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WSPD /
Planning
Dept.

Article IX.
Water Quality Regulations

9.01. Offsite Wastewater Improvements. The portion of the Property described on **Exhibit "D"** attached hereto must comply with the following City of Austin's water quality and critical water quality regulations and requirements as provided for in Section §25-3-79 – WATER QUALITY and §25-8-261 - CRITICAL WATER QUALITY ZONE DEVELOPMENT of the City of Austin's Code of Ordinances:

(a) Maintain the City of Austin Suburban Watershed impervious cover restrictions.

(b) Green stormwater water quality controls shall be provided to treat 100% of the water quality volume, as prescribed in Section 1.6.7 of the City of Austin Environmental Criteria Manual, attached hereto as Exhibit "D-1".

(c) There shall be a three-hundred-foot (300') setback from Cottonwood Creek

1. Development is prohibited in the creek setback except as prescribed for City of Austin classified waterways in the Suburban Watersheds, as prescribed in Section 1.5.3 of the City of Austin Environmental Criteria Manual, attached hereto as Exhibit "D-2."
2. Development allowed in the setback shall be revegetated and restored as prescribed in Section 1.5.3 of the City of Austin Environmental Criteria Manual, attached hereto as Exhibit "D-2."

(d) There shall be a one hundred fifty-foot (150') setback from all existing critical environmental features, as prescribed in Section 1.10.0 of the City of Austin Environmental Criteria Manual, attached hereot as Exhibit "D-3."

1. The natural vegetation cover must be retained to the <u>maximum extent practicable</u> and the owner must maintain the critical environmental feature setback in accordance with the City of Austin Environmental Criteria Manual to preserve the <u>water</u> quality function;
2. Construction and related activities are prohibited;
3. Wastewater disposal and irrigation are prohibited;
4. If located at least 50 feet from the edge of the critical environmental feature, the prohibition of Subsection (D)(d)(2) does not apply;
5. Hiking trail;
6. Green water quality control as prescribed in the City of Austin Environmental Criteria Manual

1.6.7 Green Storm Water Quality Infrastructure

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 green stormwater infrastructure practices included in this section have been reviewed and approved by the Watershed Protection Department. Acceptance of and the amount of credit allowed for such practices are based on:

- Technical merit
- Compliance with requirements for water quality protection and improvement
- Resource protection and improvement
- Advantages over 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.

F. [Placeholder].

G. Non-Required Vegetation.

H. Rain Garden.

Maintenance requirements of the approved stormwater control measures are provided in Section 1.6.3.

Source: Rule No. R161-15.12, 1-4-2016 .

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 green stormwater quality infrastructure controls distributed throughout a developed site and integrated into the landscape. The remaining required water quality volume that is not treated with Section 1.6.7 controls must be treated using other controls approved in the Environmental Criteria Manual.

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 (Equation 1.6.7-1)

Where

- WQC = Water Quality Credit, a value between 0 and 1, with 1 meaning 100% credit;
- IAF = Impervious Area Factor, or the fraction of total impervious area treated by the control; and
- BMPDF = 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, which include biofiltration and rain garden 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.

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.

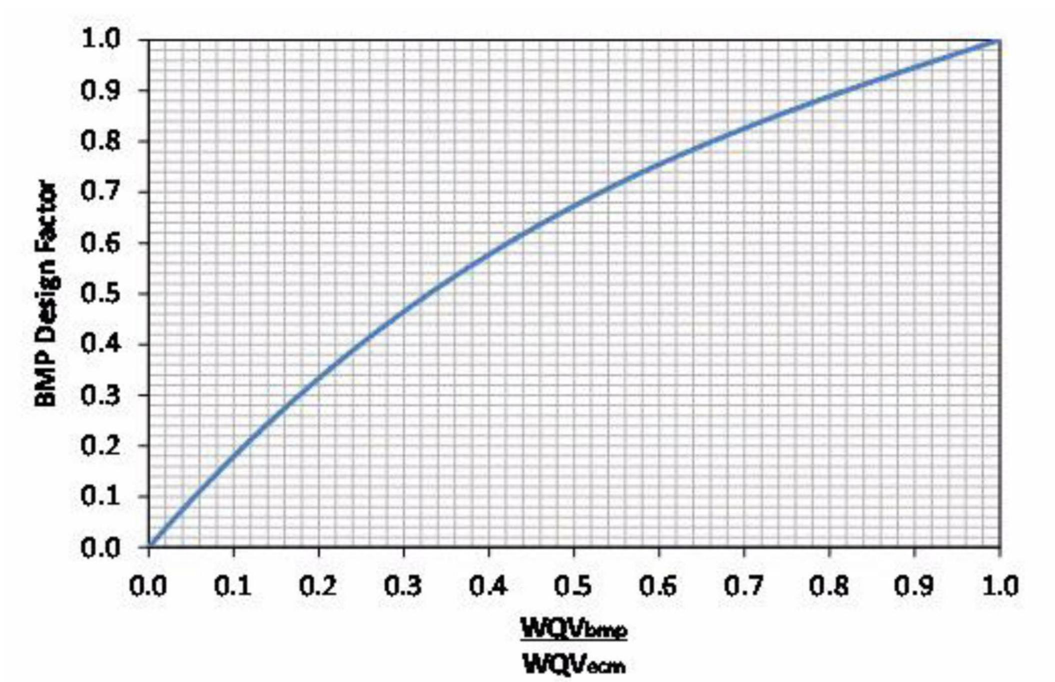


Figure 1.6.7-1. BMP Design Factor for vegetated pond-type controls.

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 Vegetative Filter Strips (VFS) the water quality credit is a function of percent infiltration and hydraulic loading rate as described in 1.6.7.B.

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.

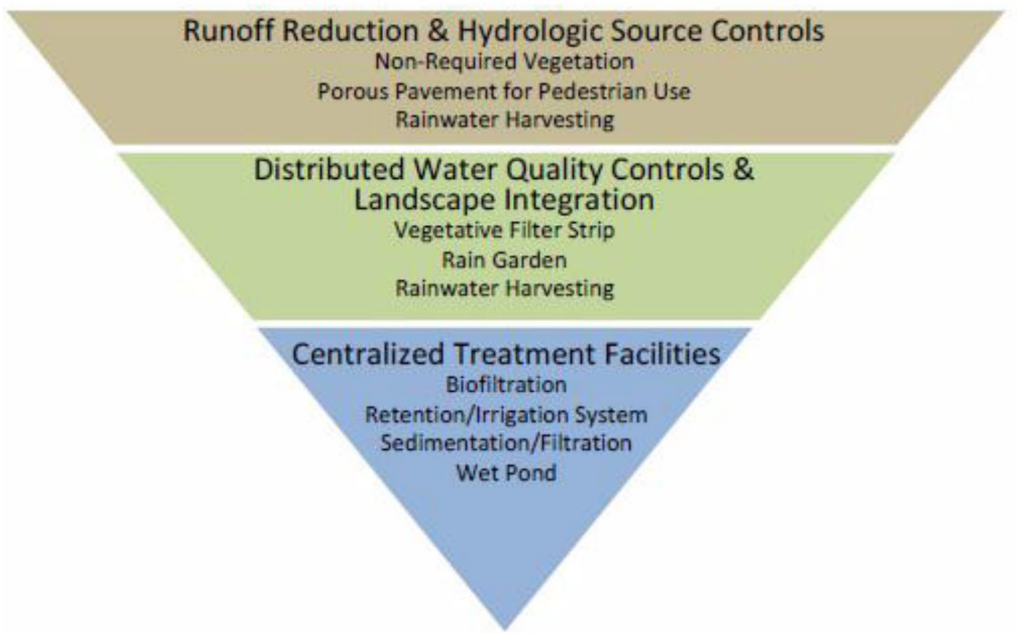


Figure 1.6.7-2. Recommended Hierarchial Approach for Selecting On-site Water Quality Controls

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 System2	•	•	
Vegetative Filter Strip	•	•	
Rainwater Harvesting1	•	•	•
Porous Pavement	•	•	•
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).

Note 2: Irrigation area and infiltration field infiltration rates cannot exceed 0.20 inches per hour, see Section 1.6.7.A.4.b.

A. 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.

B. 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.

C. 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.

D. 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.

1. 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.

2. 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 (Rf) 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.

Source: Rule No. R161-14.26, 12-30-2014 ; Rule No. R161-16.19, 11-14-16.

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/)

A. Retention/Irrigation Systems.

1. Introduction . A retention/irrigation water quality treatment system consists of two (2) primary components: (1) a basin which captures and isolates the required volume of stormwater runoff; and (2) a distribution and land application system which generally utilizes pumps, piping and spray irrigation components. The main characteristic of retention/irrigation systems is the ability to retain the entire water quality volume on site and is generally the water quality technology used to meet the SOS non-degradation requirement, Section 25-8-514(A). The design should consider factors such as basin impermeability and the irrigation area's ability to infiltrate the water quality volume. Clay liners are not acceptable for retention/irrigation systems where liners are required in the Edwards Aquifer Recharge

Zone. For technical requirements of liners, refer to Section 1.6.2. Additionally, refer to the Utilities Criteria Manual, Section 2, for high hazard backflow preventer requirements. When properly designed, this system is effective in removal of pollutants through settling in the retention basin and contact with vegetation, air and soils in the irrigation process, as well as in mitigating stream-bank erosion as required by Section 1.6.8 of the Environmental Criteria Manual. The effectiveness of this BMP at meeting required pollutant removal efficiencies is based upon the following criteria being met.

2. Minimum Design Criteria for the Retention Basin. Information on water quality volume, diversion structures, and lining requirements can be found in Section 1.6.2 (General Design Guidelines). In addition, applicable requirements of Section 1.6.3 (Maintenance and Construction Requirements) and Drainage Criteria Manual 1.2.4 (Drainage System) must be incorporated in the design.

    a. Retention Basin Volume. The basin must be of sufficient size to capture and hold the required capture volume. Retention basins are designed to capture and hold the water quality volume routed to them via diversion structures. All structural elements & piping below the Water Quality elevation shall be watertight. For development in the Barton Springs Zone, refer to Section 1.6.9.3. of this manual for the required capture volume.

    b. One-Hundred Year Storm. A bypass capable of conveying the 100-year storm around the basin must be provided.

    c. Lining. A liner will be required for a retention basin if the basin is located in the Edwards Aquifer recharge zone in accordance with Section 1. The liner must be designed in accordance with Section 1.6.2C (Basin Liners). All retention basins are subject to 1.6.3.C.4 (Maintenance and Construction Requirements).

    d. Erosion Prevention. The inlets to the retention basin must be designed to prevent erosion of the soil and liner. Rock rip-rap or other erosion prevention systems must be placed at the basin inlet to reduce velocities to less than three feet per second.

3. Minimum Design Criteria for Wet Well and Pumps.

    a. Pumps.

        (1) The retention basin must be emptied within 72-hours after a rain event ends. Emptying of the retention basin must not begin sooner than 12 hours after the end of the rainfall event. The flow rate of the pumps (gpm) shall be designed with either a 30 hour or 60 hour drawdown time (30 hrs for single zone irrigation systems and 60 hrs for multi-zone).

        (2) Pumps must be capable of delivering the required volume of water at the necessary rate and pressure to the irrigation system in the designated time period. Pumps and wet well must be sized to minimize the number of on and off-cycles of the pumps. The rate (Q_I) of inflow from the retention pond Intake Riser (see 1.6.7(A)(3)(c)) to the wet well must exceed the pump rate (Q_P).

        (3) A dual pump system must be provided, with each pump capable of delivering 100 percent of the design capacity.

            (a) Plug valves must be located outside the wet well on the discharge side of each pump to isolate the pumps for maintenance and for throttling if necessary. Butterfly valves and gate valves must not be used.

(b) Check valve(s) must be provided to prevent backflow from the irrigation system back into the pump well.

(c) Pumps must be selected to operate within 20% of their best operating efficiency.

(4) Pump Operation.

(a) The pumps must alternate on start up. The control logic must allow the system to operate normally with only one pump in service.

(b) A manual control must be provided so both pumps can be turned on if necessary.

(c) A high/low-pressure pump shut off system (to detect line clogging or breaking) shall be installed in the pump discharge piping. As an alternative, an amp draw (overloads) or other equivalent monitoring device may be used.

(5) Float controls or submersible transducers must be provided to control operation of the pumps. Three control settings must be used: (1) one for starting the pump, (2) one for shutting off the pump at the normal low water level, and (3) one for back up shut off of the pump in case the first shut-off fails.

(6) An alarm system shall be provided consisting of a red light located at a height of at least five feet above the ground level at the wet well. The alarm shall activate when:

(a) The water level is below the primary shutoff float and the pump has not turned off.

(b) The high/low-pressure pump shut off switch has been activated.

(c) Any other pump failures or system shut down indicated by control panel.

The alarm must be vandal proof and weather resistant. If the system is to be privately maintained, a sign must be placed at the wet well clearly displaying the name and phone number of a responsible party that may be contacted if the alarm is activated.

(7) A green "pump run light" shall be provided which is activated any time a pump is running. The green light should be located directly adjacent to the red alarm light.

b. <u>Wet Well.</u>

(1) A separate wet well outside of the basin must be provided for the pumps. The wet well must be constructed of precast or cast in place concrete. Complete access to the pumps and other internal components of the wet well for maintenance must be provided through a lockable hatch cover. An isolation plug valve to prevent flow from the retention basin to the wet well during maintenance activities must be provided.

(2) Calculations must be provided with the design showing that the wet well will not float under saturated-soil conditions. The top elevation of the well must be higher than the water quality elevation. The wet well, lateral inflow pipe, and pump must be designed to completely evacuate the retention pond. A space of at least two feet must be available below the bottom of the pump intake. The two-foot minimum space below the bottom of

the pump may be waived if the applicant demonstrates that adequate filtration of the water quality volume is provided.

(3) The pump installation in the wet well and access to the wet well must be designed to allow the pumps to be removed using truck-mounted hydraulic hoist equipment or a portable "A-frame." A system must be provided to allow pump removal without entering the wet well. If rails are used they must be stainless steel.

c. Intake Riser. Prior to entering the wet well, stormwater must pass through an appropriate intake riser with a screen to reduce the potential for clogging of distribution pipes and sprinklers by larger debris (e.g. cups, cans, sticks). The intake riser and screen should be designed similarly to Figure 1-54 in the Appendices of this manual. Alternative designs will be considered.

4. Minimum Design Criteria for the Irrigation System or Infiltration Field.

a. Irrigation Timing.

(1) The retention basin must be emptied within 72-hours after a rain event ends.

(2) Irrigation must be initiated no sooner than 12 hours after the rain event ceases.

(3) The irrigation controller must be set to provide alternating, equivalent irrigation and rest periods until the basin is emptied.

(4) The time of irrigation on any area must not exceed the rest time. Continuous application on any area must not exceed two hours.

(5) An adjustable rain sensor must be provided which will normally be set to temporarily halt irrigation during rainfalls exceeding one half inch. The rain sensor must be able to interrupt irrigation (stop pumps) in the event of subsequent rain events prior to emptying basin. The 12 hour pump delay may initiate after the rain sensor senses the rain event has terminated.

(6) Division of the irrigation area into two or more sections such that irrigation occurs alternately in each section is an acceptable way to meet the requirement for a rest period.

b. Irrigation Rate . The infiltration rate at which the soil can accept the irrigated storm water must be derived from the infiltration rate listed in the U.S. Department of Agriculture National Resources Conservation Service (NRCS) Soil Survey for the county, location, and soil type verified to be present at the irrigation site. If a range is given, the lower value of the range is to be used. The design irrigation rate is not to exceed 0.20 inches per hour even if the lower value of the range exceeds that rate. City of Austin field experience has shown that infiltration rates above 0.20 inches per hour do not function as designed and generate significant nuisance ponding and runoff issues. The application rate may not exceed the infiltration rate on any portion of the irrigation area.

c. Irrigation Area or Infiltration Field . Calculations must be provided which demonstrate that an adequate irrigation area or infiltration field will be provided based on the soil infiltration rate, water quality volume, and, for irrigation areas, the application rate and actual irrigation time. The irrigation area or infiltration field system must be included within the water quality easement.

d. Irrigation Area Slope. Irrigation must not occur on land with slopes greater than 10%.

e. Piping and Valves.

(1) All irrigation system distribution and lateral piping (i.e. from the pumps to the spray heads) must be Schedule 40 purple PVC. All pipes and electrical bundles passing beneath driveways or paved areas must be sleeved with PVC Class 200 pipe with solvent welded joints. Sleeve diameter must equal twice that of the pipe or electrical bundle. Buried piping must be marked with detectable marking tape labeled "CAUTION: BURIED NON-POTABLE WATER LINE BELOW".

(2) Valves. All valves must be designed specifically for sediment bearing water, and be of appropriate design for the intended purpose. All remote control, gate, and quick coupling valves must be located in ten-inch or larger plastic valve boxes with purple caps. All pipes and valves must be marked to indicate that they contain non-potable water. All piping must be buried to protect it from weather and vandalism. The depth and method of burial must be adequate to protect the pipe from vehicular traffic such as maintenance equipment. Velocities in all pipelines should be sufficient to prevent settling of solids. The irrigation design and layout must be integrated with the tree protection plan and presented as part of the Site Plan or Subdivision Construction Plan.

(3) Systems must include a plug valve to allow flushing at the end of every line.

f. <u>Sprinklers.</u> All sprinkler heads must have full or partial circle rotor pop-up heads and must be capable of delivering the required rate of irrigation over the designated area in a uniform manner. Sprinkler heads should have purple caps to indicate non-potable water. Irrigation must not occur beyond the limits of the designated irrigation area and sprinkler heads should be located at least twice the calculated spray radius from any residential lot. Partial circle sprinkler heads must be used as necessary to prevent irrigation beyond the designated limits. Sprinkler heads must be capable of passing solids that may pass through the intake. Sprinkler heads must be flush mounted and encased within a 2 feet × 2 feet concrete housing capable of protecting the head from mowing and service equipment (see Appendix V, Figure 1-59F for an example).

g. <u>Vegetation.</u> The irrigation area must have native vegetation or be restored or re-established with native vegetation, unless approved by the Director. These areas must not receive any fertilizers, pesticides, or herbicides. If landscaped areas are used for irrigation, fertilizers, pesticides, or herbicides must not be applied to those areas and this limitation must be outlined in the Integrated Pest Management (IPM) plan. For publicly maintained systems, fencing or signs must be installed to limit unauthorized use of the irrigation area. If signs are installed, they must include the phrase "Stormwater Irrigation Area - No Trespassing."

h. <u>Soil.</u> The irrigation area must contain a minimum of 12 inches of native or enhanced soil with the appropriate permeability rates. A soils report must be provided and must include at a minimum a soils map verifying soil types in the irrigation area, permeability rates, soil depths, percent of coarse fragments gravel size (2.0 mm diameter) and larger, found on the soil surface and in the subsurface soils, depth of roots, locations of borings or trenches, photographs of exposed soils, location and type of soil enhancement performed, soils testing results, etc. A site visit may be conducted by the city to confirm soil conditions, including when representative trenches have been opened or borings are being conducted. City staff must be given at least 72 hours notice of when borings or trenches are to be backfilled.

If soil is enhanced, topsoil or amended topsoil shall meet the requirements of Standard Specification 601S, Salvaging and Placing Topsoil. The condition, type, structure, and quality of the soil shall be conducive to infiltration and to plant growth. If alternative methods of amending soil can be demonstrated to increase the infiltration capacity by at least a factor of three, these methods may be used with approval from the Director of WPD.

i. Geological Features. The irrigation area must not contain any Critical Environmental Feature Buffer Zones.

j. Irrigation Area Buffer. A buffer area of un-irrigated vegetation must be provided downstream of the irrigation area to treat any runoff that may occur from the irrigation area during heavy rainfall or from excessive irrigation. This area must be a minimum of 50 feet in length (in the direction of flow) and be adjacent to all downstream edges of the irrigation area. As an option, a diversion system (e.g. a swale or berm) may be provided to route any runoff to the retention basin. This diversion system must be designed to carry the runoff from the two-year storm. Alternatively, the irrigation area may be located upstream from the development such that any runoff will be routed to the retention pond.

5. Manuals and As-Built Plans.

a. The applicant must provide two complete copies of an Operations Manual for the pumps and irrigation system, which must include:

(1) Pump curves, electrical schematics, pump and instrument technical information, components of the control panel, pump maintenance recommendations with required frequencies, irrigation controller operation instructions and a written warranty.

(2) As-built plans of the retention basin, wet well, pumps, piping and irrigation system. The plans must show the location, size, and type of all pipes, valves, wiring, wiring junctions, and sprinkler heads.

For retention-irrigation systems that are to be maintained by the City of Austin, both sets of plans and manuals shall be submitted to the Field Operations Division of the Watershed Protection and Development Review Department.

For systems that are to be maintained privately, one set of plans and one manual shall be included with the operating permit application and the second set of plans and one manual shall be retained on site at all times.

Source: Rule No. R161-14.26, 12-30-2014 ; Rule No. R161-16.19, 11-14-2016 ; Rule No. R161-21.03 , 3-9-2021.

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 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 sedimentation filtration basin). Throughout this division, the acronym VFS and the term filter strip is used when referring to vegetative filter strips. For filter strips to work effectively sheet flow shall be maintained and maximum 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, 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 Section 1.6.8) or flood flows. Additionally, vegetative filter strips are not recommended for use within the Barton Springs Zone.

3. Design Requirements for Full Water Quality Credit. 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 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 shall be at least 25 feet.

   To receive full water quality credit, 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.

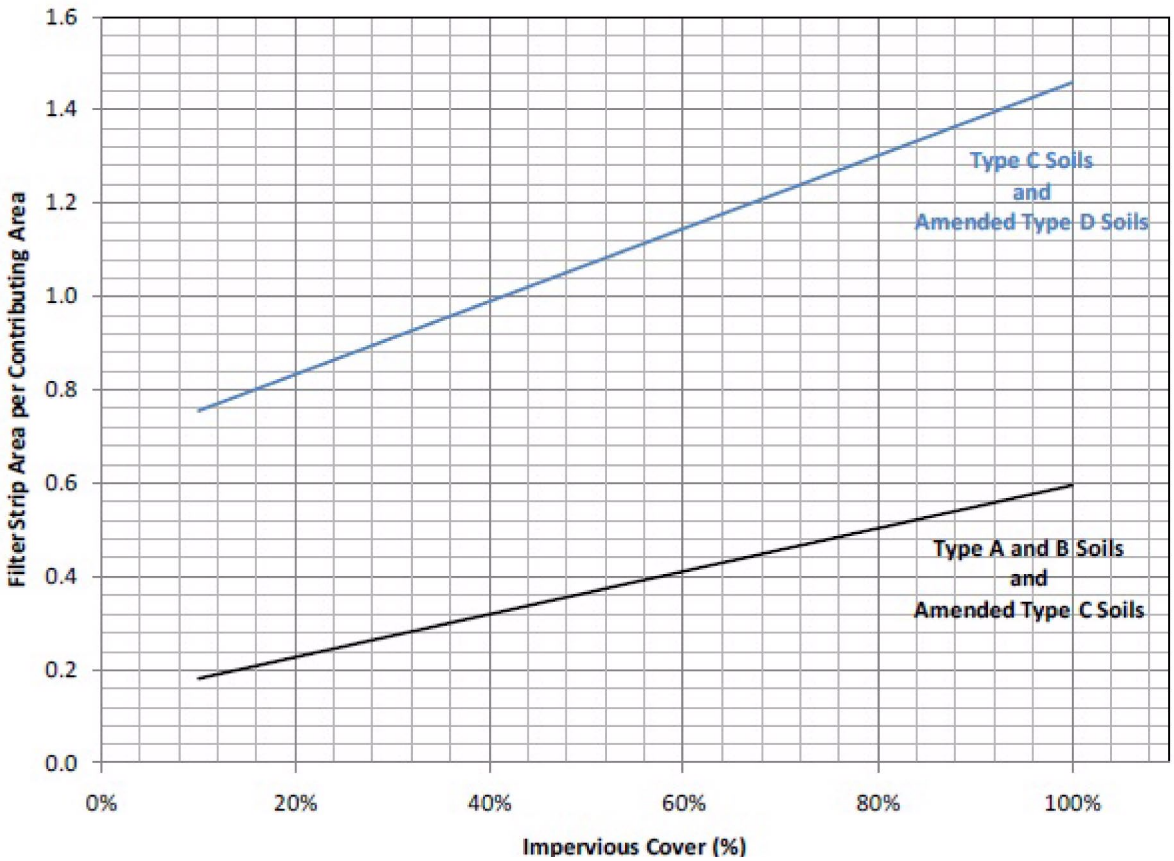


Figure1.6.7.B-1: Minimum sizing criteria for vegetative filter strips to achieve full water quality credit (i.e., 65% infiltration).

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} (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 = $(I_{VFS} / I_{65}) \times (HLR_{0.05} / HLR_{VFS})$ (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.

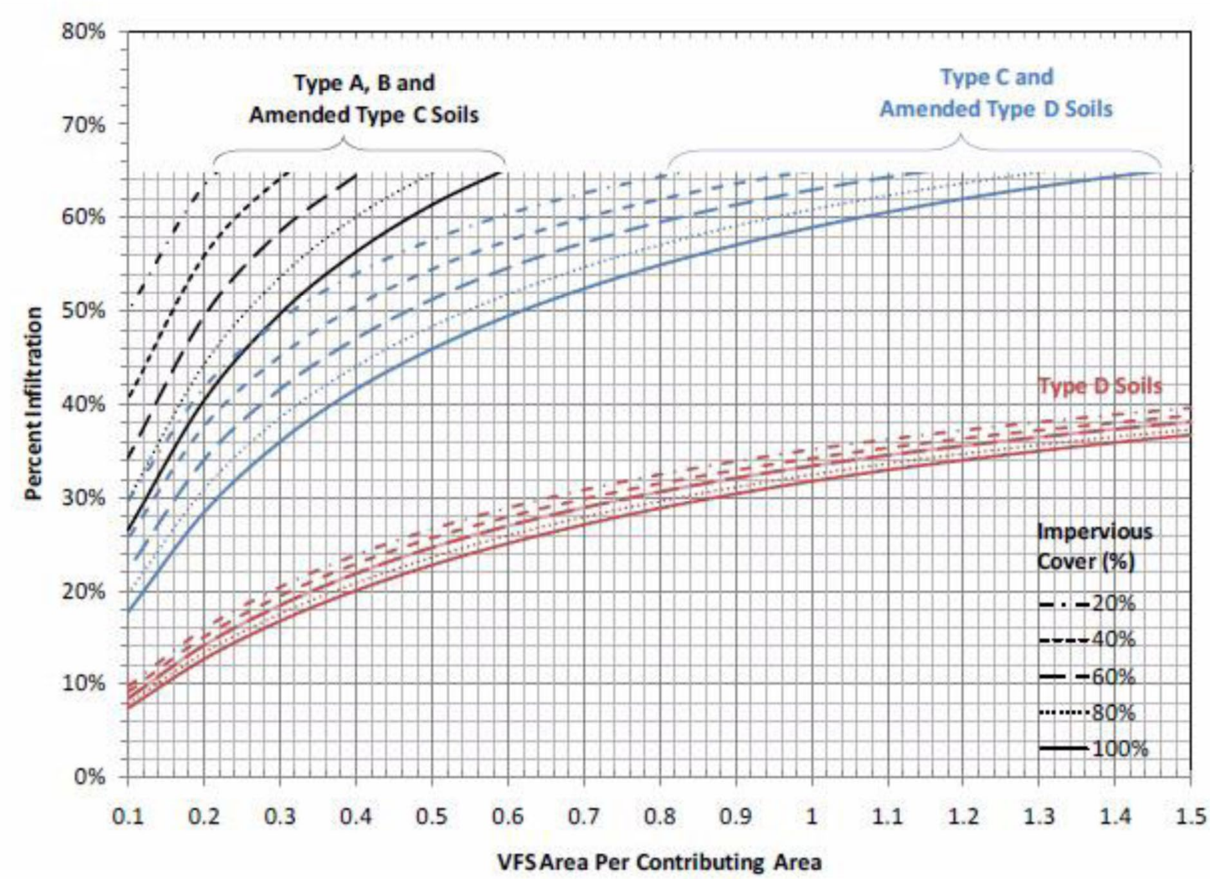


Figure 1.6.7.B-2: For partial water quality credit, use this chart to determine percent infiltration based on the size of the filter strip, size of contributing drainage area, contributing area impervious cover, and soil type.

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-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).

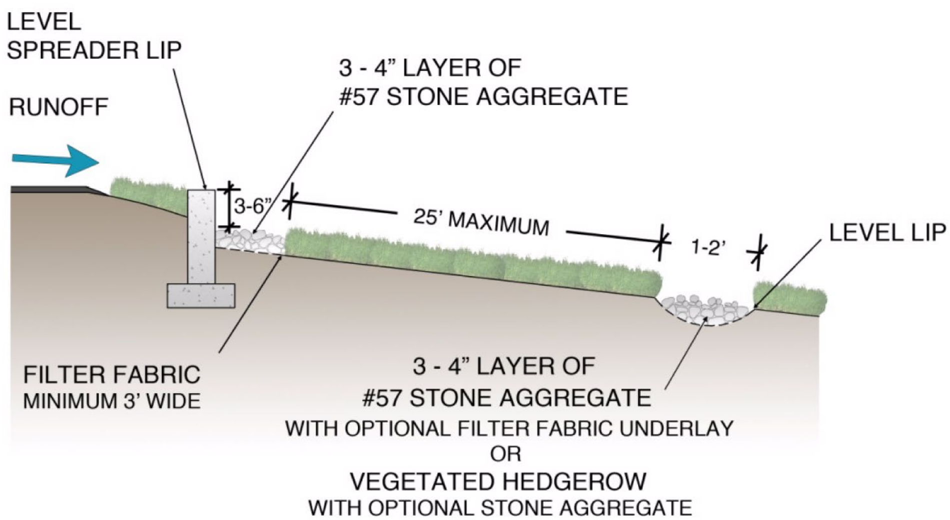


Figure 1.6.7.B-3: Recommended Level Spreader Details for Vegetative Filter Strip.

6. Landscape Elements. Vegetative filter strips shall have a minimum overall soil depth of twelve (12) inches, with at least 6 inches of topsoil at the surface and at least 6 inches of native or fill soil below it. 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.

7. Maintenance Requirements. See Section 1.6.3.

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 .

Source: Rule No. R161-14.26, 12-30-2014 .

C. Biofiltration

1. Introduction. Biofiltration devices are a type of stormwater control measure (SCM) that uses the chemical, biological, and physical properties of plants, microbes, and soils to remove pollutants from stormwater runoff. Biofiltration systems can provide equivalent treatment to a standard sedimentation/filtration system.

A biofiltration system is an enhanced filtration device that typically utilizes more than one treatment mechanisms for removing pollutants from stormwater runoff. A sedimentation basin is required as a first step in the SCM, to provide pre-treatment of runoff in order to protect the biofiltration medium from becoming clogged prematurely by sediment loads. Then, flows are directed through a biofiltration medium which removes pollutants. A defining characteristic of the biofiltration SCM is a community of plants and microorganisms that is rooted in the filter medium and that can provide more treatment of runoff, directly and by uptake from the filter medium. As well as enhancing removal of pollutants, the plant community tends to sustain the permeability of the biofiltration medium for longer periods of time without maintenance. It is the existence of this biological community that differentiates a biofiltration SCM from a typical sand filter, which is otherwise comparable in design and performance.

There are several hydraulic features or components that combine to make the biofiltration system work effectively. There is commonly a splitter box or flow spreading structure at the flow entrance to ensure flows do not concentrate and potentially channelize the filter medium (see Section 1.6.2.B). There is a sedimentation chamber to capture coarse sediments, and in some cases (described below) a separator element. The biofiltration filtration chamber typically must have an underdrain piping system beneath it, 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 SCM at the point of discharge.

For biofiltration ponds to work effectively, maximum velocities into the sedimentation chamber must not be exceeded. This requirement 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 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, and irrigation requirements.

2. Basin Surface Areas and Volumes.

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

$A_f = WQV*L/(k*t*(H_{max}/2+ L))$ (Equation C-1)

Where

- A_f = required surface area of the medium in square feet.
- WQV = the water quality volume in cubic feet as defined in section 1.6.2.
- L = Depth of the 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 (feet).
- t = Drawdown Time (two (2) days).

For design purposes, the hydraulic conductivity of the biofiltration medium can be assumed to be the same as that for sand filtration. Measured hydraulic conductivity of new biofiltration medium substantially exceeds 3.5 ft/day; however, 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. 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 discharges relatively slowly to the biofiltration basin (e.g. over 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:

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

Where

A_f = filtration area in square feet,

WQV = water quality volume in cubic feet as defined in Section 1.6.2A, and

H = 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.

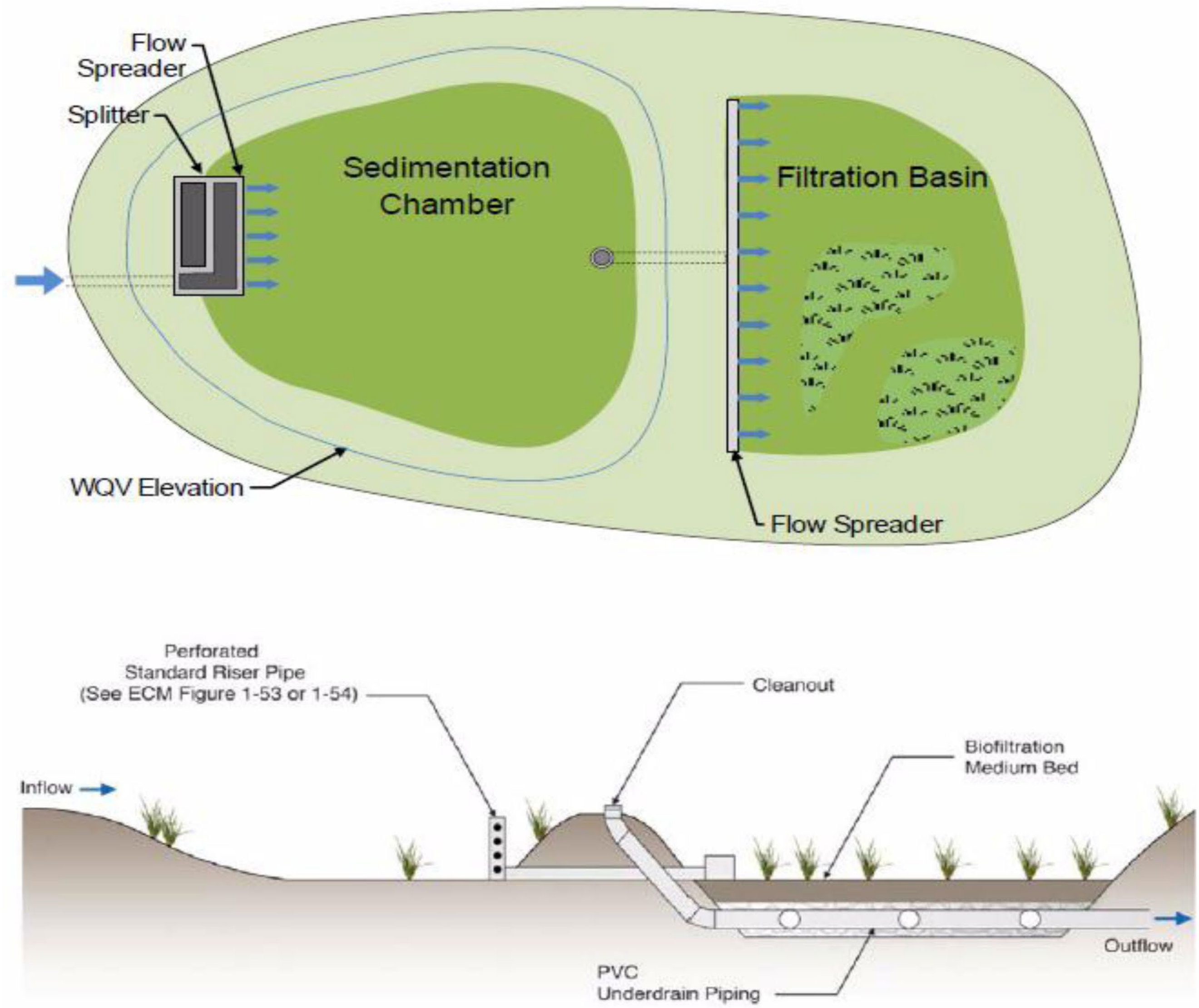


Figure 1.6.7.C-1: Full Sedimentation/Biofiltration Pond.

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 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 no less than 20 percent of the water quality volume. For general details see Figure 1.6.7.C-2, Partial Sedimentation/Biofiltration Pond, and Section 1.6.5.B, Partial Sedimentation/Filtration.

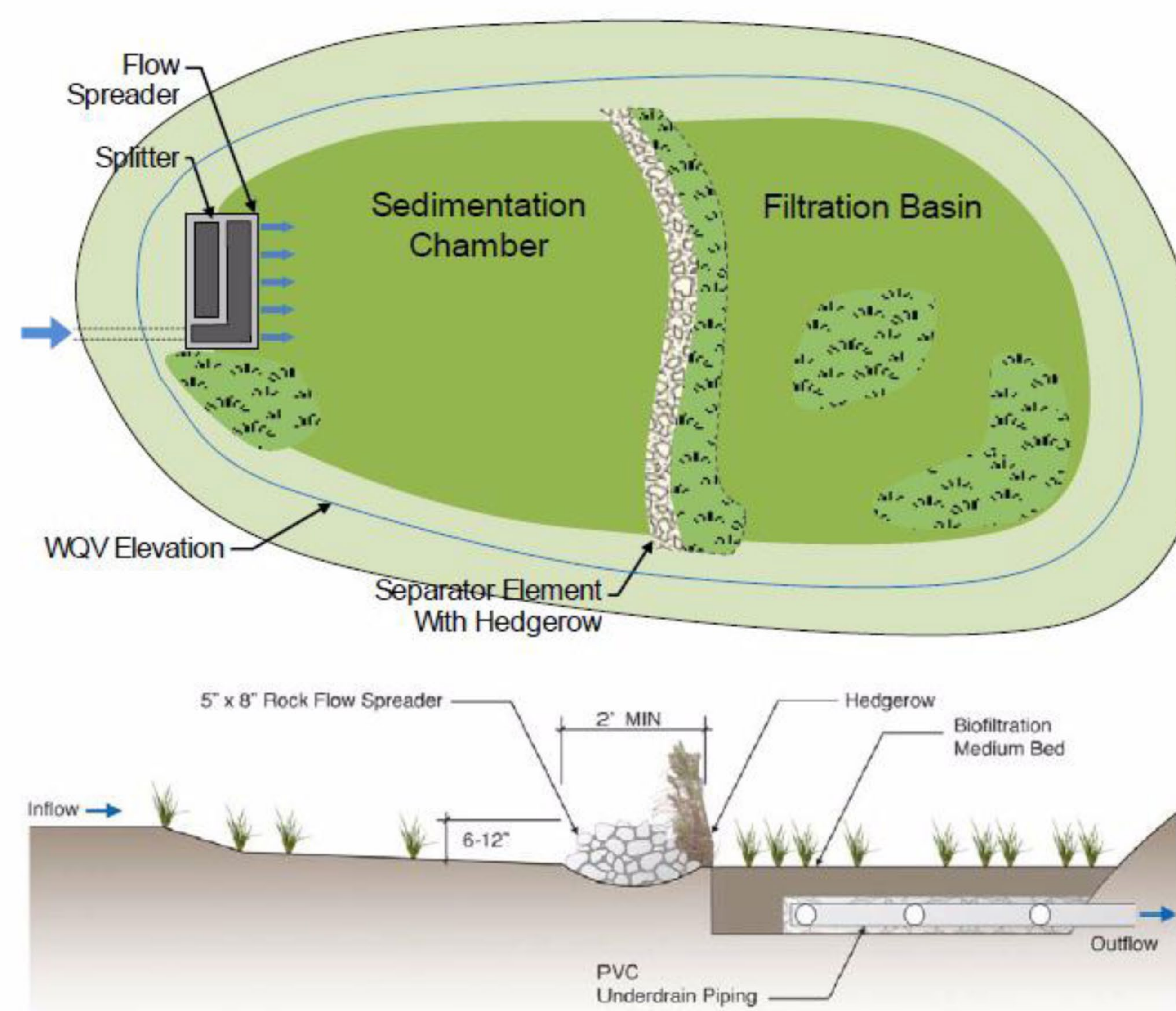


Figure 1.6.7.C-2: Partial Sedimentation/Biofiltration Pond.

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

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

Where:

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 a splitter box structure or flow spreading device (see section 1.6.2.B). Either way, the water quality volume flowing into the BMP should be discharged uniformly and at low velocity into the basin/chamber in order to 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. Flow spreading should be designed so as to restore the flows entering the BMP (i.e., after the inlet structure) to sheetflow conditions with a maximum velocity of two (2) feet per second for the peak flow rate of the twenty-five (25) year storm 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 provide resistance to flow and further spread the flows, thereby reducing runoff velocities further to improve settling, biological uptake, and adsorption.

   The basin/chamber should have a bottom slope of at least 2% 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 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). The outflow side should incorporate features to prevent gouging of the filtration medium.

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

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

      Percent Organic Matter (by weight) of 0.5—5.0%

      Texture Analysis (particle size distribution):

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

      There is ongoing research on the most appropriate sources of organic matter to incorporate into the 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 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 is intended to meet the NRCS definition of soils with "moderate" to "high" available water capacity. The criteria should ensure that the medium has 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 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 the medium, 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 medium must be certified by the project engineer or their 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.

1. Creating Biofiltration Mixture - See Standard Specification 660S, Biofiltration Medium

B. Biofiltration Bed with Underdrain. The biofiltration medium bed for biofiltration basins must be built to the Biofiltration Bed configuration illustrated in Figure 1.6.7.C-3 (for details see Standard Detail 661-3). The biofiltration medium layer is to be a minimum of eighteen (18) inches meeting the specifications stated in Section 4A above. Other materials or substances 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 biofiltration medium bed depths should be interpreted as final consolidated values rather than as initially placed. Under the biofiltration medium shall be 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. The soil medium and gravel layer must be separated by a filter material.

A filter can be of two (2) general forms. A fabric filter is a layer of geotextile filter fabric manufactured for that express purpose and a granular filter is one or more graded layers of sand, gravel or stone.

- The geotextile filter fabric must comply with Specification 620S, Table 2, High Flow Filter Fabric Requirements.
- The gradation of a granular filter design must comply with Section 1.4.6.D.6, Rock Riprap - Filter. In cases where the requirements cannot be met with a single gradation multiple layers of granular filter material of varying gradations may be required to meet the criteria.

The thickness of a granular filter layer should be no less than 1.5 times the maximum size in the filter gradation or four inches (102 mm) whichever is greater.

To avoid compaction of the biofiltration medium and promote filtration heavy equipment shall not be allowed in biofiltration area after the biofiltration medium has been placed.

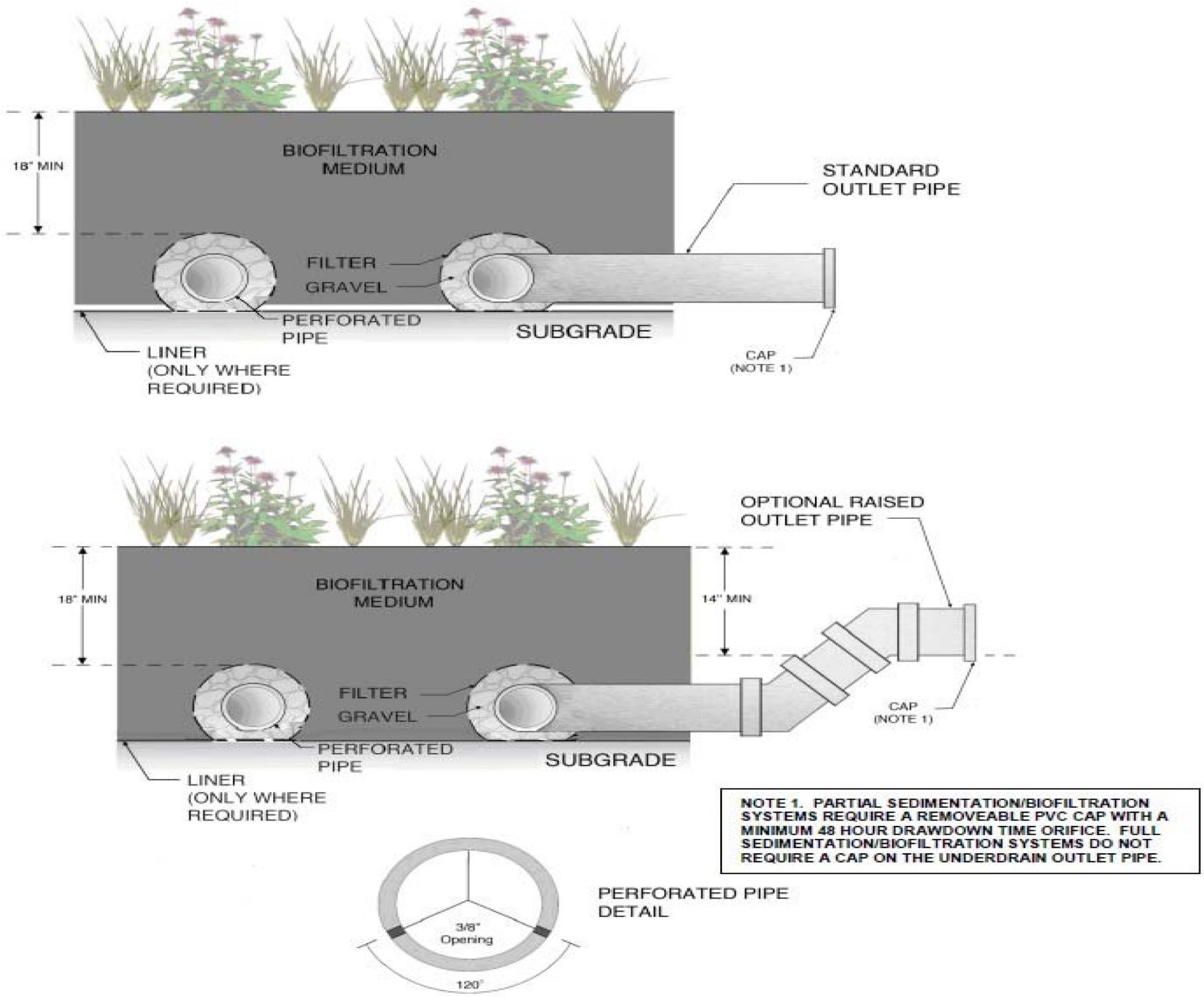


Figure 1.6.7.C-3: Biolfiltration medium bed with underdrain system.

Access must be provided for cleaning all underdrain piping. Cleanouts with a removable PVC cap are required at the ends of laterals and at every bend outside the water quality SCM (cleanouts outside of the SCM shall be set above the water quality elevation). In order to minimize damage to these cleanouts due to maintenance equipment, vandalism, and/or mowing, cleanouts may be permanently capped and set flush or just below the media bed after the 1-year warranty period if no drainage issues are observed. Outside the water quality SCM, the top of the cleanout should be set flush with the top of the ground surface from which it emerges. At least one lateral must be accessible for cleaning when the pond is full. The full pond cleanout must extend above the water quality elevation and be located outside of the water quality volume ponding area. In order to minimize vandalism or other types of damage the use of exposed piping shall be avoided or minimized.

Note: The top surface of the biofiltration medium bed must be horizontal.

C. Outlet Structure. 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 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. 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 selected based on their ability to survive under alternating conditions of inundation and extended dry periods, and in different areas within a facility (e.g., basin versus side slopes). 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 may drain more rapidly, and have less clay content. The selection of plants for the biofiltration medium depth will also be limited because the medium depth is typically about 1.5 feet, thus plants with large root systems are not appropriate. Trees shall not be used in the biofiltration chamber with underdrains. The soil characteristics and depth, and soil moisture availability including groundwater, 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.

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

A. Plant Selection, Quantities, and Spacing.

Vegetation shall be planted throughout the entire sedimentation and filtration basin areas as shown on a planting plan along with list of proposed plant species, container size, spacing, and quantity (Figure 1.6.7.C-4). The proposed vegetation must be diverse, appropriately distributed, and spaced according to the mature size of the particular plants. A landscape architect or other qualified landscape professional should be involved in the design to ensure appropriate plant species selection and layout.

a. Selection

Vegetation may comprise shrubs, perennials, bunchgrasses, succulents, groundcovers or turf, and this generally requires that there be a minimum of five (5) different species planted. Annuals are not permitted, and small trees, while allowed (see below) do not count towards the minimum species requirement. The designer can chose plants from the *Grow Green Native and Adapted Landscape Plants* guide (www.austintexas.gov/department/grow-green/plant-guide). Table 1.6.7.C-3 is a list of plants from this guide that the City of Austin does not recommend based on soil depth requirements, soil moisture requirements, and undesirable plant characteristics (e.g., short-lived, weak wood, suckering, maintenance concerns [messy fruit, thorny]).

Small trees can be incorporated:

- In the filtration basin, around the perimeter of the filtration basin, 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 8.3.3.
- In the sedimentation basin, 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.
- See Figure 1.6.7.C-3 for a list of trees not recommended for biofiltration facilities.

Plants must be selected and arranged carefully so that they serve their intended functions. In addition to choosing plants for their aesthetic properties, select plants that:

- are adapted to the pond hydrology (i.e. both periodic flooding and drought);
- are adapted to the soil types within the pond, whether native site soils or biofiltration media;
- are suitable for their specific function (e.g. erosion control, filtration, etc.);
- are durable, resilient and resistant to pests and disease;
- are tolerant of the pollution in stormwater runoff;
- have a root system of the desired type, mass and depth;
- are resistant to weed invasion;
- require minimal maintenance;
- are not invasive; and
- are commercially available.

Rooted plants may be provided in bare- or live-root form, sod, or in containers (e.g., trays, pots, tubes). 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 one-gallon plants. See Table 1.6.7.C-1 for equivalency.

Table 1.6.7.C-1
Plant Size Equivalents

Potential Substitute		Equivalent 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

b. Quantities

A certain percentage of the basins should be planted with rooted plants to provide immediate cover, whereas the other parts can be seeded or covered with turf grass (see below). All species, including turf grass will count towards the diversity minimum. No one species should comprise more than 20% of the total area of the basin. Additional rooted plants beyond the minimum is encouraged. If it can be demonstrated that there is a compelling reason to deviate from these guidelines then an alternative design may be allowed with approval from City staff.

i. Sedimentation Basin

To determine the minimum required quantity of rooted 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.

ii. Filtration Basin

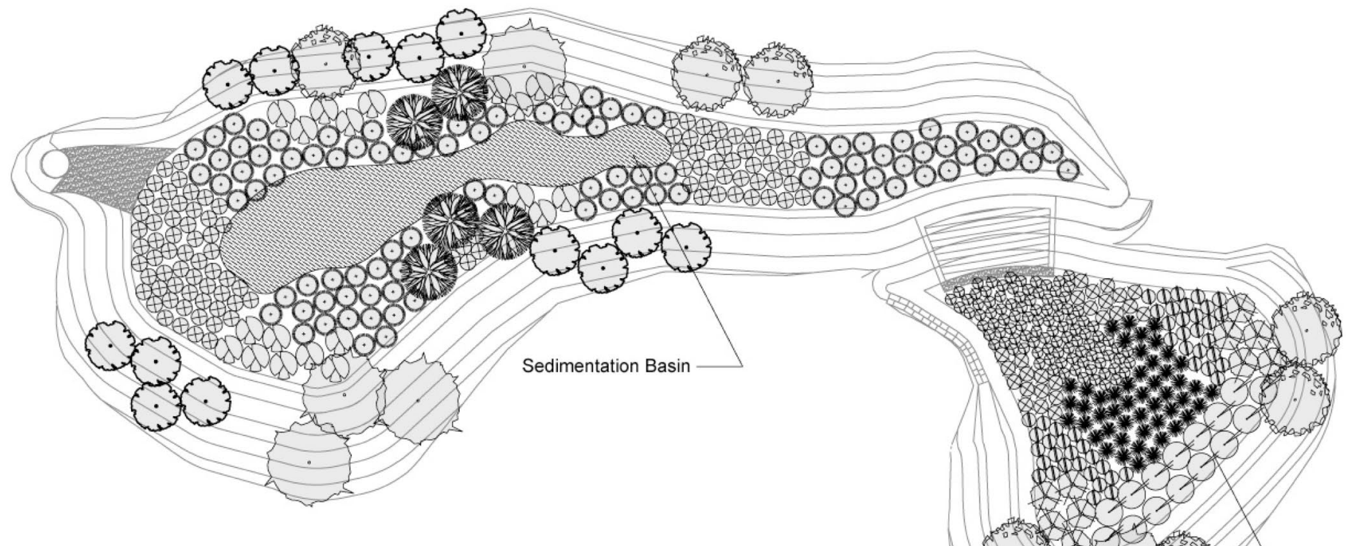
To determine the minimum required quantity of rooted plants, except turf grass, multiply the total surface area (in square feet) of the filtration basin by twenty percent (0.2). This number represents the minimum number of rooted plants to be placed in the filtration basin.

c. Spacing

The goal is to provide 95 percent vegetative coverage across the basins.

i. Rooted plants should be spaced based on mature size to allow room for growth and avoid overcrowding conditions that will cause plant mortality or impenetrable barriers for maintenance personnel.

ii. Contiguous areas of sod should be planted end to end, allowing no bare soil.



Filtration Basin 2000 sq. ft. x 0.20 = 400 plants required				
Plant	Size	Spacing	Quantity	1 gallon equivalent
Shrub	5 gal.	5' o.c.	10	40
Shrub	5 gal.	5' o.c.	15	60
Bunchgrass	5 gal.	3' o.c.	50	200
Bunchgrass	1 gal.	2.5' o.c.	25	25
Perennial	1 gal.	3' o.c.	50	50
Groundcover	4"	2' o.c.	100	25
			TOTAL	480

Sedimentation Basin 4400 sq. ft. x 0.10 = 440 plants required				
Plant	Size	Spacing	Quantity	1 gallon equivalent
Small Tree	5 gal.	10' o.c.	5	20
Shrub	5 gal.	5' o.c.	20	80
Bunchgrass	1 gal.	4' o.c.	100	100
Perennial	1 gal.	3' o.c.	100	100
Sod	square		360	180
			TOTAL	480

Figure 1.6.7.C-4: Example of Biofiltration Landscape Layout and Calculations

B. Plant Species Not Allowed or Recommended.

Various plant species are not allowed or not recommended in biofiltration facilities for various reasons. Plants listed in Table 1.6.7.C-2 are not permitted in biofiltration systems. These plants are not native, and 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 or the State of Texas are not allowed. Refer to:
    - City of Austin Top 24 list http://www.texasinvasives.org/plant_database/coa_results.php .
    - TDA Noxious Weed List http://texreg.sos.state.tx.us/fids/200701978-1.html .
    - In addition, plants in the following table are not allowed due to their potential invasiveness.

Table 1.6.7.C-2
Vegetation That Is Not Permitted For Planting

Common Name	Botanical Name	Comments
Pampas grass	*Cortaderia selloana*	Potentially invasive
Scotch broom	*Cytisus scoparius*	Invasive shrub
Weeping love grass	*Eragrostis curvula*	Invasive grass
Cogon grass	*Imperata cylindrica*	Invasive grass
Japanese silver grass	*Miscanthus sinensis*	Invasive grass
Fountain grass	*Pennisetum setaceum*	Invasive grass
Common reed	*Phragmites australis*	Tall invasive grass

Table 1.6.7.C-3
Vegetation that is Not Recommended

Plant Type	Common Name	Botanical Name	Comments
SMALL TREES/LARGE SHRUBS	Anacua	*Ehretia anacua*	Suckers; prefers well- drained soil; cold tender
	Cherry Laurel	*Prunus caroliniana*	Requires deep soils
	Crape Myrtle	*Lagerstoemia indica*	Requires deep soils
	Goldenball Lead Tree	*Leucaena retusa*	Requires consistently dry soil
	Mexican Olive	*Cordia boissieri*	Messy fruit
	Palms (non-native)	Various	Various
	Texas Persimmon	*Diospyros texana*	Messy fruit
	Pomegranate	*Punica granatum*	Messy fruit
	Retama	*Parkinsonia aculeata*	Suckers, short-lived
	Roughleaf Dogwood	*Cornus drummondii*	Suckers
	Flameleaf Sumac	*Rhus lanceolata*	Needs large space; suckers
	Viburnum	*Viburnum rufidulum*	Requires deep soils
	Wax Myrtle	*Morella cerifera*	Requires deep soils
	Xylosma	*Xylosma congestum*	Spiny; potentially invasive
SHRUBS	Japanese Aralia	*Fatsia japonica*	Requires shade and regular water
	Japanese Yew	*Podocarpus macrophyllus*	Requires shade and regular water
	Fragrant Mimosa	*Mimosa borealis*	Requires consistently dry soil
	Bush Germander	*Teucrium fruticans*	Requires consistently dry soil
	Globe Mallow	*Sphaeralcea ambigua*	Requires consistently dry soil
	Mock Orange	*Philadelphus coronarius*	Requires consistently dry soil
	Pineapple Guava	*Eijoa sellowiana*	Cold tender, messy fruit
	Rosemary	*Rosmarinus offinialis & prostratus*	May not tolerate poorly drained soil

	Texas Sage	*Leucophyllum frutescens*	Requires consistently dry soil
PERENNIALS	*Blackfoot Daisy*	Melampodium leucanthum	Requires consistently dry soil
	Bulbine	*Bulbine frutescens*	Cold tender
	Cast Iron Plant	*Aspidistra elatior*	Requires dry shade
	Frostweed	*Verbesina virginica*	Colonizes; limited commercial availability
	River Fern	*Thelypteris kunthii*	Requires shady, moist areas
	Gayfeather	*Liatris mucronata*	Requires consistently dry soil
	Hymenoxys	*Tetraneuris scaposa*	Requires consistently dry soil
	Shrimp Plant	*Justicia brandegeana*	Prone to spread to outside areas
GROUNDCOVERS	Monkey Grass	*Ophiopogon japonicus*	Requires shady, moist soil
	Purple Heart	*Setcreasea pallida*	Prone to root rot; cold tender
	Silver Ponyfoot	*Dichondra argentea*	Good drainage critical

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/.

Source: Rule No. R161-14.26, 12-30-2014 ; Rule No. R161-15.12, 1-4-2016 ; Rule No. R161-21.21 , 9-29-2021.

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 if specifically designed for this purpose. Rainwater harvesting systems can provide equivalent treatment to a standard sedimentation/filtration system and may be used within the Barton Springs Zone if the design achieves the non-degradation load requirements detailed in Section 1.6.9. 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.

For rainwater harvesting systems the BMPDF variable is a function of the following factors:

- 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_{rwh} is the rainwater harvesting system drawdown time in hours (a maximum of 120 hrs.).

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

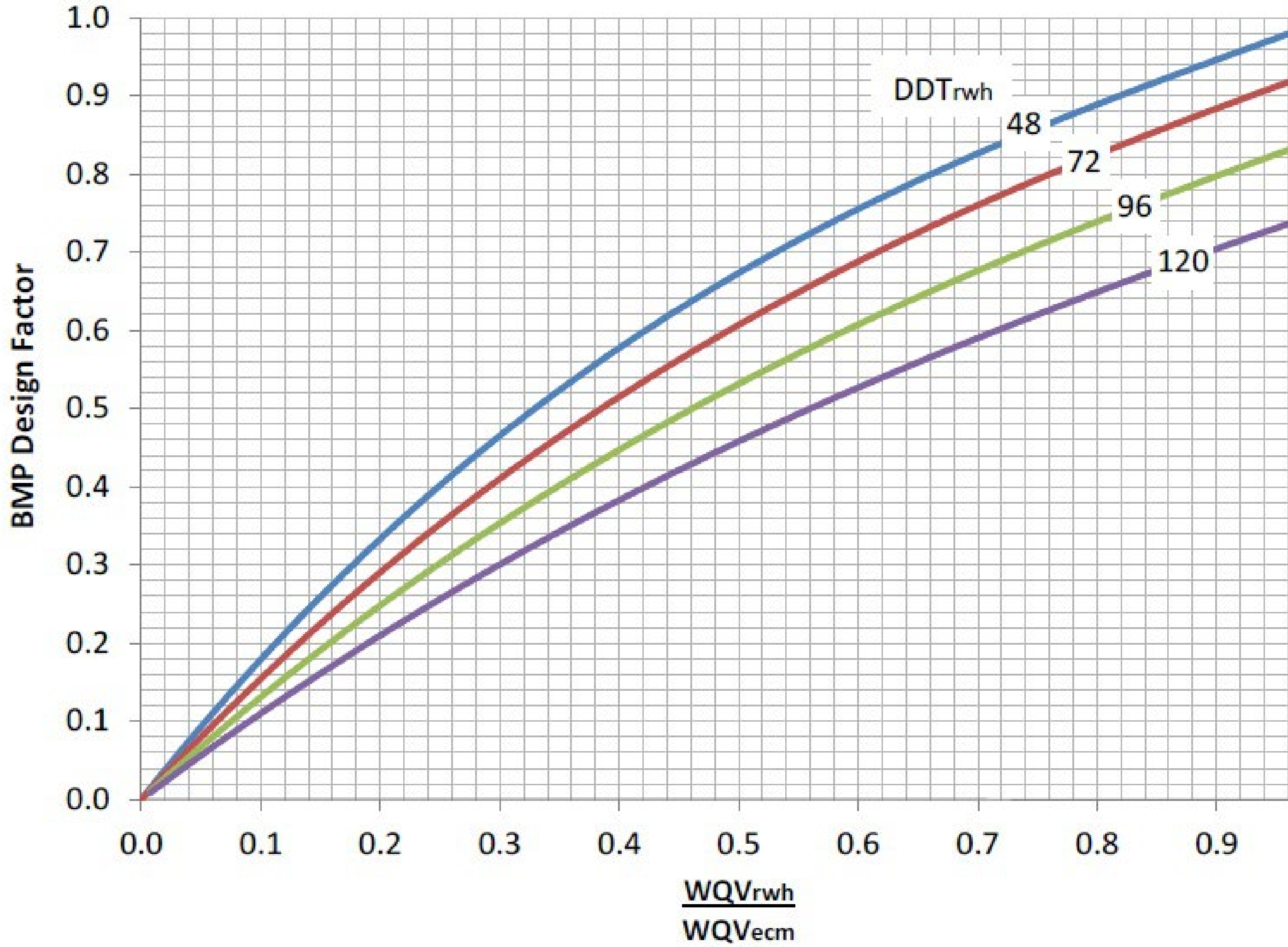


Figure 1.6.7.D-1. BMP Design Factor for Rainwater Harvesting Systems.

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:

3. Design Options.

   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 captured runoff is held 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 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) 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.

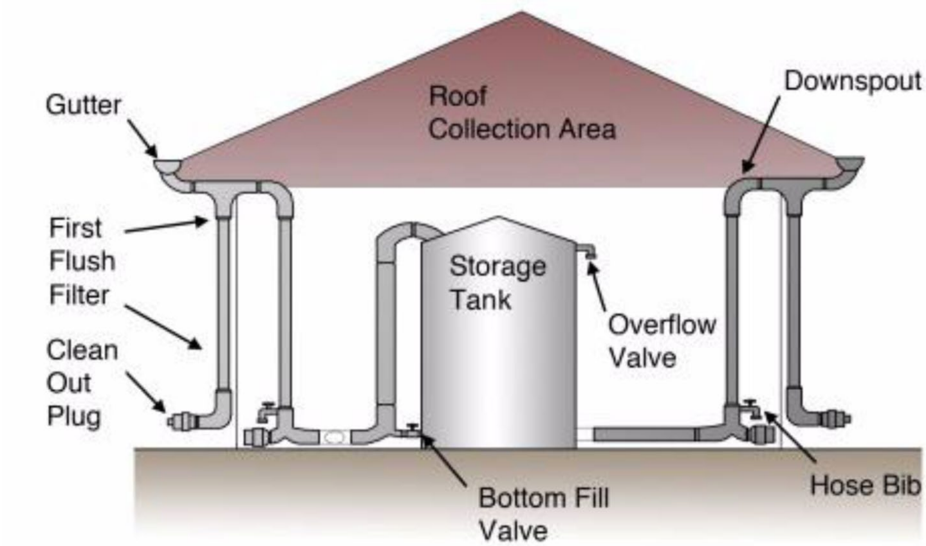


Figure 1.6.7.D-2. Typical configuration for a rainwater harvesting system.

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 hours. The designer must demonstrate that the vegetated area is sufficiently large to infiltrate the entire water quality volume within 120 hours (see Figure 1.6.7.D-3 below).

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

Q_{avg} = WQV/DDT

Where:

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:

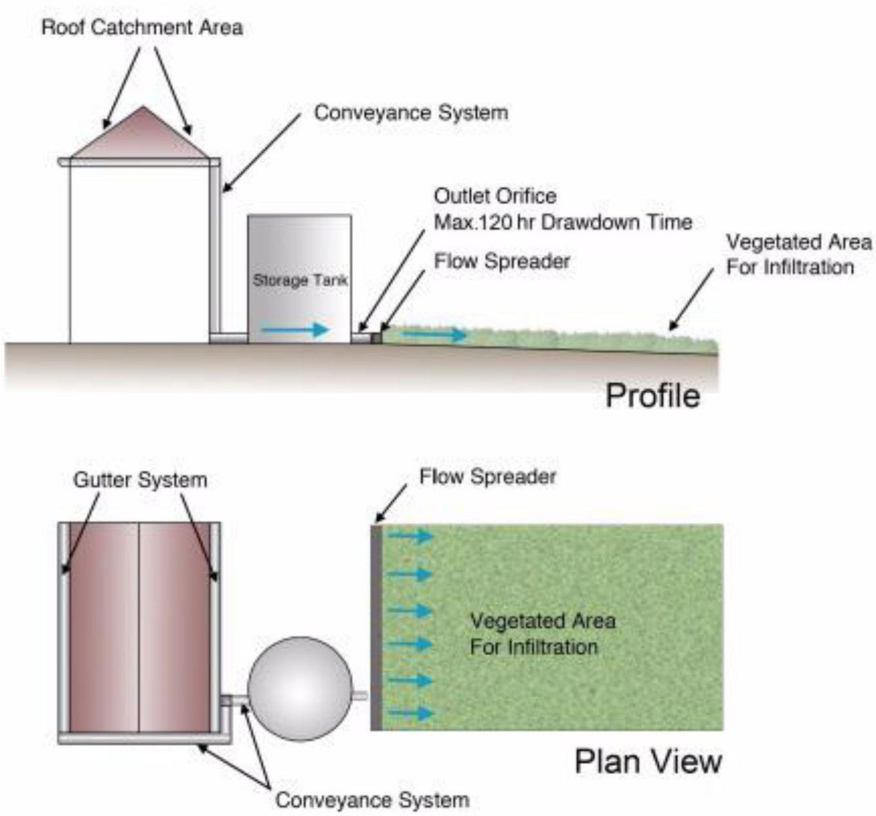


Figure 1.6.7.D-3. Design Option A with captured runoff discharged to a vegetated area for infiltration.

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:

$A = (2 * WQV)/(k * (DDT - LT)$

Where

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.

To be eligible for water quality credit the vegetated area also must meet the following criteria:

- 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 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 twelve (12) 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. The system should be designed according to the retention/irrigation criteria in Section 1.6.7.A.

Rainwater systems are considered auxiliary water sources by the Austin Water Utility. When a rainwater harvesting system meets the definition of Auxiliary Water per the City of Austin - Utility Criteria Manual (UCM) then the design of this system must comply with the backflow protection requirements established in Section 2.3.4 of the UCM, Backflow Prevention Rules and Regulations Pertaining to Sites With Both City Potable Water and Auxiliary Water.

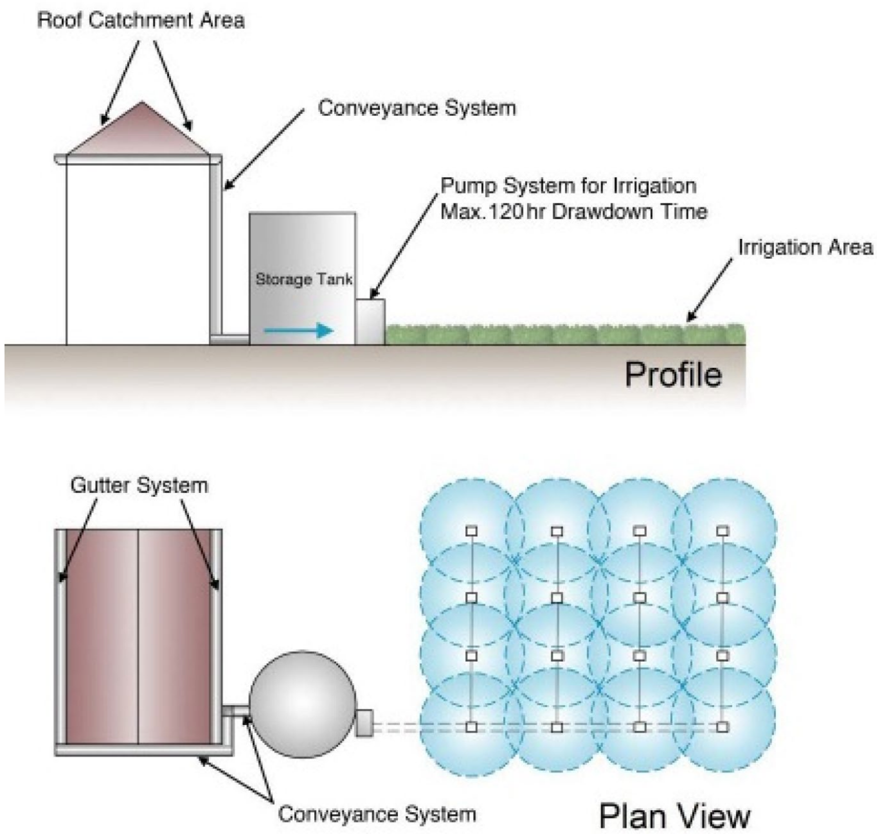


Figure 1.6.7.D-4. Design Option B with captured runoff used to irrigate a vegetated area.

4. Example.

A 5 acre commercial development with 50% impervious cover (2.5 impervious acres) is proposing a rainwater harvesting system that would capture runoff from 1 acre 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 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 of a structural control or a reduction in the fee-in-lieu cost.

As the alternative control is for 1 acres of impervious cover, and the site has a total of 2.5 impervious acres, the IAF value is 0.40 (=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 = 0.92-inch

The BMPDF value is a function of the following factors:

WQV_{rwh}/WQV_{ecm} and

DDT_{rwh}

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.

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 hours.

Is it large enough?

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

Size provided = 260′ * 90′ = 23,400 ft^2 - 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)/(96 - 12) = 80 cfh = 0.022 cfs

HLR = Q/W = 0.022/260 = 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 = 0.4 * 0.68 = 0.272

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

Source: Rule No. R161-14.26, 12-30-2014 .

E. Porous Pavement

1. **Description.** Porous pavement describes a system comprising a limited capacity load-bearing, durable surface together with an underlying layered structure that temporarily stores water prior to infiltration and releases the temporarily stored water by infiltration into the underlying permeable subgrade.

   Porous pavement can qualify for Water Quality credit if designed using the storage within the underlying structure or sub-base to infiltrate stormwater and provide ground water recharge to reduce pollutants in stormwater runoff. When proposing the use of a porous pavement system highly detailed specifications and details must be provided and an experienced contractor shall be selected, to minimize potential problems.

   A. The types of porous pavement systems that are acceptable for both pedestrian and vehicular traffic are as follows:

      1. Open-jointed block pavement, permeable interlocking concrete pavement (PICP) or concrete grid pavement (CGP): These systems consist of high strength concrete units that are separated by open or stone-filled joints that allow stormwater to infiltrate. The concrete units are laid on an open graded, single-sized granular base. See Figure 1.6.7.E-1 for a typical cross section.

      2. Porous asphalt (PA): This system consists of regular bituminous asphalt in which the fines have been screened and reduced, creating void spaces and making it permeable. See Figure 1.6.7.E-2 for a typical cross section. Permeable friction course (PFC) is a porous asphalt overlay placed over an impervious cover surface and is not eligible for water quality credit.

   B. The type of porous pavement system that is acceptable for pedestrian use only is as follows:

      1. Porous concrete pavement: This system is monolithically poured concrete produced by binding aggregate particles with a mortar created with water and cement as specified by the manufacturer. Minimal sand content results in large voids and high pavement porosity, typically between 15 and 25%. This high porosity and the weaker cement bond result in less strength compared to conventional concrete. See Figure 1.6.7.E-3 for a typical cross section.

2. **Site Selection.**

   Land Use - Porous pavement should be limited to pedestrian areas, areas with low vehicular traffic volumes, smaller axle loads and low speeds such as, parking stalls, smaller parking lots, overflow parking areas of larger parking lots and other areas with little or no traffic. Permeable surfaces are currently not considered suitable for roads with heavy traffic or high speeds due to the risks associated with failure, the safety implications of ponding, and disruption arising from reconstruction.

   Off Site Flows - Run-on from drainage area(s) outside of the porous pavement area is not allowed.

   Hot Spots - Porous pavement systems depend upon infiltration into the underlying permeable subgrade. Due to the potential for groundwater contamination, porous pavement shall not be allowed under stormwater hot spots or in areas where land use or activities generate highly contaminated runoff or yield high sediment loads. Hot spot runoff frequently contains pollutant concentrations exceeding those typically observed in stormwater. Hot spots include, but are not limited to, commercial nurseries, auto salvage facilities, hazardous materials generators (where containers are exposed to rainfall), vehicle fueling and maintenance areas, and vehicle and equipment washing 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 City Code Chapter 6-5, Article 5, Discharges into Storm Sewers or Watercourses).

Barton Spring Zone - Porous pavement is not acceptable as a water quality control and will not receive credit against water quality volume calculations.

Geotechnical Evaluation - A major factor for most design decisions is related to the existing soil conditions. It shall be necessary to obtain geotechnical/soils and subsurface information prior to the design of a porous pavement system. To demonstrate the feasibility of the design the following information must be submitted to the Planning and Development Review Department engineer with the site plan or subdivision construction permit application:

1. Soil Conditions - The subgrade saturated hydraulic conductivity must be greater than or equal to 0.20 in/hr.
    - For sites with a consistent soil type, a minimum of one soil permeability test must be taken per 5,000 square feet of planned porous surface area. The determination of the infiltration rate must follow the criteria established in Section 1.6.7.4, Infiltration Rate Evaluation.
    - Testing must be performed prior to the start of construction and prior to the placement of the base or gravel layer on the native soil to verify that design saturated hydraulic conductivity values are present. The Environmental inspector must be contacted 48 hours prior to these tests being performed so they can be present during the test and/or evaluate and approve the results.
2. Water Table - The depth to water table is greater than or equal to twelve (12) inches.
3. Bedrock -The depth to bedrock is greater than or equal to twelve (12) inches.

Setback Requirement - If a porous pavement system is proposed near a structure or a street. Then an additional geotechnical evaluation shall be undertaken to identify potential impacts and to establish minimum distances between the system and the structure.

Impermeable Barrier - Porous pavement adjacent to buildings, roadways, and other structures may require the installation of an impermeable barrier to prevent possible damage to these structures due to infiltration. The requirement for impermeable barriers may be at the discretion of the design engineer. The Public Works Director or designated representative shall review any decisions on impermeable barrier(s) within City ROW and easements.

Slopes - The use of porous pavement system shall be restricted to gentle slopes up to a 20 to 1 grade (5%). On steeper slopes the potential for water seepage out of the pavement surface limits effectiveness.

3. **Design Guidelines.** The designer must select the appropriate material properties, the appropriate pavement thickness, underlying layers, material types, and other characteristics needed to meet the anticipated traffic loads and hydrological requirements simultaneously.

For water quality credit purposes, a porous pavement area that meets the 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 City Code Section 25-8-63 (e.g. multi-use trails, fire lanes, etc.).

The following criteria must be met when designing a porous pavement system:

A. The gravel layer below porous pavement must have a minimum thickness greater than or equal to five (5) inches with an assumed effective porosity no greater than 0.30 to account for reduced volume due to sediment. The gravel layer must be an open graded (single size) aggregate, with little or no fines. Examples of standard open graded gravel materials that allow for storage and conveyance of storm water are those that meet C-33 ASTM Nos. 8, 9, 57, and 67.

B. For open-jointed block pavement, PICP, or CGP:

- It is required that the joints be filled with a durable, angular, porous, open-graded, aggregate that promotes rapid infiltration, and meeting C-33 ASTM No. 8 or 9 aggregate requirements.
- In order to preserve the porosity and permeability of the pavement fine-graded sands or aggregates, such as concrete sand, soil and mortar sand, are not allowed.

C. For porous concrete design and construction the design engineer must follow the recommendations provide by The American Concrete Institute (ACI) committee 522.

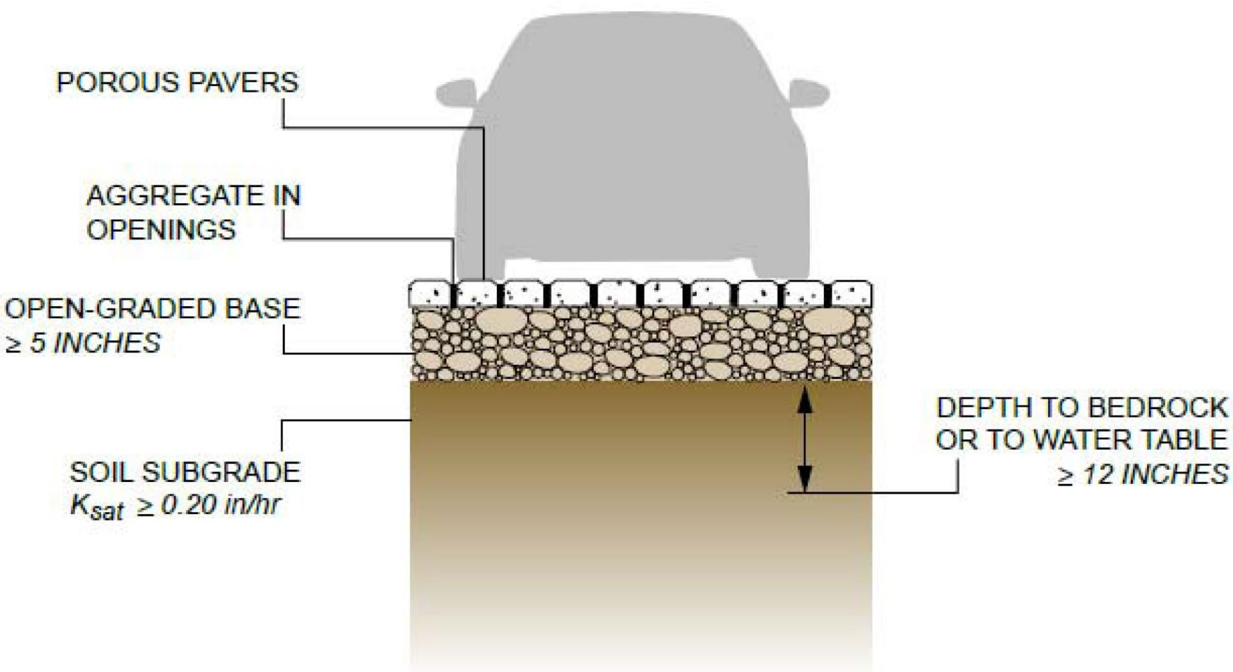


Figure 1.6.7-E.1 Typical cross section for Open-jointed block pavement, Permeable Interlocking Concrete Pavement or Concrete Grid Pavement.

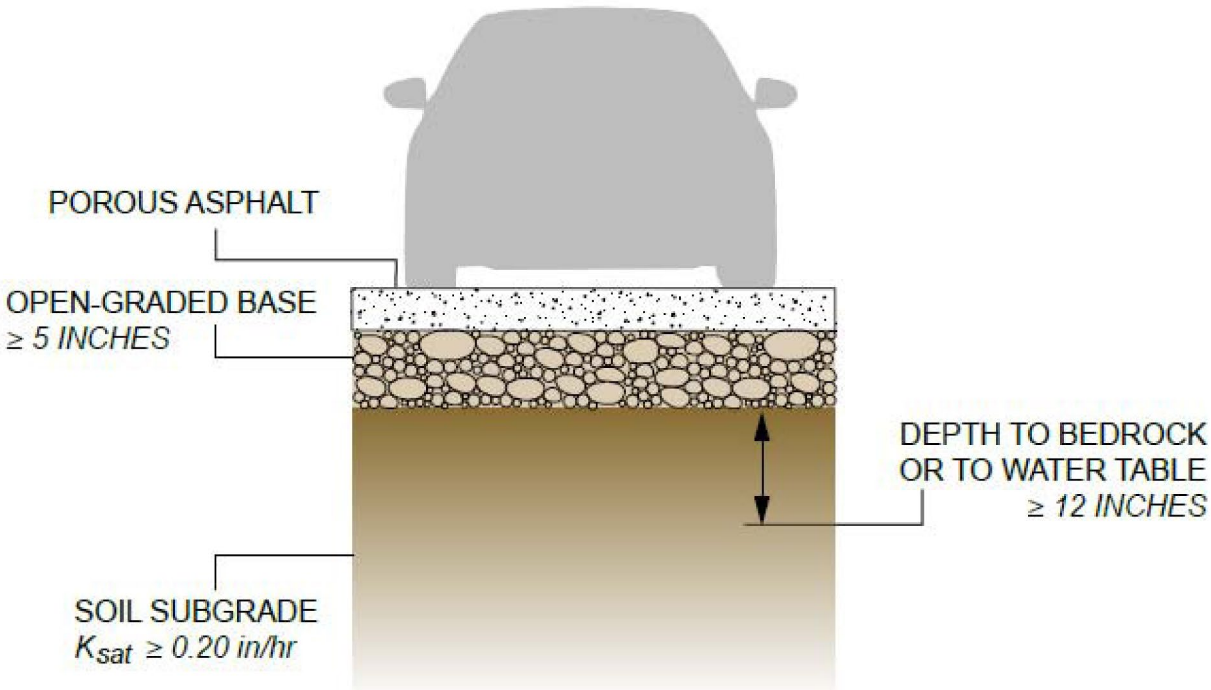


Figure 1.6.7.E-2 Typical cross-section for Porous Asphalt.

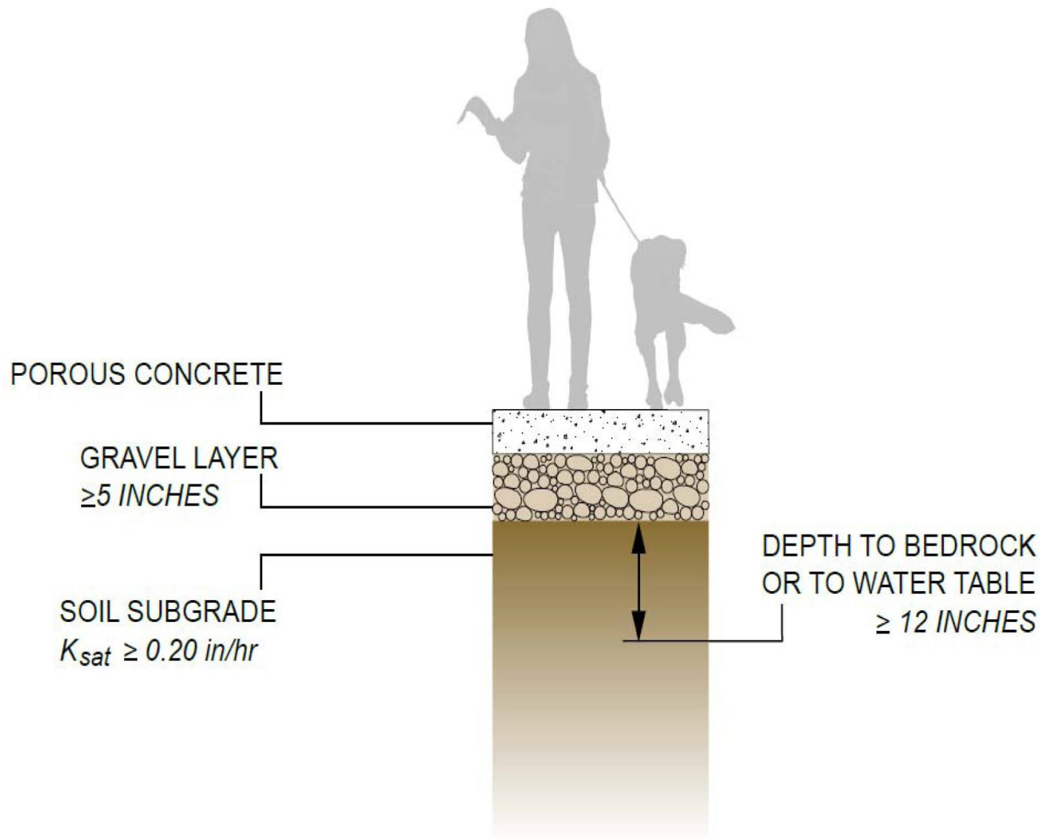


Figure 1.6.7.E-3 Typical Cross Section for porous concrete pavement.

4. **Site Plan or Subdivision Construction Plan Requirements.** The following information must be included in the Site or Subdivision Construction plan sheet(s):

   A. The standard sequence of construction must be modified to include the following special requirements:

      1. Pre-Construction - Contractor installation qualifications require that the contractor provide to the Environmental Inspector at the preliminary construction meeting a statement attesting to qualifications and demonstrating experience. Contractors must prove specialized competence by presenting a copy of current certification from an authoritative porous pavement industry association.

      Acceptable porous pavement industry associations are the following:

      - For open-jointed block pavement, permeable interlocking concrete pavement, or concrete grid pavement: Interlocking Concrete Pavement Institute, Brick Industry Association, National Concrete Masonry Association,
      - For porous asphalt: Texas or National Asphalt Pavement Associations,

- For porous concrete pavement: Texas or National Ready Mixed Concrete Associations, or
- American Society of Civil Engineers.

2. Saturated hydraulic conductivity testing must take place twice:
   a. Prior to construction, and
   b. Prior to placement of the gravel bed.
3. The Environmental inspector must be contacted 48 hours prior to the placement of the gravel bed saturated hydraulic conductivity test being performed and test results must be provided to the inspector documenting that the design saturated hydraulic conductivity has been met.

B. The construction and post-construction/inspection notes below (Sections 1.6.7.E. 5 & 6) must be included on the stormwater control measure plan sheet.

5. **Construction.** Proper construction of permeable pavement systems requires measures to preserve natural infiltration rates prior to placement of the pavement, as well as measures to protect the system from the time that pavement construction is complete to the end of site construction. The following recommendations apply to all permeable pavement systems:

A. General.

1. Keep mud and sediment-laden runoff away from the pavement area.
2. Temporarily divert runoff or install sediment control measures as necessary to reduce the amount of sediment run-on to the pavement.
3. Cover surfaces with a heavy impermeable membrane when construction activities threaten to deposit sediment onto the pavement area.
4. Low ground pressure (LGP) track equipment should be used within the pavement area to limit over-compacting the subgrade. Wheel loads such as, passenger cars and pick-up trucks should not be allowed on the pavement area during construction.

B. Subgrade Preparation. Since porous pavement is an infiltration practice it is imperative that the permeability of the underlying native soils be preserved. The following recommendations apply to all permeable pavement systems:

1. It is important to protect the subgrade from over compaction, accumulation of fines, excessive construction equipment traffic, and surface ponding. Any accumulation of debris, fines, or sediment that has occurred during subgrade preparation should be removed prior to starting the gravel bed installation.
2. Grading shall not take place during wet soil conditions to minimize sealing of the soil surface.
3. In situations where the subgrade has been over compacted or the permeability has been diminished scarification should take place to a depth sufficient to match the naturally occurring in-situ state. Typically scarification should be a minimum of four (4) to six (6) inches in depth.

C. Gravel Bed Preparation. The gravel bed should consist of clean, crushed gravel, free of mud, clay, vegetation or other debris, conforming to ASTM C 33 for stone quality. Size gradation shall conform to ASTM C-33 No. 57 or No. 67 as described in City of Austin Standard Specification 510.2.(a), Pipe Bedding Stone.

Placement of the gravel bed can occur once:

1. The design saturated hydraulic conductivity of the subgrade has been verified using the criteria stated in Section 1.6.7.4.
2. The City of Austin Environmental inspector has approved the gravel bed preparation.
3. Any accumulation of debris, fines, or sediment that has occurred during the placement of the gravel bed installation has been removed.

D. Porous Pavement Installation. Contractor installation qualifications require that the contractor provide to the City of Austin Environmental inspector, at the preliminary construction meeting, a statement attesting to qualifications and demonstrating experience with the following porous pavement procedures and tests:

For all types of porous pavement systems:

1. Contractors must prove specialized competence by presenting current certification from an authoritative industry association. (See Section 1.6.7.E.4.A.1 for examples of acceptable industry associations.)
2. Provide the addresses for a minimum of three (3) completed projects with similar geologic and climate conditions as the proposed site.

   For porous concrete and porous asphalt systems provide additional information regarding the procedures that will be followed to meet the following:

   - Measuring unit weight acceptance data.
   - Conducting in-situ pavement tests including void content and unit weight.
   - Preparing product samples.

If the installing contractor and pavement producer do not have sufficient experience with porous pavement systems, the installing contractor shall retain an experienced consultant to monitor production, handling, and placement operations at the contractor's expense.

6. **Post Construction/Inspection.** The porous pavement surface saturated hydraulic conductivity must be greater than or equal to 20 in/hr.

Use the following testing methods to verify the surface saturated hydraulic conductivity:

- For porous concrete and porous asphalt use ASTM C1701.
- For open-jointed block pavement, PICP, or CGP use ASTM C1781.

All inspection, infiltration testing, and maintenance activities shall be documented and made available to City of Austin inspection staff upon request.

7. **Flood Mitigation.**

For porous pavement systems complying with the flood detention requirements of the Drainage Criteria Manual the following criteria will apply:

- Monitoring ports will be required.
- Must provide an annual 3rd party inspection as required for Subsurface Ponds (see Section 1.6.2.E).
- The storage volume must be increased to account for losses due to sediment build up. Since no run on is allowed on the porous pavement system a minimal increase in volume of fifteen percent (15%) is required.

8. **Maintenance.** See Section 1.6.3.C.8 for requirements related to maintenance.

9. **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 0.5 acres (of the 2.5 impervious acres) of porous asphalt for parking spaces. Determine the water quality credit for this system.

   Without the porous pavement, the water quality volume required is 0.80", or 14,520 ft^3. See Section 1.6.2.A, Capture Volume or Water Quality Volume, for this base formula.

   Assuming the above criteria is met, the use of porous pavement would allow the design engineer to deduct 0.5-acre from the drainage area to the site storm water control measure, and thus the site behaves as if it is 4.5 acres with 2.0 impervious acres, or 44.4% impervious cover. This reduces the required water quality volume from 0.80" to 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 12,161 ft^3, or about a 6% reduction.

10. **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, July 1, 2007, 4-57
3. Urban Drainage and Flood Control District, Urban Storm Drainage Criteria Manual Volume 3, Best Management Practices, November 2010, pp. 6-15—6-17
4. Texas Commission on Environmental Quality, RG-348 Complying with the Edwards Aquifer Rules Technical Guidance and Best Management Practices, July 2005, pp. 3-25—3-26
5. Ferguson, Bruce K., 2005. Porous Pavements, CRC Press, pp. 2-4, 384
6. Water Environment Federation (WEF) Manual of Practice No. 23/American Society of Civil Engineers (ASCE)/Environmental & Water Resources Institute (EWRI) Manuals and Reports on Engineering Practice No. 87, 2012, Design of Urban Stormwater Controls, 384

Source: Rule No. R161-14.26, 12-30-2014 ; Rule No. R161-15.12, 1-4-2016 .

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 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.

   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 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 Standard Specification 660S.

   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.

4. References:

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

Source: Rule No. R161-15.12, 1-4-2016 .

H. Rain Garden.

1. 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 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 removal 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.

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, Multi-Family, Civic Uses, Public Right of Way , and single family residential projects. The restrictions on use of rain gardens for single family residential are as follows:

1. Rain Garden must be located in a dedicated common area or within a drainage easement that is accessible by standard maintenance equipment from the right of way.
2. A minimum of four (4) single family lots must be treated by the rain garden.
3. No rain gardens are to be located in backyards or fenced in yards.
4. The City of Austin will provide functional maintenance per City Code Section 25-8-231. Homeowners may add additional native landscaping and provide more frequent care.

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 - Rain gardens are restricted to a contributing drainage area not to exceed two acres and a ponding depth not to exceed 12 inches.

Barton Springs Zone - At this time, an unlined rain garden is not acceptable as a primary method for controlling non-point source pollution in watersheds within the Barton Springs Recharge Zone. If a rain garden is proposed for use in the Barton Springs Recharge Zone, then a liner is required and the discharge from this facility must be managed to comply with the Save Our Springs ordinance.

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 12 inches below the bottom of the rain garden. For full infiltration rain gardens, the underlying native 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. The design infiltration rate is based on applying at least a factor of safety of two (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 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 12 inches.

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 12 inches. 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.

Select native vegetation whenever possible to reduce the need for long-term irrigation and maintenance. 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.

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.

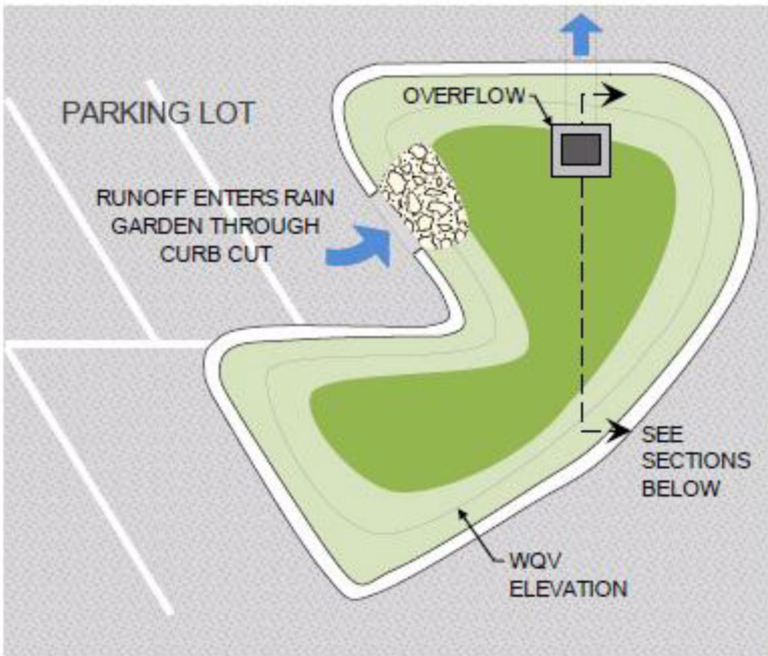


Figure 1.6.7.H-2. Rain gardens can be sized to capture and treat all or a portion of the required water quality volume (WQV).

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

- Full Infiltration

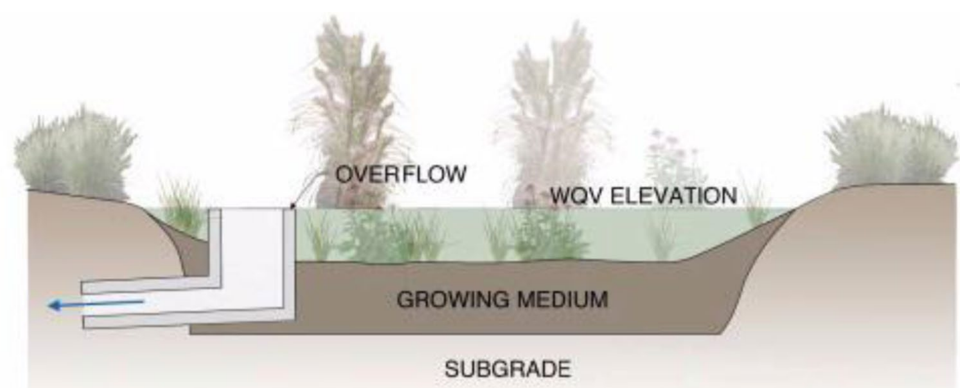


Figure 1.6.7.H-3. Full infiltration rain gardens use the infiltration capacity of the site soils to reduce stormwater runoff volume and associated pollutants.

$A_i \geq 0.87 * WQV/(H + 0.24 * L)$ (Equation H-1)

Where:

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.

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:

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

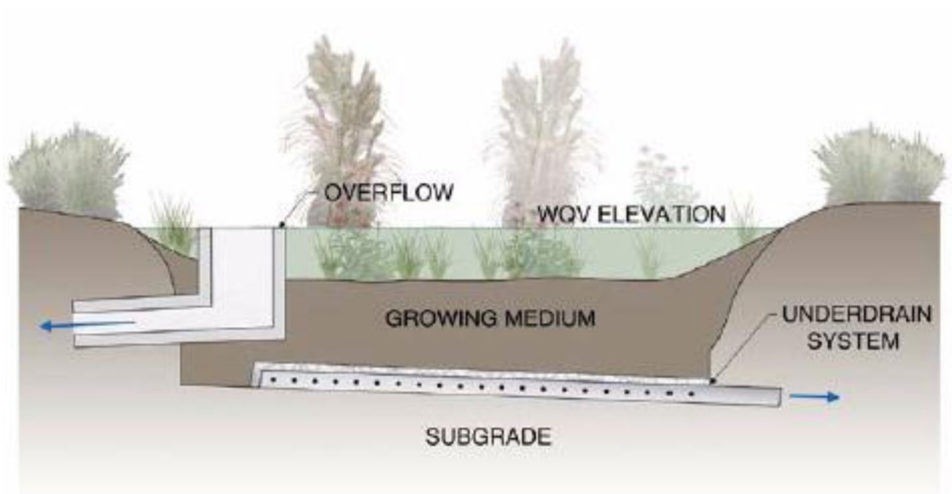


Figure 1.6.7.H-4. Full filtration rain gardens are sized to capture and convey runoff through a biofiltration bed underlain by an underdrain system.

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

Where:

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:

• Partial Infiltration

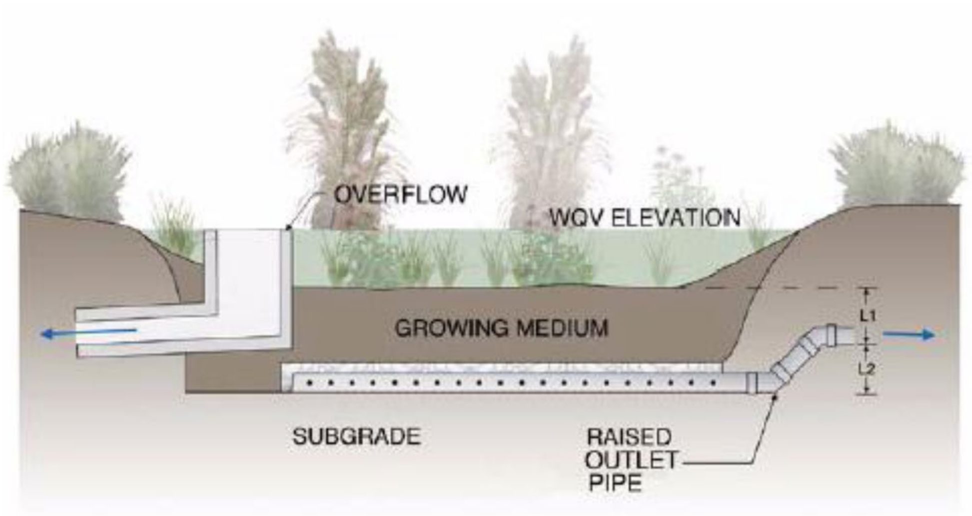


Figure 1.6.7.H-5. Partial infiltration rain gardens are designed so that treated runoff exits the biofiltration bed by discharge through a raised outlet pipe and by infiltration into the underlying soil.

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

Where:

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, If, 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,

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

Where:

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:

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

Where:

5. Growing Medium.

The rain garden growing medium should 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 should be native soil. In the event the designer is not certain about the native soil's ability to support vegetation, a 6 inch layer of topsoil may be added to the soil. This additional depth of soil must be accounted for in the depth and volume required for the pond. For full filtration and partial infiltration rain gardens, only the biofiltration medium may be used. See Standard Specification 660S Biofiltration.

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 Standard Detail 661-3).

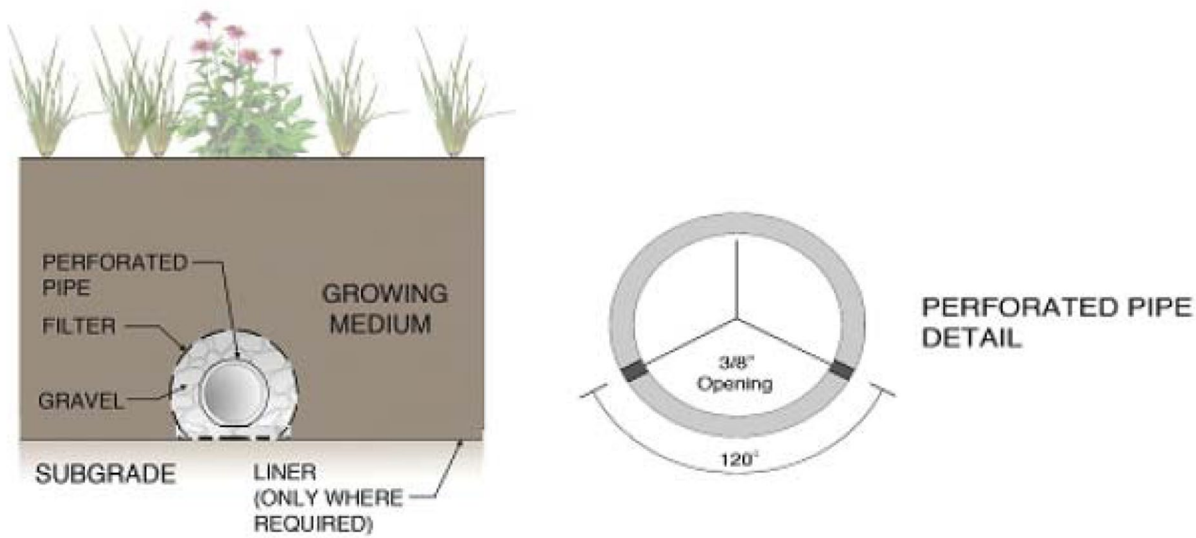


Figure 1.6.7.H-6. Underdrain design for partial infiltration and full filtration rain gardens.

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.

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.

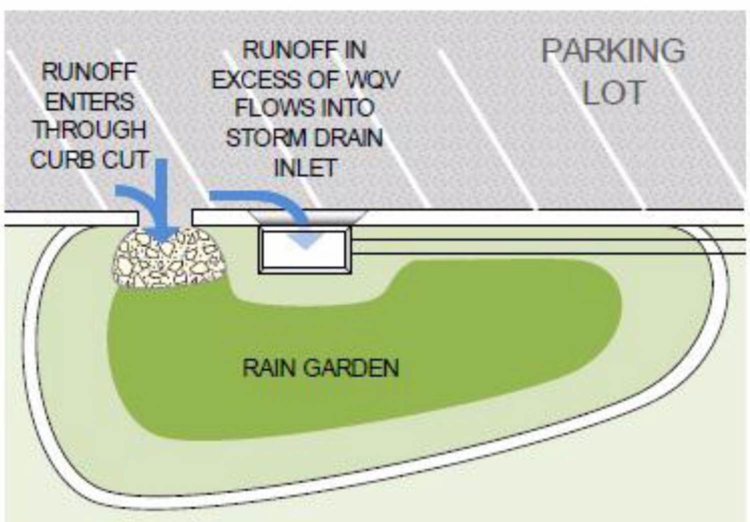


Figure 1.6.7.H-7. Example of the preferred offline system configuration for flow control.

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 ft²*

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:

$WQC = IAF \times BMPDF = ⅓ \times 0.75 = 0.25$

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,

$A^f \geq WQV/(H + 0.24 * L_1 + 0.24 * I_f)$

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:

$A_f = 7{,}351\ ft^3/(1\ ft + 0.24 * 1.2\ ft + 0.24 * 2\ ft) = 4{,}158\ ft^2.$

Source: Rule No. R161-14.26, 12-30-2014 ; Rule No. R161-15.12, 1-4-2016 .

1.5.3 Development Allowed in the Critical Water Quality Zone

In all watersheds, development is prohibited in the Critical Water Quality Zone except as provided by Sections 25-8-261 (Critical Water Quality Zone Development) and 25-8-262 (Critical Water Quality Zone Street Crossings) of the Land Development Code. The uses allowed in the Critical Water Quality Zone are described in more detail below. Any development allowed within the Critical Water Quality Zone shall be revegetated and restored within the limits of construction in accordance with the vegetative stabilization requirements of 1.4.0 (Erosion and Sedimentation Control Criteria) and Standard Specification 609S (Native Grassland Seeding and Planting for Erosion Control).

A. **Fencing**

Fences are permitted as long as flood flows are not obstructed in accordance with Chapter 25-7 of the Land Development Code and the Drainage Criteria Manual.

B. **Open Space**

- **General.** Open space is permitted in a Critical Water Quality Zone if an Integrated Pest Management Plan is approved by the Watershed Protection Department. The design of the open space should not significantly alter the existing natural vegetation, drainage patterns, or increase erosion. For open space uses other than multi-use trails, significant alteration of existing natural vegetation and/or drainage patterns includes:

  - clearing of dense, diverse, riparian woody vegetation for an area greater than fifteen feet wide or a smaller area if the proposed clearing is not commensurate with the use and anticipated maintenance needs (Note: Measurement of woody vegetation cover does not include critical root zones);

  - removal of native, non-invasive trees greater than eight inches in diameter;

  - grading or earthwork that exceeds two feet of cut and fill;

  - the installation of impervious cover with a connected footprint of greater than 250 square feet, if located more than 25 feet from the centerline of an urban waterway, 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, or 150 feet from the centerline of a major waterway;

  - the installation of impervious cover with a connected footprint of greater than 100 square feet, if located less than 25 feet from the centerline of an urban waterway, 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, or 150 feet from the centerline of a major waterway; or

  - the installation of impervious cover such that the cumulative total within the Critical Water Quality Zone for the site is greater than 500 square feet or 5 percent of the total gross area of the Critical Water Quality Zone, whichever is smaller.

A project proposing to exceed these guidelines due to unique site conditions may be evaluated and approved by the Planning and Development Review Department.

In addition, the project shall ensure that runoff is dispersed back to overland sheet flow and maximum projected flows and velocities are below erosive values for the particular soil conditions.

Open space includes the following uses:

- *Public or Private Park.* Park facilities include uses like picnic facilities, benches, community gardens, and other recreational amenities and appurtenances. However, parking lots are not an allowed use within the Critical Water Quality Zone. Requirements and guidance for sustainable urban agriculture and community gardens are discussed further below.
- *Multi-Use Trail.* A multi-use trail means a facility designed for the use of pedestrians, bicycles, and/or other non-motorized users, including associated bridges. A multi-use trail can be either hard-surfaced (e.g. concrete) or have a more natural surface. Requirements and guidance for trails are discussed further below.
- *Golf Cart Path.* The requirements for a golf cart path within the Critical Water Quality Zone shall be identical to those for a hard-surfaced trail, with the exception of allowing a motorized use.
- *Portion of a Golf Course Left in a Natural State.* Portions of the golf courses, including disc golf, that are actively managed or significantly disturbed by use (i.e., mowed, irrigated, compacted, and/or fertilized) cannot be located within the Critical Water Quality Zone. An "Out of Bounds" area would be an example of a portion left in a natural state.
- *Area Intended for Outdoor Activities.* An area or facility intended for outdoor recreational activities such as a multi-purpose playfield. Outdoor facilities may include athletic fields, stables, or corrals for animals; however, these uses are prohibited within the Drinking Water Protection Zone. Requirements and guidance for athletic fields are discussed further below.

In a water supply rural watershed, a water supply suburban watershed, or the Barton Springs Zone, open space is limited to sustainable urban agriculture, community gardens, multi-use trails, picnic facilities, and outdoor facilities, excluding stables, corrals for animals, and athletic fields. A master planned park that is approved by Council may include recreational development other than the uses described under open space.

- **Trails**

  Requirements

  In all watersheds, multi-use trails—including hard-surfaced trails—may cross a Critical Water Quality Zone of any waterway. A trail with an earthen surface or soft surface (e.g. mulch, decomposed granite) is allowed anywhere within the Critical Water Quality Zone, provided that the trail follows the basic guidance for placement and design provided below. A trail with an earthen or soft surface should not exceed 6 feet in width if located closer to the waterway than the requirements for hard-surfaced trails. Otherwise, the maximum width shall be 12 feet, unless a wider trail is designated in the Urban Trails Master Plan. A hard surface (e.g. concrete) of less than or equal to 100 square feet may be installed for a limited length of what is otherwise an earthen surface or soft surface trail to avoid drainage or erosion problems.

  A hard-surfaced trail includes a trail constructed using concrete or asphalt. A hard-surfaced trail is allowed within the Critical Water Quality Zone if:

  1. Located outside of the erosion hazard zone, unless protective works are provided in accordance with the Drainage Criteria Manual;
  2. A maximum of 12 feet wide, unless a wider trail is designated in the Urban Trails Master Plan;
  3. In an urban watershed, located not less than 25 feet from the centerline of a waterway;

4. In a watershed other than urban, located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, or 150 feet from the centerline of a major waterway;
5. Located not less than 50 feet from the shoreline of Lake Travis, Lake Austin, Lady Bird Lake, and Lake Water E. Long; and
6. Located not less than 100 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam.

In addition to these conditions, hard-surfaced trails should also follow the basic guidance for placement and design provided below.

Placement and Design

Avoid Sensitive Environmental Areas. A natural surface trail for hiking may be located within 50 feet of a critical environmental feature (CEF). Otherwise, multi-use trails are prohibited within CEF setbacks. The trail should avoid other environmentally sensitive areas where possible or take sufficient steps to minimize impacts on these systems. Other environmentally sensitive areas include priority or other significant woodlands and prairies as identified by the Environmental Resource Inventory. The trail should not be located along the sideslope of an embankment or in other areas with high erosion potential. If the applicant is proposing a hard-surfaced trail within 100 feet of the centerline of the waterway, within 100 feet of the ordinary high water mark of the Colorado River downstream from Longhorn Dam, or in a location where significant erosion is present, they will need to perform an erosion hazard zone analysis.

Utilize Areas that are Already Disturbed. Where feasible, locate trails in areas that have already been influenced by human activity, such as abandoned roads, utility easements, and existing paths. However, the trail must be located such that it does not threaten existing infrastructure, including, but not limited to, structural stormwater controls, engineered channels, storm drains, culverts, and dams, as determined by the department responsible for maintenance of the impacted infrastructure.

Promote Sustainable Trail Design. One of the most critical components of trail design is how the trail affects water flow and how the trail is affected by water. Trails that limit natural drainage patterns will often result in erosion, surface ponding, and high frequency of flows on the trail which limits access and can significantly degrade the trail over time. The trail should promote the sheet flow of stormwater runoff and maintain natural drainage paths whenever possible through design considerations like trail location, grade, and cross slope. Trails using decomposed granite should limit the running slope and cross slope to reduce sloughing and gullying. A running slope of less than 3 percent and a cross slope of less than 2 percent are recommended.

For further guidance on sustainable trail design, see the following references:

U.S. Forest Service, Trail Construction and Maintenance Notebook
http://www.fhwa.dot.gov/environment/recreational_trails/publications/fs_publications/07232806/

Federal Highways Administration, Recreational Trails Program, Guidance
http://www.fhwa.dot.gov/environment/recreational_trails/guidance/manuals.cfm

American Trails, Resources and Library
http://www.americantrails.org/resources/trailbuilding/index.html

Administrative Variance

An administrative variance is available under Section 25-8-42 to allow a hard-surfaced trail to be placed closer to the waterway than designated in Section 25-8-261(B)(3). To qualify for this variance, the applicant will need to demonstrate that placement of the trail in the outer half of the Critical Water Quality Zone is infeasible due to unique site conditions including but not limited to.

- Location of existing development or infrastructure within the outer half of the Critical Water Quality Zone.
- Not owning land within the outer half of the Critical Water Quality Zone.
- Location of environmentally sensitive features (e.g., critical environmental features, steep slopes) within the outer half of the Critical Water Quality Zone.
- A hard surface (e.g. concrete) of greater than 100 square feet is necessary for a limited length of what is otherwise an earthen or soft surface trail within the inner half of the Critical Water Quality Zone to avoid drainage or erosion problems.

The proposed trail alignment under the variance should be a minimal departure from the requirements. The trail should only cross into the inner half of the Critical Water Quality Zone where necessary to avoid existing features and to minimize the overall disturbance.

- **Sustainable Urban Agriculture**

Sustainable urban agriculture promotes environmentally-sensitive management practices, such as water conservation and integrated pest management methods. Sustainable urban agriculture can include either a community garden, market garden, or urban farm, as defined by Section 25-2-7 (Agricultural Uses Described) of the Land Development Code. A community garden use involves the growing or harvesting of food crops or ornamental crops on an agricultural basis by a group of individuals for personal or group use, consumption, or donation. A market garden is less than one acre in size and cultivated primarily for the sustainable production of agricultural products to be sold for profit. An urban farm is at least one acre in size and cultivated primarily for the sustainable production of agricultural products to be sold for profit.

Sustainable urban agriculture is allowed in the Critical Water Quality Zone if:

1. In an urban watershed, the area is located not less than 25 feet from the centerline of a waterway.
2. In a watershed other than urban, the area is located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, or 150 feet from the centerline of a major waterway.
3. The area is located not less than 50 feet from the shoreline of Lake Travis, Lake Austin, Lady Bird Lake, and Lake Water E. Long.
4. The area is located not less than 100 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam.
5. The area is limited to garden plots and paths, with no storage facilities or other structures over 500 square feet. Raised beds and garden plots shall not be considered structures. The square footage of all storage facilities and other structures (e.g., toolsheds) shall be totaled for the area and shall not exceed 500 square feet on a cumulative basis. A single storage

facility or structure should comply with the general open space requirements above for connected impervious cover (100 or 250 square feet depending on distance from the waterway).

The raising of fowl or livestock is prohibited. All compost and stored materials areas must be contained to prevent runoff and sedimentation. Manure is not allowed to be stored in the Critical Water Quality Zone. Fuel storage is prohibited on site. The use of synthetic inputs (i.e. synthetic fertilizers, herbicides, and pesticides) is prohibited. An Integrated Pest Management Plan must be approved by the Watershed Protection Department. Water conservation practices must be followed, at minimum in accordance with Chapter 6-4 (Water Conservation) of the City Code.

- **Athletic Fields**

Athletic fields within the Critical Water Quality Zone shall be limited to vegetated sports fields, such as soccer, football, and baseball fields. Impervious sport courts, such as tennis or basketball courts are not allowed. Minor necessary appurtenances like bleachers are allowed as long as the connected impervious footprint does not exceed 100 square feet.

Athletic fields are allowed in the Critical Water Quality Zone if:

1. In an urban watershed, the area is located not less than 25 feet from the centerline of a waterway.
2. In a suburban watershed, the area is located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, or 150 feet from the centerline of a major waterway.
3. The area is located not less than 50 feet from the shoreline of Lady Bird Lake and Lake Water E. Long.
4. The area is located not less than 100 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam.
5. The owner of the athletic field submits a maintenance plan to keep the athletic field well vegetated and minimize compaction. The plan must be approved by the Watershed Protection Department.

The maintenance plan shall include:

- An Integrated Pest Management (IPM) Plan.
- A minimum mowing height for turf.
- A provision for aerating the field and top dressing the field. This should be performed annually or more frequently on an as needed basis.
- A provision for amending the soil twice a year or more frequently on an as needed basis with compost or organic fertilizers to replenish deficient minerals and nutrients.
- A provision for long term soil rehabilitation if regular maintenance is insufficient to loosen compacted soils. Long term soil rehabilitation would include scarifying and amending the soil. After completion of the soil rehabilitation, the athletic field should be sodded with appropriate turf for athletic use.

C. **Boat Docks, Piers, Wharfs, and Marinas**

Boat docks, piers, wharfs, and marinas, as well as necessary access and appurtenances, are permitted along Lake Travis, Lake Austin, and Lake Travis. These uses are not permitted along the Colorado River downstream of Longhorn Dam. Approval by the Watershed Protection Department of chemicals used to treat the building materials that will be submerged in water is required before a permit may be issued or a site plan released.

D. **Utility Crossings**

Utility lines, including storm drains, may extend into or through the Critical Water Quality Zone if the applicant demonstrates the crossing is necessary and that a feasible alternative to the crossing does not exist. This includes a partial crossing of the Critical Water Quality Zone that may be necessary to connect to existing infrastructure or discharge stormwater from a site. A crossing may also include a minor connection between existing infrastructure entirely within the Critical Water Quality Zone if the total length of the connection is less than the total width of the Critical Water Quality Zone.

In addition, the utility line must demonstrate compliance with the following:

- The line must follow the most direct path into or across the Critical Water Quality Zone to minimize disturbance unless boring or tunneling is the proposed method of installation for the entire crossing and all bore pits are located outside of the Critical Water Quality Zone;
- The depth of the line and associated access shafts may not be located within the surface or subsurface erosion hazard zone, as defined by Appendix F of the Drainage Criteria Manual, unless protective works are provided; and
- In the Barton Springs Zone, the crossing must be approved by the director of the Watershed Protection Department.

E. **Parallel Utilities**

In addition to necessary crossings, utility lines may be located parallel to and within the Critical Water Quality Zone in urban and suburban watersheds if:

1. In an urban watershed, the area is located not less than 50 feet from the centerline of a waterway.
2. In a suburban watershed, the area is located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, or 150 feet from the centerline of a major waterway.
3. The area is located not less than 50 feet from the shoreline of Lady Bird Lake and Lake Water E. Long.
4. The area is located not less than 100 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam.
5. The utility line is located outside of the erosion hazard zone, unless protective works are provided.
6. In addition to restoring within the limits of construction in accordance with the vegetative stabilization requirements of 1.4.0 (Erosion and Sedimentation Control Criteria), the project restores an area within the Critical Water Quality Zone equal in size to the area of disturbance. In other words, for every square foot disturbed, the applicant shall restore an additional square foot within the Critical Water Quality Zone outside of the area of disturbance.

The alignment may not cross setbacks for critical environmental features (CEFs) and should avoid other environmentally sensitive areas or take sufficient steps to minimize impacts on these systems. Other environmentally sensitive areas include priority or other significant woodlands and prairies as identified by the Environmental Resource Inventory. The proposed alignment should not disturb significant amounts of vegetation.

The applicant will need to perform a Zone 2 functional assessment of the Critical Water Quality Zone to determine which restoration techniques (if any) should be applied. See Section 1.7.4 and Appendix X (Functional Assessment of Floodplain Health) of this manual for further guidance. If the condition of the Critical Water Quality Zone is determined to be poor or fair, the applicant shall prepare and submit a Riparian Restoration Plan to be reviewed and approved by the Watershed Protection Department. See Section 1.7.5 (Restoration) of this manual for further guidance on the components of the Riparian Restoration Plan. If a Zone 2 functional assessment shows the Critical Water Quality Zone is already in good condition or better or the site does not have enough area within the adjacent Critical Water Quality Zone to meet the restoration requirements, then the applicant shall pay into the Riparian Zone Mitigation Fund a non-refundable amount established by ordinance (see Appendix Q-7 of this manual).

F. **Detention Basins and Wet Ponds**

In-channel detention basins and in-channel wet ponds can be located within the Critical Water Quality Zone if the requirements of Sections 25-8-364 (Floodplain Modification), 25-7 (Drainage), and other provisions 25-8 Subchapter A are met. For guidance on how to demonstrate compliance with these requirements, see Section 1.7.3.C (Development Allowed within the Critical Water Quality Zone) of the Floodplain Modification Criteria in this manual.

G. **Floodplain Modification**

Floodplain modifications are prohibited in the Critical Water Quality Zone unless:

1. the floodplain modifications proposed are necessary to address an existing threat to public health and safety, as determined by the director of the Watershed Protection Department;
2. the floodplain modifications proposed would provide a significant, demonstrable environmental benefit, as determined by a functional assessment of floodplain health; or
3. the floodplain modifications proposed are necessary for development allowed in the Critical Water Quality Zone under Section 25-8-261 (Critical Water Quality Zone Development) or Section 25-8-262 (Critical Water Quality Zone Street Crossings).

For additional guidance on floodplain modification within the Critical Water Quality Zone, see Section 1.7.0 (Floodplain Modification Criteria) of this manual.

H. **Green Water Quality Controls**

In urban and suburban watersheds, vegetative filter strips, rain gardens, biofiltration ponds, and areas used for irrigation or infiltration of stormwater are allowed within the Critical Water Quality Zone if:

1. In an urban watershed, located not less than 50 feet from the centerline of a waterway;
2. In a suburban watershed, located not less than 50 feet from the centerline of a minor waterway, 100 feet from the centerline of an intermediate waterway, or 150 feet from the centerline of a major waterway;
3. Located not less than 50 feet from the shoreline of Lady Bird Lake and Lake Water E. Long;

4. Located not less than 100 feet from the ordinary high water mark of the Colorado River downstream from Longhorn Dam;
5. Located outside the 100-year floodplain; and
6. Located outside the erosion hazard zone, unless protective works are provided as prescribed in the Drainage Criteria Manual.

Green water quality ponds within the Critical Water Quality Zone shall be constructed using earthen side slopes rather than concrete retaining walls. Mortared limestone block may be utilized to construct walls up to 12 inches in height. In addition, the project engineer should consider the following guidance when siting and designing green water quality ponds within the Critical Water Quality Zone:

- Locate the ponds as far from the waterway as feasible to minimize encroachment into the buffer.
- Place the outfall as far from the waterway as feasible to maximize the distance of overland flow.
- Evaluate opportunities for using smaller-scale distributed controls to minimize the depth of excavation within the buffer.

I. **Residential Lots**

A new residential lot that is 5,750 square feet or less in size may not include any portion of the Critical Water Quality Zone.

J. **Street Crossings**

In all watersheds, multi-use trails may cross a Critical Water Quality Zone of any waterway. In an urban watershed, an arterial, collector, or residential street may cross a Critical Water Quality Zone of any waterway. In a watershed other than urban, the following restrictions apply to street crossings:

- a major waterway may be crossed by an arterial street identified in the Transportation Plan.
- an intermediate waterway may be crossed by an arterial or collector street, except:
  - a collector street crossing must be at least 2,500 feet from a collector or arterial street crossing on the same waterway; or
  - in a water supply suburban or water supply rural watershed, or the Barton Springs Zone, a collector street crossing must be at least one mile from a collector or arterial street crossing on the same waterway.
- a minor waterway may be crossed by an arterial and collector streets, except:
  - a collector street crossing must be at least 900 feet from a collector or arterial street crossing on the same waterway; or
  - in a water supply suburban or water supply rural watershed, or the Barton Springs Zone, a collector street crossing must be at least 2,000 feet from a collector or arterial street crossing on the same waterway.
- a minor waterway may be crossed by a residential or commercial street if necessary to provide access to property that cannot otherwise be safely accessed.

Notwithstanding the restrictions above, a street or driveway may cross the Critical Water Quality Zone if the street or driveway is located in a designated center or corridor on the Imagine Austin growth concept map and if the proposed crossing is:

- located outside of the Barton Springs Zone;
- necessary to facilitate development or redevelopment of a designated center or corridor as recommended in the Imagine Austin Comprehensive Plan; and
- maintains the quality and quantity of recharge if located in a center or corridor designated as a sensitive environmental area in the Edwards Aquifer recharge zone or contributing zone, as determined by the director of the Watershed Protection Department.

Designated Imagine Austin centers or corridors must have an adopted boundary to qualify for this provision.

Source: Rule No. R161-14.22, 9-2-2014 ; Rule No. R161-18.05 , 6-12-2018.

1.10.0 CRITICAL ENVIRONMENTAL FEATURE IDENTIFICATION AND PROTECTION

1.10.1 Statement of Intent

The intent of these guidelines is to assist applicants in complying with the Land Development Code (LDC) Sections 25-8-121, 25-8-151, 25-8-281, 25-8-282, 30-5-151, 30-5-281 and 30-5-282. The guidelines specify and outline the decision-making process for the identification, evaluation and determination of protective buffers for critical environmental features (CEFs) for the Environmental Resource Inventory (ERI) Report.

Source: Rule No. R161-14.25, 12-30-2014 .

1.10.2 Background

A. In adopting the Land Development Code, the Austin City Council found that:

1. Protection of critical environmental features such as caves, sinkholes, springs, canyon rimrocks and bluffs is necessary to protect water quality in those areas most susceptible to pollution;

2. Minimum standards should be adopted and applied as general principles for the conservation and development of land. The purpose of the standards are:

(a) To prevent loss of recharge to localized aquifers supplying local seeps and springs essential to the maintenance of the ecosystem and the baseflow and water quality of many of Austin's creeks; and

(b) To maintain or enhance the water quality of the Edwards Aquifer by protection the water quality of surface water recharging the Edwards Aquifer.

B. Thus, the underlying principles and objectives of the watershed regulations with respect to critical environmental features are the:

1. Protection of the natural character and function of CEFs;

2. Protection of groundwater quality and quantity through protecting and maintaining recharge; and,

3. Protection of surface water quality and quantity through maintaining the quality and quantity of surface water runoff and overland flow.

Source: Rule No. R161-14.25, 12-30-2014 .

1.10.3 Critical Environmental Feature Identification

The intent of the following section is to assist applicant in the identification of critical environmental features (CEFs) by providing general criteria and specific indicators for the field identification of CEFs not included in the general definition stated in LDC 25-8-1, 30-5-1 and ECM 1.10.3 defined in LDC 25-8-1 and 30-5-1.

A. **Bluffs** are an abrupt vertical change in topography of more than 40 feet with an average slope steeper than four feet of rise for one foot of horizontal travel (400% or 76 degrees). Bluffs are any steep slopes in soil, rock, or alluvial deposits that meet the dimensions and slope requirements stated above and are not manmade cuts such as roadside rock outcrops and active rock quarry walls. Generally, bluffs are associated with riparian areas.

B. **Canyon Rimrocks** are an abrupt vertical rock outcrop of more than 60% slope (31 degrees), greater than 4 feet vertically, and a horizontal extent equal or greater than 50 feet. All outcrops that meet the dimensions and slope requirements stated above are critical environmental features. Rock outcrop means naturally occurring aggregate of one or more minerals that are visible at the Earth's surface such as Quaternary-age alluvial deposits, basalt, limestone, shale, or claystone layers. Rock outcrop does not mean soil. Rimrocks are continues rock layers or beds that are traceable along the slope for 50 feet. A person measuring the length of canyon rimrock should not interpret any faulting and fracturing of the rock outcrop and/or mass wasting covering a portion of the outcrop is not a break in the overall length of the feature. Canyon rimrock do not include man-made cuts such as roadside rock outcrops and rock quarry walls. Generally, rimrocks are associated with riparian areas and tributary canyons.

C. **Point Recharge Features** consist of several types of natural openings and topographic depressions formed by the dissolution of limestone that lies over the Edwards Aquifer recharge zone and may transmit a significant amount of surface water into the subsurface. Point recharge feature means a cave, sinkhole, a fault, joint or other natural features.

1. Caves are natural underground voids formed by the dissolution of limestone and are large enough for a person to enter. Applicants must determine the subsurface extent of all caves identified on their property. If a cave map is not available, the applicant should then conservatively estimate the cave footprint to be within 300 feet of the cave's entrance or have the cave passage surveyed. Geologist may use at least two rock cores along with geophysical surveys methods to determine the cave's dimensions. Rock cores should be located with the intent to correlate anomalies and to verify the finding of the geophysical survey. The cores should extend least five feet beyond the depth of the geophysical surveys results.

2. Fractures also referred to as a parting or a joint; are a measureable, larger than hairline, separation in a rock. Only those fractures that are solution enlarged (or fissures) and show evidence of direct or indirect of potential infiltration are CEFs.

3. Faults are fractures along which there has been displacement of the rocks on one side of the fracture relative to the other side. Not all faults and fractures are CEFs. A CEF determination for all faults must demonstrate that there has been solution-enlargement of the fault, the solution-enlargement should extend into subsurface and show direct or indirect evidence of potential infiltration.

4. Joints are fractures (see fracture above).

5. Other natural features are all natural cavities formed by the dissolution of limestone that are too small for a person to enter or are smaller than 18 cubic feet that are not epikarst features or a clustering of epikarst features. Epikarst is the zone of weathering at the upper surface of a limestone that includes the solutionally modified (karren) bedrock surface and the overlying and include the regolith. Other natural recharge features include solution cavities and swallow holes or swallets. Swallet is used in a general sense to indicate the place where losing (or sinking) streams infiltrate into the subsurface. Swallets can vary in shape and size. The transportation and deposition of organic debris, soil, sediment, and gravel by the stream or creek during periods when it is flowing may obscure swallets. Stream gauging is the best method for detecting a swallet hole.

6. Sinkholes are topographic depressions formed by karst dissolution of limestone that have bowl volume of at least 18 cubic feet. Sinkhole formation implies that karst processes including collapse, soil sapping, and subsidence has caused the land surface to sink relative to the surrounding area. The amount of subsidence can be subtle, as little as 6-inches in cross-section; the subsidence may have a funnel-shaped pit, a vertical shaft, or a bowl shape. Exposed rock may be present at the perimeter of the sinkhole. Land clearing activities may have obscured many sinkholes by filling and covering them with soil fill material, trash, brush, and rock. To be defined as a CEF, a sinkhole must exhibit either direct and/or indirect evidence of potential infiltration. Sinkholes may also contain a cave.

Karst features that may not be CEFs include closed and karst depressions, karren, and epikarst features. They are immature karst features that are associated with surficial weathering of limestone or the weathered zone at the soil/bedrock interface… A brief description of these immature karst features is below:

1) Closed depressions that have a bowl volume of less than 18 cubic feet. These features should be hand-excavated to confirm that they do not have a karst origin or direct or indirect evidence of potential infiltration.

2) Karst depressions are closed depressions that have a bowl volume of less than 18 cubic feet. These features should be hand-excavated to confirm that they lack evidence of potential infiltration.

3) Karren is minor surficial dissolution or weathering of limestone. They are not CEFs but may be associated with CEFs.

4) Epikarst is the upper weathered rock zone where limestone dissolution occurs at the surface or beneath the soil. The extent of the dissolution will diminish with depth. They are not CEFs but may be associated with CEFs.

Over the Edwards Aquifer Recharge Zone, an engineer qualified to practice geology (ECM 1.12.2) and/or a geologist (ECM 1.12.2) familiar with local hydrogeological characteristics and ordinance objectives should determine the occurrence of karst features by completing a karst survey. The survey method should consist of walking transects 50 feet apart across the project site completed by a Texas Licensed Geoscientist in the discipline of geology with experience in Central Texas.

Direct evidence of recharge includes flow observations, decreased flow downgradient of a point recharge feature, the presence of flow indicators, brief duration of ponding, a positive infiltration or percolation test and the detection of air movement. The observation of surface flow infiltrating into the feature is direct evidence of rapid infiltration. For point recharge features located in drainages with flowing water, verifying infiltration is determined by a direct measurement of a decrease of surface flow downgradient of a point recharge feature. Indicators of potential infiltration include the presence of erosion and depositional patterns such as debris lines, high water markers, leaf litter lines, and drainage patterns. Flow indicators should be evaluated even if the recharge feature has an accumulation of soil, sticks, and leaves. A person may prefer to conduct an on-site infiltration or percolation test at a potential recharge feature to demonstrate the presence or absence of recharge. An infiltration result of greater than 1×10^{-6} cm/sec is a positive infiltration result. In addition, the brief duration of ponding water in a closed depression is an indicator of rapid infiltration. Short duration of ponding indicates that infiltration is likely related to a subsurface conduit that is partially plugged. Air movement into or out of a karst opening is an indication of significant interconnected subsurface conduits and passageways. Air movement may not always be noticeable, depending upon atmospheric conditions.

Indirect evidence of recharge includes the presence and characteristics of subsurface voids as determined by geotechnical or geophysical investigations or speleological surveys, the sapping of fines through epikarst, or an interpreted karst origin suggesting the capacity of rapid infiltration.

Potential karst features filled with rock, soil, trash, or leaves must be excavated, and their relative infiltration rate assessed. Recharge features may be partially plugged from the natural or anthropogenic deposition of sediment. Historically, recharge features may have been filled with trash or rocks or other fill, which may obscure a recharge feature. The probing and excavation through materials to expose the opening or underlying bedrock is preferred. Soil filling of a point recharge feature does not rule out potential infiltration. In some cases, heavy equipment may be needed to excavate and adequately assess the feature. This level of investigation requires written approval from TCEQ, if in their jurisdiction under the Edwards Aquifer Protection Program, and/or from the City of Austin Watershed Protection Department. Please refer to TCEQ's Instructions to Geologists (TNRCC—0585) for details. Notification for hand excavation is not required; however, protocol must follow U.S. Fish and Wildlife Services Requirements for Conducting Presence/Absence Surveys for Endangered Karst Invertebrates in Central Texas (September 8, 2011). Excavations should extend into the subsurface until bedrock or a karst conduit is encountered. The geologist must document the excavation of all potential recharge features by taking photographs, descriptions and measurements before, during and after excavation of a feature and include this information in the ERI report.

D. **Springs and Seeps** are points or zones of natural groundwater discharge that produce measurable flow , or a pool of water, or maintain a hydrophytic plant community (refer to Facultative-wet or Obligate plant species as listed in the National List of Plant Species That Occur in Wetlands, South Plains, Region 6, U.S. Department of the Interior, Washington D.C.), or other physical indicators; especially during drought conditions. Physical indicators of a spring or a seep include the existence of a pool of water, even if small, the presence of hydrophytic plants, the mineralization of calcium carbonate such as travertine and/or tufa, and/or the detection of a water temperature gradient in the creek or pool. Geologic indicators include lithologic contacts and structural features such as a fracture, a conduit, a fault zone, and a bedding plane.

1. Some common hydrophytic plants associated with springs and seeps may include:

Liverworts and mosses	*Marchantiohyta and Bryophyta*
Maidenhair fern	*Adiantum capillus-veneris*
Wood fern	*Thelypteris kunthii*
Wooly dicanthelium	*Dichanthelium scabriusculum*
Spicebush	*Lindera benzoin*
Muhly grass	*Muhlenbergia sp.*
Water-pimpernel	*Samolus valerandi ssp parviflorus*
Bushy bluestem	*Andropogon glomeratus*

2. Common lithologic contacts with springs and seeps in the Austin area are:

Quaternary Alluvial Deposit overlying Limestone or Claystone

Austin Chalk and Eagle Ford Shale Contact

Buda Limestone and Del Rio Clay Contact

Edwards Group and Comanche Peak Formation

Edwards Group and Walnut Formation

Walnut Formation and Glen Rose Formation

Dolomitic Member and Basal Nodular Contact within the Edwards Group

Cedar Park Member and Bee Cave Member within the Walnut Formation

E. **Wetlands** are transitional lands between terrestrial and aquatic systems where the water table is usually at or near the surface and may have shallow water present. An area shall be classified as a wetland if it meets the Army Corps of Engineers three parameter technical criteria as outlined in the Corps of Engineers 1987 Wetlands Delineation Manual (Section D. Routine Determinations):

The identification of wetlands should be completed by someone familiar with the Army Corps of Engineers three-parameter technical criteria as outlined in the Corps of Engineers 1987 Wetlands Delineation Manual (Section D. Routine Determinations). The three parameters for wetland determination include prevalence of hydrophytic vegetation, hydric soil formation, and the presence of adequate hydrology. The recommended routine method assumes adequate hydrology and hydric soils if if the area under examination is dominated (over 50% vegetative cover) by Facultative-wet and/or Obligate plant species (as listed in the National List of Plant Species That Occur in Wetlands, South Plains, Region 6, U.S. Department of the Interior, Washington D.C.) and an abrupt boundary is evident between these Facultative-wet and/or Obligate plant community and the Upland plant communities. If the area is dominated by Facultative plant species, the hydric soil and hydrology parameters cannot be assumed and must be examined to determine if an area is a wetland.

Permitted water quality wet ponds, roadside ditches, and ponds fed by wells or other artificial sources of hydrology are not considered wetlands.

Atypical situations are unauthorized activities such as the alteration or removal of wetland vegetation, placement of dredge or fill material over hydric soils, construction of levees, drainage systems, or dams that significantly alter the wetland hydrology are considered as atypical situations. Wetland areas under these circumstances should be delineated in accordance to Section F of the Corps of Engineers 1987 Wetlands Delineation Manual.

Source: Rule No. R161-14.25, 12-30-2014 .

1.10.4 Determining Size of Critical Environmental Feature Protective Buffers

The establishment of CEF protective buffers is required by Code and as part of the Environmental Resource Inventory (ERI) report. The standard buffer distance for all CEFs is 150 feet with 300 feet maximum for point recharge features. Buffers are also three-dimensional, extending across the land as well as above and below the land surface. The intent of this section is to explain the reasons for buffering CEFs and to provide guidance for determining CEF buffers.

The Watershed Protection Department may administratively reduce the standard buffer or approve wetland mitigation. Wetland mitigation occurs at least at a 1:1 ratio for wetland CEFs and their associated 150 feet buffer. In general, the standard CEF buffers are not administratively reduced below 50 feet for point recharge features and springs. The director may grant a variance to the standard buffers described in Subsection (B) only after determining that the development proposed with the variance meets the objective of the requirement for which the variance is requested. In regards to critical environmental features, the minimum standard for the conservation of and the development around a CEF is:

1. For a property within the Barton Springs Zone, the granting of the variance will result in water quality that is at least equal to the water quality achievable without the variance.
2. All characteristics of the CEF will be preserved and additional protective measures are provided to maintain or enhance the feature. The CEF existing characteristics include the surrounding vegetation, ecological habitat, natural hydrology, and the water quality and quantity benefits associated to the feature.
3. The variance, if granted, must be a minimum departure from the Code. In regards to CEF buffers, minimum departure means by providing the maximum buffer distance feasible. Feasibility is not based on marketing or economic considerations or unique conditions derived because of the method by which a person voluntarily subdivides or develops land, except as provided under the "Hardship Provisions" of Section 25-8-25 of the LDC.

If the Watershed Protection Department denies an applicant's request for a buffer reduction per LDC 25-8-42, then the applicant may request a Land Use Commission variance in accordance with LDC 25-8-41.

A. **Bluffs & Canyon Rimrocks** - Construction of impervious cover and land use activities in the upslope area adjacent to canyon rimrocks and bluffs often results in an increase in the velocity and the frequency of surface water runoff flowing over canyon rimrocks and bluffs. The resulting erosion associated with the increased runoff causes sediment-laden runoff to enter down-gradient watercourses and causes slope instability, particularly in those rimrocks and bluffs with underlying clay soils or shales. The entrained sediment in runoff water often has water quality contaminants attached that can accumulate in the watercourses downstream.

   If a steep rock outcrop area meets the requirements for a bluff or canyon rimrock as stated in ECM 1.10.3(A), then the standard buffer required is 150 feet. An applicant may request and reduce this buffer distance to less than 150 feet if:

   1. The upgraded slopes do not exceed 15% and the average slope does not exceed 10%.
   2. There is no evidence of erosion and/or preferential flow paths within 50-ft. of the crest of the bluff or canyon rimrock.
   3. The rimrock is stable and there is no evidence of instability such as rock mass-wasting of the slope or undercutting.

   Recommended protective measures for granting a reduction of the buffer for a rimrock or bluff CEF include:

   1. Provide or enhance up-gradient vegetation within 50 feet of rimrock to at least 95% vegetative cover, with unvegetated areas not exceeding 10 square feet.
   2. Provide structural controls to spread the water over the land up-gradient of the rimrock to achieve sheet flow through the buffer area.
   3. Provide additional CEF buffer area equal to or greater than the standard buffer area along the drainage on site.

B. **Point recharge features** are conduits for karst aquifer recharge. Epikarst features are not CEFs, however they provide the subsurface drainage network of fractures, conduits, and voids that store and transport water to the recharge feature. Knowledge of the full underground extent of any subsurface voids associated with a point recharge feature and its associated catchment area will aid in determining the appropriate buffer size.

Construction around point recharge features can alter surface, epikarst and subsurface drainage patterns or sever karst conduits that may carry water to the aquifer or nearby springs and seeps and wetlands. The increase in impervious cover and land use activities within the catchment area for a point recharge feature can diminish the water quality of water infiltrating into an aquifer by increasing contaminant load. The establishment of a protective buffer is a standard approach to reduce the effects of urbanization on surface and subsurface water inflows into the aquifer. The purpose of the buffer is to protect water quality and quantity through the protection of the native vegetation; the surface, subsurface and epikarst drainage patterns; and to maintain compatible land-use activities up-gradient and overlying the point recharge feature.

1. **Standard Buffers** - The standard buffer for point recharge features is dependent on the surface and subsurface characteristics of the feature and surrounding land use and conditions. The buffer should extend to protect the surface drainage area to the feature and the subsurface extent of caves. In some cases where several point recharge features occur in close proximity (i.e., two (2) or more features within a 1.6-acre area or 150 feet), buffer provisions may be applied collectively or buffers may overlap, provided that the minimum standard buffer for each feature is retained. Buffers are also three-dimensional, extending across the land as well as above and below the land surface.

    a. **Surface expression and drainage** - The standard buffer shall be 150 feet measured from the edge of the immediate catchment area of the point recharge feature. If the catchment area of the recharge feature extends beyond 150 feet, the buffer zone may extend up-gradient to a maximum 300 feet measured from the edge of the immediate catchment area of the karst feature.

    b. **Subsurface (cave footprint)** - The standard buffer also shall extend 150 feet, as measured from the surface projection of the cave footprint. For a mapped cave, if the accessible footprint extends less than 100 feet from the cave opening, no additional buffer is required. For caves of an unknown extent and configuration, the assumed extent of the cave is 300 feet in all directions and the required buffer will be 300 feet measured from the edge of the immediate catchment area of the cave.

2. **Administratively Approved Modified Buffers** - An administratively reduced buffer for point recharge features may not be granted to less than 50 feet.

    a. **Surface expression and drainage** - If the topographic break or catchment area draining to a point recharge feature is less than 150 feet from the immediate catchment area, the buffer may be reduced to coincide with the topographic break but not to less than 50 feet. If the catchment area of the recharge feature extends beyond 150 feet but is less than 300 feet, the buffer zone may be reduced to coincide with the topographic break as measured from the edge of the immediate catchment area of the karst feature.

       Reductions in the standard buffer should not occur if any of the following are present within the catchment area or standard setback area:

        1) Where epikarst bedrock is exposed at surface.

2) Where direct evidence of potential infiltration is present (See ECM 1.10.3.C).

3) A fracture zone is present within 150-ft.

4) A fault is present within 150 feet of the recharge feature.

5) A cave footprint is within 50 feet of the surface.

6) There are springs and/or seeps CEFs within 500 feet of the recharge feature.

7) The vegetation cover within the catchment area is less than 95% and bare soil areas larger than 10 feet by 10 feet are present.

8) The upslope area beyond the standard buffer has an impervious cover greater than 40 percent; or

9) The upslope area drains off of roadways, parking lots, commercial, office or retail land uses or residential lots of SF-4 or greater densities; or

10) Hazardous materials regulated by the City of Austin's Hazardous Materials Storage and Registration Ordinance or applicable state or federal statutes are or will be stored or used adjacent to the catchment area; or

11) The upslope area above the feature drains an area that is managed or landscaped in a way (e.g., with herbicides or pesticides) which presents a reasonable doubt that water quality can be protected.

b. **Subsurface (cave footprint)** - The cave footprint must be protected by at least a 50 foot buffer. Since factors potentially impacting water quality and quantity in caves are less understood and more complex than for surface features, reductions in the standard buffer around a cave footprint will be determined on a case-by-case basis. Factors for consideration include:

1) Depth of the cave from the surface.

2) Extent of the cave.

3) Development of the cave along structural features such as faults and fractures.

4) Epikarst bedrock is exposed at the surface over or adjacent to the cave foot print.

5) A fracture zone is present within 150-ft of the cave foot print.

6) A fault is present within 150 feet of the cave foot print.

7) A cave footprint is within 50 feet of the surface.

8) There are springs and/or seeps CEFs within 500 feet of the cave.

9) The vegetation cover within catchment area is less than 95% and bare soil areas larger than 10 feet by 10 feet are present.

10) The upslope area beyond the standard buffer has an impervious cover greater than 40 percent; or

11) The upslope area drains off of roadways, parking lots, commercial, office or retail land uses or residential lots of SF-4 or greater densities; or

12) Hazardous materials regulated by the City of Austin's Hazardous Materials Storage and Registration Ordinance or applicable state or federal statutes are or will be stored or used adjacent to the catchment area; or

13) The upslope area above the feature drains an area that is managed or landscaped in a way (e.g., with herbicides or pesticides) which presents a reasonable doubt that water quality can be protected.

Nothing prevents the voluntary protection of small karst features, which lack evidence of significant recharge. A person should consider in their project design how to negate the possibility of these features becoming pathways for the infiltration of contaminated runoff during and after construction. Restrictions on excavation and grading activities, which could expose subsurface voids or otherwise create additional avenues of recharge within the construction area, may be required.

Note: The diversion of drainage out of or away from the catchment area of a point recharge feature will not constitute evidence of the protection of water quality and will not be considered, alone, a legitimate basis for reducing buffer zones. The provisions of Section 25-8-151 of the LDC (Innovative Management Practices — see Section 1.10.6 below) provide an alternative pathway towards protection of point recharge features. It should be anticipated, however, that plans relying on Section 25-8-151 of the LDC would be reviewed under the highest standards of environmental reliability and engineering performance.

Undesirable Pre-existing Conditions - In such situations in which actions prior to the effective date of the Comprehensive Watershed Ordinance (May 18, 1986) resulted in incompatible land use within the drainage catchment of a point recharge feature, or in degraded runoff being diverted to the feature, mitigation actions should be taken in conjunction with any proposal and are subject to these criteria. The following solutions should be sought as part of any new development proposal, in the following order of preference:

- Re-establish required buffers in accordance with these criteria;
- Employ innovative management practices to improve the quality of runoff entering the recharge feature; and lastly
- Divert untreated runoff from the point recharge feature.

Newly Discovered or Identified Features. If, after development has begun, a karst feature becomes a point recharge feature (e.g., by excavation of a previously undetected large underground void), a person must report the occurrence in writing to the Watershed Protection Department (LDC 25-8-281 (D)). The report shall contain an evaluation of the significance of the point recharge feature and a plan to mitigate any negative impacts, if necessary. (see ECM: Void and Water Flow Mitigation 1.12.0)

C. **Springs and seeps** - The protection of springs and seeps helps to maintain baseflow of Austin Area creeks. Baseflow is essential for maintaining water levels in local reservoirs. Springs or seeps that are located up-gradient of the recharge zone maintain water quantity in local aquifers. Spring/seep buffers protect the spring orifice or zone of seeps from disturbance and help preserve their groundwater flow paths.

The reduction of the standard buffer for springs/seeps is rare. Often the standard buffer is not adequate for protecting the ground water flow paths to springs/seeps from surrounding trenching and construction activities which can alter the groundwater flow paths to them. Spring and seeps buffers are only reduced if there is preexisting development within the setback area. In the case for buffer reductions, the greatest maximum setback distance should be provided, so that is it a minimum departure from the 150 feet required. Buffer for springs and seeps can only be administratively reduced to 50 feet on case-by-case basis and only if the applicant provides justification that the flow quantity and quality shall be preserved. A site-specific investigation of the hydrogeologic conditions associated with the spring or seep is required. Recommended protective measures for granting, on a case-by-case basis, a reduction of the buffer for a spring and seeps CEF included both:

1. Provide additional CEF buffer equal to or greater than the standard buffer area along the drainage on site.
2. Prohibit subsurface activities within 150 feet of spring or seep.

Applicants must demonstrate that proposed measures preserve all characteristics of the spring or seep, per LDC 25-8-42 (D)(3). Applicants requesting a spring or seep buffer to be reduced to less than 50-ft, must seek a Land Use Commission variance in accordance with LDC 25-8-41.

D. **Wetlands** - The protection of wetlands and the ecosystem services they provide is critical to maintaining and restoring the chemical, physical and biological integrity of surface water resources. Among these ecosystem services, wetlands can reduce the impacts from storm runoff, retain pollutants, reduce sediment, support instream baseflow, replenish groundwater, sequester carbon and provide critical resources for wildlife.

1. Standard Setback - The standard setback for a wetland CEF is a 150-foot CEF buffer around the outside edge of the wetland area. The protection of the Standard Setback may be appropriate to maintain the source water which supports saturation, or to maintain the surrounding physical or biological characteristics which support the wetland. The Standard Setback should be applied and preserved for wetlands that are fed by sheet flow from multiple directions, wetlands with pronounced diversity and vigor, or wetlands located in ecologically significant or sensitive areas.
2. Administratively approved modified setback - The standard setback may be modified so that the same square footage as the standard setback is applied to the natural drainage patterns above and below the wetland, or to adjacent surface water resources that would not otherwise be protected. The minimum setback average width should not be less than 50 ft from centerline. An administratively approved modified setback may be applied based on the source of water supporting the wetland, the biological characteristics of the wetland and the physical characteristics of the area around the wetland.
3. Mitigation - The Wetland CEF, the standard buffer, and/or administratively approved modified setback can be reduced on a case-by-case basis if 1:1 mitigation in the form of in-kind and on-site wetland enhancement or replacement is provided. Enhancements and replacements may include, but are not limited to, the following examples:
   a. On-site constructed wet ponds (for guidance see ECM, Section 1.6.6, Design Guidelines For Wet Ponds).
   b. On-site detention ponds landscaped with a native wet prairie (for guidance see COA Standard Specification Manual, Section 609S, Native Grassland Seeding and Planting For Erosion Control).
   c. Additional on-site buffers around existing water features or CEFs.

d. On-site bio-filtration and infiltration enhancement of standard sedimentation/filtration water quality and/or detention ponds.

e. Wetland restoration or enhancement for water quality controls; appropriate for existing ponds in-line with unclassified waterways or isolated ponds that can treat a development's storm water runoff (ECM, Section 1.6.6).

The Director of Watershed Protection Department may grant an administrative variance to further reduce setbacks for CEFs. The applicant for a variance must demonstrate that the proposed measures used in place of setbacks preserve all characteristics of the CEF.

Source: Rule No. R161-14.25, 12-30-2014 .

1.10.5 Critical Environmental Feature Buffer Maintenance and Inspection

1.10.5.1 Statement of Intent

The City of Austin has determined that Critical Environmental Feature buffers require ongoing maintenance to preserve their water quality function. This section describes the requirements for maintaining and inspecting buffers that are established by Sections 25-8-281 and 25-8-282 of the Land Development Code. Periodic inspections are necessary in order to verify that the vegetation, other natural characteristics, and protective infrastructure remain intact within the buffer area.

Additional guidelines for establishing the buffer and protection of point recharge features are in Section 1.10.4 (Determining Size of Critical Environmental Feature Protective Buffers), of the Environmental Criteria Manual.

This section applies to all Critical Environmental Feature buffers, as defined below.

Source: Rule No. R161-14.09, 3-5-2014 ; Rule No. R161-14.25, 12-30-2014 .

1.10.5.2 Requirements

(A) Definitions

(1) CATCHMENT AREA. The land area that drains to a point recharge feature. The upslope limits extend to the highest topographic contour above and around the feature, irrespective of the degree of slope. A sharp slope break present at the perimeter of a well-defined, bowl-shaped depression is the rim of the sinkhole and is within the catchment area.

(2) CRITICAL ENVIRONMENTAL FEATURE BUFFER. A land area established to protect or mitigate for the impacts to a Critical Environmental Feature (CEF). The natural vegetative cover must be retained to the maximum extent practicable. Construction disturbance must preserve all characteristics of the CEF and is limited to low-impact, minor modifications such as trails and protective structures.

(3) DRAINAGE WAY. The land surface that conveys surface flow to a larger body of water. This includes any channel that concentrates stormwater runoff.

(4) NATIVE VEGETATION. A native, or indigenous, species of Central Texas known to this region to exist as a result of only natural processes, with no human intervention. Once established, native

species do not require irrigation, fertilization, or other chemical support when located in appropriate habitat. Native species of trees, shrubs, grasses, and wildflowers are listed in the Native Plant database of the Lady Bird Johnson Wildflower Center website.

(5) NUISANCE VEGETATION. Vegetation that is of an invasive or detrimental nature and may be harmful to the functioning or water quality protection of a Critical Environmental Feature. This may include terrestrial or aquatic plants such as kudzu (Pueraria lobata), Bermuda grass (Cynodon dactylon), elephant ear (Colocasia), arundo cane (Arundo donax), hydrilla (Hydrilla verticillata), and greenbriar (Smilax bona-nox L.). Refer to the City of Austin Invasive Species Management Plan for additional plant species.

(6) NON-MECHANIZED EQUIPMENT. Equipment that is operated by hand and may include the use of hand-held motorized tools, such as chain saws.

(B) The protection of a Critical Environmental Feature buffer may require perimeter controls such as a perimeter fence, physical barrier, other structures, and signage. Fencing must meet the specifications of the City of Austin Standard Specifications Manual or a standard approved by the Watershed Protection Department. If a fence is constructed, then at least one access gate with a lockable latch must be installed. Fencing is recommended for the following conditions:

(1) The buffer is located adjacent to industrial, commercial, multi-family, or single-family residences.

(2) The buffer contains the catchment area of a cave or sinkhole.

(3) The buffer area contains an ecological community that is sensitive to disturbances that may impact water quality or alter the natural characteristics of the Critical Environmental Feature.

(4) The buffer area contains steep slopes and is located outside of a Critical Water Quality Zone.

(5) The buffer area is potentially hazardous or dangerous to individuals.

(6) The buffer area contains State or Federally protected species.

(C) Cave gates may be required. The materials and construction method must be approved by the Watershed Protection Department.

(D) Other proposed structures, such as diversion berms or recharge enhancement structures, within the buffer must retain the functionality and integrity of the Critical Environmental Feature. Generally diversion berms would only be allowed inside a buffer to direct clean or treated runoff toward recharge features. Otherwise, diversion berms outside the buffer would direct untreated runoff away from a recharge features. The materials and construction method must be approved by the Watershed Protection Department.

(E) Native vegetation within the buffer must be maintained such that it provides water quality benefits such as filtering sediment, allowing infiltration, promoting sheetflow of stormwater runoff, and preventing erosion. This maintenance does not include the requirement to provide supplemental irrigation for upland vegetation. Removal is to be conducted with non-mechanized equipment and without the use of herbicides. Removal of nuisance vegetation including seedling ash junipers may be conducted with prior approval and documentation from the Watershed Protection Department.

(F) Inspection of a Critical Environmental Feature buffer should occur at least every 6 months. The vegetation within the buffer area and associated infrastructure (fences, gates, berms, signs, trails, etc.) should be inspected. Additional conditions, such as red-imported fire ant activity, should be noted within cave buffers. Inspection records must be retained for three years by the land management entity for the City of Austin review.

(G) The owner must maintain the area within the buffer in a natural, vegetated state and preserve the natural characteristics of the Critical Environmental Feature. Maintenance activities shall utilize non-mechanized equipment. Mowing of ground cover is specifically not allowed. The following activities must be conducted:

(1) Trash must be removed from the buffer area on an as needed basis.

(2) Herbicide and pesticide use is prohibited within Critical Environmental Feature buffers on sites that are subject to the Save Our Springs Ordinance, per ECM 1.6.9.2 D.

(3) Upland vegetation must be replaced under the following conditions:

(a) A contiguous area greater than 10% total area of the buffer has dead, native vegetation. The type of vegetation may be an area of dead forbs and grasses or shrubs or trees. If Austin Water Utility has implemented Stage 2 or greater water restrictions, then revegetation may be postponed until watering is allowed twice per week.

(b) The area must be stabilized immediately if bare soil greater than 10 square feet in area results from vegetation death. Stabilization shall comply with other applicable sections of the Environmental Criteria Manual.

(4) Wetland vegetation located outside of a drainage way must be replaced under the following conditions:

(a) A contiguous area greater than 10% total area of the buffer consists of dead obligate, wetland vegetation; or

(b) Wetland vegetation was removed for infrastructure repair. Re-establish the hydrophytic wetland plant community per original, approved site or construction plans or as approved by the Watershed Protection Department.

(5) Routine preventive maintenance for gates, fences and trails should occur at least annually. If infrastructure damage exists, then repair must occur within two (2) months.

(6) Any observed condition that represents an immediate threat to water quality or public health must be remedied as soon as possible.

(H) Additional maintenance activities may be required. These activities may include:

(1) Trail surfaces that have eroded should be repaired within two (2) months.

(2) Missing or damaged signs should be replaced within six (6) months.

(3) Recharge enhancement structures should be maintained per the design recommendations. This may require clearing debris and sediment on a periodic basis.

(I) Any other conditions required by a legal document, such as a restrictive covenant or conservation easement, shall be followed.

(J) Failure to maintain a Critical Environmental Feature buffer that results in water quality degradation is considered to be a violation of City Code Chapter 6-5 (Water Quality). Penalties may be imposed.

Source: Rule No. R161-14.09, 3-5-2014 ; Rule No. R161-14.25, 12-30-2014 .

1.10.6 Guidelines for Review of Innovative Management Practices Proposing Transfer of Recharge Sites

Where extenuating circumstances exist and development over a significant point recharge feature and its catchment is proposed, the applicant should consider the following guidelines:

A. **Demonstrate That No Feasible Alternatives to Construction Over the Point Recharge Feature Exist.** Feasibility of alternatives shall be based primarily on technical, engineering and environmental criteria. Feasibility should not be based predominantly on marketing or economic considerations or special or unique conditions which are created as a result of the method by which a person voluntarily subdivides or develops land, except as provided under the "Hardship Provisions" of Section 25-8-25 of the LDC.

B. **Evaluate Alternative Recharge Areas Capable of Providing Recharge of a Quality and Quantity Approximately Equivalent to the Area Lost.** Compensating recharge or other mitigation, should be provided on-site, where feasible. Involved City departments will be available to discuss appropriate mitigation measures and sites. In all cases, measures shall be taken to assure that the quality of enhanced or induced recharge is adequate to protect ground water quality.

C. **Alternative Compensation or Mitigation Measures May be Approved by the Watershed Protection and Development Review Department.** The Watershed Protection and Development Review Department may approve alternative mitigation measures which achieve the objectives of maintaining recharge on a site. For example, a surface water feature designed and managed to augment baseflow in an adjacent stream might be accepted as compensation for loss of recharge to a local ground water system feeding springs which discharge to the stream.

D. **Restoration of Karst Features.** An applicant may voluntarily restore a karst feature to it's original, natural state; as reasonably possible. Restoration may include removing dumped trash, rock rubble, organic debris, or filled or washed in soil and restoring native vegetation according to Item No. 609S of the City of Austin Standard Specifications Manual. For safety reasons, opening a karst feature may necessitate installation of a cave gate to restrict public access to the feature. Restoration efforts should result in improving the quantity and quality of recharge water. The directing of treated or untreated stormwater to a recharge feature may require a Class V injection well permit from the Texas Commission on Environmental Quality.

   Requests to restore karst features will be reviewed by the director of the Watershed Protection Department on a case-by-case basis.

Source: Rule No. R161-14.25, 12-30-2014 .

1.10.7 Reserved

Editor's note(s)—Rule No. R161-14.25, adopted December 30, 2014 , repealed 1.10.7, which pertained to Evaluation Flow Chart for Karst and Point Recharge Features.