be demonstrated to increase the infiltration capacity by at least a factor of 3, these methods may be used with approval from the Director.

The condition, type, structure and quality of the soil shall be conducive to infiltration and to plant growth. Soil, if compacted, must be loosened. Compact soils are defined as those having a reading of greater than 300 psi at a depth of three inches (using a soil compaction penetrometer). Non-compacted soils, or loosened soils, shall have a reading of less than 300 psi.

Decompaction shall be completed in two phases: (1) the existing subsoil shall be aggressively fractured (ripped) to the required depth and (2) topsoil shall be added to the subsoil, and the topsoil shall be tilled simultaneously with the existing subsoil to ensure proper mixing and prevent partial recompaction.

The filter strip should have dense vegetative cover (minimum 95% coverage as measured at the base of the vegetation). Suitable vegetation for VFS includes grasses, forbs, shrubs and trees. The use of native grasses is strongly recommended due to their resource efficiency and their ability to enhance soil infiltration. In the case of natural wooded areas where 95% vegetative cover is not present, a minimum of four inches of leaf litter, mulch or other organic matter must be in place. In these areas, lower tree limbs should be removed, the canopy opened and the area seeded with appropriate grasses and forbs in order to enhance ground cover.

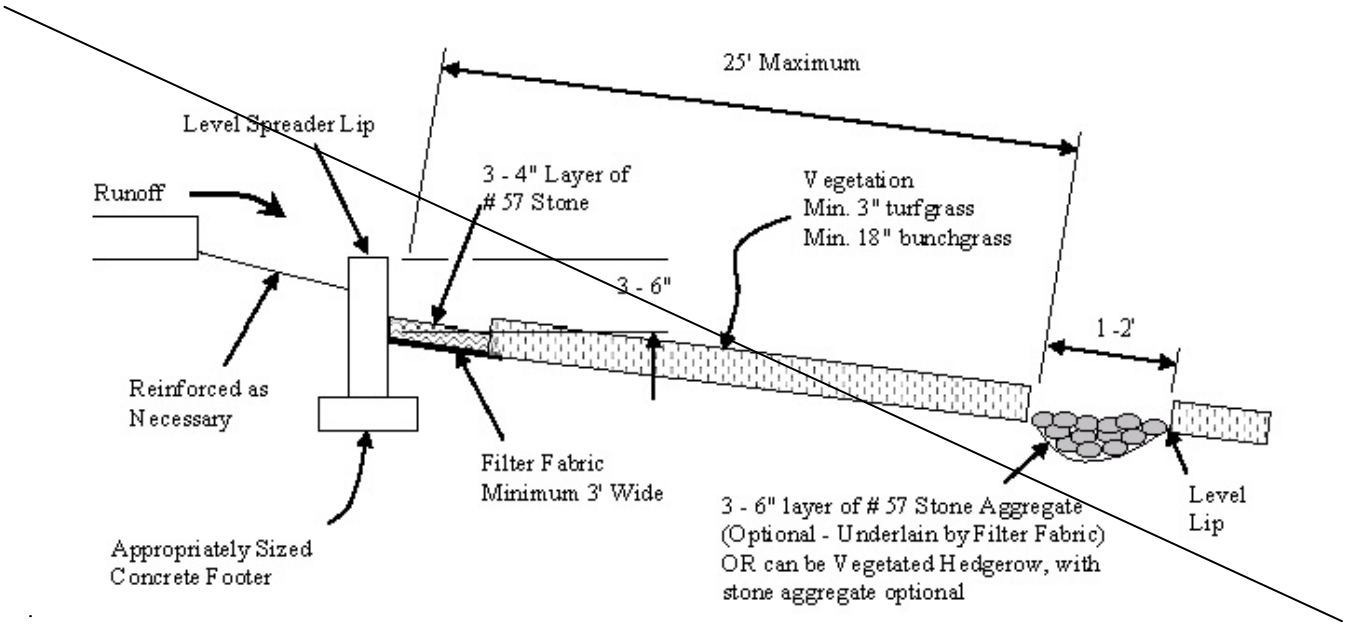
Turfgrasses shall be a minimum of three (3) inches in height and bunchgrasses a minimum of eighteen (18) inches in height.

Existing vegetation can be used as filter strips if all other design criteria are met. An appropriate selection of plants will vary with site conditions and the user is referred to growgreen.org for guidance regarding appropriate plants and their use. The VFS should not include invasive and pest species (e.g., Johnson Grass). To establish a dense and healthy vegetative cover, temporary irrigation and limited fertilization may be required.

~~Signage should be provided to delineate the boundaries of the filter strip, and to notify residents, inspection, and maintenance staff of its function and proper management.~~

~~5~~7. Maintenance Requirements. See Section 1.6.3.

~~Figure 1.6.7.B.1 Recommended Level Spreader Details for Vegetative Filter Strip.~~



8. Example

A 5-acre commercial site with 50% impervious cover (2.5 impervious acres) is required to provide on-site water quality treatment. It is proposed to route 1 acre of parking lot (100% impervious cover) to a 0.8-acre vegetative filter strip (VFS), with dimensions 350 feet wide by 100 feet long. The proposed VFS area has type C soils and the soils will not be amended. Without the VFS the water quality volume required is 0.8", or 14,520 ft^3. What water quality credit can be applied to this site?

As the parking lot area to be treated is 1 acre, and the total site impervious cover is 2.5 acres, the Impervious Area Factor (IAF, see Equation 1.6.7-1) is 1/2.5 = 0.4.

For determining the BMPDF value, refer to Figure 1.6.7.B.2. The proposed VFS is 0.8-acre. The ratio of VFS area to contributing drainage area is 0.8-acre per 1 acre, or 0.8. For 100% impervious cover and type C soil, the corresponding percent infiltration is 55%. Next calculate the peak flow rate for the 2-year, 3-hour rainfall event, then determine if the proposed HLR is less than or equal to 0.05 cfs/ft. width. In this case this criterion is met, thus from Equation B-1:

BMPDF = 55 / 65 = 0.85

Inserting the values into the water quality credit Equation 1.6.7-1:

WQC = IAF * BMPDF = 0.4 * 0.85 = 0.34

The vegetative filter strip reduces the required WQV by 4,937 ft^3, or to 9,583 ft^3.

C. Biofiltration

1. Introduction. Biofiltration devices~~ponds~~ are a type of water quality control best management practice (BMP) that uses the chemical, biological, and physical properties of plants, microbes, and soils to remove ~~for removal of~~pollutants from stormwater runoff. Biofiltration can be~~is~~ a critical component of an integrated Low Impact Development (LID) strategy, or can be employed by itself. ~~LID is a philosophy of development in which steps are taken to maintain predevelopment hydrology, as near a possible. Green space is made functional to keep storm water onsite, to minimize runoff and to employ natural processes for water quality improvement.~~ Biofiltration systems can provide equivalent treatment to a standard sedimentation/filtration system but are not acceptable as a primary method for controlling non-point source pollution in watersheds within the Barton Springs Zone or Barton Springs Contributing Zone.

A biofiltration system is an enhanced filtration device that typically utilizes more than one~~several~~ treatment mechanism~~s~~ for removing pollutants from stormwater runoff. ~~As with a sand filtration system, a~~A sedimentation basin is often placed as a first step in the BMP, to provide~~s~~ pre-treatment of runoff in order to protect the biofiltration ~~media~~ medium from becoming clogged prematurely by sediment loads. ~~Likewise, sand filtration and~~ Then, flows are directed through a ~~biofiltration both remove pollutants through physical filtration~~a biofiltration medium which removes pollutants. ~~The primary difference between the two is that the presence of a~~A defining characteristic of the biofiltration BMP is a ~~biological~~community of plants and microorganisms that is rooted in the filter medium and that ~~in a biofiltration system~~ can ~~theoretically~~provide more treatment of runoff, directly and by uptake from the filter medium. ~~Another benefit of having a~~As well as enhancing removal of pollutants, the plant community ~~is that the~~tends to sustain the permeability of the biofiltration medium ~~a may be sustained~~ for longer periods of time without maintenance. It is the existence of this biological community that differentiates a biofiltration BMP from a typical sand filter, which is otherwise comparable in design and performance.

~~The health of the biological (plant and microorganism) community is intimately tied to the soil-water-moisture conditions of the filtration media, thus it is important to have a basic understanding of soil-water-plant dynamics, in particular "available water capacity." During periods of rainfall, soils are often saturated, meaning the pore spaces are largely filled with water. The volume of water held in a saturated soil can be estimated as being equal to the porosity, or the volume fraction of pores. Most soils have similar porosity values, in the range of 0.4 – 0.5, i.e., pores represent 40-50% of the total soil volume. During saturated conditions, plants are largely inactive due to the absence of oxygen in the soil. Once rainfall and runoff have ceased, water will gravity drain out of the soil through larger pores down to a level known as "field capacity." At field capacity, reaeration of the soil has also typically begun, and plant (and microorganism) activity resumes. The plant uptake and evapotranspiration processes will then proceed and, without additional water inputs, the soil wetness will decrease to a level known as "wilting point", a level below which many plants cannot survive for extended periods. Thus, to sustain a healthy plant and microorganism community, the soil wetness should be maintained between the "field capacity" and "wilting point" levels; this range is known as the "available water capacity" of the soil. Compared to most soils, sand has a low available water capacity, thus it has a limited ability to provide "biological" treatment of pollutants (see following table).~~

~~**Soil Texture**~~	~~Available Water Capacity~~

	~~ft/ft~~
~~Coarse Sand and Gravel~~	~~0.02 – 0.06~~
~~Sand~~	~~0.04 – 0.09~~
~~Loamy Sand~~	~~0.06 – 0.12~~
~~Sandy Loam~~	~~0.11 – 0.15~~
~~Fine Sandy Loam~~	~~0.14 – 0.18~~
~~Loam and Silt Loam~~	~~0.17 – 0.23~~
~~Clay Loam and Silty Clay Loam~~	~~0.14 – 0.21~~
~~Silty Clay and Clay~~	~~0.13 – 0.18~~

There are several hydraulic features or components that combine to make the biofiltration system work effectively. There is commonly a~~A biofiltration pond consists of a~~ splitter box or comparable diversion structure at the flow entrance to provide some control over flows admitted to the device. There is also generally a flow spreading structure to ensure flows do not concentrate and potentially channelize the filter medium. There is usually a~~, a~~ sedimentation chamber to capture coarse sediments, and in some cases (described below) a separator element. The~~, a~~ biofiltration ~~media~~ filtration chamber typically must have~~with~~ an underdrain piping system beneath ~~the biofiltration media~~it,~~an outlet structure, and~~with native or adapted vegetation rooted in the medium and selected for tolerance to ponding and dry soil conditions. Finally, there is an outlet structure from the BMP at the point of discharge.

For biofiltration ponds to work effectively, maximum velocities into the sedimentation chamber must ~~shall~~ not be exceeded. This requirement ~~will~~tends to limit the size and amount of impervious cover that is practical for treatment using this kind of device. Biofiltration ponds are relatively low maintenance once native plantings are well established. These devices~~and~~ should be restricted from any use that may negatively affect the function of the biofiltration pond (e.g. pet use, application of herbicides and pesticides, excessive mowing, etc.). To ensure this, an approved and recorded Integrated Pest Management plan will be required for the drainage area up to and including the pond area. See section 1.6.3 for maintenance, irrigation, and sequence of construction requirements.

2. Basin Surface Areas and Volumes.

The following equation gives the minimum surface area required for the filtration basin:

$$A_f = WQV*L/kt(H_{max}/2+ L) \qquad \text{(Equation C-1)}$$

Where~~,~~

- A_f = required surface area of the medium~~a~~ in square feet
- WQV = the water quality volume in cubic feet as defined in section 1.6.2.
- L = Depth of the ~~soil media~~filter medium (typ. 1.5 feet)
- k = Hydraulic Conductivity (3.5 ft/day for “full” sedimentation-filtration systems; 2 ft/day for “partial” systems)

- H_{max} = Maximum head over the filter medium ~~soil media~~ (feet)

- t = Drawdown Time (two (2) days)

For design purposes,~~As can be seen~~ the hydraulic conductivity ~~for~~of the biofiltration ~~media~~medium can be~~is~~ assumed to be the same as that for sand filtration. Measured hydraulic conductivity of new biofiltration ~~media~~medium substantially exceeds 3.5 ft/day; however, ~~This is a reasonable assumption based on several factors (but the assumptions may change in the future as monitoring data becomes available). For sand filtration, the assumptions reflect the fact that the media will typically experience~~ a significant reduction in conductivity over time due to surface crusting and clogging of void spaces by lower-permeability silt and clay particles will occur. ~~For example, the hydraulic conductivity of sand that does not have sediment-laden water applied can exceed 100 ft/day, but values of less than 1 ft/day have been observed for sand filters treating stormwater. For biofiltration systems it will be difficult to estimate the actual hydraulic conductivity, primarily because the media will be an artificial soil mixture whose texture and structure may be different than true soils. Testing of various soil mixtures conducted by the City of Austin, the University of Texas Center for Research in Water Resources, and others have documented that candidate soil mixtures generally drain slower than sand, but at rates greater than 3.5 ft/day.~~ If surface crusting and clogging can be minimized (which should be the case for biofiltration systems due to the presence of vegetation) it is reasonable to assume that the hydraulic conductivity of biofiltration systems should be comparable to sand filters.

Full Sedimentation/Biofiltration Systems.

In these systems the entire water quality volume is stored in the sedimentation basin, and then~~which~~ discharges ~~the volume~~ relatively slowly to the biofiltration basin (e.g. over~~in~~ a period of 48 hours). See 1.6.5.A. for additional design criteria and Figure 1.6.7.C~~.~~-1, Full Sedimentation/Biofiltration Pond, for general details. It is recommended that the bottom of the sedimentation basin be ≥ 2" higher than the top of the filtration basin in order to uniformly discharge flow at or above the biofiltration vegetation, and to prevent excessive drawdown times due to tailwater effects. See Figure 1.6.5.A.

Based on the equation and assumptions given above, the minimum surface area required for the biofiltration basin is:

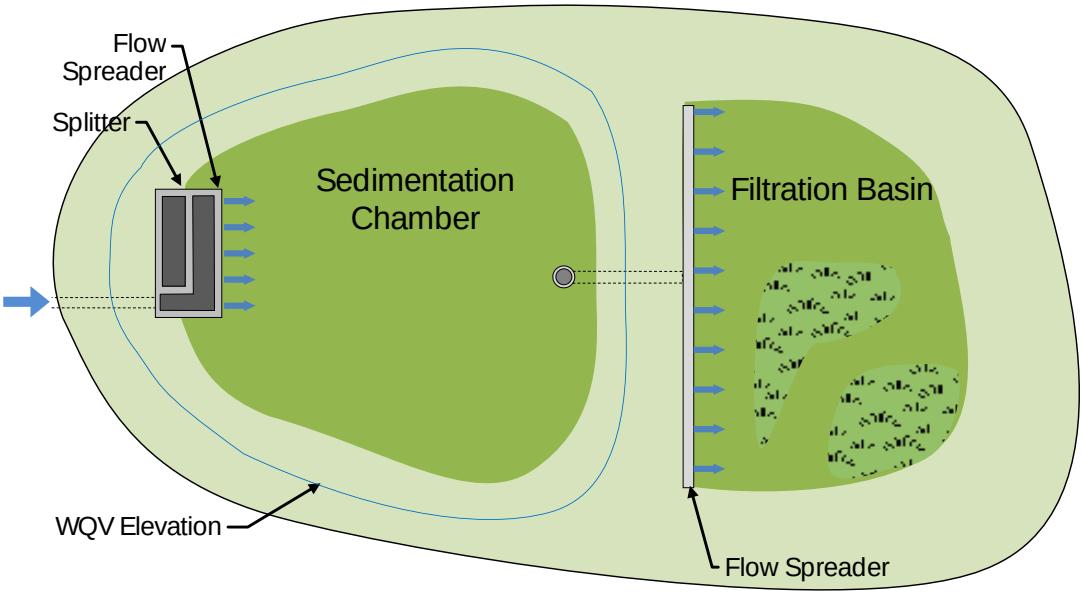
$A_f = WQV/(7 + 2.33*H)$ (Equation C-2)

Where

~~"~~A_f~~" is the~~ = filtration area in square feet,

~~"~~WQV~~" is the~~ = water quality volume in cubic feet as defined in section 1.6.2A, and

~~"~~H~~" is the~~ = maximum ponding depth in the filtration basin. The assumed maximum ponding depth of the filtration basin should be at least one (1) foot less than the maximum ponding depth in the sedimentation basin, to account for tailwater effects.



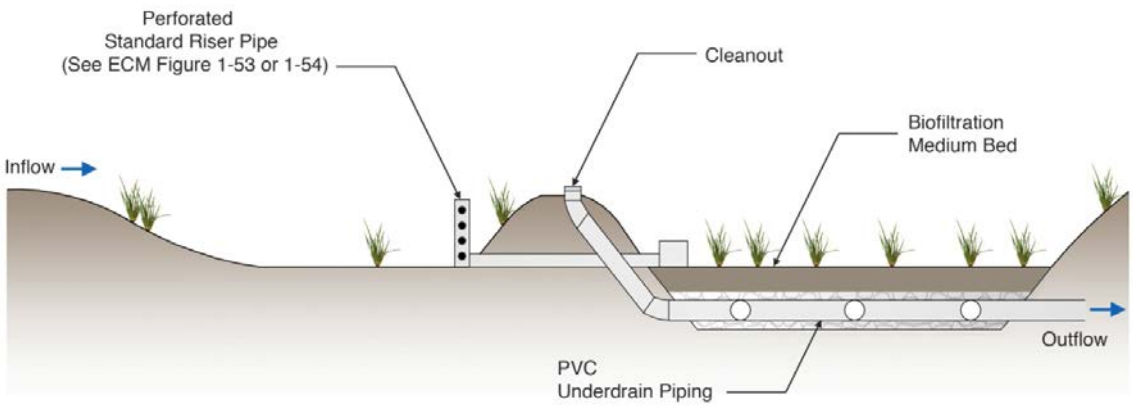
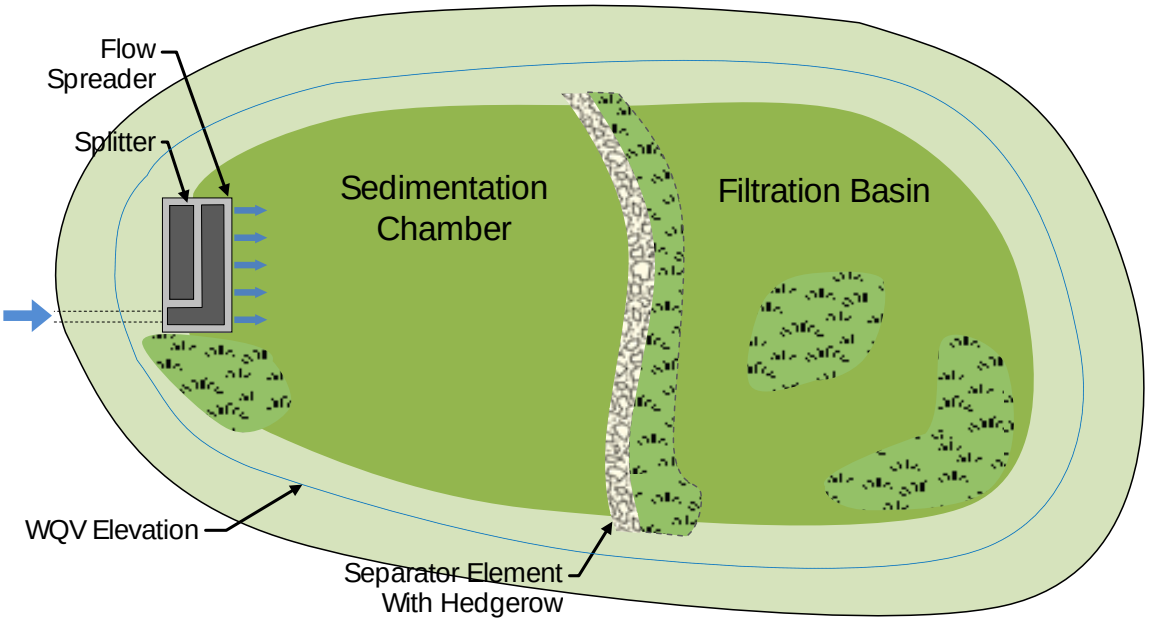


Figure 1.6.7.C-1: Full Sedimentation/Biofiltration Pond.

Partial Sedimentation-Biofiltration Systems.

In this case, the sediment chamber is not large enough to store the whole water quality volume, so that volume must be stored partly over the sediment chamber and partly over the biofilter. The combined volume of the sediment chamber and filtration basin must ~~be~~ therefore equal ~~to~~ the water quality volume, i.e., $V_s + V_f$ = water quality volume where "V_s" is the sediment chamber volume and "V_f" is the filtration basin volume. The volume of the sediment chamber, "V_s", shall be ~~a minimum of~~ no less than 20 percent of the water quality volume. The water quality pond design shall allow enough freeboard to pass the design flow rate for the 100 year storm over the splitter/diversion structure without overtopping of any side walls of the pond, plus an additional 5% of the total fill height or three inches, whichever is greater, to allow for construction irregularities and long term soil settling. The design shall ensure that under no circumstances does the sediment chamber allow water to return to the isolation/diversion structure, ~~i.e., isolation of the water quality volume and minimal mixing must be ensured.~~ For general details see Figure 1.6.7.C~~.~~-2, Partial Sedimentation/Biofiltration Pond, and Section 1.6.5.B, Partial Sedimentation/Filtration.



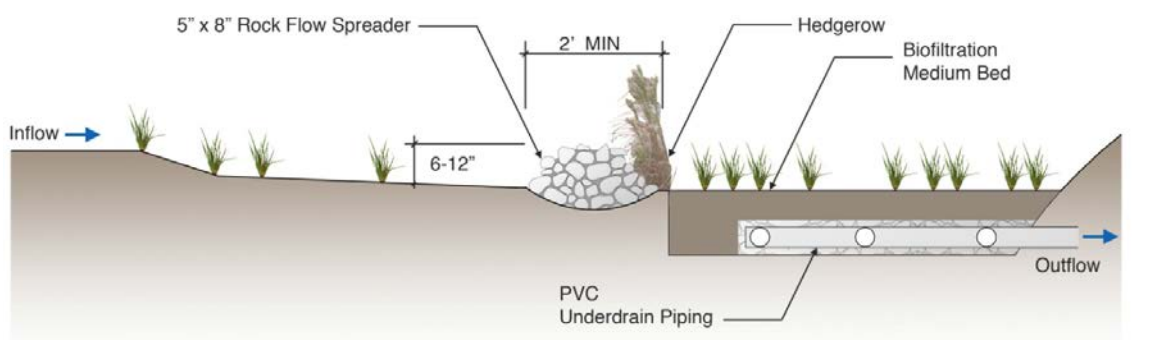


Figure 1.6.7.C-2: Partial Sedimentation/Biofiltration Pond.

Based on the equation and assumptions given above, the minimum surface area required for the biofiltration basin is:

A_f = WQV/(4 + 1.33*H) (Equation C-3)

Where:

~~"~~A_f~~" is the~~ = required surface area of the ~~media~~medium in square feet~~and~~

~~"~~WQV~~: is the~~ = water quality volume in cubic feet as defined in section 1.6.2A, and

~~"~~H~~" is the~~ = maximum ponding depth above the filtration ~~media~~medium in feet.

3. Sedimentation Basin/Sediment Chamber Details. The system consists of an inlet structure, flow spreader, vegetative settling area, and separator element. It is recommended that the bottom of the sediment chamber be ≥ 2" higher than the top of the filtration basin in order to uniformly discharge flow at or above the biofiltration vegetation, and to prevent excessive drawdown times due to tailwater effects.

A. Inlet Structure/Flow Spreader. The inflow of the water quality pond should pass through~~ the~~ a splitter structure where the water quality volume is separated (see section 1.6.2.B). Either way, t~~T~~he water quality volume flowing into the BMP should be discharged uniformly and at low velocity into the basin/chamber in order to ~~maintain near quiescent conditions which are necessary for effective treatment~~promote settling of entrained sediments, to avoid re-suspension of previously deposited sediments and, in extreme cases, to avoid flow concentration and subsequent channelizing of the basin/chamber substrate. ~~It is desirable for the heavier suspended material to drop out near the front of the basin.~~ Flow spreading should ~~occur after the inlet~~be designed so as to ~~return~~restore the flows entering the BMP (i.e., after the inlet structure) to sheetflow conditions with~~of~~ a maximum velocity of two (2) feet per second for the peak flow rate of the ~~developed~~ twenty-five (25) year storm ~~when entering the basin/chamber~~with the assumption that the catchment area has reached its fully development condition. See Section 1.6.2.D. Plantings in the sedimentation basin may ~~are to~~ provide resistance to flow and further spread the flows,~~;~~ thereby~~fore~~ reducing runoff velocities further to improve settling, biological uptake, and adsorption.

The basin/chamber should have a bottom slope of at least~~minimum~~ 2% ~~bottom slope~~ to ensure that the pond will drain adequately even after silt accumulation. Depending on the planned approach to maintenance and sediment removal, it may be desirable for the heavier suspended material to drop out near the inlet end of the basin.

B. Separator Element. A~~The~~ Separator Element structure is required for the Partial Sedimentation Biofiltration pond and should be designed to discharge the flow evenly across the filtration basin. This is important to avoid channelizing and destruction of the filtration medium surface. A reinforced vegetated hedgerow is recommended that uses five (5) inch by eight (8) inch rock flow spreaders or low gabion structures, two (2) feet wide and six (6) inches to twelve (12) inches deep, with hedgerows located within the structure (see Figure ~~1.6.7.C.2~~1.6.7.C-2). The outflow side should incorporate features to prevent gouging of the ~~soil~~filtration ~~media~~medium.

4. Biofiltration Basin Details. The Biofiltration ~~media~~medium bed filtration system consists of the biofiltration ~~media~~medium bed, underdrain piping, and outlet structure.

A. Biofiltration ~~Media~~Medium. In order to provide acceptable drainage and plant growth characteristics, the biofiltration ~~media~~medium shall meet the following performance criteria:

Percent Organic Matter (by weight) of ~~0~~ 0.5 – 5.0%

Texture Analysis (particle size distribution):

- Percent Sand 70 - 90%
- Percent Clay 3 - 10%
- Percent Silt plus Clay ≤ 27%

~~Laboratory testing will be required to verify percent organic matter and texture analysis. The date of the laboratory analysis must be no more than six months prior to the date of installation of the biofiltration media.~~ Suppliers of biofiltration media must have laboratory testing conducted at a minimum of six month intervals to verify percent organic matter-and texture analysis. The ~~media~~medium must not contain any contaminated soils and be free of any household or hazardous waste. It must be free of stones, trash, and other undesirable

material, and should not contain weeds or weed seeds. A saturated hydraulic conductivity of k ≥ 2.0 in/hr can be presumed if the organic matter and texture analysis criteria are met.

The hydraulic conductivity needs to be high enough to provide adequate drainage, support healthy plant growth, and prevent nuisance conditions.

The criteria are intended to meet the NRCS definition of soils with "moderate" to "high" available water capacity. The criteria should ensure that the ~~media~~medium has sufficient water holding capacity to support vigorous plant growth, enhancing the ability for plants to survive during dry periods. ~~In~~It should also sustain a healthy microorganism population which, in concert with the plants, should enhance biological removal of pollutants in stormwater.

The percent organic matter criterion is needed to ensure healthy vegetation. Most native soils in the Austin area have less than 4% organic matter, and native plants in the area have adapted to surviving in these types of soils. A higher organic matter content is not desirable as nutrients may be exported from~~out of~~ the ~~media~~medium~~; an unacceptable situation for a system intended to reduce nutrient loads~~, which is counter to the removal that is intended in this type of device. Immature compost, manure, compost derived from animal or human sources, and unstable forms of organic matter that may export nutrients should not be included in the biofiltration medium. Recommended sources of organic matter include that found naturally in native topsoil, humus, coconut coir fiber, and mature plant-derived composts with an established fungal component. The biofiltration ~~media~~medium must be certified by the project engineer or their~~his/her~~ designee (e.g.~~,~~ contractor, soil supplier, or appropriate qualified alternative individual) as meeting the above performance criteria (based on submittal of delivery tickets, test results, etc.) before acceptance by the City (see Biofiltration Sequence of Construction requirements in Section 1.6.3.C.6). Guidance for creating and certifying the ~~criteria~~ medium may be found on the City's website at:
~~http://www.cityofaustin.org/watershed/stormwater_treatment.htm.~~
http://www.austintexas.gov/department/stormwater-management

1. Creating Biofiltration Mixture

The biofiltration media should be a mixture of sand and other ingredients. Recognizing the difficulty in determining the correct types and proportions of various ingredients, the City has tested various media in order to characterize physical and chemical properties. The recommendations below reflect the test results and research conducted by the City and other stormwater professionals.

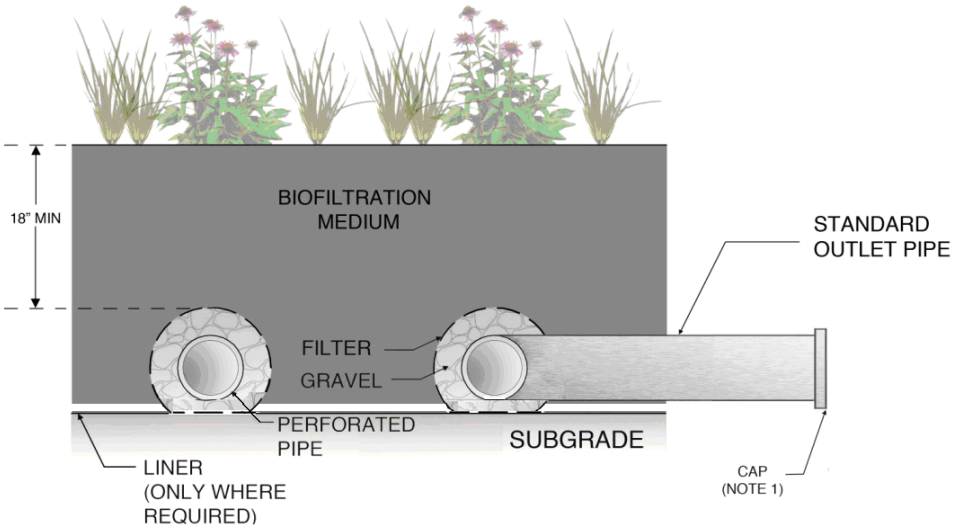
The following mixture (% by volume) should create an appropriate biofiltration media, subject to specific characteristics of the topsoil and compost ingredients, which may exhibit considerable variability:

- 70-80% concrete sand and/or screened decomposed granite sand
- 20-30% screened bulk topsoil (chocolate loam is also acceptable)
- The source materials must be free of stones, trash, and other undesirable material, and should not contain weeds or weed seeds.
- The ingredients must be well-mixed to create a homogenous media.

A commercially available fill material that should not be used is typically marketed as "sandy loam." This product is often referred to by landscapers as "red death", which refers to the color of the material, and is an infertile fill material that has poor drainage characteristics.

Some shrinkage of the media is to be expected after installation, in the range of 5-15%. As a general recommendation, about 20 inches of media should be installed to achieve the required depth of 18 inches. Wetting of the media at the time of installation is needed in order to determine actual shrinkage and amount of "make-up" material needed.

B. Biofiltration ~~Media~~ Bed with Underdrain~~Gravel Layer~~. The biofiltration ~~media~~medium bed for biofiltration basins must be built to the ~~"Sand~~ Biofiltration Bed ~~with Gravel Layer"~~ configuration illustrated in Figure 1.6.7.C-3 (for details see Figure 1-56D in Appendix V of this manual)~~(substitute biofiltration media for sand and use Figure 1-56 in Appendix V of this manual)~~. The biofiltration ~~media~~medium layer is to be a minimum of eighteen (18) inches meeting the specifications stated in Section 4A above. The biofiltration ~~media~~medium shall be a uniform mix, free of stones, stumps, roots or other similar objects larger than two inches. ~~No~~ Other materials or substances ~~shall be mixed or dumped within the biofiltration area~~ that may be harmful to plant growth, or prove a hindrance to the planting or maintenance operations shall not be mixed or dumped within the biofiltration area. Note: Required b~~B~~iofiltration ~~media~~medium bed depths should be interpreted as~~are~~ final consolidated values rather than as initially placed~~. Consolidation effects must be taken into account.~~ Under the biofiltration medium~~a~~ shall be ~~a layer~~ an underdrain system that consists of one-half (0.5) to one and one-half (1.5) inch diameter washed, rounded, river gravel surrounding 6 inch Schedule 40 PVC underdrain lateral pipes. The maximum spacing for the laterals should be ten (10) feet between laterals and five (5) feet from a wall or side. The minimum thickness of the gravel envelope is 3 inches. ~~which provides a minimum of three (3) inches of cover over the top of the 6", Schedule 40, PVC underdrain lateral pipes.~~ The soil medium~~a~~ and gravel layer must be separated by a filter material. The filter material may be a gravel separation lens consisting of 3/4 – 1/4-inch washed, rounded, river gravel (no limestone) 2 to 3 inches in thickness or a layer of geotextile fabric meeting the specifications listed in Section 1.4.5.P, Inlet Protection. To avoid compaction of the biofiltration ~~media~~medium and promote filtration ~~do not allow~~ heavy equipment shall not be allowed in biofiltration area after the biofiltration ~~media~~medium has been placed.



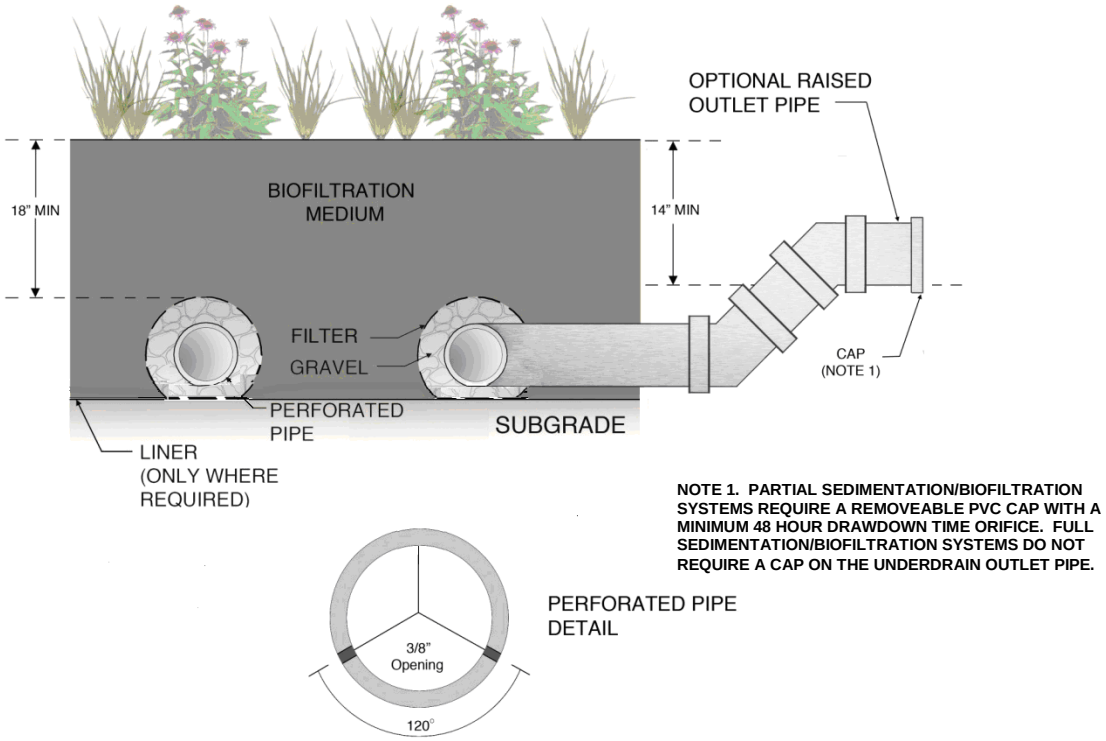


Figure 1.6.7.C-3: Biofiltration medium bed with underdrain system.

Access must be provided for cleaning all underdrain piping~~is needed~~. Cleanouts with a removable PVC cap are required within fifty (50) feet of every portion of lateral, at collector drain lines, and at every bend. In order to minimize damage to these cleanouts due to maintenance equipment, vandalism, and mowing, ~~set~~the top of the cleanout should be set flush with the top of the biofiltration medium~~ia~~ bed or ground surface from which it emerges. It is recommended that cleanouts be located outside of the water quality volume ponding area and above the water quality volume elevation when feasible to reduce short circuiting caused by loss or damage to the cleanout caps. At least one lateral must be accessible for cleaning when the pond is full. The full pond cleanout ~~should~~ must extend above the water quality elevation and/or be located outside of the water quality volume ponding area. In order to minimize vandalism or other types of damage ~~to this full pond cleanout~~ the use of exposed piping shall be avoided or minimized.

Note: The top surface of the biofiltration medium~~a~~ bed must be horizontal~~, i.e. no grade is allowed~~.

C. Outlet Structure. ~~The outlet structure controls the water quality volume from the biofiltration basin.~~ The outlet structure shall be designed in accordance with ECM section 1.6.5, Design Guidelines for Sedimentation/Filtration Systems, but may also include a raised outlet as shown in Figure 1.6.7.C-3 to create a saturated zone within the underdrain gravel area and part of the biofiltration ~~media~~medium. The advantages of a raised outlet are that the retained water is partially available to support plants in the filtration basin during extended dry periods and it reduces the total headloss across the system.

The surface discharge from the underdrain pipe shall be non-erosive. A splash pad or other dissipation system may be necessary. ~~Where feasible t~~Unless site conditions make it impossible, the underdrain pipe should discharge to a gravel trench in order to diffuse the discharge flow and promote infiltration and recharge

(see Figure 1.6.5.A.4, Sand Filtration Basin Details). The trench should be the width of the filtration basin and filled with gravel (See Figures 1-52 and 1-58 in Appendix V).

5. Landscape Design. Although an essential role of the landscaping is to make the pond attractive, the highest priority shall be to meet the pond's water quality and soil stabilization functional requirements. A diverse suite of plants should be ~~Plants should be~~ selected based on their ~~and~~ ability to survive under alternating conditions of inundation and extended dry periods. High plant diversity will provide resiliency to the system and help prevent a situation where all vegetation is lost. Over time, the plant species that are best suited to the unique conditions of each basin will naturally self-select and spread.

The landscape elements for the sedimentation basin or chamber may be different than for the biofiltration basin, due primarily to different soil characteristics. Compared to most native soils in the Austin area, the biofiltration medium~~a~~ may drain more rapidly, ~~have a greater percent organic matter,~~ and have less clay content~~, but should have comparable water holding characteristics~~. The selection of plants for the biofiltration medium~~a~~ depth will also be limited because the medium~~a~~ depth is typically ~~only~~ about 1.5 feet, thus plants with large root systems~~, such as trees,~~ are not appropriate. Trees shall not be used in the biofiltration chamber with underdrains. The soil characteristics and depth in the sedimentation basin or chamber will probably vary widely from site to site, and this will have a significant effect on the plant selection.

~~In general, the biofiltration basin should be planted with native or adapted grasses and forbs. Small trees (< 8" diameter at maturity) can be incorporated around the perimeter, above the water quality volume, as long as the underdrain system is protected from penetration by the tree root system and the structure does not met meet the definition of a dam or levee/floodwall as defined in the Drainage Criteria Manual section 8.3.4.~~

~~Vegetative elements in the sedimentation basin or chamber can be similar, but small trees (< 8" in diameter) can be placed in the floor and side slopes within the water quality volume, if soil conditions and depth are appropriate, and measures are taken to prevent root penetration into the adjacent filtration underdrain system.~~

City of Austin maintained biofiltration systems may be designed with ~~short herbaceous~~ turf grass and/or ground cover plants only.

A. Plant Quantities.

Vegetation should be planted throughout the entire sedimentation and filtration basin areas. Any portion of the basin not planted with containerized vegetation should be planted with turf grass/groundcovers.

Vegetation must be diverse and appropriately distributed. This generally requires that there be~~include~~ a minimum of five (5) different species planted. Both containerized plants and turf grass/ground covers will count towards the diversity minimum. Each species must comprise a minimum of 5 percent of the total number of containerized plants to provide adequate root and seed stock for future propagation. If it can be demonstrated that there is a compelling reason to deviate from these guidelines than an alternative design may be allowed with approval from the Director.

~~The minimum quantity of total required plants (rooted) for the pond is described. Place these plants in specific areas according to the following restrictions.~~

~~1. Pond bottom: Pond bottom shall be vegetated with a uniform cover of turf grass sod or an approved equivalent, with containerized plants interspersed according to Table 1-12.To determine the~~

~~minimum quantity of total required plants for the biofiltration system, multiply the surface area (in square feet) of the entire pond bottom by ten percent (0.1). This number represents the minimum number of plants to be placed in the pond bottom. These plants must be rooted one-gallon equivalents.~~

~~2. Sedimentation basin: A minimum of 20% of the total required rooted plants shall be placed in the sedimentation basin.~~

~~3. Filtration basin: A minimum of 50% of the total required plants shall be placed in the filtration basin. A minimum of 20% of the total required rooted plants shall be comprised of tall herbaceous species. No more than 30% of the total required plants may be medium herbaceous plants. Table 1-12 establishes the plant quantity requirements per plant category for the filtration basin.~~

Filtration Basin

1. To determine the minimum required quantity of containerized plants, multiply the total surface area (in square feet) of the filtration basin by twenty percent (0.2). This number represents the minimum number of plants to be placed in the filtration basin. Additional vegetation beyond this minimum is encouraged. All vegetation must be rooted one-gallon containers or the allowed equivalent shown in Table 1.6.7.C-1.
2. 50 percent of the containerized vegetation should come from Table 1.6.7.C-2, the remaining 50 percent can be any plant selected by the designer that is suitable to the growing conditions of the basin and is not a known invasive species ~~or~~ and is not listed in section G Invasive Plants or Table 1.6.7.C-3.
3. Small trees (< 8" diameter at maturity) can be incorporated around the perimeter, above the water quality volume, as long as the underdrain system is protected from penetration by the tree root system and the structure does not meet the definition of a dam or levee/floodwall as defined in the Drainage Criteria Manual section 8.3.4.

Sedimentation Basin

1. To determine the minimum required quantity of containerized plants, multiply the total surface area (in square feet) of the sedimentation basin by ten percent (0.1). This number represents the minimum number of plants to be placed in the sedimentation basin. Additional containerized plants beyond the minimums is encouraged. Plants must be rooted one-gallon containers or the allowed equivalent shown in Table 1.6.7.C-1.
2. 50 percent of the containerized plants should come from Table 1.6.7.C-2, the remaining 50 percent can be any plant selected by the designer that is suitable to the growing conditions of the basin and is not a known invasive ~~or~~ species and is not listed in section G Invasive Plants or Table 1.6.7.C-3.
3. Vegetation can be similar to the filtration basin however small trees (< 8” in diameter) can be placed in the floor and side slopes within the water quality volume, if soil conditions and depth are appropriate, and measures are taken to prevent root penetration into the adjacent filtration underdrain system.

~~4. Additional plants: Additional plants beyond the established minimums are encouraged. Additional plants must comply with other pertinent criteria (i.e. Table 1-18 Plants That Are Not Permitted).~~

Example: The following example demonstrates the minimum plant quantity for a sedimentation basin and filtration basin that are 500 square feet each.

- Sedimentation basin plant requirements

Area of sedimentation basin x 10% = minimum number of one gallon containerized plants or equivalent required

500 s.f. x 0.1 = 50 containerized plants required in sedimentation basin

Number of containerized plants required x 80% = minimum number of plants that must come from Table 1.6.7.C-2

50 x 0.8 = 40 containerized plants must be selected from Table 1.6.7.C-2

Number of containerized plants x 20% = maximum number of plants that are not required to be listed in Table 1.6.7.C-2.

50 x 0.2 = 10 containerized plants are not required to be listed in Table 1.6.7.C-2

- Filtration basin plant requirements

Area of filtration basin x 20% = minimum number of one gallon containerized plants or equivalent required

500 s.f. x 0.2 = 100 containerized plants required in filtration basin

Number of containerized plants required x 80% = minimum number of plants that must come from Table 1.6.7.C-2

100 x 0.8 = 80 containerized plants must be selected from Table 1.6.7.C-2

Number of containerized plants x 20% = maximum number of plants that are not required to be listed in Table 1.6.7.C-2.

100 x 0.2 = 20 plants are not required to be listed in Table 1.6.7.C-2

~~5. Example: The following example demonstrates the minimum plant quantity and location requirements for a pond bottom area of 3,000 square feet.~~

- ~~Overall Pond requirements~~

~~3,000 s.f. x 0.1 = 300 total required plants (one-gallon plants – refer to Table 1-13 for plant size equivalents)~~

- ~~Sedimentation basin requirements~~

~~300 total required plants x 0.2 = 60 plants (minimum) must be placed in the sedimentation basin~~

- ~~Filtration Basin requirements~~

~~300 total required plants x 0.5 = 150 rooted plants (minimum) must be placed in the filtration basin~~

~~150 total required plants for filtration x 0.4 = 60 tall herbaceous plants (minimum) must be placed in the filtration basin~~

~~300 total required plants x 0.3 = 90 medium herbaceous plants (maximum) are allowable in the filtration basin~~

~~300 total required plants x 0.3 = 90 short herbaceous plants (maximum) are allowable in the filtration basin~~

~~Table 1-12~~
~~Plant Quantity Requirements – Filtration Basin~~

~~**Pond Bottom (PB)**~~ ~~0.1 x PB sq. ft. = minimum quantity of rooted plants for the entire pond~~		
~~**Plant Category**~~ ~~Refer to Tables 1-15, 1-16, and 1-17 for allowable herbaceous species~~	~~**Filtration Basin Requirements**~~ ~~0.5 x total reqd. plants (min.)~~	
~~% of total required plants – minimum~~	~~% of total required plants – maximum~~	
~~Tall Herbaceous~~	~~40%~~	~~No maximum~~
~~Medium Herbaceous~~	~~-~~	~~50%~~
~~Short Herbaceous~~	~~-~~	~~30%~~
~~Optional: Designer's choice*~~	~~-~~	~~10%~~

~~*Designer's choice includes plants that are not restricted to the plants listed in tables 1-15, 1-16, and 1-17. (See item 1.6.7 (C) 5).~~

B. Plant Size.

Rooted plants may be provided in bare-root form, sod or in containers. Root mass of bare-root plants must be equal in mass to the equivalent container sizes. For the purpose of fulfilling the required minimum plant quantity, it is assumed that the plants to be installed will be 1-gallon size. Other sizes are acceptable but overall the quantity must be equivalent to the required minimum 1-gallon plants. See Table ~~1-13~~1.6.7.C-1 for equivalency.

Table 1.6.7.C-1~~13~~
Plant Size Equivalents

Potential	Equivalent

Substitute	To		
Quantity	**Plant Size**	Quantity	Plant Size
1	Five-gallon or larger	4	One-gallon
1	Two or Three-gallon	2	One-gallon
4	4” pots or quarts	1	One-gallon
8	Plugs	1	One-gallon
2	Pieces of sod	1	One-gallon

C. Plant Spacing.

1. Containerized plants should be spaced based on mature size to allow room for growth and avoid over crowding conditions that will cause plant mortality or impenetrable barriers for maintenance personnel.
2. Contiguous areas of sod should be planted end to end, allowing no bare soil.
3. At the time of planting, an 18” inch gap should be provided between the vegetative base (stems) of containerized plants and turf grass/groundcovers to allow room for growth and avoid overcrowding.

~~Table 1-14 establishes specific requirements for the arrangement of plants. There are no minimum spacing requirements. While dense plantings are encouraged, tall plants shall not be spaced so close to each other as to form an impenetrable barrier for maintenance personnel.~~

~~**Table 1-14**~~
~~**Plant Spacing Requirements**~~

~~**Plant Category**~~	~~Spacing Requirement~~
~~Tall Herbaceous~~	~~Maximum distance is 13’ (4 mtrs) from another tall or medium herbaceous plant~~
~~Medium Herbaceous~~	~~Maximum distance is 13’ (4 mtrs) from another medium or tall herbaceous plant~~
~~Short Herbaceous~~	~~Maximum width of turf (i.e. short herbaceous plants) is 10’ (3 mtrs)~~

D. Plant Selection.

~~Select and locate plants carefully so that they serve their intended function~~ ~~Both rooted plants and seed are required to meet the landscape requirements of biofiltration.~~ Plants must be s~~S~~elected and arranged ~~plants~~carefully so that they serve their intended functions. In addition to choosing plants for their aesthetic properties, select plants that:

- a~~A~~re adapted to the pond hydrology (i.e. periodic flooding and drought)
- a~~A~~re adapted to the soil types within the pond
- a~~A~~re suitable for their specific function (e.g. erosion control, filtration, etc.)
- a~~A~~re durable, resilient and resistant to pests and disease
- a~~A~~re tolerant of the pollution in stormwater runoff
- h~~H~~ave a root system of the desired type, mass and depth
- a~~A~~re resistant to weed invasion
- r~~R~~equire minimal maintenance and
- a~~A~~re not invasive

~~Choose from among the plants listed in Tables 1-15, 1-16, and 1-17 to meet the requirements established in item 1.6.7 (C) 5. Plant Quantities.~~

E. Recommended Plant Species.

Table 1.6.7.C-2-~~15~~

Recommended Plant Species

Botanical Name	**Common Name**
~~Agrostis stolonifera~~	~~Creeping bentgrass~~
Andropogon gerardii	Big bluestem
~~Andropogon glomeratus~~	~~Bushy bluestem~~
Buchloe dactyloides	Buffalo grass
~~Calyptocarpus vialis~~	~~Horseherb~~
~~Capsicum annuum~~	~~Chili pequin~~
~~Carex cherokeensis~~	~~Cherokee sedge~~
~~Carex emoryi~~	~~Emory's sedge~~
~~Chasmanthium latifolium~~	~~Inland sea oats~~
~~Conoclinium coelestinum~~	~~Blue mistflower~~
~~Distichlis spicata~~	~~Salt grass~~
~~Eleocharis palustris~~	~~Common spikerush~~
~~Eleocharis quadrangulata~~	~~Squarestem spikerush~~
Elymus canadensis	Canada wildrye

~~Elymus virginicus~~	~~Virginia wildrye~~
~~Equisetum hyemale~~	~~Horsetail~~
~~Helianthus angustifolius~~	~~Swamp sunflower~~
Helianthus maximiliani	Maximilian sunflower
~~Juncus effusus~~	~~Soft rush~~
~~Juncus tenuis~~	~~Slender rush~~
~~Justicia americana~~	~~American Water-willow~~
~~Leersia hexandra~~	~~Clubhead cutgrass~~
~~Leptochloa dubia~~	~~Green sprangletop~~
~~Liatris pycnostachya~~	~~Prairie blazing star~~
~~Lobelia cardinalis~~	~~Cardinal flower~~
~~Marsilea macropoda~~	~~Water clover~~
Muhlenbergia capillaris	Gulf coast muhly
Muhlenbergia filipes	Purple muhly
Muhlenbergia dumosa Muhlenbergia lindheimeri	Pine muhly Big muhly
Muhlenbergia rigens	Deer muhly
~~Muhlenbergia utilis~~	~~Aparejograss~~
~~Panicum obtusum~~	~~Vine mesquite~~
Panicum virgatum	Switchgrass
~~Paspalum distichum~~	~~Knotgrass~~
~~Paspalum vaginatum~~	~~Seashore paspalum~~
Penstemon tenuis	Brazos penstemon
~~Phyla nodiflora~~	~~Frogfruit~~
Physostegia spp.	Obedient plant
~~Pluchea odorata~~	~~Marsh fleabane~~
~~Poa arachnifera~~	~~Texas bluegrass~~
~~Rivina humilis~~	~~Pigeonberry~~
~~Rudbeckia hirta~~	~~Black-eyed Susan~~
~~Saccharum alopecuroides~~	~~Silver plumegrass~~
Schizachyrium scoparium	Little bluestem
~~Schoenoplectus acutus~~	~~Hardstem bulrush~~
~~Setaria parviflora~~	~~Knotroot bristlegrass~~
~~Solidago altissima~~	~~Tall goldenrod~~
~~Solidago nemoralis~~	~~Gray goldenrod~~
Sorghastrum nutans	Indian grass
~~Spartina pectinata~~	~~Prairie cordgrass~~
Sporobolus airoides	Alkali sacaton
~~Sporobolus virginicus~~	~~Seashore dropseed~~
Stenotaphrum secundatum	St. Augustine grass
~~Symphyotrichum praealtum~~	~~Tall aster~~
~~Teucrium canadense~~	~~Canada germander~~
~~Thelypteris ovata~~	~~Shield Fern~~

~~Tridens strictus~~	~~Longspike tridens~~
Tripsacum dactyloides	Eastern gamagrass
~~Verbesina virginica~~	~~Frostweed~~

~~1. Tall Herbaceous Plants: This category includes grasses, forbs, sedges and rushes that usually attain a height greater than 4' at maturity. These plants are well-suited for biofiltration. Certain grasses are ideal species for use as hedgerows as well. When spaced closely together (e.g. 3' o.c.) the hedgerow grasses shade the ground so effectively that most weeds cannot survive.~~

~~Table 1-15~~
~~Tall Herbaceous Plants~~

~~This table includes grasses, sedges, rushes and forbs that are usually taller than 4' at maturity~~

~~Botanical Name~~	~~Common Name~~	~~Sed~~	~~Filt~~
~~Andropogon gerardii~~	~~Big bluestem~~	~~x~~	~~x~~
~~Andropogon glomeratus~~	~~Bushy bluestem~~	~~x~~	-
~~Helianthus maximiliani~~	~~Maximilian sunflower~~	-	~~x~~
~~Juncus effusus~~	~~Soft rush~~	~~x~~	~~x~~
~~Muhlenbergia lindheimeri~~	~~Big muhly~~	~~x~~	~~x~~
~~Panicum virgatum~~	~~Lowland switchgrass~~	~~x~~	~~x~~
~~Panicum virgatum~~	~~Upland switchgrass~~	~~x~~	~~x~~
~~Saccharum alopecuroides~~	~~Silver plumegrass~~	~~x~~	-
~~Schizachyrium scoparium~~	~~Little bluestem~~	-	~~x~~
~~Schoenoplectus acutus~~	~~Hardstem bulrush~~	~~x~~	-
~~Sorghastrum nutans~~	~~Indian grass~~	~~x~~	~~x~~
~~Spartina pectinata~~	~~Prairie cordgrass~~	~~x~~	-
~~Tridens strictus~~	~~Longspike tridens~~	-	~~x~~
~~Tripsacum dactyloides~~	~~Eastern gama grass~~	~~x~~	~~x~~
~~Verbesina virginica~~	~~Frostweed~~	~~x~~	~~x~~

~~2. Medium Herbaceous Plants: This category includes grasses, forbs, sedges, ferns, and rushes that are from 2' to 4' tall. The cool-season grasses are typically green in the winter, extending the growing season. Certain plants can tolerate some shade.~~

~~Table 1-16~~
~~Medium Herbaceous Plants~~

~~This table includes grasses, sedges, rushes, ferns and forbs that are from 2' to 4' at maturity~~

~~Botanical Name~~	~~**Common Name**~~	~~Sed~~	~~Filt~~
~~Carex emoryi~~	~~Emory's sedge~~	~~x~~	~~-~~
~~Capsicum annuum~~	~~Chili pequin~~	~~x~~	~~x~~
~~Chasmanthium latifolium~~	~~Inland sea oats~~	~~x~~	~~x~~
~~Eleocharis quadrangulata~~	~~Squarestem spikerush~~	~~x~~	~~-~~
~~Elymus canadensis~~	~~Canada wildrye~~	~~x~~	~~x~~
~~Elymus virginicus~~	~~Virginia wildrye~~	~~x~~	~~x~~
~~Equisetum hyemale~~	~~Horsetail~~	~~x~~	~~-~~
~~Justicia americana~~	~~American Water-willow~~	~~x~~	~~-~~
~~Leptochloa dubia~~	~~Green sprangletop~~	~~-~~	~~x~~
~~Liatris pycnostachya~~	~~Prairie blazing star~~	~~x~~	~~-~~
~~Lobelia cardinalis~~	~~Cardinal flower~~	~~x~~	~~-~~
~~Muhlenbergia capillaris~~	~~Gulf coast muhly~~	~~x~~	~~x~~
~~Muhlenbergia filipes~~	~~Purple muhly~~	~~x~~	~~x~~
~~Muhlenbergia rigens~~	~~Deer muhly~~	~~-~~	~~x~~
~~Physostegia spp.~~	~~Obedient plant~~	~~x~~	~~-~~
~~Pluchea odorata~~	~~Marsh fleabane~~	~~x~~	~~x~~
~~Solidago altissima~~	~~Tall goldenrod~~	~~x~~	~~x~~
~~Sporobolus airoides~~	~~Alkali sacaton~~	~~-~~	~~x~~
~~Sporobolus virginicus~~	~~Seashore dropseed~~	~~x~~	~~x~~
~~Symphyotrichum praealtum~~	~~Tall aster~~	~~x~~	~~x~~
~~Teucrium canadense~~	~~Canada germander~~	~~x~~	~~-~~
~~Thelypteris ovata~~	~~Shield fern~~	~~x~~	~~-~~

~~3. Short Herbaceous Plants: This category includes grasses, forbs, sedges, ferns, and rushes that are shorter than 2' at maturity. Certain plants are shade tolerant. Many will colonize an area by way of rhizomes, stolons or seed. The colonizers include sod-forming grasses that may be managed as turf. Mowing/trimming restrictions will apply to these areas. Other colonizers form attractive groundcovers and may serve as "fillers" in a garden.~~

~~**Table 1-17**~~ ~~**Short Herbaceous Plants**~~ ~~This table includes grasses, sedges, rushes and forbs that are usually shorter than 2' at maturity~~			
~~**Botanical Name**~~	~~Common Name~~	~~Sed~~	~~Filt~~
~~Agrostis stolonifera~~	~~Creeping bentgrass~~	~~x~~	~~-~~
~~Buchloe dactyloides~~	~~Buffalo grass~~	~~x~~	~~x~~

~~Calyptocarpus vialis~~	~~Horseherb~~	-	~~x~~
~~Carex cherokeensis~~	~~Cherokee sedge~~	~~x~~	-
~~Conoclinium coelestinum~~	~~Blue mistflower~~	~~x~~	-
~~Distichlis spicata~~	~~Salt grass~~	~~x~~	~~x~~
~~Eleocharis palustris~~	~~Common spikerush~~	~~x~~	-
~~Helianthus angustifolius~~	~~Swamp sunflower~~	-	~~x~~
~~Juncus tenuis~~	~~Slender rush~~	~~x~~	-
~~Leersia hexandra~~	~~Clubhead cutgrass~~	~~x~~	-
~~Marsilea macropoda~~	~~Water clover~~	~~x~~	-
~~Muhlenbergia utilis~~	~~Aparejograss~~	~~x~~	~~x~~
~~Panicum obtusum~~	~~Vine mesquite~~	~~x~~	~~x~~
~~Paspalum distichum~~	~~Knotgrass~~	~~x~~	-
~~Paspalum vaginatum~~	~~Seashore paspalum~~	~~x~~	-
~~Penstemon tenuis~~	~~Brazos penstemon~~	~~x~~	-
~~Phyla nodiflora~~	~~Frogfruit~~	~~x~~	~~x~~
~~Poa arachnifera~~	~~Texas bluegrass~~	~~x~~	-
~~Rivina humilis~~	~~Pigeonberry~~	-	~~x~~
~~Rudbeckia hirta~~	~~Black-eyed Susan~~	-	~~x~~
~~Salvia penstemonoides~~	~~Big red sage~~	~~x~~	-
~~Setaria parviflora~~	~~Knotroot bristlegrass~~	~~x~~	~~x~~
~~Solidago nemoralis~~	~~Gray goldenrod~~	-	~~x~~
~~Stenotaphrum secundatum~~	~~St. Augustine grass~~	~~x~~	~~x~~
~~Viola missouriensis~~	~~Missouri violet~~	~~x~~	~~x~~

F. Optional Plant<u>s</u>: Designer's Choice.

Plants in this category are counted towards the minimum quantity requirements (See item 1.6.7 (C) 5). While native grasses dominate the plant list~~s~~, many designers will want to use ~~non-native~~ <u>other</u> ornamental grasses and plants. Ornamental ~~grasses~~ <u>plants</u> are used chiefly for ornament, however the plants in biofiltration have a greater purpose. <u>Designers may want to include plants that exhibit tolerance to extreme droughts such as cherry sage or twist-leaf yucca.</u> The following restrictions apply:

- Plant types must conform to the requirements explained in ~~the opening paragraph of~~ Section 5 – Landscape Design

- Plant species may not include plants that are considered invasive. <u>See section G below and Table 1.6.7.C-3</u>. ~~(refer to the Grow Green Native and Adapted Plant Guide – published by the City of Austin).~~

- ~~Plant species may not include plants listed in Table 1-18 (Plants That Are Not Permitted).~~

G. Plant Species That Are Not Permitted.

Plants listed in Table 1.6.7.C-3~~1-18~~ are not permitted in biofiltration systems. These plants are not native, yet have shown the capacity to naturalize here or in other areas of the country. The intent is to avoid future problems with invasive plants. The following restrictions apply:

§ Plant species listed as invasive by the City of Austin Grow Green Native and Adapted Plant Guide or the state of Texas are not allowed. Two lists are maintained.

§ Refer to http://www.texasinvasives.org/Invasives_Database/Invasives.html

§ TDA Noxious Weed List

§ TPWD Prohibited Exotic Species

§ USDA NRCS – Texas, State-listed noxious weeds
http://plants.usda.gov/java/noxious?rptType=State&statefips=48

Table 1.6.7.C-3~~18~~
~~Plants That Are Not Permitted~~ Vegetation That Is Not Permitted For Planting

Botanical Name	**Common Name**	Comments
Arundo donax	Giant reed	Tall invasive grass
Bothriochloa ischaemum var. songarica	'King Ranch' bluestem (KR bluestem)	Invasive grass
Cortaderia selloana	Pampas grass	Potentially invasive
~~Cynodon dactylon~~	~~Bermuda grass~~	~~Invasive grass~~
Cytisus scoparius	Scotch broom	Invasive shrub
Eragrostis curvula	Weeping love grass	Invasive grass
Imperata cylindrica	Cogon grass	Invasive grass
Miscanthus sinensis	Japanese silver grass	Invasive grass
Pennisetum setaceum	Fountain grass	Invasive grass
Phragmites australis	Common reed	Tall invasive grass
Sapium sebiferum	Chinese tallow	Invasive tree

~~H. Maintenance, Irrigation, and Sequence of Construction - See Section 1.6.3.~~

6. References:

1. Maryland Department of the Environment, Center for Watershed Protection, 2000, *2000 Maryland Stormwater Design Manual, Volumes I and II*

2. New Jersey Department of Environmental Protection, 2004, *Stormwater Best Management Practices Manual*, Division of Watershed Management Trenton, NJ.

3. Prince George's County Department of Environmental Resources Programs and Planning Division, 2001, *The Bioretention Manual*, Maryland

4. Low Impact Development (LID), Urban Design Tools, lid-stormwater.net

5. USEPA, NPDES, Stormwater Best Management Practices, cfpub.epa.gov/npdes/stormwater/

~~*Click here to view a PDF of Figure 1.6.7.C.1 and Figure 1.6.7.C.2*~~

Figure 1.6.7.C.1: Full Sedimentation / Biofiltration Pond

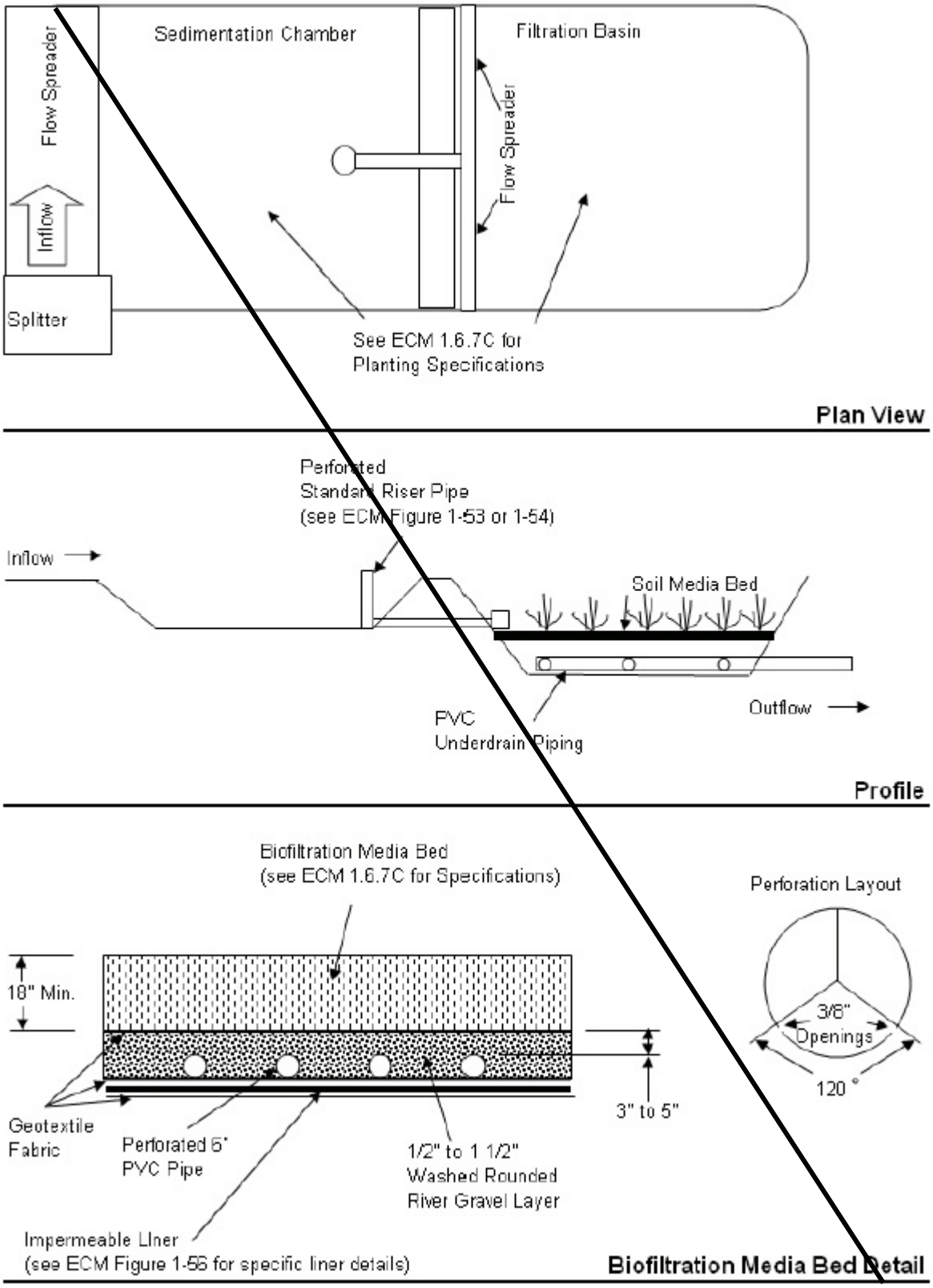
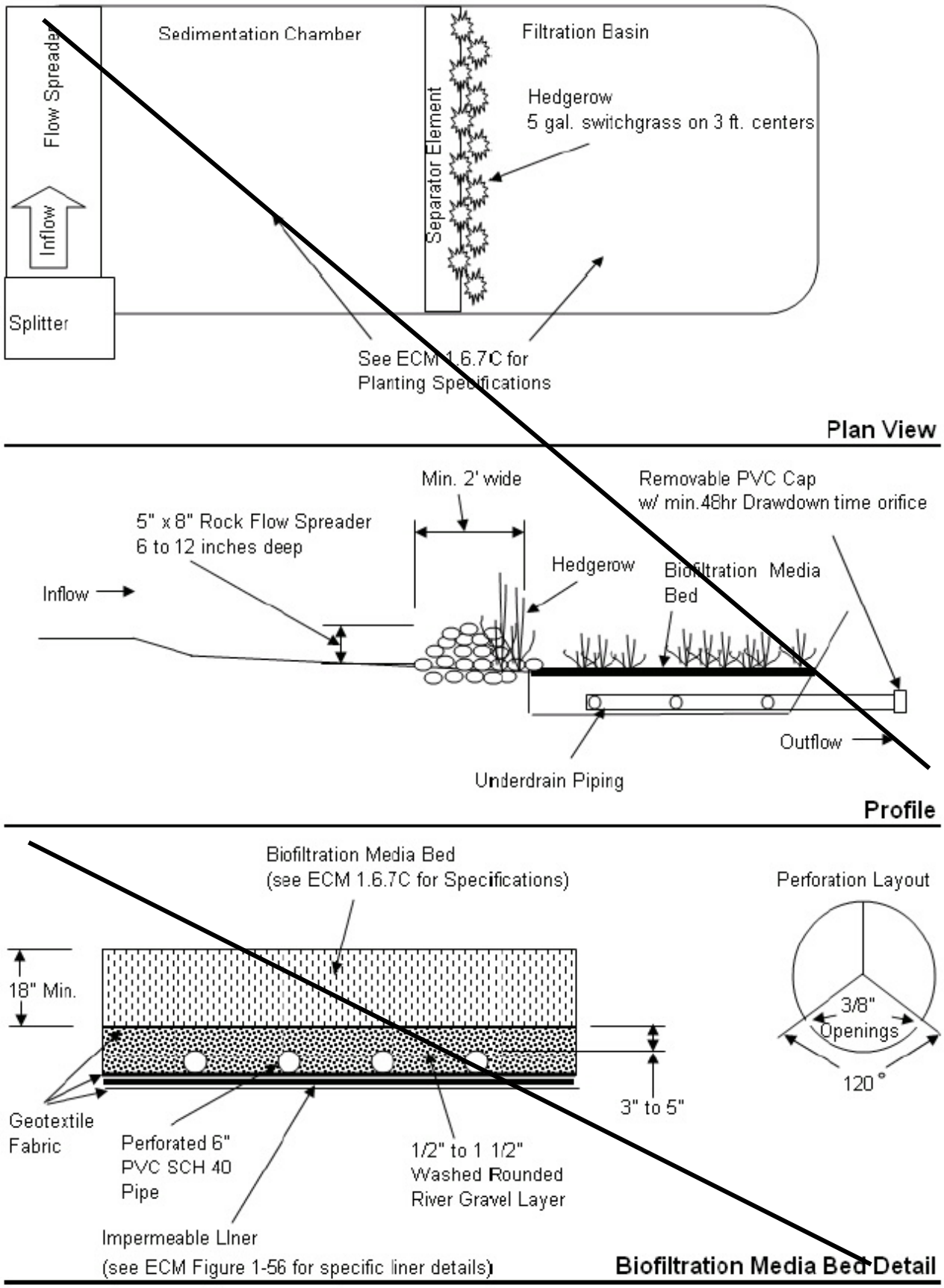


Figure 1.6.7.C.2: Partial Sedimentation / Biofiltration Pond



D. Rainwater Harvesting

1. Introduction. Rooftops can generate large volumes of runoff which, when discharged to paved surfaces and landscaped areas, can generate large pollutant loads. Rainwater harvesting systems can capture this runoff before it is discharged, thus preventing pollution while also putting the captured water to beneficial use, such as landscape irrigation or cooling water. The amount of runoff captured will depend on the size (water quality volume) and drawdown time of the rainwater harvesting system. The systems can also control the peak flow rate for the 2-year storm see section 1.6.8 of the Environmental Criteria Manual (ECM) if specifically designed for this purpose. Rainwater harvesting systems can provide equivalent treatment to a standard sedimentation/filtration system but only the irrigation design (Option B) described below will meet retention irrigation system standards and therefore can be used as a primary method for controlling non-point source pollution in watersheds within the Barton Springs Zone or Barton Springs Contributing Zone. Rainwater Harvesting systems will only be permitted for commercial developments.

In an effort to promote water conservation, the State of Texas offers financial incentives and tax exemptions to offset the equipment costs. Additionally, the Water Conservation staff of the City of Austin Water Utility Department is available to provide input on how to achieve cost efficient design and equipment selection that will also help reduce water and wastewater costs.

2. Water Quality Credit.

The water quality credit will typically be applied as either a reduction in the water quality volume for a structural control or a reduction in the fee-in-lieu cost. The basic water quality credit equation is calculated using Equation 1.6.7-1.~~The basic credit equation is:~~

~~WQC = IAF * BMPDF~~

- ~~WQC = Water Quality Credit, a value between 0 and 1, with 1 meaning 100% credit.~~
- ~~Where IAF is the Impervious Area Factor, or the ratio of the impervious area treated by the control to the total site impervious area..~~
- ~~BMPDF is the BMP Design Factor, a value between 0 and 1, is a measure of the potential effectiveness of the control.~~

For rainwater harvesting systems the BMPDF variable is a function of the following factors: ~~will be calculated as:~~

~~$BMPDF = (WQV_{rwh}/WQV_{ecm}) * (DDT_{ecm}/ DDT_{rwh})$~~

- WQV_{rwh} is the water quality capture depth provided by the rainwater harvesting system in inches,
- WQV_{ecm} is the ECM required water quality capture depth in inches, and
- ~~DDT_{ecm} is the ECM required drawdown time for sedimentation-filtration system in hours (a minimum 48 hrs.).~~
- DDT_{rwh} is the rainwater harvesting system drawdown time in hours (a maximum of 120 ~~72~~ hrs.).

~~It is assumed that the rainwater harvesting system will be capturing runoff from rooftops that are 100% impervious cover. The water quality capture depth for 100% impervious cover is 1.30 inch for projects located outside of the Barton Springs Zone. The drawdown time for equivalency, based on sedimentation-filtration systems, is 48 hours. Inserting these values into the BMPDF equation, with rounding, gives:~~

~~$BMPDF = 37 * WQV_{rwh}/ DDT_{rwh}$~~

- ~~Where WQV_{rwh} is in inches~~
- ~~DDT_{rwh} is in hours~~

The BMPDF shall be determined using Figure 1.6.7.D-1 below:

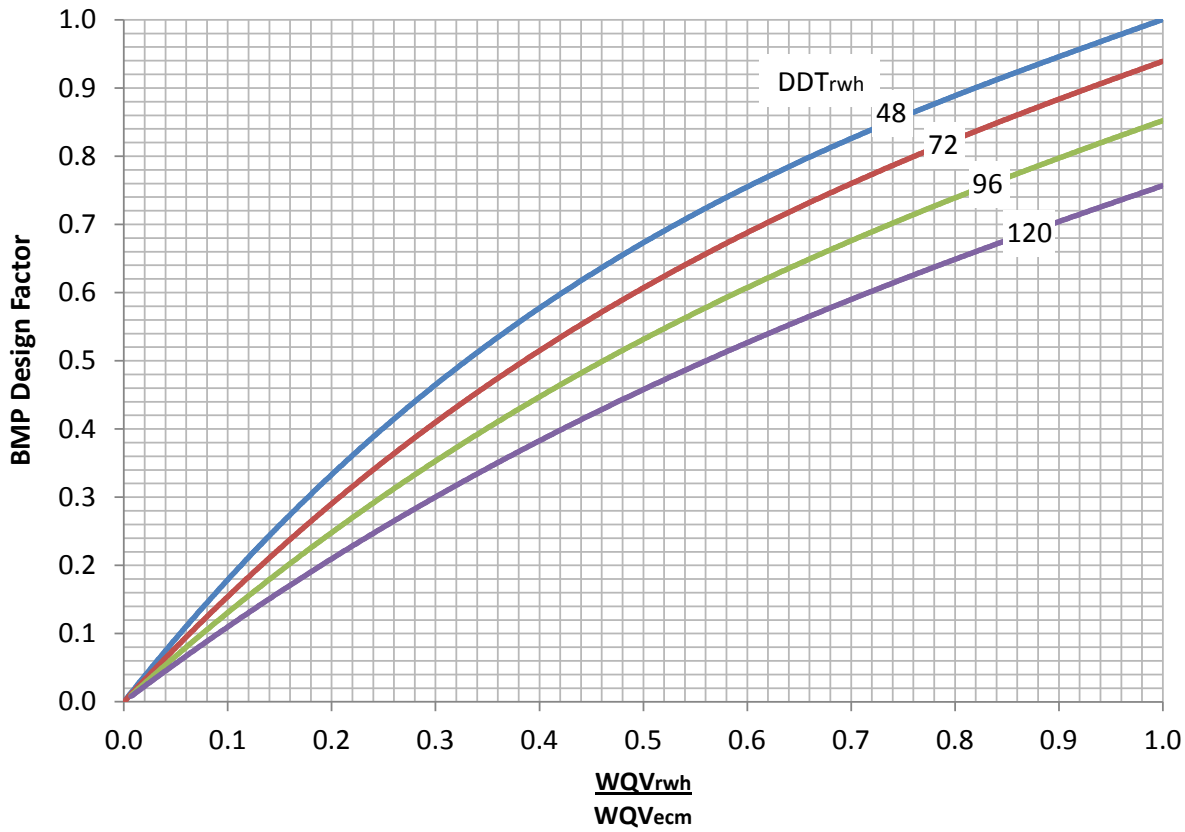


Figure 1.6.7.D-1. BMP Design Factor for Rainwater Harvesting Systems.

The derivation of the drawdown time will vary with the type of system, as described below for specific design options. In all cases the drawdown is calculated as:

$DDT = WQV/Q_{rwh}$

Where:

- ~~Where~~ DDT is the drawdown time
- WQV is the water quality volume
- Q_{rwh} is the rate of discharge from the rainwater harvesting system

~~A.~~ **3. Design Options: ~~Rainwater harvesting with Infiltration or Irrigation of a Vegetated Area in = 72 hours~~**

A typical configuration for a rainwater harvesting system is shown in Figure 1.6.7.D-2. To receive water quality credit, rainwater harvesting systems must be designed so that~~In this design, the~~ captured runoff is held ~~in the rainwater harvesting system~~ for at least 12 hours after rainfall has ceased, then either gravity-drained to a vegetated area sized large enough to infiltrate all the water (Option A), or used to irrigate the vegetated area (Option B). The latter design is similar to a retention/irrigation system and ECM section 1.6.7(A) should be referenced for guidance. The vegetated area can also serve as a vegetated filter strip for flows that by-pass the rainwater harvesting system.

Because the required drawdown time is no more than five (5) ~~three (3)~~ days, these systems generally cannot be used to meet water conservation-oriented landscape irrigation needs (e.g., 5-day watering schedule). However, the portion of the system capacity that is recovered during the 5-day (maximum) drawdown period may be eligible for water quality credit. For example, water in the system may be pumped to a separate tank for

subsequent beneficial reuse such as landscape irrigation during dry conditions. Or, a portion of the tank may be designated as water quality volume that empties within 5 days and the remaining portion of the tank is reserved for beneficial reuse. The amount of water harvested for beneficial reuse should be evaluated so that it may be usefully deployed over the service area to which it is directed. The annual capture and annual use (for irrigation, etc.) for the device should balance, and if they do not the annual use becomes the limiting capture quantity. Note that the rainwater harvesting storage tank is considered impervious cover that counts toward the required capture water quality volume.

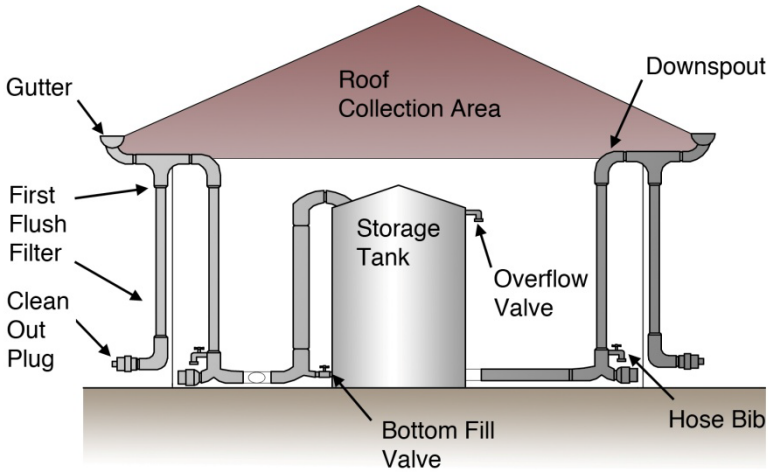


Figure 1.6.7.D-2. Typical configuration for a rainwater harvesting system.

Alternatively, and with approval from the Director, the system may be designed to empty or partially empty prior to the next forecasted rain event using an advanced real-time controller.

Option A - Captured Runoff Gravity-Drained to a Vegetated Area for Infiltration

The water quality volume must be provided by the system designer, with the drawdown time set to a maximum of 120 ~~72~~ hours. The designer must demonstrate that the vegetated area is sufficiently large to infiltrate the entire water quality volume within 120 ~~72~~ hours (see Figure ~~1.6.7.D.1~~1.6.7.D-3 below). ~~In lieu of a detailed analysis the procedure described below can be used.~~

The average "treatment" rate of the rainwater harvesting system is:

Q_{avg} = WQV/DDT

Where:

- ~~Where~~ Q_{avg} is the treatment rate
- WQV is the water quality volume
- DDT is the drawdown time, which is set to a maximum of 120 ~~72~~ hours

It is reasonable to assume saturated conditions, and the infiltration rate of the vegetated area can be calculated as:

Q_{veg} = k * i * A

Where:

- ~~Where~~ k ~~is the~~= soil hydraulic conductivity
- i ~~is the~~= hydraulic gradient, and

- A ~~is the~~= infiltration (vegetated) area.

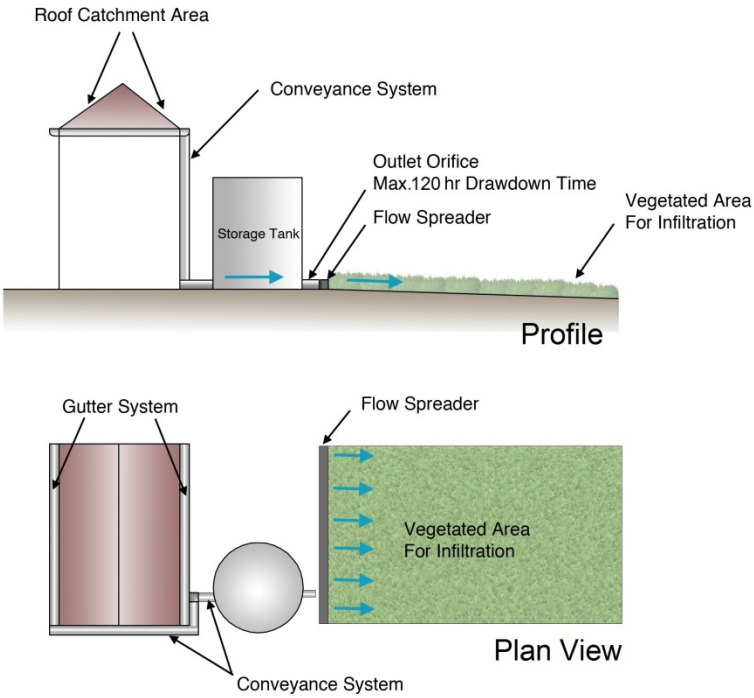


Figure 1.6.7.D-3. Design Option A with captured runoff discharged to a vegetated area for infiltration.

As minimal ponding of water over the vegetated area is expected, the hydraulic gradient can be assumed equal to 1, thus:

$Q_{veg} = k * A$

To be conservative, design the vegetated area for the maximum flowrate discharged from the rainwater harvesting system. A reasonable assumption is to assume a value twice Q_{avg}, and to also assume a lag time (LT) between the time runoff ends and when the rainwater harvesting system begins discharging:

$Q_p = (2 * WQV)/(DDT – LT)$

Setting the peak flow rate discharged from the rainwater harvesting system equal to the vegetated area infiltration rate, and solving for A:

$A = (2 * WQV)/(k * (DDT – LT))$

~~A low hydraulic conductivity value that is typical of Austin area soils should be used, and 0.06 in/hour, or 0.005 ft/hour, is assumed. The lag time LT should be set to 12 hours. Inserting these assumptions into the infiltration (vegetated) area gives:~~

~~A = (400 * WQV)/(DDT – 12)~~

Where

- ~~Where~~ A ~~is the~~= minimum required infiltration (vegetated) area in ft^2
- WQV ~~is the~~= water quality volume in ft^3
- k ~~is the~~= hydraulic conductivity in ft/hour
- DDT ~~is the~~= drawdown time in hours
- LT ~~12 is the~~= lag time ~~(LT)~~ in hours

A design infiltration rate (i.e., hydraulic conductivity) for the site must be established through desktop study and field sampling as described in Section 1.6.7.4. The lag time LT should be set to a minimum of 12 hours.

~~Assuming a 72 hour drawdown time the equation becomes:~~

~~A = 6.67 * WQV~~

- ~~Where A is the minimum required infiltration (vegetated) area in ft^2~~
- ~~WQV is the water quality volume in ft^3~~

~~A larger area will be needed for drawdown times less than 72 hours. A drawdown time greater than 72 hours is not allowed.~~

To be eligible for water quality credit the vegetated area also must meet the ~~vegetated filter strip~~ following criteria ~~in ECM 1.6.7(B) and 1.6.7 (F), with the following additions~~:

- The length (dimension in direction of flow) of the vegetative area should be at least 15 feet.
- The average slope of the vegetative area must be between 1% and 10%, with no portion exceeding 15%.
- The hydraulic loading rate should not exceed 0.05 cfs per ft. width for the maximum flowrate applied to the ~~filter strip~~vegetated area (see below for procedure to calculate peak flowrate). Higher hydraulic loading rates are allowed but will reduce water quality credit. In this case, a maximum allowable rate of 0.15 cfs per ft. width is allowed.
- The soil depth should be a minimum of eight (8) inches.
- The vegetated area should have dense vegetative cover (minimum 95% coverage as measured at the base of the vegetation). The use of native grasses is strongly recommended due to their resource efficiency and their ability to enhance soil infiltration. In the case of natural wooded areas where 95% vegetative cover is not present, a minimum of four inches of leaf litter or mulch must be in place.
- An irrigation plan is required.

Option B - Captured Runoff Used to Irrigate Vegetated Area

A typical design configuration in which captured runoff is used to irrigate a vegetated area is shown in Figure 1.6.7.D-4 below. The water quality volume must be provided by the system designer, with the drawdown time set to a maximum of 120 hours ~~72 hours~~. The system should be designed according to the retention/irrigation criteria in section 1.6.7.A of the Environmental Criteria Manual ~~should be used (see Figure 1.6.7.D.2)~~.

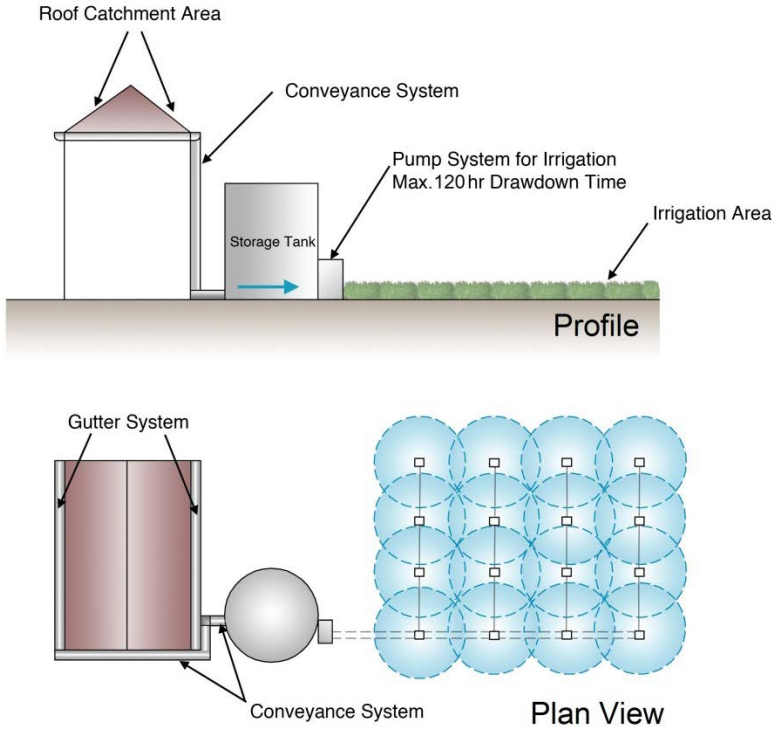


Figure 1.6.7.D-4. Design Option B with captured runoff used to irrigate a vegetated area.

4. Example ~~– Captured runoff gravity-drained to vegetated area (Option A)~~

A 5 acre commercial development with ~~8~~50% impervious cover (~~4~~2.5 impervious acres) is proposing a rainwater harvesting system that would capture runoff from ~~2~~1 acre~~s~~ of rooftop and drain it by gravity to a vegetated area (Option A). The development is located outside of the Barton Springs Zone. The system would have a water quality volume of 25,000 gallons, which would be emptied in 96 ~~72~~ hours by discharging to a vegetated area that is 260' wide by 90' long. The design hydraulic conductivity for the site was established to be 0.06 in/hour, or 0.005 ft/hour. Evaluate this design and determine the water quality credit it may be eligible for.

The water quality credit will typically be applied as either a reduction in the water quality volume ~~for~~ of a structural control or a reduction in the fee-in-lieu cost.

As the alternative control is for ~~2~~1 acres of impervious cover, and the site has a total of 2.5~~4~~ impervious acres, the IAF value is 0.~~5~~40 (= ~~2/4~~1/2.5).

The BMPDF factor is a function of two components, the rainwater harvesting system and the vegetated area. The BMPDF value for the rainwater harvesting system is based on the water quality volume and drawdown time, subject to the requirement that the vegetated area must be large enough to infiltrate the captured volume.

To determine the BMPDF value, first convert the water quality volume from gallons to inches:

WQV_{rwh} = (25,000 gallons * 1 ft^3/7.481gal) = 3,342 ft^3 = ~~0.460~~ 0.92-inch

The BMPDF value is a function of the following factors: ~~calculated as:~~

~~BMPDF = (~~

WQV_{rwh}/WQV_{ecm}~~) * (DDT$_{ecm}$/~~ and

DDT_{rwh}~~)~~

~~BMPDF = 37 * WQV/DDT~~

~~• Where WQV is in inches~~

~~• DDT is in hours~~

The rainwater harvesting system will be capturing runoff from a rooftop that is 100% impervious cover. The water quality capture depth for 100% impervious cover is 1.30-inch for projects located outside of the Barton Springs Zone. Therefore, the factors to determine BMPDF are:

WQV_{rwh}/WQV_{ecm} = 0.92/1.3 = 0.71, and

DDT_{rwh} = 96 hours.

~~Or BMPDF = 37 * 0.46/72= 0.236~~

Inserting these values into Figure 1.6.7.D-1, gives:

BMPDF = 0.68.

Before this credit can be applied first determine if the vegetated area is sufficient to infiltrate the water quality volume in 96 ~~72~~ hours.

Is it large enough?

Minimum size A = ~~6.67 * WQV = 6.67 * 3,342 = 22,290 ft^2~~ (2 * WQV)/(k * (DDT – LT)) = (2 * 3,342)/(0.005 * (96-12) = 15,914 ft^2.

Size provided = 260’ * 90’ = 23,400 ft^2 – ~~just~~ this is large enough

Is the length of the vegetated area at least 15 feet?

Yes as the proposed length is 90 feet.

Does it meet the 0.05 cfs/ft. width hydraulic loading rate for the discharge from the rainwater harvesting system?

To estimate peak flowrate and hydraulic loading rate:

Q_p = (2 * WQV)/(DDT – LT) = (2 * 3,342)/(~~72~~ 96 – 12) = 80 ~~111~~ cfh = ~~0.031~~ 0.022 cfs

HLR = Q/W = ~~0.031~~ 0.022/260 = ~~0.00012~~ 0.00008 cfs/ft width – Okay as < 0.05

All other slope, soil depth, vegetative cover, etc. criteria is also met, thus the vegetated area is acceptable and:

The total water quality credit for the proposed system is:

WQC = IAF * BMPDF = ~~0.5 * 0.235= 0.118~~ 0.4 * 0.68 = 0.272.

~~3. Maintenance. See Section 1.6.3.~~

5. References~~:~~

1. The Texas Manual on Rainwater Harvesting, 3rd edition 2005
2. City of Tucson Water Harvesting Guidance Manual, October 2005
3. City of Austin Energy, Green Building Program, 1995

~~*Click here to view a PDF of Figure 1.6.7.D.1, and Figure 1.6.7.D.2.*~~

Figure 1.6.7.D.1: Rainwater Harvesting Option A

Captured Runoff discharged to a Vegetative Filter Strip for Infiltration (< 72 hr drawdown time)

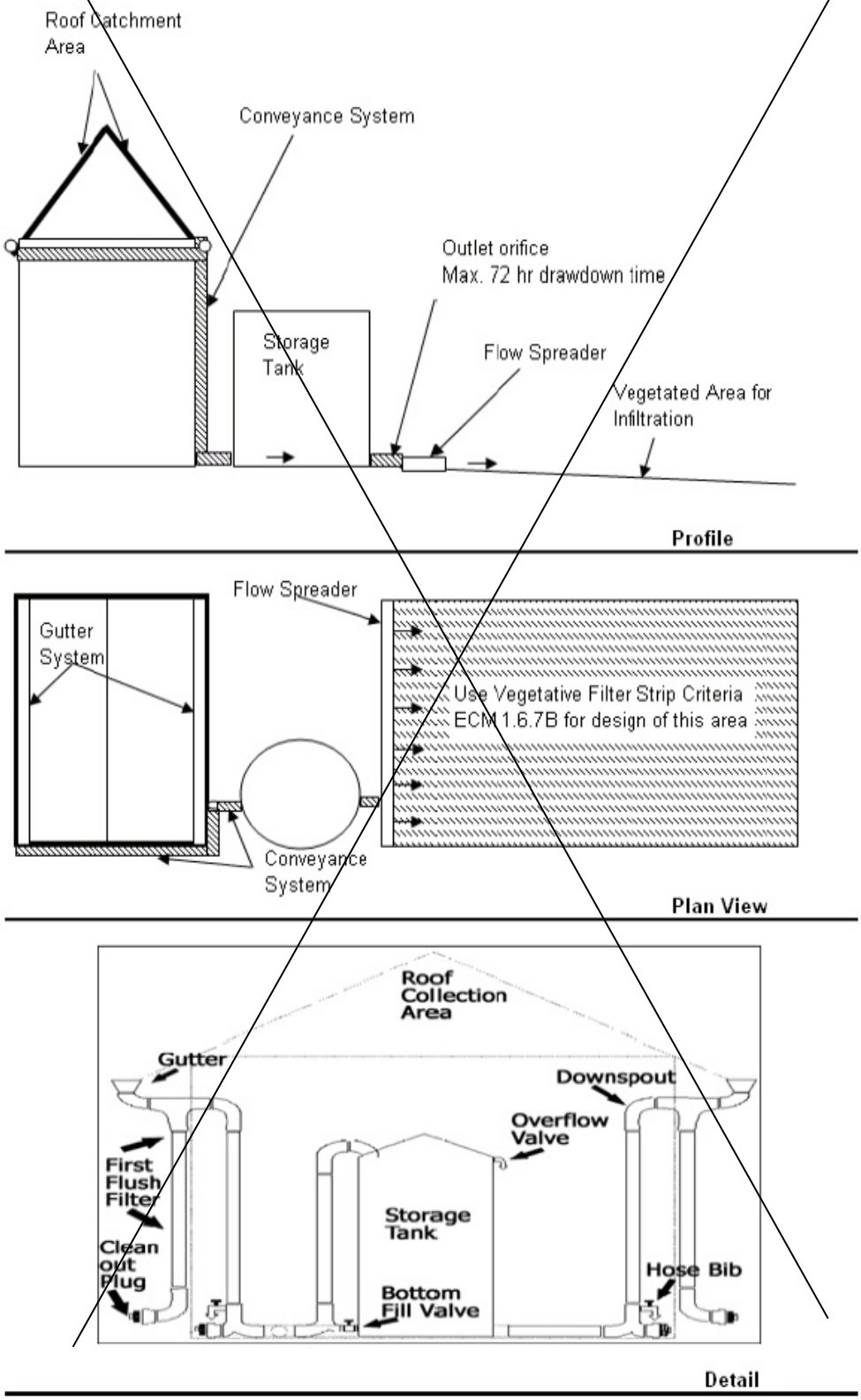
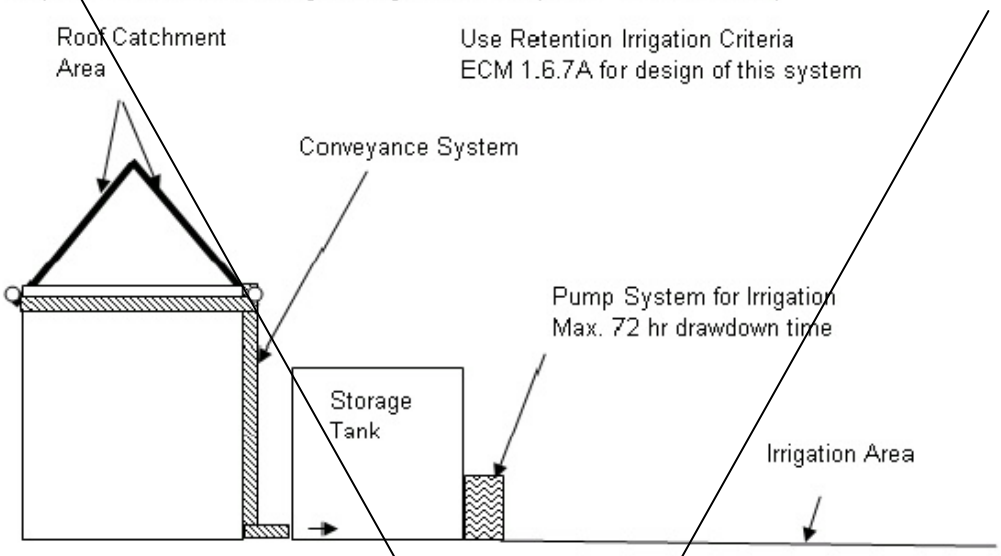
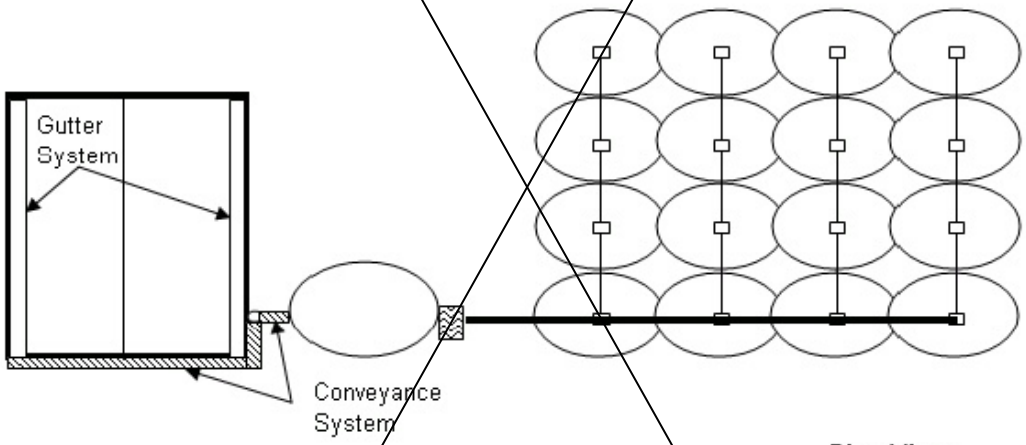


Figure 1.6.7.D.2: Rainwater Harvesting Option B

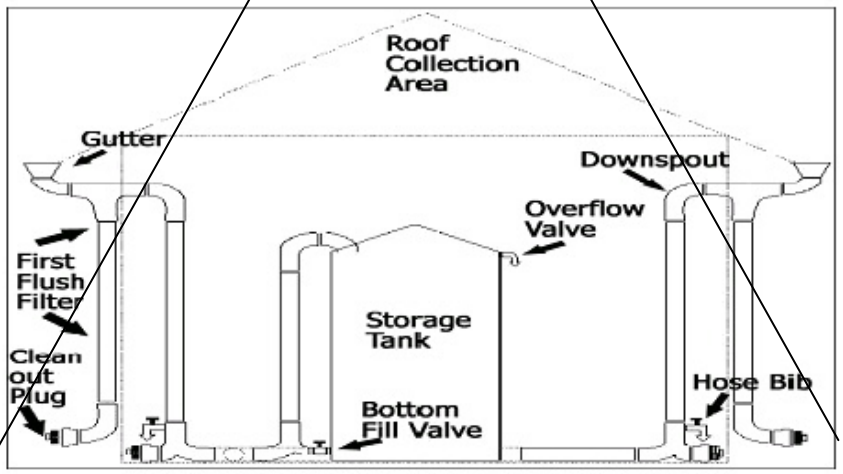
Captured Runoff Used to Irrigate Vegetated Area (<72 hr drawdown time)



Profile



Plan View



Detail

E. Porous Pavement for Pedestrian Use

1. Introduction. Porous Pavement describes a system comprising a load-bearing, durable concrete surface together with an underlying layered structure that temporarily stores water prior to infiltration. Porous Pavement is a water quality control best management practice (BMP) using the storage within the underlying structure or sub-base to provide ground water recharge and to reduce pollutants in stormwater runoff. Unlike traditional pavement, porous pavement contains little or no "fine" materials; instead, it contains voids that encourage infiltration. Porous pavement consists of an open-graded coarse aggregate, bonded together by asphalt cement, with sufficient interconnected voids to make it highly permeable to water. When proposing the use of this material be sure to provide highly detailed specifications and ensure that an experienced contractor is used to minimize potential problems.

Porous pavement for vehicular use is not allowed as a water quality control and will not receive credit against water quality volume calculations. If porous pavement is proposed for non-pedestrian use in the recharge zone of a Drinking Water Protection Watershed or in the Barton Springs Recharge or Contributing Zone then a liner is required underneath the porous pavement structure and the runoff from this structure must drain to an approved Water Quality control.

Porous pavement for pedestrian use is not acceptable as a water quality control and will not receive credit against water quality volume calculations within the Barton Springs Recharge or Contributing Zone.

Porous pavement is not allowed under stormwater hot spots or areas where land use or activities generate highly contaminated runoff. Hot spot runoff frequently contains pollutant concentrations exceeding those typically found in stormwater. Hot spots include commercial nurseries, auto ~~recycle~~ salvage facilities, ~~public works storage areas,~~ hazardous materials generators (if containers are exposed to rainfall), vehicle ~~service~~ fueling and maintenance areas, and vehicle and equipment washing~~, and~~ dry or steam cleaning facilities, food production/distribution loading dock and trash compactor areas (Note: Some of these land uses/activities may have additional discharge restrictions under Chapter 6-5, Article 5 (Discharges into Storm Sewers or Watercourses) of the City Code). Since porous pavement is an infiltration practice, it should not be applied at stormwater hot spots due to the potential for ground water contamination.

Porous pavement adjacent to buildings, roadways, and other structures may require an impermeable barrier to prevent possible damage to these structures due to infiltration. The requirement for impermeable barriers will be at the discretion of the design engineer.

2. Water Quality Credit and Design Guidelines.

For water quality credit purposes, porous pavement area that meets the following criteria can be deducted from the drainage area used for sizing the water quality control; however it is not eligible for impervious cover credit unless allowed under § 25-8-63 of the Land Development Code:

- Porous pavement hydraulic conductivity > 20 in/hr.
- Subgrade saturated hydraulic conductivity > 0.20 in/hr.
- Gravel layer below porous pavement thickness ≥ 3 inches with effective porosity ≥ 0.30.
- COA walkways standard sidewalk dimensions used (i.e., no over-sized walkways that may encourage vehicular use).
- No off-site runoff
- No irrigation
- Depth to water table ≥ 3 feet

- Depth to bedrock ≥ 12”
- Industrial vacuuming or pressure washing every six months.
- See Figure 1.6.7.E.~~-~~1 for typical cross-section~~general details~~.

See Section 1.6.3 for requirements related to construction, maintenance, signage, and sequence of construction.

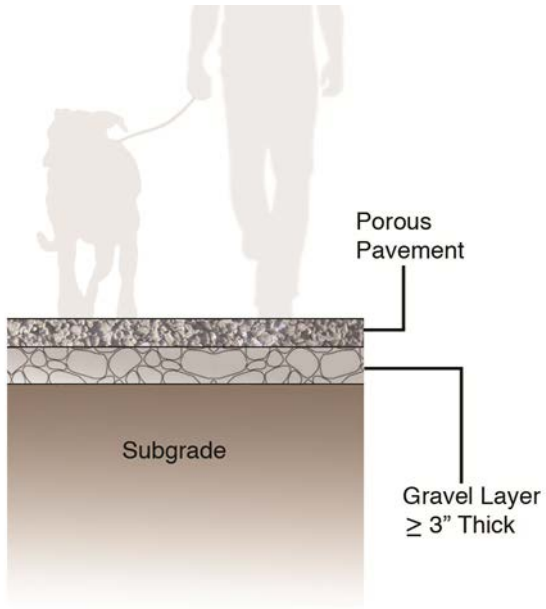


Figure 1.6.7.E-1. Typical cross-section for porous pavement.

3. Example ~~1~~

A 5 acre commercial site with ~~8~~50% impervious cover (~~4~~2.5 impervious acres) is required to implement on-site water quality controls. The development proposes to use 0.5 acres (of the 2.5 impervious acres) of porous pavement for pedestrian walkways. Determine the water quality credit for this system.

Without the porous pavement, the water quality volume required is ~~1.1~~0.80”, or ~~19,965~~14,520 ft^3.

Assuming the above criteria is met, the porous pavement deducts 0.5-acre from the site impervious cover, thus the site behaves as if it is 4.5 acres with ~~3.5~~2.0 impervious acres, or ~~77.8~~44.4% impervious cover. This reduces the required water quality volume from ~~1.1~~0.80” to ~~1.078~~0.744” and the drainage area is also reduced from 5 acres to 4.5 acres. The required water quality volume with porous pavement is thus ~~17,605~~12,161 ft^3, or about a 1~~2~~6% reduction.

~~3. Construction, Maintenance, Signage, and Sequence of Construction - See Section 1.6.3.~~

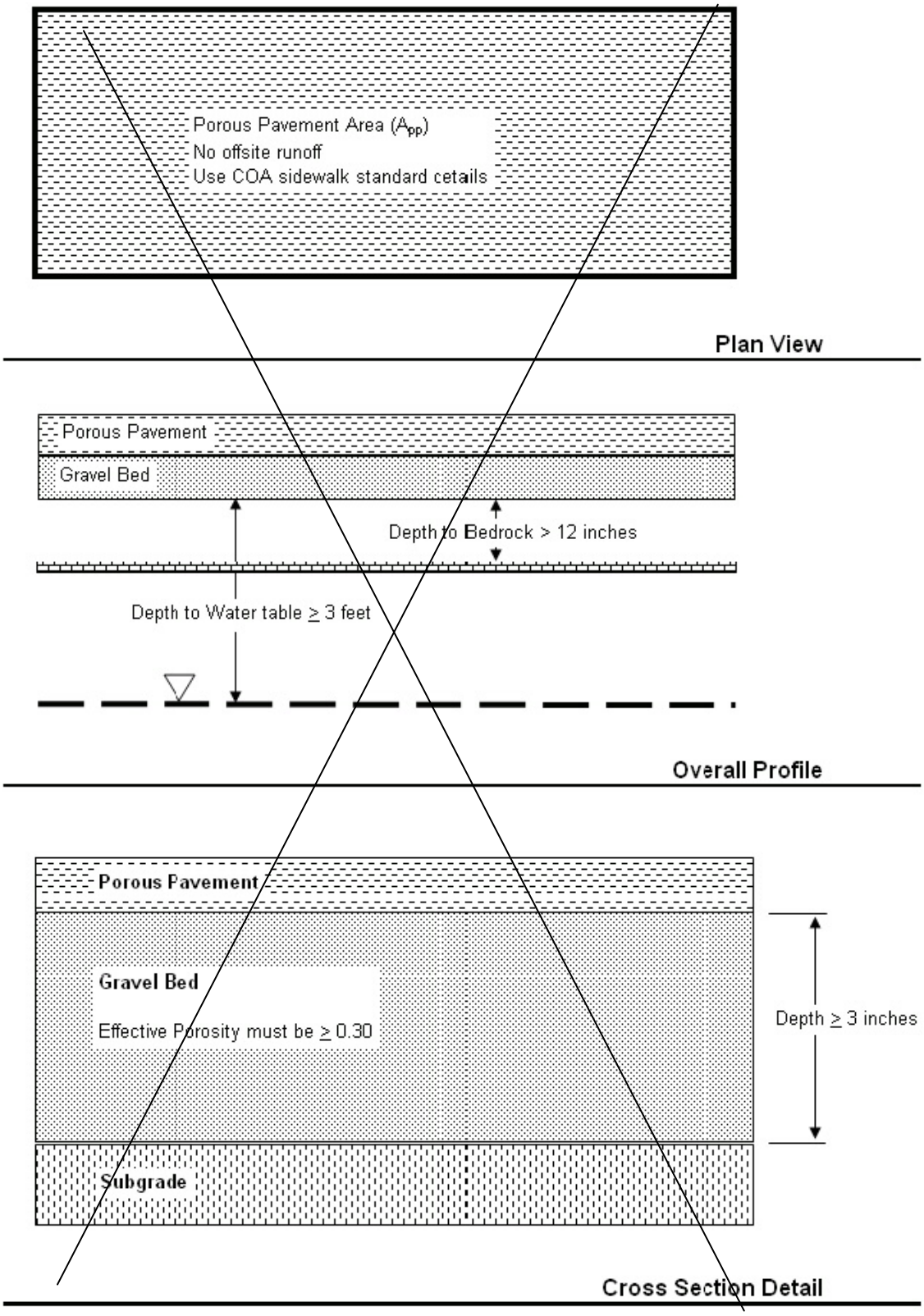
4. References:

1. USEPA, NPDES, Stormwater Best Management Practices, cfpub.epa.gov/npdes/stormwater/

2. Lower Colorado River Authority, Highland Lakes Watershed Ordinance, *Water Quality Management Technical Manual*, February 1, 2006

~~*Click here to view a PDF of Figure 1.6.7.E.1*~~

Figure 1.6.7.E.1: Porous Pavement for Pedestrian Use Only



G. Non-Required Vegetation

1. Introduction. Additional non-required vegetation, especially trees, can help reduce stormwater runoff and enhance ground water recharge by breaking the impact of raindrops and improving soil structure. A tree's effectiveness in this capacity is correlated with the size of the crown and root zone area. There are numerous environmental and stormwater benefits to additional vegetation. Non-required vegetation can act as natural stormwater management area by filtering particulate matter, including pollutants, some nutrients, sediments, and pesticides, and by absorbing water. A study done by the U.S. Department of Agriculture's Center for Urban Forest Research found that a medium-sized tree can intercept 2,380 gallons of rain per year (Center for Urban Forest Research ~~2002~~2003). A factor that can reduce the life and health of trees in urban areas, and thus their effectiveness, is compaction of or pavement over root systems. The criteria below are designed to protect the root system.

Non-required vegetation is eligible for water quality credit except in watersheds within the Barton Springs Zone and Contributing Barton Springs Zone.

2. Water Quality Credit and Design Guidelines

For water quality credit purposes, non-required vegetation can be deducted from the drainage area used for sizing the water quality control; however it is not eligible for impervious cover credit~~: See example in porous pavement for pedestrian use in Section 1.6.7.E~~.

The following factors affect non-required vegetation Water Quality credit:

- The available planting area, see ECM 3.5.0;
- The anticipated rate of survival of vegetation planted;
- The quantity of vegetation to be planted; and
- The types of vegetation proposed.

The vegetation area eligible for credit is the 25-year growth root system. For trees, the root system is assumed to be equal to the canopy cover. To be eligible for credit the entire spatial area of the 25-year root system must be pervious (landscape and/or pedestrian-only porous pavement).

Direct rainfall is assumed to be the primary source of stormwater and no off-site runoff is allowed.

Minimum soil depths of twelve (12) inches for new trees and eight (8) inches for plants and grasses will be required. For the soil media requirements use the biofiltration media specifications shown in Environmental Criteria Manual (ECM) 1.6.7(C) Biofiltration.

For Non-required vegetation where porous pavement is used above the root zone the design criteria for porous pavement should be followed, see ECM 1.6.7 (E). However, no observation ports are required for non-required vegetation.

Note: No Water Quality credit will be given for the 25-year growth root system of non-required vegetation located within vehicular parking areas. Additionally, porous pavement is not allowed under stormwater hot spots or areas where land use or activities generate highly contaminated runoff as described in ECM 1.6.7(E).

3. Example

A 5 acre commercial site with 50% impervious cover (2.5 impervious acres) is required to implement on-site water quality controls. The development proposes to use 0.2 acre (of the 2.5 pervious acres) of non-required vegetation determined based on the 25-year growth root system. Determine the water quality credit for this system.

Without the non-required vegetation, the water quality volume required is 0.80”, or 14,520 ft^3.

Assuming the above criteria is met, the non-required vegetation deducts 0.2-acre from the site total area but does not reduce the amount of impervious cover. Thus the site behaves as if it is 4.8 acres with 2.5 impervious

acres, or 52.1% impervious cover. This increases the required water quality volume from 0.80" to 0.821" but the drainage area is also reduced from 5 acres to 4.8 acres. The required water quality volume with non-required vegetation is thus 14,305 ft^3 or about a 1.5% reduction.

~~3. Maintenance. For additional maintenance requirements see Section 1.6.3.~~

4. References:

1. USDA Forest Service, PSW, Center for Urban Forest Research, Rainfall Interception by Santa Monica's Municipal Urban Forest, September 2003

H. Rain Garden.

1. ~~Introduction~~ Description.

A rain garden is a vegetated, depressed landscape area designed to capture and infiltrate and/or filter stormwater runoff. The growing medium for the rain garden consists of either amended native soil or biofiltration media. If the infiltration capacity of the subgrade soils is limited, the rain garden can be underlain by an underdrain system. Rain gardens will provide sedimentation and physical filtration of pollutants in stormwater runoff similar to other treatment systems. However, because they are restricted to smaller drainage areas and shallower ponding depths, which necessitate a larger surface area, infiltration, evapotranspiration, and biological uptake mechanisms may be more significant for rain gardens than other treatment BMPs.

There are three different types of rain garden designs included in this section:

- full infiltration (no underdrain);
- partial infiltration (filtration system with raised outlet or partial underdrain); and
- filtration system with no infiltration.~~a filtration and/or infiltration system that~~

2. Site Selection.

Rain gardens can be used in new developments or as a retrofit within an existing site. Unlike conventional centralized stormwater management systems, multiple rain gardens may be dispersed across a development, and incorporated into the landscape, providing aesthetic as well as ecological benefits. Rain gardens allow for all or a portion of the water quality volume (WQV) to be treated within landscaped areas, and therefore may reduce landscape irrigation requirements by making use of stormwater runoff. Rain gardens are especially suited for small sites and are typically installed in locations such as parking lot islands, site perimeter areas, and other landscape areas.

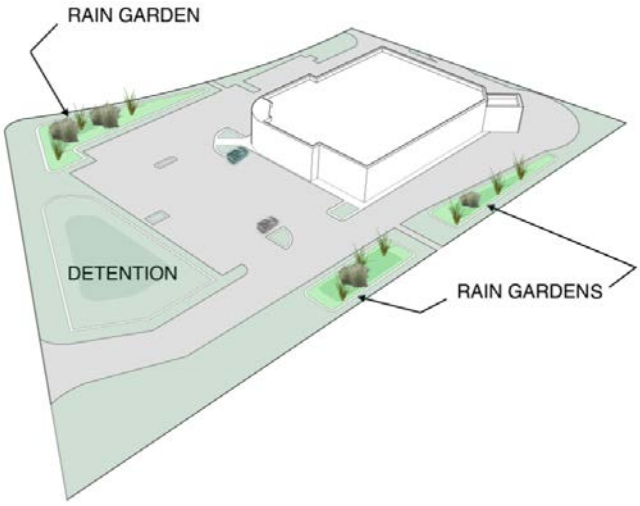


Figure 1.6.7.H-1. Multiple rain gardens may be dispersed across a development, and incorporated into the landscape, providing aesthetic as well as ecological benefits.

The following site characteristics must be considered when designing a rain garden.

Land Use – The use of rain gardens as a water quality control is limited to Commercial and Multi-Family developments only. Full infiltration and partial infiltration rain gardens are not allowed in areas where land use or activities generate highly contaminated runoff due to the potential for ground water contamination. These areas include commercial nurseries, auto recycle facilities, hazardous materials generators (if containers are exposed to rainfall), industrial process areas, gas stations, , food production/distribution loading dock and trash compactor areas, vehicle fueling and maintenance areas, and vehicle and equipment washing and steam or dry cleaning facilities.

Drainage Area ~~– has a contributing drainage area not to exceed 1.0 (one) acre, and a ponding depth not to exceed 6 (six) inches.~~ Rain gardens are restricted to a contributing drainage area not to exceed two acres and a ponding depth not to exceed 12 inches. ~~Unlike conventional centralized stormwater management systems, the rain garden approach may employ multiple controls dispersed across a development, and incorporated into the landscape, providing aesthetic as well as ecological benefits. Other than what is specifically mentioned in this section, all other design, construction, landscape, inspection and maintenance criteria for Biofiltration in Section 1.6.7(C) must be met.~~

Barton Springs Zone ~~–~~ A ~~Rain Garden~~ rain garden can provide partial treatment equivalent to a standard sedimentation/filtration system but is not acceptable as a primary method for controlling non-point source pollution in watersheds within the Barton Springs Zone and Contributing Barton Springs Zone. If a rain garden is proposed for use in the Barton Springs Recharge or Contributing Zone, then a liner is required and the discharge from this facility must be managed to comply with the Save Our Springs ordinance.~~The use of a Rain Garden as a water quality control is limited to Commercial and Multi-Family developments only.~~

Setbacks – Rain gardens must be designed to prevent adverse impacts to building foundations, basements, wellheads, and roadways from the infiltration of water.

Slopes – Rain gardens should not be located on slopes exceeding 15 percent.

Soil conditions – When siting a full or partial infiltration rain garden, appropriate soil conditions must be present. The depth to an impermeable layer must be at least two feet below the bottom of the rain garden. For full infiltration rain gardens, the underlying soil must have a design infiltration rate that will draw down the full ponded depth in less than 48 hours. For example, for a 12 inch maximum ponding depth, the design infiltration rate must be at least 0.25 inches per hour. For a 6 inch maximum ponding depth, the design infiltration rate must be least 0.13 inches per hour. For a 3 inch maximum ponding depth, the minimum design infiltration rate is 0.06 inches per hour. Design infiltration rate should be based on applying at least a factor of safety of 2 to the measured steady state saturated infiltration rate (i.e., the design infiltration rate is equal to one half of the measured infiltration rate). A higher factor of safety may be used at the discretion of the design engineer to take into variability associated with assessment methods, soil texture, soil uniformity, influent sediment loads, and compaction during construction. For full infiltration systems the infiltration rate of the soil subgrade below the growing medium of the rain garden must be determined using in-situ testing as described in ECM Section 1.6.7.4. If a range of values are measured then the geometric mean should be used.

Water Table – Full and partial infiltration rain gardens are not allowed in locations where the depth from the bottom of the growing medium to the highest known groundwater table is less than three feet.

Bedrock – Full and partial infiltration rain gardens are not allowed in locations where depth from the bottom of the growing medium to bedrock is less than one foot. In cases with bedrock less than 3 feet from the bottom of the growing media, soil testing should be conducted in-situ to account for the effect of this limiting horizon.

Groundwater and Soil Contamination – Full and partial infiltration rain gardens are not allowed in locations where infiltration would cause or contribute to mobilization or movement of contamination in soil or groundwater or would interfere with operations to remediate groundwater contamination. If filtration rain gardens are proposed under these conditions, the potential for incidental infiltration should be evaluated to determine whether an impermeable liner must be used.

3. Maintenance Considerations

Maintenance requirements are included in ECM Section 1.6.3. During design, the following should be considered to facilitate long-term maintenance:

Whenever possible, design the rain garden to be offline (whereby surface flow enters and exits (only when full) the system through the same opening), with runoff by-passing the system once ponding depth equals the water quality volume elevation. This configuration may reduce erosion from larger storm events and will also minimize mixing of the water quality volume.

While not required, consider providing pre-treatment to help reduce the extent and frequency of maintenance, especially if the contributing drainage area is expected to generate sediment, debris, or other pollutant that may cause decreased system functionality. Pre-treatment may include a sedimentation chamber, a vegetated or manufactured separator element (to functionally separate the rain garden into higher deposition and lower deposition zones), a vegetated filter strip, or an inlet designed at a minimal slope to encourage sediment deposition prior to flows entering the rain garden. ~~As with sand and biofiltration systems, a rain garden will provide physical filtration of pollutants in stormwater runoff. However, because of the small drainage area and shallow ponding depth, which necessitate a larger surface area, biological and plant uptake mechanisms may be more significant for rain gardens. In addition, rain gardens may receive lower sediment loads than other systems, and this can also potentially enhance their pollutant removal performance, and prolong operational life.~~

Select native vegetation whenever possible to reduce the need for long-term irrigation and maintenance. ~~On the negative side, if~~ If rain gardens are over-irrigated and receive significant applications of fertilizers and herbicides, they can become sources of pollution rather than pollutant removal BMPs. Thus, it is essential that these rain garden systems be managed carefully and that an approved and recorded Integrated Pest Management plan be required for the drainage area up to and including the rain garden.

Whenever possible, vegetation should be planted throughout the entire rain garden to provide a fully stabilized surface. Containerized plants are typically grown in a looser growing medium conducive to drainage whereas grass sod is sometimes grown in more cohesive soils that may inhibit drainage. Avoid the use of wood chips because they tend to float and may clog the outlet or be washed downstream. Coarsely-shredded hardwood mulch such as that obtained from the primary run through an industrial tub grinder will be more resistant to movement and is recommended. Gravel or stone mulch is also resistant to movement but may cause sediment to build up and inhibit infiltration.

If pedestrian traffic is expected, provide stepping stone paths along a predefined route to discourage trampling of vegetation and compaction of soil. Planting spiny vegetation such as yucca, sotol, or agarita along the edge of the rain garden may effectively discourage pedestrian use.

Design the rain garden depression to be as shallow as possible to facilitate mowing and reduced erosion.

~~Like all filtration systems in the City of Austin, isolation of the Water Quality volume and the minimization of mixing of additional flows are necessary, as is pre-treatment in order to protect the filtration media from sediment loads. The preferred design to minimize mixing is illustrated by Figure 1.6.7.H.1, whereby surface runoff enters and exits the system through the same opening, with runoff by-passing the~~

~~system once ponding depth equals the water quality volume elevation. Pre-treatment can be provided by a sediment chamber, analogous to a "partial" sedimentation-filtration system, or by a vegetative filter strip, as shown in Figure 1.6.7.H.3.~~

~~Good sources of information for rain gardens are North Carolina State University (http://www.bae.ncsu.edu/topic/bioretention/), University of Maryland Department of Civil and Environmental Engineering (http://www.ence.umd.edu/~apdavis/LID-Publications.htm), and the Low Impact Development Center (http://www.lowimpactdevelopment.org/).~~

~~2. Surface Area.~~4. Sizing

Rain gardens may be sized to capture and treat the entire water quality volume, or a water quality credit may be provided for rain gardens that capture and treat only a portion of the water quality volume. In each of the three rain gardens designs, the storage volume provided is the combined volume of the ponded water in the basin and the effective porosity volume in the growing medium. Growing medium requirements are provided in Part 5 of this section. Because rain gardens have comparatively smaller drainage areas and larger surface areas, water quality credit is provided for 80% of the effective porosity (assumed to be 30%) of the growing medium.

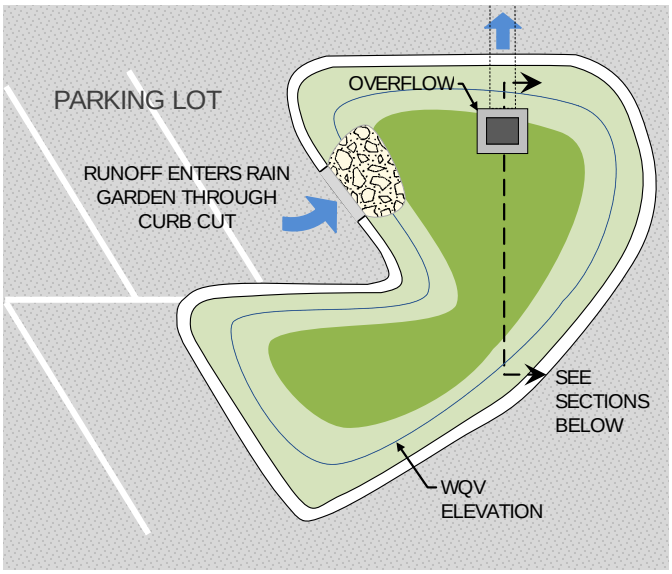


Figure 1.6.7.H-2. Rain gardens can be sized to capture and treat all or a portion of the required water quality volume (WQV).

Sizing criteria for the three general types of rain gardens are provided below:

- Full Infiltration

  Full infiltration rain gardens are sized to capture and fully infiltrate runoff. The infiltration area is the average surface area of the rain garden basin (i.e., the area at full ponding depth plus the area at zero ponding depth divided by two). If the sideslopes of the basin are not permeable (e.g., masonry or concrete walls), then the infiltration area is the bottom permeable footprint. For runoff up to the design volume, full infiltration rain gardens provide 100% total suspended solids (TSS) removal compared to 87% TSS removal for sedimentation/filtration systems. To provide equivalent treatment to a sedimentation/filtration system, the minimum required storage volume is 87% of the water quality volume determined from ECM Section 1.6.2. Equation H-1 below provides the infiltration area required for a full infiltration rain garden.

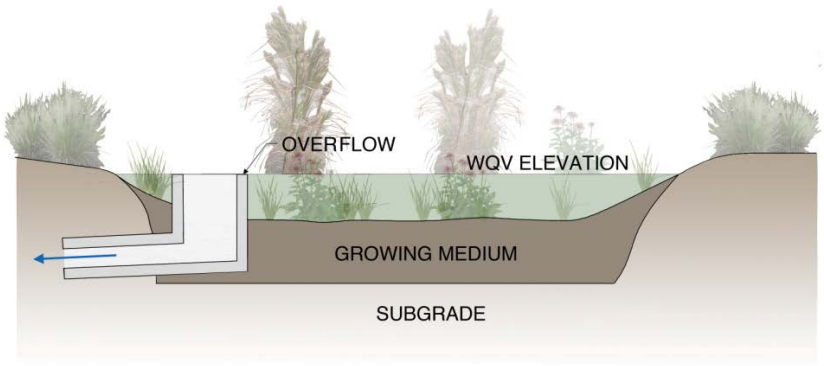


Figure 1.6.7.H-3. Full infiltration rain gardens use the infiltration capacity of the site soils to reduce stormwater runoff volume and associated pollutants.

~~The total area of the system is the sum of the filtration and sediment chamber areas.~~

~~A Darcy's Law approach is used to determine the minimum filtration area required:~~

~~$Q = k * i * A_f$~~

- ~~Where Q is the treatment rate of the BMP~~
- ~~K is the saturated hydraulic conductivity~~
- ~~i is the hydraulic gradient~~
- ~~A_f is the filtration media surface area~~

~~Because of the shallow ponding depth it is reasonable to set the hydraulic gradient i to a value of 1.0:~~

~~$Q = k A_f$~~

~~By definition:~~

~~Q = WQV/DDT~~

- ~~Where WQV is the water quality volume~~
- ~~DDT is the drawdown time; 48 hours is used~~

~~Setting the two equations equal and solving for A:~~

~~$A_f = WQV/(k * DDT)$~~ $A_i \geq 0.87 * WQV / (H + 0.24 * L)$ (Equation H-1)

Where:

A_i = infiltration area (ft^2),

WQV = water quality volume (ft^3),

H = maximum head over the growing medium (ft), and

L = depth of the growing medium (ft).

The maximum allowable head over the growing medium for a full infiltration rain garden is 12 inches provided the design infiltration rate of the subgrade soil allows for draw down of the ponded depth in at most 48 hours (see soil condition requirements in Site Selection section above). Ponding depths in excess of 12 inches are not permitted.

The depth of the growing medium must be at least 1.5 times the maximum head over the growing medium. For example, if the maximum ponding depth is 12 inches, the minimum depth of growing medium is 18 inches.

~~Pending local monitoring data a k value of 3.5 ft/day is recommended for filtration media. If an infiltration system is proposed the saturated hydraulic conductivity of the soil must be determined. If a range of values are available then the lowest value should be used. For design purposes, the soil conductivity value should be reduced by at least a factor of safety of 2 to account for potential clogging over time.~~

Partial Water Quality Credit – For calculating partial water quality credit (see Equation 1.6.7-1 and Figure 1.6.7-1), the water quality capture depth for a full infiltration rain garden can be calculated using the following equation:

$WQV_{BMP} = 12 * A_i * (H + 0.24 * L) / (0.87 * A)$ (Equation H-2)

Where:

WQV_{BMP} = water quality capture depth of the full infiltration rain garden (inches),

A_i = infiltration area (ft^2),

H = maximum head over the growing medium (ft),

L = depth of the growing medium (ft), and

A = contributing drainage area (ft^2).

Note that maximum ponding depth and minimum design infiltration rate criteria are based on a maximum 48 hour drawdown time. Drawdown times less than 48 hours are permitted (and encouraged).

- Full Filtration

Full filtration rain gardens are sized to capture and convey runoff through a biofiltration bed underlain by an underdrain system. The filtration area is the flat surface area at the bottom of the rain garden basin (i.e., the flat area above the growing medium). The maximum ponding depth for a full filtration rain garden is 12 inches. Equation H-3 below provides the filter surface area (i.e., the flat bottom surface of the rain garden) required for a full filtration rain garden.

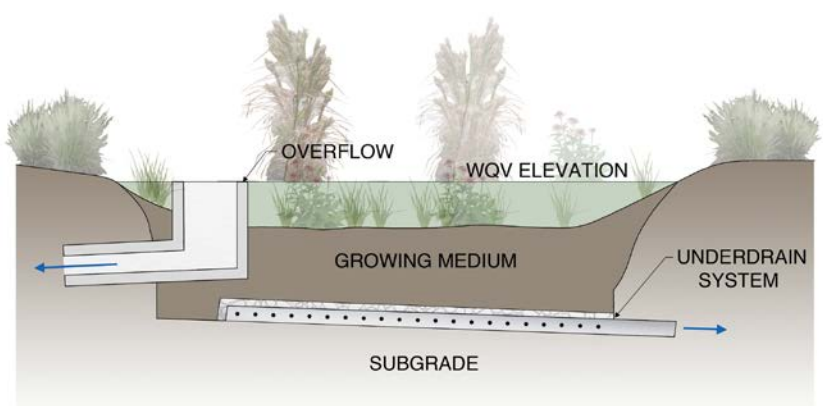


Figure 1.6.7.H-4. Full filtration rain gardens are sized to capture and convey runoff through a biofiltration bed underlain by an underdrain system.

$A_f \geq WQV / (H + 0.24 * L)$ (Equation H-3)

Where:

A_f = filtration area (ft^2),

WQV = water quality volume (ft^3),

L = depth of the biofiltration growing medium (ft) (a minimum of 2 ft); and

H = maximum head over the growing medium (ft).

~~Assuming a filtration system with 3.5 ft/day hydraulic conductivity, and a 48 hour drawdown time gives:~~

~~$A_f = WQV/7$~~

- ~~Where A_f is the minimum required filtration media surface area in ft^2~~
- ~~WQV is in ft^3~~

~~Because of significant uncertainties as to the actual k value over the life of the rain garden, the underdrain system is to have an orifice installed that is sized to provide a 48 hour drawdown time.~~

Partial Water Quality Credit – For calculating partial water quality credit (see Equation 1.6.7-1 and Figure 1.6.7-1), the water quality capture depth for a full filtration rain garden can be calculated using the following equation:

$WQV_{BMP} = 12 * A_f * (H + 0.24 * L) / A$ (Equation H-4)

Where:

WQV_{BMP} = water quality capture depth of the full filtration rain garden (inches),

A_f = filtration area (ft^2),

H = maximum head over the growing medium (ft) (a maximum of 12 inches),

L = depth of the growing medium (ft) (a minimum of 2 ft), and

A = contributing drainage area (ft^2).

- Partial Infiltration

Partial infiltration rain gardens are sized to capture and treat runoff through a biofiltration bed. Runoff exits the biofiltration bed by discharge through a raised outlet pipe and by infiltration into the underlying soil. The filtration area is the flat surface area at the bottom of the rain garden basin (or the flat area above the growing medium). The maximum ponding depth for a partial infiltration rain garden is 12 inches. Equation H-5 below provides the filter surface area (i.e., the flat bottom surface of the rain garden) required for a partial infiltration rain garden.

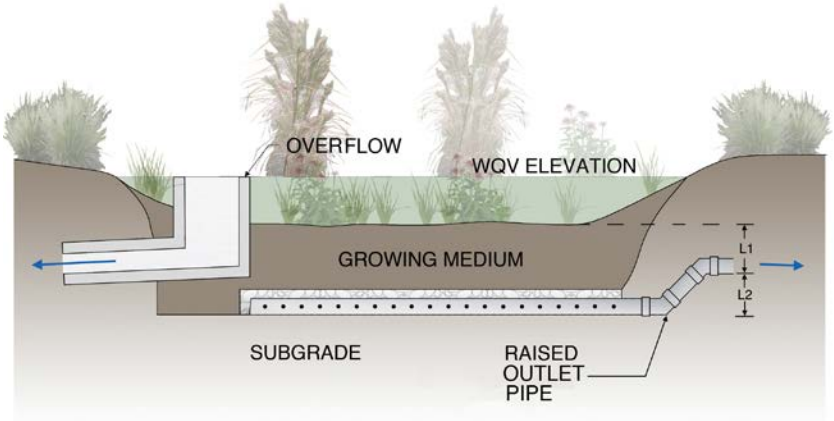


Figure 1.6.7.H-5. Partial infiltration rain gardens are designed so that treated runoff exits the biofiltration bed by discharge through a raised outlet pipe and by infiltration into the underlying soil.

$A_f \geq WQV / (H + 0.24 * L_1 + 0.28 * I_f)$ (Equation H-5)

Where:

A_f = filtration area (ft^2),

WQV = water quality volume (ft^3),

H = maximum head over the growing medium (ft) (a maximum of 12 inches),

L_1 = depth from the top of growing medium to the invert of the raised outlet pipe (ft) (a minimum of 1.2 ft); and

I_f = infiltration factor (ft).

Growing medium or gravel must be placed across the bottom of the rain garden below the invert of the raised outlet pipe to provide additional storage. Use of growing medium is recommended to promote greater rooting depths and biological activity. The available storage is a function of the depth below the invert of the raised outlet pipe and the porosity of the material. The ability to regenerate storage is a function of the infiltration rate of the subgrade. The infiltration factor, I_f, is based on the depth of storage below the invert of the raised outlet (L_2) and the 2-day drawdown provided by the soil subgrade design infiltration rate (i_{sub}):

For cases where $L_2 \geq i_{sub} * 2$ days,

$I_f = L_2$ (Equation H-6a)

For cases where $L_2 < i_{sub} * 2$ days,

$I_f = i_{sub} * 2$ days (Equation H-6b)

Where:

i_{sub} = design infiltration rate of subgrade (ft/day), and

L_2 = depth from the invert of the raised outlet pipe to the subgrade surface (ft) (a minimum of 0.8 feet).

For partial infiltration rain gardens, the design infiltration rate of the soil subgrade below the growing medium may be estimated using the desktop study and field sampling methods as described in ECM

Section 1.6.7.4. For design purposes, the estimated infiltration rate must be reduced by at least a factor of safety of 2 to account for uncertainty in infiltration rate estimates and potential clogging over time.

Partial Water Quality Credit – For calculating partial water quality credit (see Equation 1.6.7-1 and Figure 1.6.7-1), the water quality capture depth for a partial infiltration rain garden can be calculated using the following equation:

$WQV_{BMP} = 12 * A_f * (H + 0.24 * L_1 + 0.28 * I_f) / A$ (Equation H-7)

Where:

WQV_{BMP} = water quality capture depth of the partial infiltration rain garden (inches),

A_f = filtration area (ft^2),

H = maximum head over the growing medium (ft),

L_1 = depth from the top of growing medium to the invert of the raised outlet pipe (ft) (a minimum of 1.2 ft),

I_f = infiltration factor (ft) (see Equation H-6), and

A = contributing drainage area (ft^2).

5. Growing Medium

The rain garden growing medium must have sufficient water holding capacity to support vigorous plant growth, enhancing the ability for plants to survive during dry periods. It should also sustain a healthy microorganism population which, in concert with vegetation, should enhance biological removal of pollutants in stormwater.

Requirements for the growing medium depend on the type of rain garden design being considered. For full infiltration rain gardens, the growing medium may be amended topsoil or biofiltration medium. For full filtration and partial infiltration rain gardens, only the biofiltration medium may be used. Criteria for each of these media are provided below.

Amended Topsoil

- Screened bulk topsoil: 75 – 95% (by volume)
- Soil Amendment (to improve growing conditions for roots): 5 to 25% (by volume).

Biofiltration Medium (see ECM section 1.6.7.C.4, Biofiltration)

~~The sediment chamber area is the total area minus the filtration area; this area should be determined after accounting for the water quality volume held in and above the filtration media (see design example below).~~

~~3. Water Quality Volume.~~

~~The water quality volume is the combined volume of the filtration and the sedimentation chamber areas. The sediment chamber must hold at least 20% of the water quality volume. Due to the small drainage area and large surface area of these systems, the filtration media should be protected better against sedimentation~~

~~than typical filtration systems. Because of this water quality volume credit will be allowed for 80% of the effective porosity volume of the filtration media, or:~~

~~$WQV = WQV_{ne} + WQV_{ponded}$~~

- ~~Where WQV is the total water quality volume in ft^3~~
- ~~WQV_{ne} is 80% of the filtration media effective porosity volume~~
- ~~WQV_{ponded} is the ponded volume, with a maximum ponding depth (H) of 6 inches~~

~~To calculate WQVne in ft^3:~~

~~$WQV_{ne} = 0.8 * A_f * L * n_e$~~

- ~~Where A_f is the surface area of the filtration media is ft^2~~
- ~~L is the depth of the filtration media, a minimum of 1.5 ft~~
- ~~n_e is the effective porosity of the media. As a default assumption a value of 0.3 can be used.~~

~~Inserting the values and assumptions results in:~~

~~$WQV_{ne} = 0.24 * A_f * L$~~

- ~~Where A_f is the surface area of the filtration media is ft^2~~
- ~~L is the depth of the filtration media in ft~~

~~The ponded water quality volume is then calculated as:~~

~~$WQV_{ponded} = WQV - WQV_{ne}$~~

~~Also WQV_{ponded} can be estimated as:~~

~~$WQV_{ponded} = (A_f + Ased) * H$~~

~~The two equations can be combined and, setting H equal to 6 inches (0.5 feet), the sediment chamber area can be calculated:~~

~~$A_{sed} = [2 * (WQV - WQVne)] - A_f$~~

~~4. Minimum and Maximum Sizes.~~

~~The criteria above gives minimum sizing criteria but it should be recognized that the size of the rain garden filtration area can be increased significantly. Assuming 6 inch ponding depth with 1.5 feet of filtration media, the following table summarizes sizing options. Also see Figure 1.6.7.H.1, Figure 1.6.7.H.2, and Example Case Study 1 below.~~

~~**Rain Garden Sizing Equations**~~				
~~**Compartment**~~	~~**Parameter**~~	~~**Unit**~~	~~**Minimum**~~	~~**Maximum**~~
~~Sediment Chamber~~	~~Area~~	~~ft^2~~	~~WQV/2.5~~	~~WQV/0.57~~
-	~~Volume~~	~~ft^3~~	~~WQV/5~~	~~WQV/1.14~~
~~Filtration Basin~~	~~Area~~	~~ft^2~~	~~WQV/7~~	~~WQV/1.075~~

-	~~Volume~~	~~ft^3~~	~~WQV/8.14~~	~~WQV/1.25~~

~~WQV is Water Quality Volume in ft^3.~~

~~5. Vegetative Filter Strip Pretreatment Option.~~

~~If runoff can enter the Rain Garden as sheet flow then the option may exist to provide pretreatment with a vegetative filter strip. The vegetative filter strip must meet all requirements of Section 1.6.7.B except for the length (dimension in direction of flow) can be much less. A minimum length of 5 feet is required. The entire water quality volume is to be stored in the rain garden, and no sediment chamber is required. This design is illustrated below in Figure 1.6.7.H.3 and Example Case Study 2.~~

6. Underdrain System

- Full Infiltration Rain Garden – A full infiltration rain garden does not have an underdrain system and does not require a geotextile under the growing medium.
- Partial Infiltration and Full Filtration Rain Garden – The underdrain for a partial infiltration and full filtration rain garden consists of gravel-surrounded perforated pipes as illustrated in Figure 1.6.7.H-6 (for details see Figure 1-56D in Appendix V of this manual).

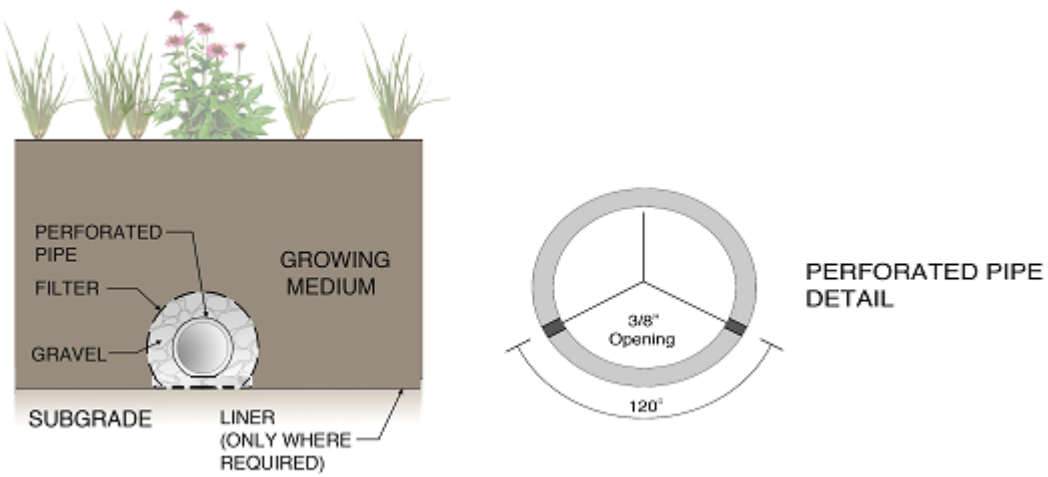


Figure 1.6.7.H-6. Underdrain design for partial infiltration and full filtration rain gardens.

The underdrain piping must comply with the criteria located in ECM section 1.6.7.C.4.B, Biofiltration Basin Details. For partial infiltration systems with raised outlets, the pipe does not require a slope.

For full filtration designs, if an impermeable liner is required it shall meet the specifications given in Section 1.6.2.C. A geotextile (or gravel separation lens) is not required at the bottom of unlined rain gardens.

~~6. Infiltration Design Option.~~

~~Because a Rain Gardens has a small drainage area and large surface area (due to shallow ponding depth), an infiltration design is possible if appropriate soils are present. The primary differences are (1) the system has no underdrain system and (2) no geotextile fabric is required under the biofiltration media. This design is illustrated below in Figure 1.6.7.H.3 and Example Case Study 3. Design variations of partial filtration/infiltration systems are also possible, as illustrated in Figure 1.6.7.H.4.~~

~~7. Maintenance - See Section 1.6.3.~~

7. Flow Control

Inflow: How runoff enters (and for larger storms overflows or bypasses) the rain garden depends on the overall drainage configuration for the site. Runoff may enter via sheet flow from surrounding areas (for example, a parking lot with a ribbon curb), or runoff may enter as concentrated flow through a curb cut, a splitter box, or other inlet. When using a curb cut approach, ensure that inflow curb cuts have sufficient positive slope into the rain garden to prevent minor obstructions such as leaves in the curbline from obstructing flow into the system. Provide energy dissipation for rain gardens with concentrated points of inflow. The maximum velocity discharged to the rain garden should not exceed 2 feet per second.

Internal Flow Management: Rain gardens located on a sloped area can be designed to pool to a specified water quality elevation and then overflow into downstream cells through a raised outlet structure or level spreader.

Outflow: The preferred design to manage volume in excess of the WQV is to use an offline system configuration such that when the rain garden is full, additional runoff does not enter the system and instead flows past the inflow opening. Outflow of volume in excess of the WQV can also be managed through the use of standpipe risers, elevated catch basins, or down gradient curb cuts. When selecting the type and location of the outlet structure, incorporate enough detail in the design to prevent unintentional bypass of the rain garden before it is full. For example, when using an adjacent curb inlet to a storm drain for overflow, make sure to include sufficient grade control to establish preferential flow to the rain garden. The surface discharge from the rain garden shall be non-erosive with a maximum permissible flow velocity of 2 feet per second.

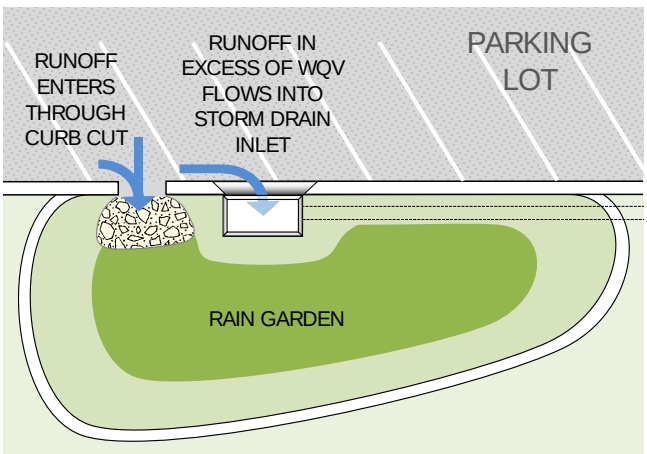


Figure 1.6.7.H-7. Example of the preferred offline system configuration for flow control.

8. Landscape Design

Although an essential role of the vegetation is to make the rain garden attractive, the highest priority shall be to meet the water quality and soil stabilization functional requirements. Another important function of the vegetation is to help reduce clogging of the growing medium. Vegetation should be selected based on its ability to survive under alternating conditions of inundation and extended dry periods. High plant diversity is recommended and will provide resiliency to the system and help prevent a situation where all vegetation is lost. Over time, the plant species that are best suited to the unique conditions of each rain garden will naturally self-select and spread.

Vegetation quantity, size, spacing, and selection shall meet the requirements for filtration basins as provided in ECM Section 1.6.7C, Biofiltration, with the exception that rain gardens do not require a minimum of five different species (i.e., one species is acceptable), although higher diversity is recommended.

9. Examples

EXAMPLE CASE STUDY 1 – Full Infiltration Rain Garden (no underdrain system)

A 5 acre site has a total of 3 acres of impervious cover. Runoff from a 1 acre parking lot will be routed to a 0.08 acre parking lot island which will be designed as a full infiltration rain garden to capture and treat a fraction of the water quality volume. Based on the 1 acre parking lot and 0.08 acre parking lot island, the rain garden drainage area has a total impervious cover of 92.4%. The depressed parking lot island is 18 ft wide, 200 ft long, and 6 inches deep. The flat bottom of the parking lot island is 14 ft wide and 190 ft long. Infiltration tests indicate the infiltration rate of the subgrade is 0.25 in/hr. Determine the BMP Design Factor (BMPDF) and water quality credit for the rain garden (Figure 1.6.7-1 and Equation 1.6.7-1).

From Equation H-2,

$WQV_{BMP} = 12 * A_i * (H + 0.24 * L) / (0.87 * A)$

Based on the proposed geometry, the infiltration area, A_i, of the proposed rain garden is:

*(area @ full depth + area @ zero depth) / 2 = (18' * 200' + 14' * 190') / 2 = 3,130 ft^2*

The growing medium is proposed to be topsoil amended with 15% expanded shale to a depth, L, of 1 ft.

Thus, the water quality capture depth provided by the rain garden is:

$WQV_{BMP} = 12 * 3130\ ft^2 * [(0.5\ ft + 0.24 * 1\ ft)] / (0.87 * 43560\ ft^2) = 0.73$ *inches*

WQV_{ECM} *for a 92.4% impervious cover area is 1.22 inches.*

Next determine the BMPDF:

BMPDF is determined using Figure 1.6.7-1 and is a function of WQV_{BMP}/WQV_{ECM}

$WQV_{BMP}/WQV_{ECM} = 0.73$ in. / 1.22 in. = 0.60

Using Figure 1.6.7-1, BMPDF = 0.75

The water quality credit from Equation 1.6.7-1 can be calculated as follows:

$WQC = IAF \times BMPDF = 1/3 \times 0.75 = 0.25$

Therefore, the rain garden design would provide treatment for 25% of the required water quality volume for the entire site. The remainder of the required water quality volume must be treated using additional down gradient controls or through fee-in-lieu costs.

EXAMPLE CASE STUDY 2 – Full Filtration Rain Garden (underdrain system with orifice)

A 1.75 acre site includes a 1.5 acre parking lot (total impervious cover of 86%) and proposes to use a full filtration rain garden at the perimeter of the parking lot to capture and treat the full water quality volume for the site. Determine the required filtration area for the rain garden.

From Equation H-3,

$A_f \geq WQV / (H + 0.24 * L)$

Assume a maximum ponding depth of H = 1 ft and a minimum biofiltration growing medium depth of L = 2 ft. The ECM required water quality volume for 86% impervious cover is 1.16 inches. Converting this depth into a volume results in the following:

$WQV = 1.75\ ac * 43{,}560\ ft^2/ac * 1.16\ in * 1\ ft/12\ in = 7{,}351\ ft^3$

The required filtration area for full treatment can be calculated as

$A_f = 7{,}351\ ft^3 / (1\ ft + 0.24 * 2\ ft) = 4{,}967\ ft^2$

EXAMPLE CASE STUDY 3 – Partial Infiltration Rain Garden (raised outlet pipe)

The same 1.75 acre site with a 1.5 acre parking lot (86% impervious cover) discussed in Example 2 is to be designed with a partial infiltration rain garden to capture and treat the full water quality volume. Desktop studies and field sampling indicate the subgrade consists of a Hydrologic Soil Group B type soil with a design infiltration rate of approximately 0.5 in/hr accounting for a factor of safety of 2. Determine the required filtration area for the rain garden.

From Equation H-5,

$A_f \geq WQV / (H + 0.24 * L_1 + 0.28 * I_f)$

Assume a maximum ponding depth of H = 1 ft and a minimum depth from the top of the growing medium to invert of the raised outlet pipe of L_1 = 1.2 ft. The proposed depth from the invert of the raised outlet pipe to the subgrade surface is L_2 = 0.8 ft. The infiltration factor is based on the depth of storage below the underdrain (L_2) and the 2-day drawdown provided by the subgrade infiltration rate of i_{sub} = 0.5 in/hr.

For this case,

$L_2 = 0.8\ ft$ *and*

$i_{sub} * 2\ days = 0.5\ in/hr * 48\ hr * 1\ ft/12\ in = 2\ ft.$

Therefore, $L_2 < i_{sub} * 2\ days.$

The infiltration factor is determined from Equation H-6b

$I_f = i_{sub} * 2\ days = 2\ ft$

The ECM required water quality volume is the same as in Example 2, WQV = 7,351 ft^3

The required filtration area for full treatment can be calculated as

$A_f = 7{,}351\ ft^3 / (1\ ft + 0.24 * 1.2\ ft + 0.28 * 2\ ft) = 3{,}978\ ft^2$

~~*EXAMPLE CASE STUDY 1 - Rain Garden Filtration System (underdrain system with orifice).*~~

~~*A 1 acre parking lot (100% impervious cover) proposes to use a rain garden for water quality treatment. Design the system using the criteria presented above, and determine the minimum and maximum sizes for the sediment chamber and filtration basin.*~~

~~*The water quality volume (WQV) for a 100% impervious cover site is 1.30 inches, or 4,719* ft^3 *for a 1 acre site. With a 6" ponding depth (H = 0.5 ft) and ignoring for now void space credit in the filtration media, the approximate total surface area of the system is:*~~

~~$A_t = A_s + A_f$ » $WQV/H = 4719/0.5 = 9438\ ft^2$~~

~~*Minimum Filtration Area and Maximum Sediment Chamber Area.*~~

~~*The minimum filtration area required to drain the WQV in 48 hours is:*~~

~~$A_f = WQV/7 = 4719/7 = 674\ ft2$~~

~~*As can be seen, the minimum filtration area is less than 10% of the total surface area. The volume of water ponded above the filtration bed is:*~~

~~$V_{f_ponded} = A_f * H = 674 * 0.5 = 337\ ft^3$~~

~~*The void space credit (effective porosity, or n_e) for the filtration media with 1.5 feet of media depth is:*~~

~~$V_{ne} = 0.24 * A_f * L = 0.24 * A_f * 1.5 = 0.36 * A_f = 0.36 * 674 = 243\ ft^3$~~

~~*Therefore the total water quality volume attributed to the filtration basin is:*~~

~~$V_f = V_{f_ponded} + V_{ne} = 337 + 243 = 580\ ft^3$~~

~~*This means that the volume of the sediment chamber is:*~~

~~$V_s = WQV - V_f = 4719 - 580 = 4139\ ft^3$~~

~~*With a 6 inch ponding depth the sediment chamber surface area is:*~~

~~$A_s = V_s/H = 4139/0.5 = 8278\ ft^2$~~

~~*The total surface area for the system is thus:*~~

~~$A_t = A_s + A_f = 8278 + 674 = 8952\ ft^2$ which is about 5% less than the 9438 ft^2 calculated above, due to void space credit~~

~~*Maximum Filtration Area and Minimum Sediment Chamber Area.*~~

~~*The minimum sediment chamber size is 20% of the WQV, or:*~~

~~$V_s = 0.2 * WQV = 0.2 * 4719 = 944\ ft^3$~~

~~*With a 6 inch ponding depth the sediment chamber surface area is:*~~

~~$A_s = V_s/H = 944/0.5 = 1888\ ft^2$~~

~~*The water quality volume attributed to the filtration basin can be determined as:*~~

~~$V_f = WQV - V_s = 4719 - 944 = 3775\ ft^3$~~

~~*By rearranging the sizing equations the maximum filtration area can be calculated as:*~~

~~$A_f = V_f/(H + 0.36) = 3775/(0.5 + 0.36) = 4390\ ft^2$~~

~~*The total surface area for the system is thus:*~~

~~$A_t = A_s + A_f = 1888 + 4390 = 6278$~~

~~*Summary Table:*~~

-	~~*Area (ft^2)*~~		~~*Volume (ft^3)*~~	
~~*Compartment*~~	~~*Minimum*~~	~~*Maximum*~~	~~*Minimum*~~	~~*Maximum*~~
~~*Sediment Chamber*~~	~~*1888*~~	~~*8278*~~	~~*944*~~	~~*4139*~~
~~*Filtration Basin*~~	~~*674*~~	~~*4390*~~	~~*580*~~	~~*3775*~~
-	-	-	-	-
~~*Total System*~~	~~*6278*~~	~~*8952*~~	~~*4719*~~	~~*4719*~~

~~*EXAMPLE CASE STUDY 2 - Rain Garden Filtration System with Vegetative Filter Strip Pretreatment*~~

~~*A rain garden is proposed for a 0.5-acre asphalt parking lot, with pretreatment to be provided by a vegetative filter strip (VFS). All VFS criteria in Section 1.6.7.B can be met, except that the proposed length of the VFS is 6 feet (minimum 5 feet required for pretreatment). The parking lot dimensions are 180 feet wide by 121 feet long. Evaluate this design.*~~

~~*Size Vegetative Filter Strip*~~

~~*The proposed width of the VFS is 180 feet, to match the width of the parking lot drainage area (recall that width is the dimension perpendicular to direction of flow).*~~

~~*Determine the minimum required VFS width based on a hydraulic loading rate (HLR) of 0.05 cfs/ft width for the 2-year, 3-hour storm event. Using the rational method with a 5 minute time of concentration, C value of 0.73 (Drainage Criteria Manual Table 2-1), rainfall intensity of 5.76 in/hr ((Drainage Criteria Manual Table 2-5), and 0.5 acre drainage area:*~~

~~$Q = CiA = 0.73 * 5.76 * 0.5 = 2.1$ cfs~~

~~*Minimum VFS width W ³ Q/HLR = 2.1/0.05 = 42 ft.*~~

~~*The proposed VFS is acceptable as the width of 180 feet exceeds 42 feet.*~~

~~*The dimensions of the proposed VFS are thus 180 feet wide by 6 feet long.*~~

~~*Size Rain Garden*~~

~~*The required water quality volume for the 0.5-acre parking lot is 1.3-inch, or 2,360 ft³. The rain garden will be sized to store this entire volume, and no sediment chamber will be provided. The required area of the rain garden, assuming a 6 inch ponding depth, can be calculated using the sizing equations:*~~

~~$WQV = V_{ne} + V_{ponded} = (0.24*A*L) + (A*H)$~~

~~*Setting H to 0.5-ft (6 inches) and L to 1.5 feet:*~~

~~$WQV = 0.86 * A$~~

~~*Thus the surface area of the rain garden is:*~~

~~$A = WQV/0.86 = 2{,}744.2$ ft² – for design use 2,745 ft²~~

~~*The rain garden width is set equal to the VFS width of 180 feet, thus the rain garden length (direction of flow through VFS) is:*~~

~~$L = A/W = 2745/180 = 15.3$ feet~~

~~*Summary Table:*~~

~~*Component*~~	~~*Dimensions (ft)*~~	~~*Area (ft²)*~~
~~*Vegetative Filter Strip*~~	~~*180 x 6*~~	~~*1080*~~
~~*Rain Garden*~~	~~*180 x 15.3*~~	~~*2745*~~

~~*EXAMPLE CASE STUDY 3 - Rain Garden Infiltration System (no underdrain system)*~~

~~*For the Case Study 1 example above (1 acre parking lot) the minimum soil permeability is 0.50 in/hr. Evaluate the possibility of designing the rain garden as an infiltration system.*~~

~~*Conservative design assumptions will be required due to the high failure rate of infiltration systems. A factor of safety of at least 2 is to be applied to the soil permeability. From porous pavement criteria, the soil depth and depth to bedrock is to be at least 12 inches, with depth to high water table of at least 3 feet.*~~

~~*First determine the minimum area required to infiltrate the 4719 ft3 WQV in 48 hours. A factor of safety of 2 is applied to the minimum saturated hydraulic conductivity, thus k is assumed to be 0.25 in/hr, or 0.021 ft/hr.*~~

~~$A_{inf} = WQV/(k * DDT) = 4719/(0.021 * 48) = 4719\ ft^2$~~

~~*As infiltration will occur via percolation through the bottom of the rain garden biofiltration media, the surface area of the biofiltration media is estimated as 4719 ft^2.*~~

~~*The volume attributed to the biofiltration area, assuming 6" of ponding depth and 1.5 feet of biofiltration media is:*~~

~~$V_f = V_{ne} + V_{ponded} = (0.24*A_f*L) + (Af*H) = 0.86 * A_f$~~

~~$V_f = 0.86 * 4719 = 4058\ ft^3$~~

~~*The remainder of the WQV must be contained in the sediment chamber:*~~

~~$V_s = WQV - V_{inf} = 4719 - 4058 = 661\ ft^3$~~

~~*The minimum required sediment chamber volume is 20% of the WQV:*~~

~~*Minimum Vs = 0.2 * 4719 = 944 ft^3*~~

~~*As 661 < 944 the sediment chamber is set to 20% of the WQV, or 944 ft^3.*~~

~~*The surface area of the sediment chamber is:*~~

~~$A_s = V_s/H = 944/0.5 = 1888\ ft^2$~~

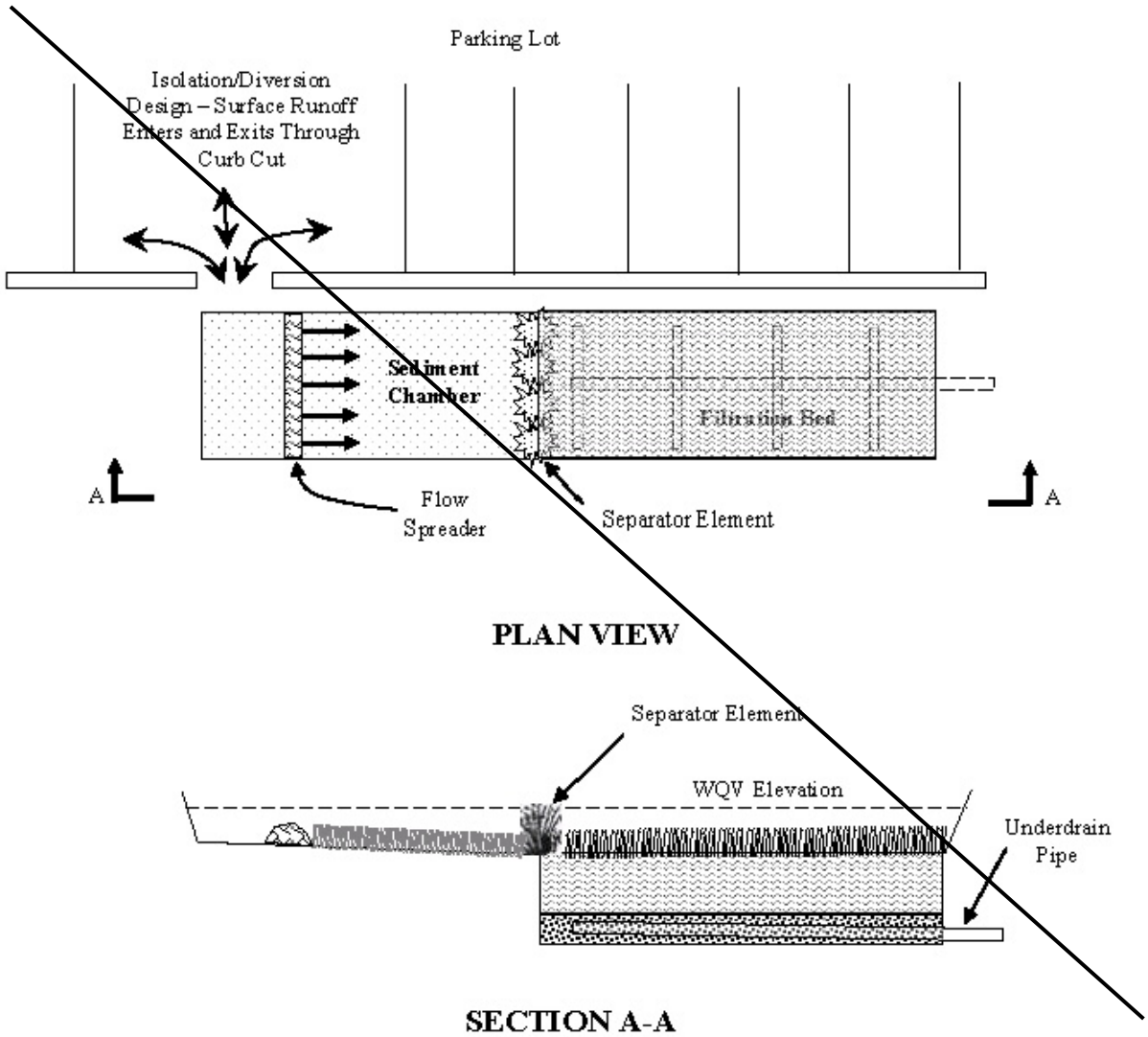
~~*Summary Table:*~~

~~*Compartment*~~	~~*Area (ft^2)*~~	~~*Volume (ft^3)*~~
~~*Sediment Chamber*~~	~~*1888*~~	~~*944*~~
~~*Biofiltration/Infiltration Basin*~~	~~*4719*~~	~~*4058*~~
~~*Total*~~	~~*6607*~~	~~*5002*~~

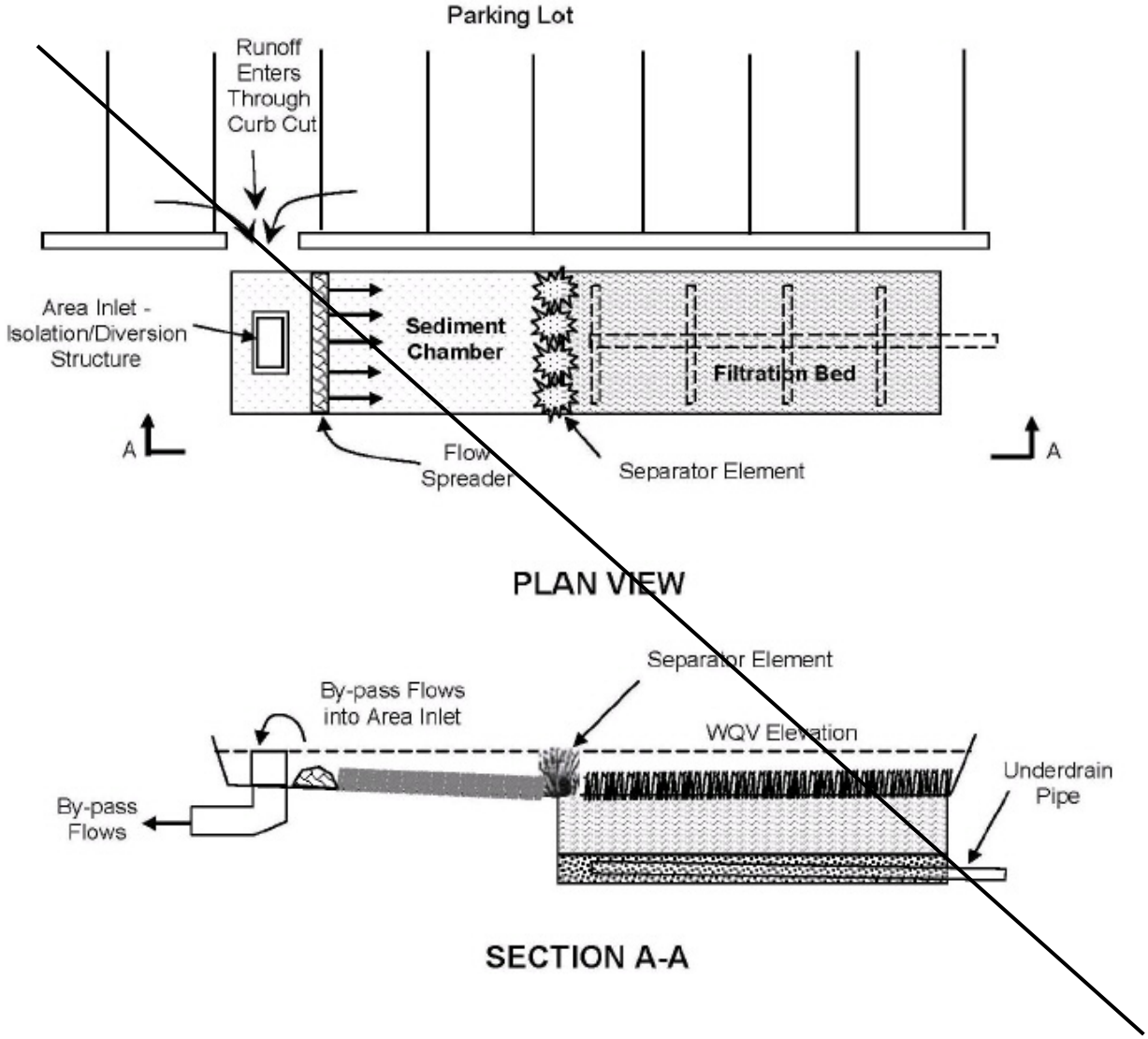
~~*The infiltration design falls within the range of surface areas for the filtration design.*~~

~~**Click here to view a PDF of Figure 1.6.7.H.1; Figure 1.6.7.H.2; Figure 1.6.7.H.3; Figure 1.6.7.H.4**~~

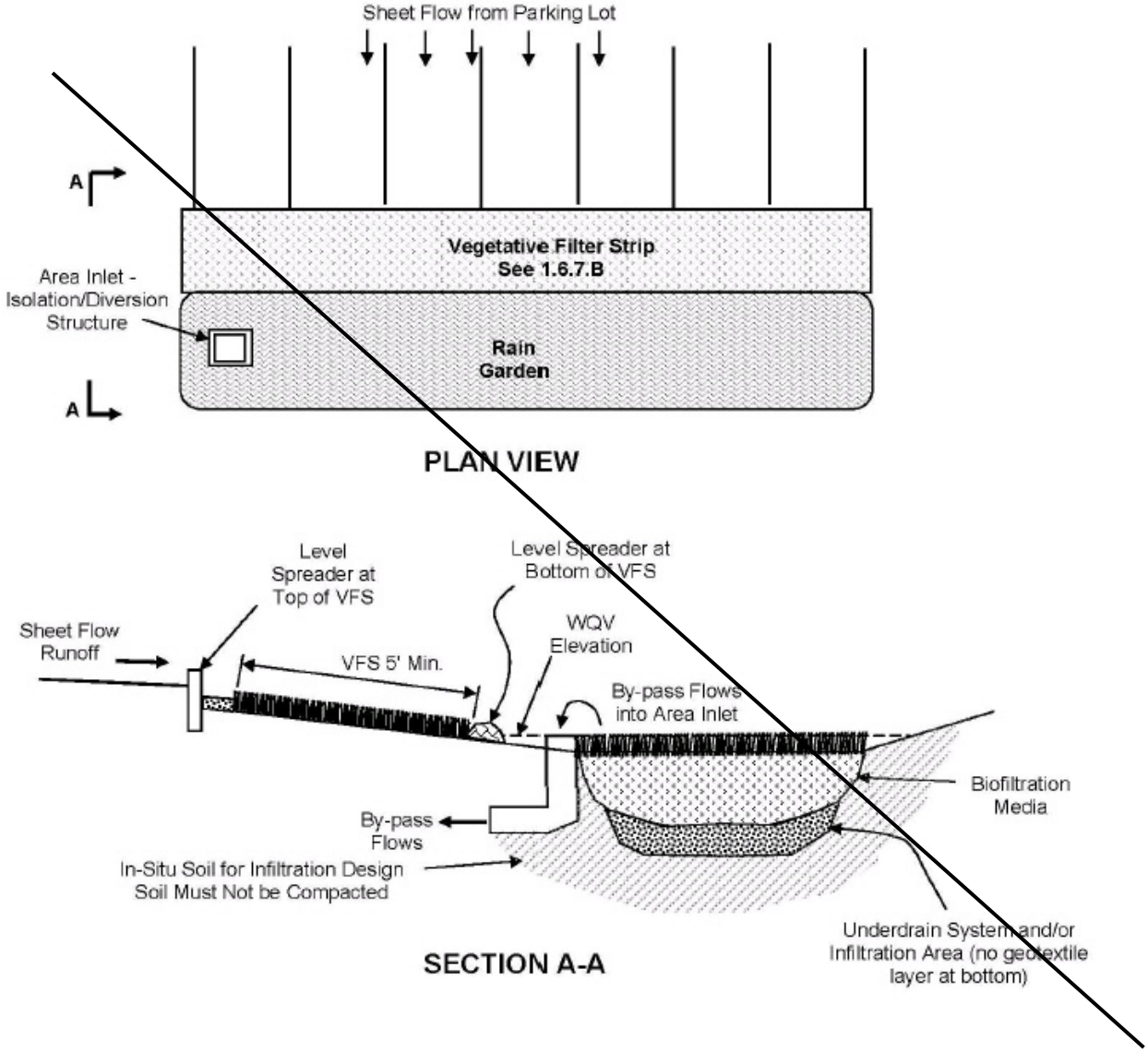
~~**Figure 1.6.7.H.1 Example Rain Garden for Parking Lot with Sediment Chamber Pretreatment - Preferred Isolation/Diversion Design**~~



~~Figure 1.6.7.H.2 Example Rain Garden for Parking Lot with Sediment Chamber Pretreatment.~~



~~Figure 1.6.7.H.3 Example Rain Garden for Parking Lot with Vegetative Filter Strip Pretreatment and Infiltration Option - Alternative Isolation/Diversion Design.~~



~~Figure 1.6.7.H.4 Rain Garden Filtration and Infiltration Design Variations from the Bioretention Manual (Prince George's County Maryland, 2004). NOTE: These figures are for illustration only and do not necessarily reflect City of Austin criteria.~~

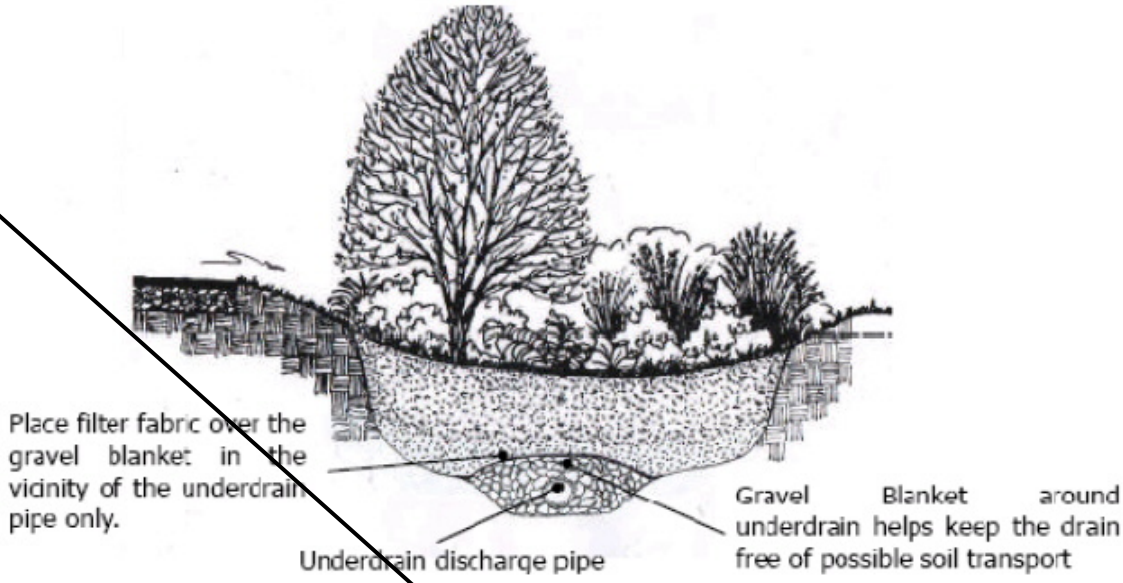


Figure 2.7: Filtration/Partial Recharge Facility

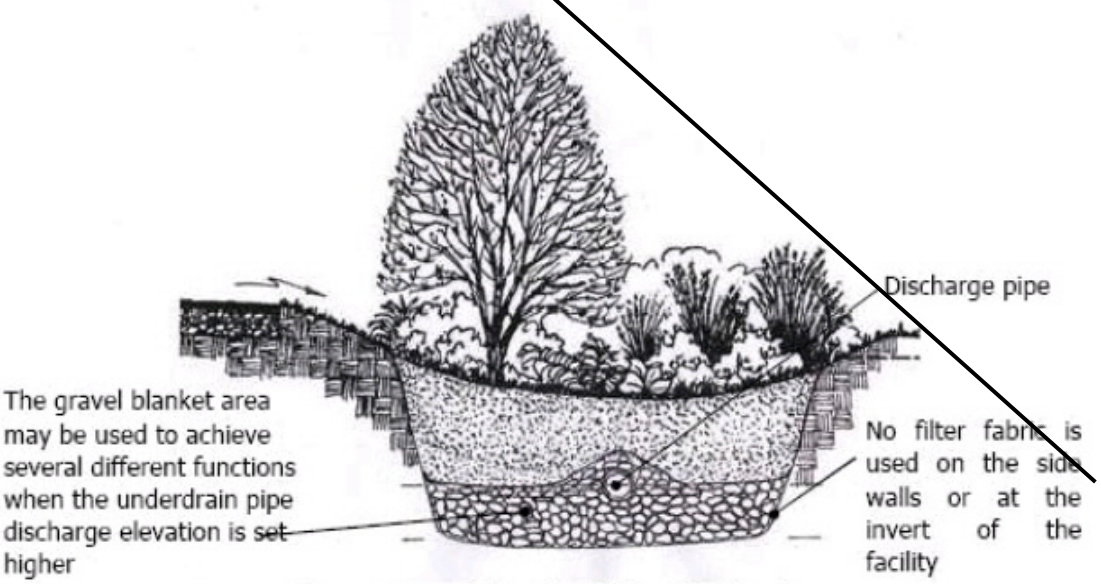


Figure 2.8: Infiltration/Filtration/Recharge

NEW - REPLACES EXISTING APPENDIX R-11

APPENDIX R-11

RAIN GARDEN CALCULATIONS
FOR DEVELOPMENT PERMITS

DRAINAGE AREA DATA:

Drainage Area to Control (DA - Maximum 2.0 Ac.)	_____	Ac.
Drainage Area Percent Impervious Cover	_____	%
Capture Depth (CD)	_____	in.

WATER QUALITY CONTROL CALCULATIONS:	**Required**		**Provided**	
Water Quality Volume	_____	cf.	_____	cf.
100 Year Peak Flow Rate to Control (Q100)	_____	cfs.		
Filtration Pond Area (Af)	_____	sf.	_____	sf.
Depth of Ponding (D)	Maximum 1.0	ft.	_____	ft.
Depth of Filtration Media (L)	Minimum 1.5	ft.	_____	ft.
Effective Porosity Water Quality Volume (WQV_{ac} = 024 * Af * L)			_____	cf.
Ponded Water Quality Volume (WQV_{ponded} = WQV - WQV_{ac})			_____	cf.
		Total WQV	_____	cf.
Water Quality Elevation (WQE)			_____	ft. MSL
Elevation of Splitter/Overflow Weir (Minimum WQE)			_____	ft. MSL
Length of Splitter Weir			_____	ft.
Required Head to Pass Q100	Maximum 0.5	ft.	_____	ft.
Pond Freeboard Provided to Pass Q100	Minimum 0.25	ft.	_____	ft.

FOR FILTRATION RAIN GARDENS:

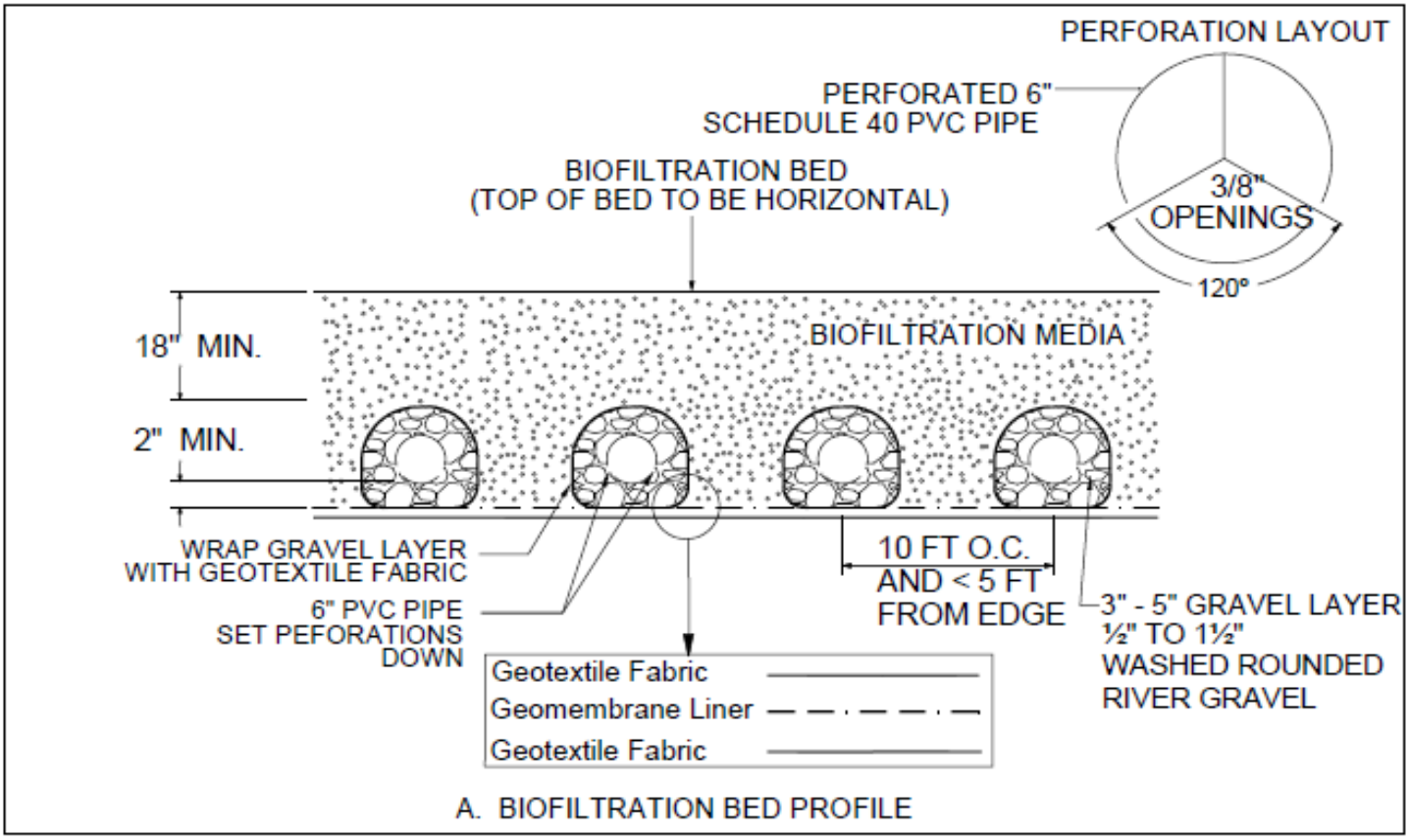
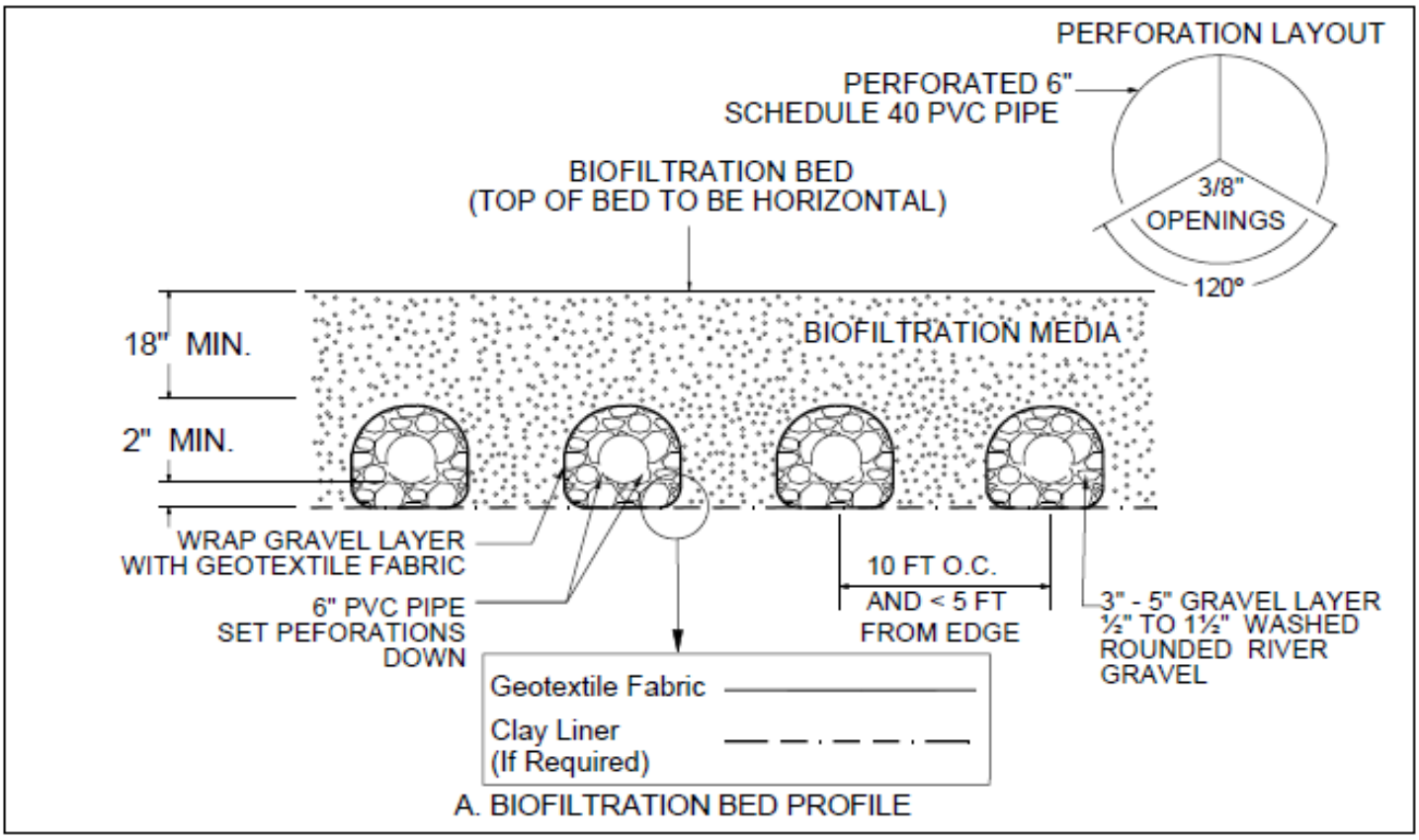
Rain Garden Pond Drawdown Time	Minimum 48	hr.	_____	hr.
Underdrain Orifice Size (Diameter)			_____	in.
Underdrain Orifice Size (Area)			_____	sq. in.

FOR INFILTRATION RAIN GARDENS:

Infiltration Rate (in/hr)	_____	in./hr.
Rain Garden Pond Drawdown Time	_____	hr.

NEW APPENDIX V, FIGURE 1-56D

Figure 1-56D Biofiltration Bed Configurations Using Geomembrane Liner



Biofiltration Bed Configurations Using Clay Liner / No Liner Required