

Chapter 6: Technical Guidance for Specific Treatment Measures

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Introduction

The *C.3 Regulated Projects Guide (this Guide)* and the new companion *Green Infrastructure Design Guide (GI Design Guide)* comprise the Countywide Program’s *GreenSuite*. Both of the documents provide technical guidance on stormwater control measures and related issues, however this Guide focuses on Regulated Projects on parcels or sites while the *GI Design Guide* includes guidance for sites as well as recommendations for projects in streets and other public areas. Figure 6-1 below displays how the two Guides overlap and describes what is covered in **Chapters 2 through 4 of the *GI Design Guide*** related to site-based projects.

This chapter of the Guide is intended to help designers select and design appropriate treatment measures for parcel-based projects. This chapter covers the most common treatment measures used in San Mateo County (see Table 6-1) and was developed using best engineering judgment based on a review of various documents (see references at the end of this Guide), experience with review of designs and inspection of installations of treatment measures, and guidance from Water Board staff as available. The cross-section and plan view details provided are not intended for use in construction plans without customization for the conditions on the specific projects. This chapter primarily provides **design** guidance with some recommendations related to how design and maintenance considerations need to be integrated and maintenance issues that should be considered and planned for during the design stage.

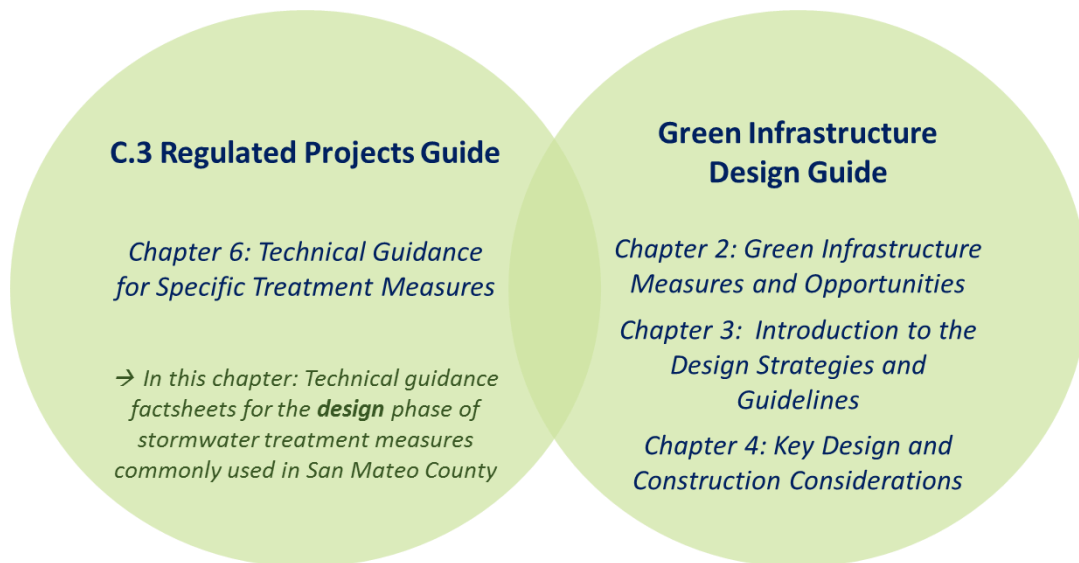


Figure 6-1: Chapter 6 details and cross-references to the Green Infrastructure Design Guide

Categories of Treatment Measures

Design guidance for each measure is provided in the corresponding section shown in Table 6-1. Most of the treatment measures presented in this chapter are considered LID measures in the context of the Municipal Regional Permit. Terminology used below is consistent with the GI Design Guide to the extent feasible – some differences arise out of the variable conditions in which treatment measures, non-LID measures, and alternative treatment measures are designed and built.

Table 6-1: Treatment Measures for which Technical Guidance is Provided

| Category | Treatment Measures | Section |
|-----------------|--------------------------------|---------|
| LID | Bioretention Area | 6.1 |
| LID | Flow-through Planter | 6.2 |
| LID and Non-LID | Tree Well Filter | 6.3 |
| LID | Infiltration Trench | 6.4 |
| Non-LID | Extended Detention Basin | 6.5 |
| LID | Pervious Pavement | 6.6 |
| LID | Reinforced Grid Paving | 6.7 |
| LID | Green Roof | 6.8 |
| LID | Rainwater Harvesting and Use | 6.9 |
| Non-LID | Media Filter | 6.10 |
| LID | Subsurface Infiltration System | 6.11 |

Location

Control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections (see Table 6-2 for example locations). **Control measures should not be located in inaccessible private property**, such as residential backyards (exceptions exist for pervious pavement). Ensure requirements needed for access are in place (e.g., easements, access routes for vehicles, material delivery or equipment for maintenance, and permission to access areas in maintenance agreements).

Table 6-2: Recommended Locations for Treatment Measures

| Location | Bioretention Area | Flow-through Planter | Tree Well Filter | Infiltration Trench | Extended Detention Basin | Pervious Pavement | Reinforced Grid Paving | Green Roof | Rainwater Harvesting and Use | Media Filter | Subsurface Infiltration System |
|---------------------|-------------------|----------------------|------------------|---------------------|--------------------------|-------------------|------------------------|------------|------------------------------|--------------|--------------------------------|
| Parking Lot | • | • | • | • | | • | • | | • | • | • |
| Roof | | • | | | | | | • | • | | |
| Driveway | • | • | • | • | | • | • | | | • | • |
| Podium-level | | • | | | | | | • | • | | |
| Close to Buildings | | • | • | | | • | | | • | • | |
| Away from Buildings | • | • | • | • | • | • | • | | • | • | • |
| Underground | | | | | | | | | • | • | • |

6.1 Bioretention Area

Overview



Figure 6-2: Bioretention area (Credit: City of Brisbane)

Description

Bioretention areas (also known as “rain gardens”) are concave or low and flat landscaped areas that function as soil and plant-based filtration devices that remove pollutants through physical and biological treatment processes. Bioretention areas can be any shape, including linear. Linear bioretention areas are sometimes referred to as stormwater planters. The GI Design Guide alternatively refers to bioretention areas as stormwater planters, stormwater curb extensions or rain gardens depending on the setting/location. Rain gardens in residential settings are sometimes simple bowl-shaped landscapes.

Bioretention areas consist of the following layers, starting from the top: a surface ponding area, plants, a layer of mulch, Biotreatment Soil Media (BSM), and an underlying layer of Class 2 Permeable material (Class 2 Perm) with an underdrain (if needed) that connects to the municipal storm drain system.

Bioretention areas should be designed to distribute stormwater runoff evenly within the surface ponding area. The water is temporarily stored in the ponding area and infiltrates through the BSM, which is engineered to have a high rate of permeability. From there, the water filters down into the underlying Class 2 Perm layer.

The Class 2 Perm layer of the bioretention area may be designed to either maximize infiltration or prevent infiltration to the underlying soils. In bioretention areas that maximize infiltration, the underdrain should be raised at least 6 inches above the bottom of the Class 2 Perm layer, and there should be no liner between the bottom of the Class 2 Perm layer and the surrounding soils. Maximizing infiltration is encouraged where conditions are suitable for infiltration – check with the geotechnical engineer. Where infiltration is precluded, the bioretention area should be fully lined with waterproof material, and the underdrain placed at the bottom of the Class 2 Perm layer.

Best uses

- Any type of development
- Drainage area up to two acres
- Landscape design element

Advantages

- Detains low flows
- Landscape feature
- Low maintenance
- Reliable once established

Limitations

- Not appropriate where soil is unstable
- Typically requires irrigation
- Susceptible to clogging if installed without protection from construction site soils

6.1 Bioretention Area

For strategies and examples of how to retrofit sites and parcels to include bioretention areas, see Sections 3.2 and 3.3 of the GI Design Guide.

Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. Bioretention units should not be located on inaccessible private property such as residential backyards. See Table 6-3 below for recommended bioretention area locations.

Siting

Table 6-3: Recommended locations for bioretention areas (rain gardens)

| Recommended Locations | Bioretention |
|-----------------------|--------------|
| Parking Lot | ● |
| Roof | |
| Driveway | ● |
| Podium-level | |
| Close to building | |
| Away from Buildings | ● |
| Underground | |



Figure 6-3: Bioretention area in a multi-family residential property in Redwood City (top; Credit: EOA, Inc.) and in a parking lot in Burlingame (bottom; Credit: SMCWPPP)

Design and Sizing Guidelines

Drainage Area and Setback Requirements

- Setback from structures 10' or as required by structural or geotechnical engineer, or local jurisdiction.
- Follow property line set-back requirements per local jurisdiction zoning. If the bioretention area is on or near the property line, consider if flow from adjacent properties that may cross the property line will affect the sizing of the system.
- Area draining to the bioretention area should not exceed 2 acres.
- Area draining to the bioretention area should not contain a significant source of soil erosion, such as high velocity flows along slopes not stabilized with vegetation or hardscape.
- Areas immediately adjacent to bioretention area should have slopes more than 0.5% for pavement and more than 1% for vegetated areas.

Treatment Dimensions, Grading and Sizing

- It is recommended that bioretention areas be sized to 4% of the impervious surface area on the project site which corresponds to a surface loading rate of 5 inches per hour and a rainfall intensity of 0.2 inches per hour. The area of impervious surface multiplied by 0.04 sizing factor will equal the footprint of the bioretention area. Alternatively, if there are site or infiltration constraints, bioretention sizing may be calculated using the flow-based treatment standard, or the combination flow- and volume-based treatment standard described in Section 5.1 based on the flow entering the basin at the treatment flow rate over the initial hours of the storm until the treatment volume is attained. See Appendix E for more guidance on infiltration issues.
- Where there is a positive surface overflow, bioretention areas should have freeboard of at least 0.2 feet to the lowest structural member versus the 100-year storm water level in the bioretention area, unless local jurisdiction has other requirements.
- Where the bioretention area is in a sump that depends on outflow through a catch basin, the bioretention area should have a freeboard of at least 0.5 feet to the lowest building finished floor elevation (including garage and excluding crawl space) for conditions with the outlet 50 percent clogged, unless local jurisdiction has other requirements. Where the freeboard cannot be provided, an emergency pump may be allowed on a case-by-case basis.
- Allow 2 inches of freeboard between the rim elevation of the outfall grate and elevation of the emergency overflow above the overflow grate such as the top of a flow-through planter wall.
- Side slopes should not exceed 3:1; downstream slope for overflow should not exceed 3:1.
- Bioretention areas, including linear treatment measures, should not be constructed on slopes greater than 4%, unless constructed as a series of relatively horizontal bioretention cells. A bioretention facility should be one level (maximum 2% inner cell slope), shallow basin or a series of basins. As runoff enters each basin, it should flood and fill throughout before runoff overflows to the outlet or to the next downstream basin. This will help prevent movement of surface mulch and soil. In a linear bioretention area, check dams should be placed for every 4 to 6 inches of elevation change and so that the top of each dam is at least as high as the toe of the next upstream

dam. A similar principle applies to bioretention facilities built as terraced roadway shoulders³¹. The slope within cells should not exceed 2% and check dams should be used to hold flow above the 2% level before allowing flow to enter the next cell. Bioretention cells are not recommended if overall slope exceeds 8%. If designing a sloped bioretention area with a surface reservoir (volume method or combined flow and volume method), the slope will have to be factored in the calculation of the surface reservoir height. See Appendix E for more guidance on infiltration measures. **See Section 4.3 of the GI Design Guide for guidance on how to deal with steep topography** using check dams and weirs.

- Surface ponding depths may vary, with a recommended depth of 6 inches (measured from the top of the BSM layer – not the mulch layer - to the overflow rim elevation) and a maximum depth of 12 inches. If ponding depths exceed 6 inches, the landscape architect may want to consider effects on the planting palette. The 3" mulch layer can be within the 6" ponding depth.

Inlets to Treatment Measure

- Flow may enter the treatment measure in the following ways (see example drawings in Section 5.13):
 - As overland flow from landscaping (no special requirements);
 - As overland flow from pavement (cutoff wall required);
 - Through a curb opening;
 - Through a curb drain;
 - Within a drop structure through a stepped manhole (refer to Figure 5-1 in Section 5.6);
 - Through a bubble-up emitter; and/or
 - Through a roof leader or other conveyance from a building roof.
- Where flows enter the biotreatment area, allow a change in elevation of 4-6 inches between the paved surface and the biotreatment soil media elevation (i.e. a recommended 2" drop from the inlet to the mulch or splash block), so that vegetation or mulch build-up does not obstruct flow.
- Splash blocks or splash aprons with or without grouted cobble, pea gravel, plants or mulch should be installed to dissipate flow energy and velocity where runoff enters the treatment measure, and at the downstream side of tiers, weirs and check dams to prevent erosion.

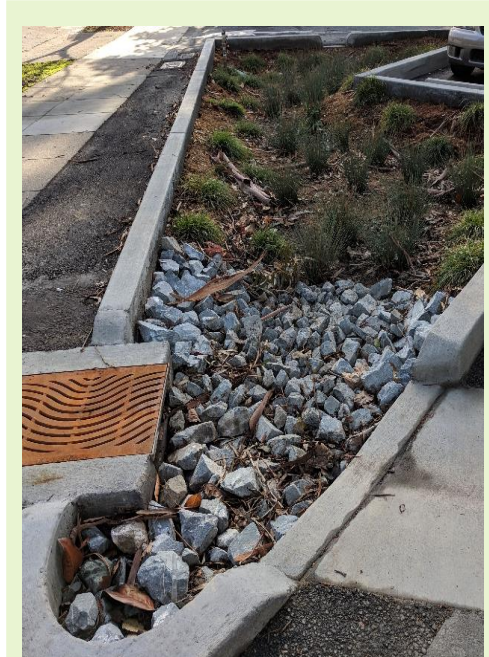


Figure 6-4: Examples of curb cut inlets at a bioretention area in Burlingame (Credit: City of Burlingame)

³¹ Contra Costa Clean Water Program. February 2012. C.3 Stormwater Guidebook, 6th Edition and Stormwater Management Handbook: Implementing Green Infrastructure in Northern Kentucky Communities, 2009. www.epa.gov/smartgrowth/publications.htm

- Curb openings should be a minimum of 18 inches wide (or 12" if allowed by the municipality), with the number and locations designed so that runoff is dispersed throughout the bioretention area or through the use of a flow spreading system.
- Bubble-up emitters and pipes to bubble-up emitters should have weep holes to avoid standing water inside after storm events.

Vegetation



Figure 6-5: Bioretention area featuring several plant types (Credit: City of Burlingame)

- Plant species should be suitable to well-drained soil and occasional inundation. See planting guidance in Appendix A.
- Shrubs and small trees should be placed to anchor the bioretention area cover.
- Tree planting should be as required by the municipality. If larger trees are selected, plant them at the periphery of the bioretention area, where roots can access non-BSM soils outside the area.
- Underdrain trenches can be placed at the edge of tree planting zones, as needed, to maximize distance between tree roots and the underdrain, but the underdrain trench must still be located somewhere under the BSM section and within the Class 2 Perm material layer.
- Use integrated pest management (IPM) and/or Bay-Friendly principles in the landscape design to help avoid or minimize any use of synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction for any local policies regarding the use of pesticides and fertilizers.
- Irrigation should be provided as needed to maintain plant health. If irrigation cannot be provided, then watering by hand should be accommodated weekly through plant establishment – typically through the first six months depending on the season and levels of precipitation.
- Trees and vegetation should not block inflow, create traffic or safety issues, or obstruct utilities.

Soil and Drainage Considerations Specific to Bioretention Areas

- Consideration of groundwater level and placement of the underdrain:
 1. If there is less than a 5-foot separation between the bottom of the facility and the seasonal high groundwater level, or infiltration is not allowed due to other site constraints, an impermeable liner should be placed between the Class 2 Perm and the bottom of the facility and the underdrain placed on top of that liner.
 2. If there is at least a 5-foot separation between the bottom of the facility and the seasonal high groundwater level, and geotechnical conditions allow infiltration, the facility should be unlined and the underdrain should be raised at least 6 inches above the bottom of the Class 2 Perm to allow storage and infiltration of treated water.

Soil and Drainage Considerations for All Biotreatment Systems

- Soil used in the bioretention area must meet the biotreatment soil media (BSM) specification included in Appendix K. Check with municipality for any additional requirements.
- Bioretention areas should have a minimum BSM depth of 18 inches.
- Install and maintain a 3-inch layer of composted arbor mulch (also called “aged mulch”) in areas between plantings. Rock mulches such as river cobble or pea gravel, or other mulches that resist floating may be used, but large rock mulch, such as cobble, should be used sparingly and only where absolutely necessary. Dyed, “micro-bark”, or “gorilla hair” mulches, as well as chipped wood mulch from recycled pallets and dimensional lumber, are not recommended. **See Sections 4.9 and 6.3 of the GI Design Guide** for more information on mulch.
- An underdrain system is generally required. Depending on the permeability of in situ soils, the local jurisdiction may allow installation without an underdrain on a case-by-case basis.
- Filter fabric should not be used around the underdrain or between the BSM and Class 2 Perm layer. Class 2 Perm performs the function of filter fabric (keeping the BSM from exiting the system through the underdrain) but is less prone to clogging.
- The underdrain should consist of a solid perforated or slotted HDPE or PVC pipe connected to a cleanout pipe(s) and to a storm drain or discharge point. Solid HDPE or triple-walled HDPE pipe, with smooth inner and outer layers and a corrugated middle layer, are recommended. The cleanout should consist of a vertical, rigid, non-perforated, non-corrugated PVC or HDPE pipe, with a minimum diameter of 4 inches and a watertight cap fit, raised or flush with the ground, or as required by municipality. There should be adequate fall (min. 0.5% slope) from the underdrain to the storm drain or discharge point. See Section 5.14 for more information on underdrains.
- The underdrain should be placed in a 12-inch thick layer of Caltrans Class 2 permeable material, or similar municipality-approved material. See Section 5.14 for more information on Class 2 permeable material.

Construction Requirements and Maintenance Plans

Construction Requirements for All Biotreatment Systems

- When excavating, avoid spreading fines of the soils on bottom and side slopes. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate.
- Minimize compaction of existing soils. Protect from construction traffic.
- Protect the area from construction site runoff. Runoff from unstabilized areas should be diverted away from biotreatment facility.
- ***For additional construction guidelines, see Chapters 2, 4 and 5 of the GI Design Guide.*** Specifically, see Sections 4.3 through 4.9 for construction strategies for dealing with slopes, overflows, poor soils, utilities, runoff capture, etc.

Remember

Maintenance Considerations for All Treatment Measures

- See Chapter 8 of this Guide for specific maintenance guidance. Specifically, see Section 8.3.1 for common maintenance concerns encountered for bioretention areas.
- ***See Chapter 6 of the GI Design Guide*** for landscape maintenance recommendations and information.
- A Maintenance Agreement should be provided and should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement. Maintenance plan templates are in Appendix G

Typical Design Details

Note that even though not shown in the details below, 3" of mulch will need to be added on top of the biotreatment soil media for all bioretention area measures - 2" of freeboard is also recommended.

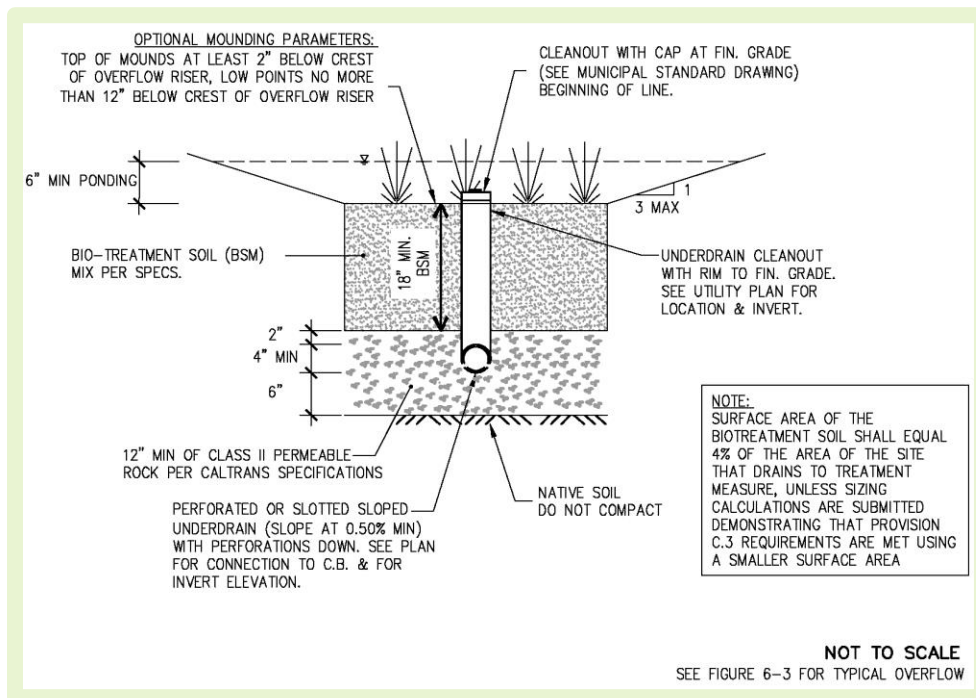


Figure 6-6: Cross Section, Bioretention Area with Infiltration

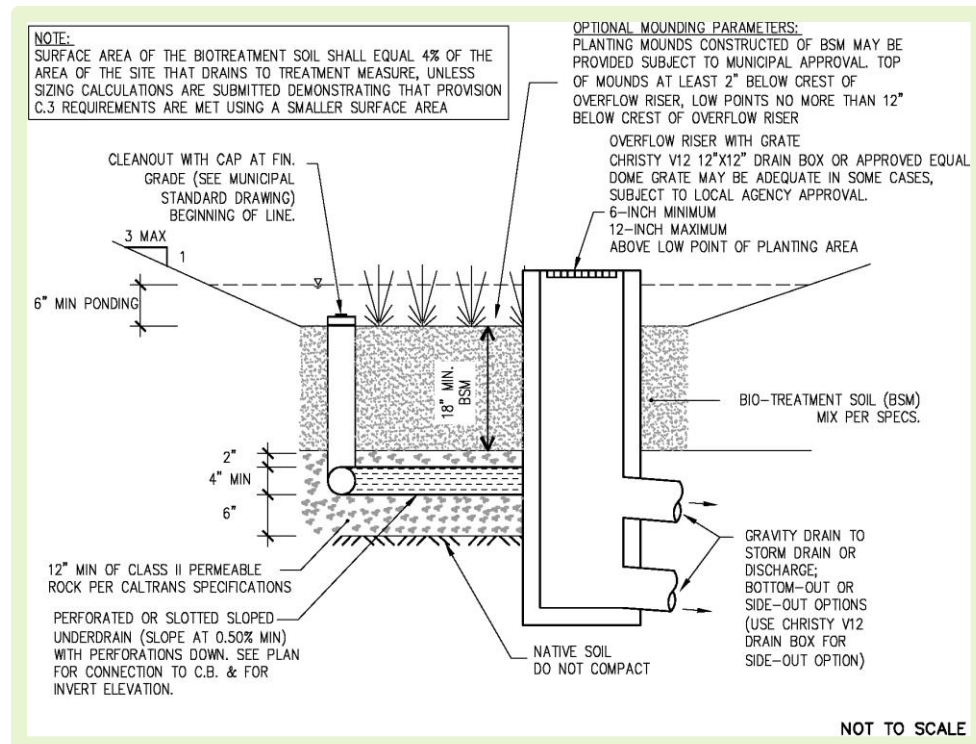


Figure 6-7: Cross Section, Bioretention Area (side view) with Infiltration

6.1 Bioretention Area

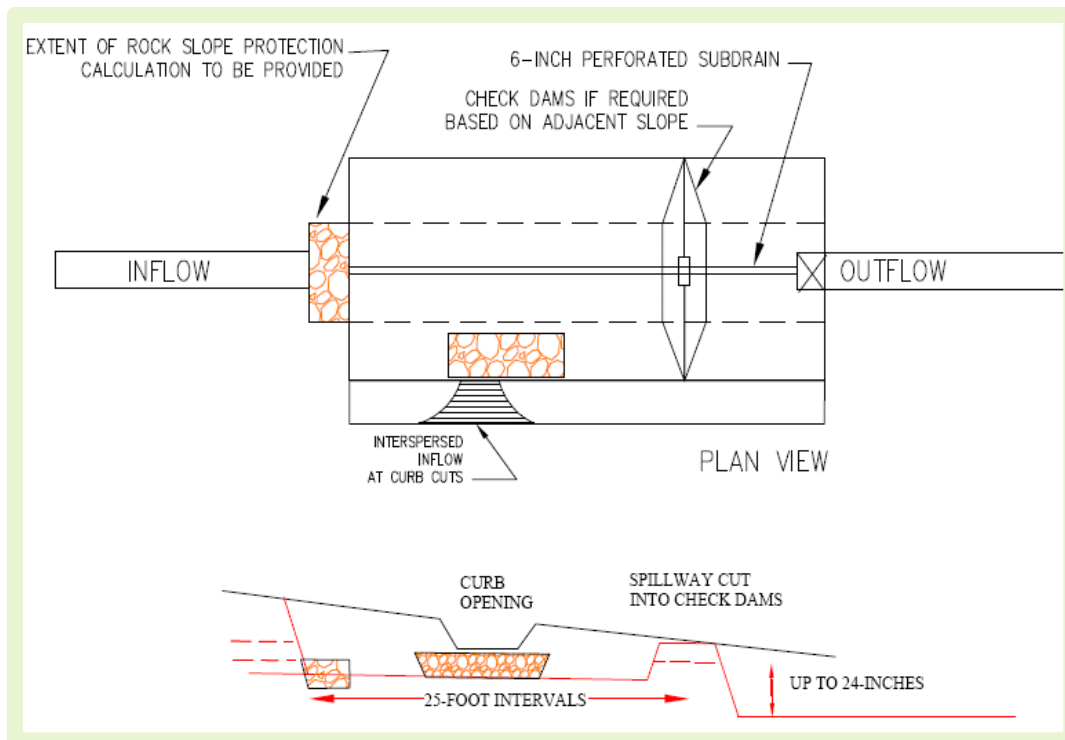


Figure 6-8: Check dam (plan view and profile) for installing a series of linear bioretention cells in sloped area

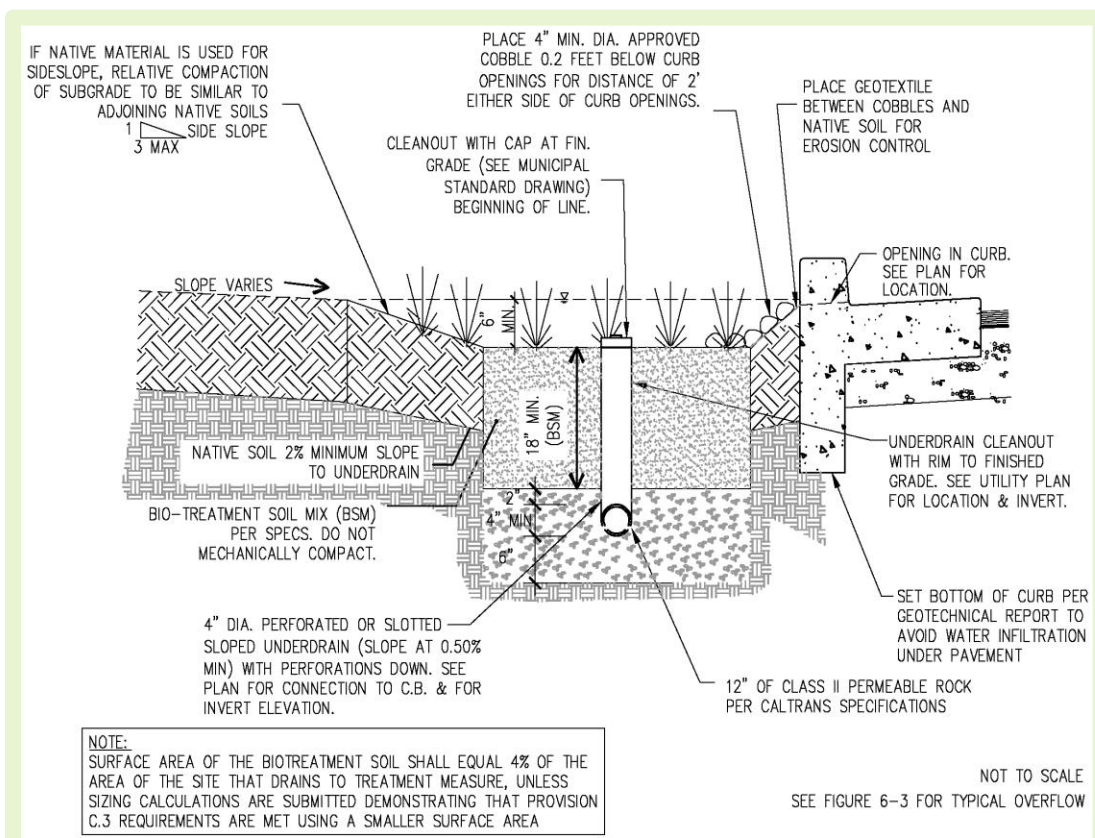


Figure 6-9: Cross section of bioretention area with infiltration showing inlet from pavement.

6.1 Bioretention Area

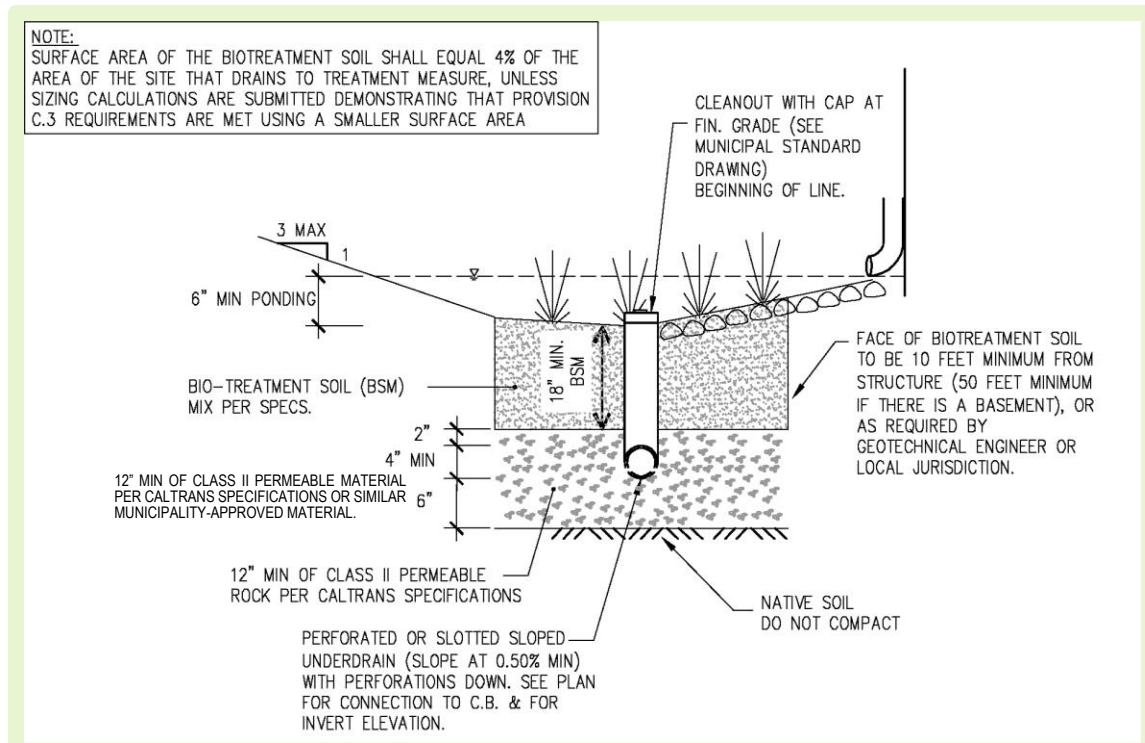


Figure 6-10: Bioretention area in landscaping to treat runoff from rainwater leaders (Not to Scale)

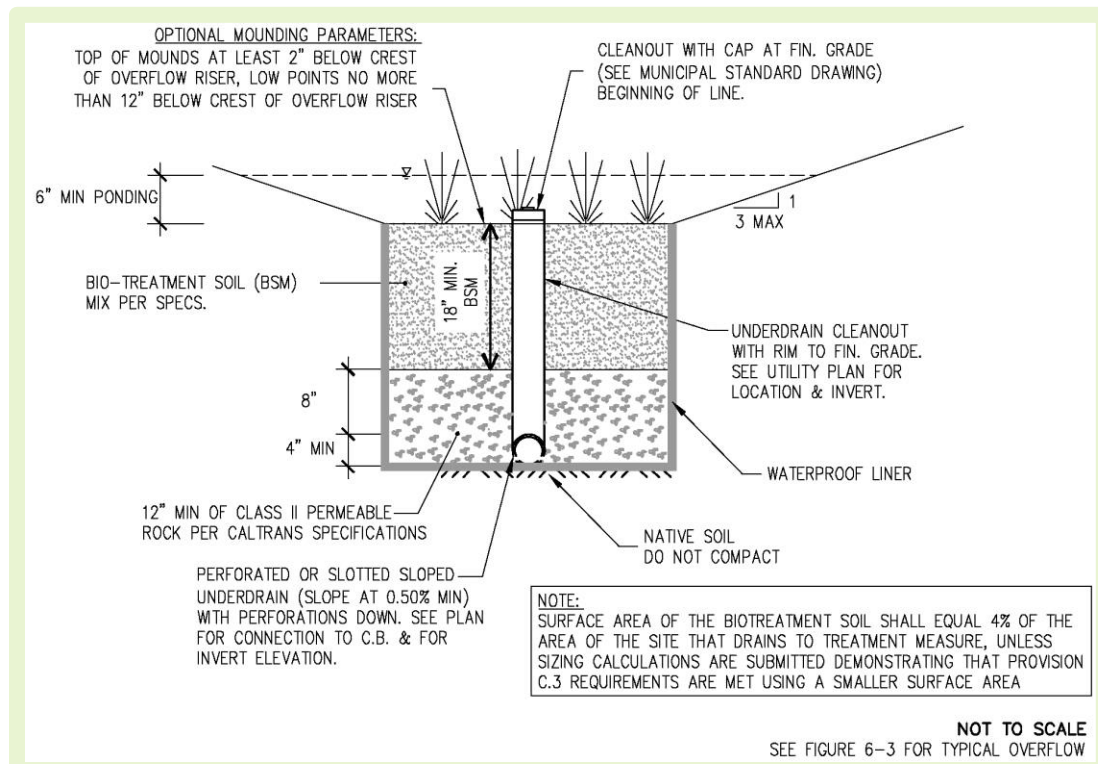


Figure 6-11: Cross section of lined bioretention area, for locations where infiltration is precluded.

6.2 Flow-through Planter

Overview

Description

Flow-through planters are a type of contained biotreatment system designed to treat and detain runoff without allowing infiltration into the underlying soil. They can be used next to buildings and other locations where soil moisture, water infiltration or intrusion is a potential concern. Flow-through planters are typically constructed above grade in concrete boxes receiving runoff via downspouts from roofs of adjacent buildings. However, they can also be built level with surrounding surfaces receiving sheet flow (“below-grade flow-through planter”). Pollutants are removed as the runoff passes through the BSM and is collected in an underlying layer of Class 2 permeable material. A perforated underdrain must be directed to a storm drain or other discharge point. An overflow inlet conveys flows that exceed the capacity of the planter.



Figure 6-12: Flow-through planter (Credit: EOA, Inc.)

Best uses

- Treating roof runoff
- Next to buildings
- Dense urban areas
- Locations where infiltration is not desired and/or feasible

Advantages

- Can be adjacent to structures
- Multi-use
- Versatile
- May be any shape
- Low maintenance

Limitations

- May require sufficient head
- Careful selection of plants
- Does not allow for infiltration of water into native soil
- Needs redundant systems in case of clogging.

6.2 Flow-through Planter

For strategies and examples of how to retrofit sites and parcels to include flow-through planters, see **Sections 3.2 and 3.3 of the GI Design Guide**.

Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. Flow-through planters should not be located on inaccessible private property such as residential backyards. Ideally, planters should be located in areas that are visible from the nearby walkway/patio. Make sure the planter wall is low enough to allow for visual inspection from the adjacent walking surface. A maximum height of 5 feet from the walking surface to the top of the planter wall is recommended.

Siting

Table 6-4: Recommended locations for flow-through planters

| Recommended Locations | Flow-through Planter |
|-----------------------|----------------------|
| Parking Lot | ● |
| Roof | ● |
| Driveway | ● |
| Podium-level | ● |
| Close to building | ● |
| Away from Buildings | ● |
| Underground | |



Figure 6-13: Flow-through planter with gravel rock mulch. (Credit: City of Burlingame)

Design and Sizing Guidelines

Treatment Dimensions and Sizing

- It is recommended that flow-through planters be designed with a 4% sizing factor (percentage of the surface area of planter compared to the surface area of the tributary impervious area). The area of impervious surface multiplied by 0.04 sizing factor will equal the footprint of the flow-through planter. Alternatively, if there are site constraints, calculations may be performed using either the hydraulic sizing criteria for flow-based treatment measures or the hydraulic sizing criteria for combination flow- and volume-based treatment measures, included in Section 5.1.
- Install an overflow system adequate to meet municipal drainage requirements.
- Flow-through planters can be used adjacent to building and within set back areas, if allowed.
- Flow-through planters can be used above or below grade and on podiums or roof tops with sufficient structural capacity and waterproofing.
- Size the overflow grate per the MRP C.3.d sizing or per any locally-required design storm, set rim elevation of grate at least 2" below top of planter box walls and top of water proofing on building side. A minimum sized grate opening of 4" is recommended to allow for cleanout.
- Planter wall set against the building should be at least 2" higher than the opposite side of the planter to avoid overflow against building.
- Elevation of the surface area should be generally level, but may vary as needed to distribute stormwater flows throughout the surface area. For example the BSM can be graded slightly (1%) away from inlet(s) to the rest of the planter area. If the available planter surface area exceeds the C.3.d-required sizing (4%), then the excess square footage can be mounded, can have different soil types, and/or can have different plant types in those areas providing more variety.
- Provide a minimum of 2 inches, and a maximum of 12 inches of water surface storage between the BSM and rim of overflow. 6 inches is the recommended design ponding depth.
- Flow-through planters should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. A maximum planter wall height (measured from the walking surface to top of wall) of 5 feet is recommended for inspections.

Inlets to Treatment Measure

- Flow may enter the treatment measure (see example drawings in Section 5.13):
 - As overland flow from landscaping (no special requirements);
 - As overland flow from pavement (cutoff wall required);
 - Through a curb opening;
 - Through a curb drain;
 - Within a drop structure through a stepped manhole (refer to Figure 5-3 in Chapter 5);
 - Through a bubble-up inlet or storm drain emitter with sufficient head;
 - Through a roof leader, downspout or other conveyance from building roof; and/or
 - Through a runnel, swale, valley gutter or other conveyance system.

6.2 Flow-through Planter

- If the flow-through planter is installed at grade, allow a change in elevation of 4 to 6 inches between the surrounding paved surface and the biotreatment soil media elevation, so that vegetation or mulch build-up does not obstruct flow.
- If the flow-through planter is installed above grade, sufficient head must be provided for bubble-up emitters to discharge to the planter surface.
- Bubble-up emitters and pipes to bubble-up emitters should have weep holes to avoid standing water inside after storm events.
- Splash blocks, inlet boxes, strategically located plants or rock mulch should be installed to dissipate flow energy where runoff enters the treatment measure.
- Curb openings should be a minimum of 18 inches wide (or 12" if allowed by the municipality) with the number of openings and locations designed so that runoff is dispersed throughout the bioretention area or with the use of a flow spreader system.
- For long linear planters, space inlets to planter at 10-foot intervals or install a flow spreader.



Figure 6-14: Close-up of flow-through planter with flow spreader. (Credit: EOA, Inc)

Vegetation

- Plantings should be selected for viability in a well-drained soil. See plant guidance in Appendix A.
- Use ReScape (Bay-Friendly) principles and practices such as choosing the right plant for the right place and integrated pest management (IPM) in the landscape design to help avoid or minimize any use of synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction for any local policies regarding the use of pesticides and fertilizers.
- Irrigation should be provided, as needed, to maintain plant life. If irrigation cannot be provided, then watering by hand should be accommodated weekly through plant establishment – typically through the first six months depending on the season and levels of precipitation.

- Choose vegetation that will not block inflows, outlets, create traffic or safety issues, or obstruct utilities at the time of installation or when plants grow to their mature size.

Soil and Drainage Considerations Specific to Flow-through Planters

- Waterproofing should be installed as required to protect adjacent building foundations.
- An underdrain system is required for flow through planters.
- To avoid excess hydraulic pressure on subsurface treatment system structures:
 - The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the structure.
 - A geotechnical engineer should be consulted for situations where the bottom of the structure is less than 5 feet from the seasonal high groundwater level.

Soil and Drainage Considerations for All Biotreatment Systems

- The biotreatment soil media should have long term minimum permeability of 5 inches per hour (although the initial permeability may exceed this to allow for a tendency of the permeability to reduce over time.) Soil specifications are provided in Appendix K. Check with municipality for additional requirements.
- The biotreatment soil media layer should be a minimum of 18 inches deep.
- Soil used in the planter must meet the BASMAA biotreatment soil media (BSM) specification included in Appendix K. Check with municipality for any additional requirements.
- Install and maintain a 3-inch layer of composted arbor mulch (also called “aged mulch”) in areas between plantings. Rock mulches such as river cobble or pea gravel, or other mulches that resist floating may be used, but large rock mulch, such as cobble, should be used sparingly and only where absolutely necessary. Dyed, “micro-bark”, or “gorilla hair” mulches, as well as chipped or ground wood mulch from recycled pallets and dimensional lumber, are not recommended. **See Sections 4.9 and 6.3 of the GI Design Guide** for more information on mulch.
- Filter fabric should not be used around the underdrain or between the BSM and Class 2 Perm layer. Class 2 Perm performs the function of filter fabric (keeping the BSM from exiting the system through the underdrain) but is less prone to clogging.
- The underdrain should consist of a solid perforated or slotted HDPE or PVC pipe connected to a cleanout pipe(s) and to a storm drain or discharge point. Solid HDPE or triple-walled HDPE pipe, with smooth inner and outer layers and a corrugated middle layer, are recommended. The cleanout should consist of a vertical, rigid, non-perforated, non-corrugated PVC or HDPE pipe, with a minimum diameter of 4 inches and a watertight cap fit, raised or flush with the ground, or as required by municipality. There should be adequate fall (min. 0.5% slope) from the underdrain to the storm drain or discharge point. See Section 5.14 for more information on underdrains.
- The underdrain should be placed at the bottom of a 12-inch thick layer of Caltrans Class 2 permeable material, or similar municipality-approved material. See Section 5.14 for more information on Class 2 Perm material.

Construction Requirements and Maintenance Plans

Construction Requirements for All Biotreatment Systems

- Minimize compaction of BSM. Protect from construction traffic.
- Protect the area from construction site runoff. Runoff from unstabilized areas should be diverted away from the Flow-through Planter.
- For **additional construction guidelines, see Chapter 4 of the GI Design Guide**. Specifically, **see Sections 4.3 through 4.9 of the GI Design Guide** for construction strategies for dealing with slopes, overflows, poor soils, utilities, runoff capture, etc.

Remember

Maintenance Considerations for All Treatment Measures

- See Chapter 8 for specific maintenance guidance. Specifically, see Section 8.3.2 for common maintenance problems specific to flow-through planters.
- **See Chapter 6 of the GI Design Guide** for landscape maintenance recommendations and practices.
- A Maintenance Agreement should be provided and should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement. Maintenance plan templates are in Appendix G.

Typical Design Details

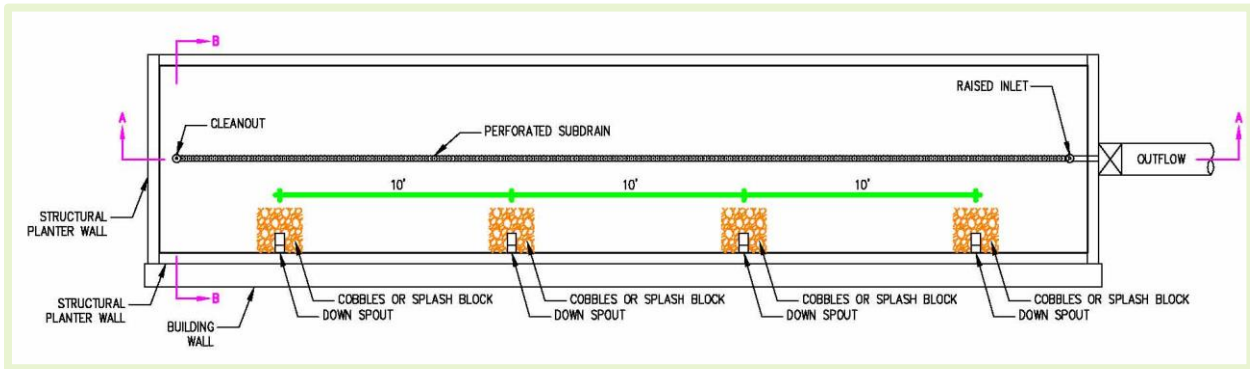


Figure 6-15: Plan view of long, linear planter, with inlets to the planter distributed along its length at 10' intervals.

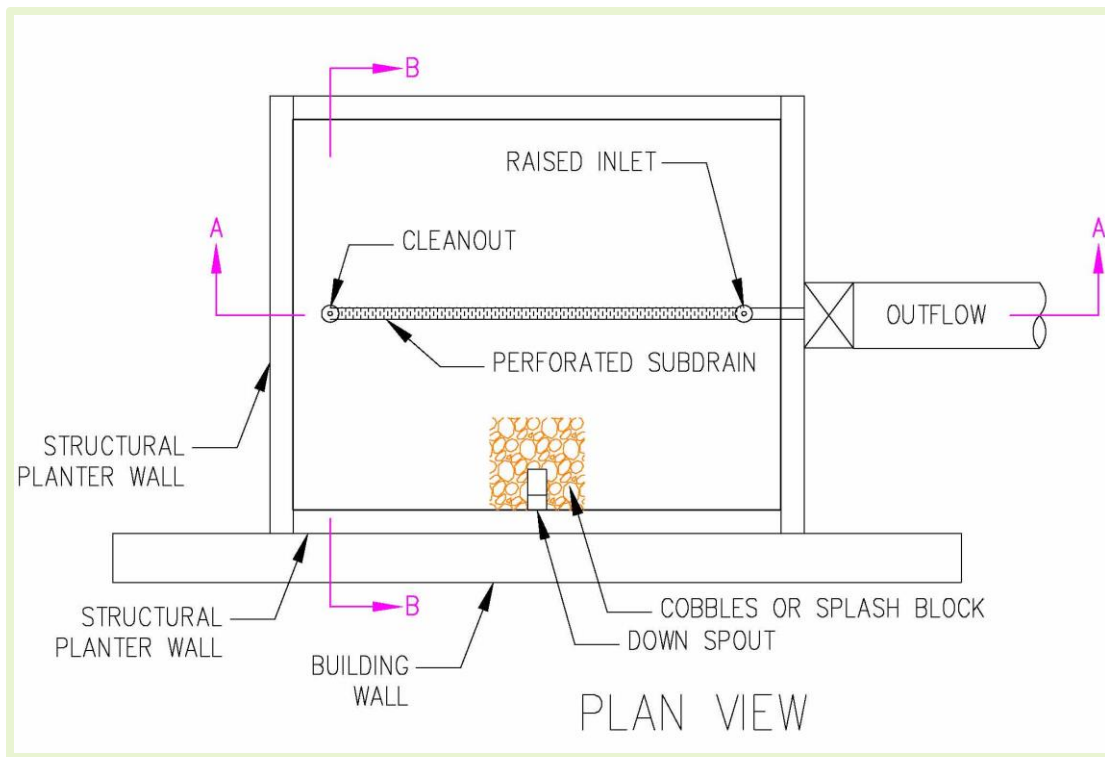


Figure 6-16: Plan view of planter designed to disperse flows adequately with only one inlet to planter

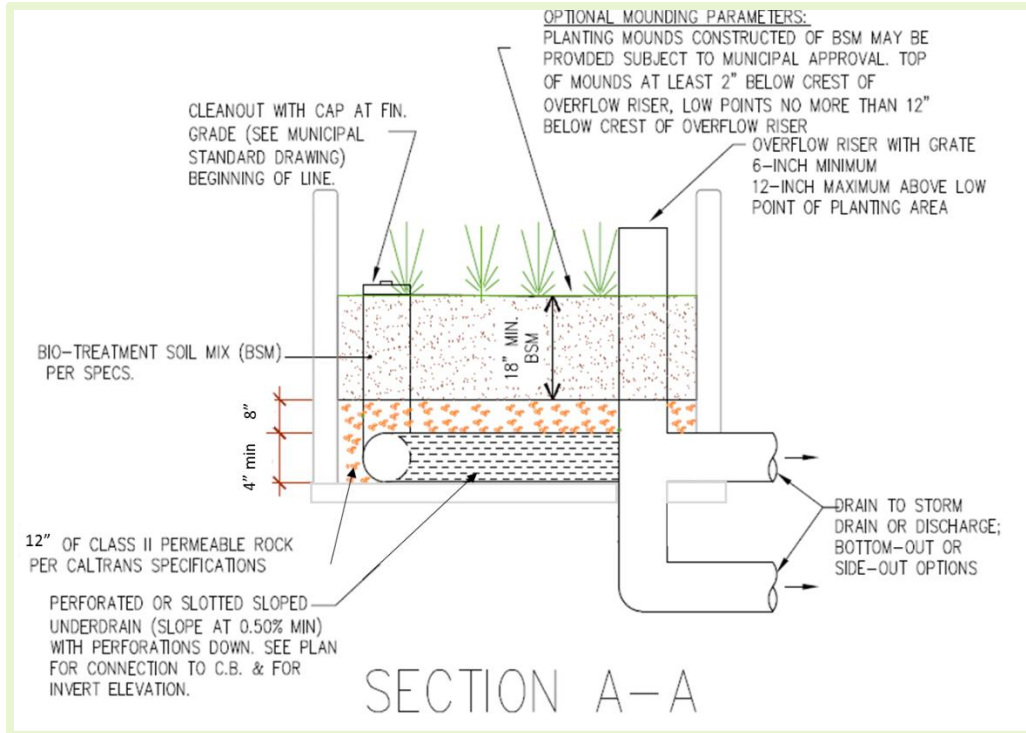


Figure 6-17: Cross section A-A of flow-through planter, shows side view of underdrain (Not to Scale)

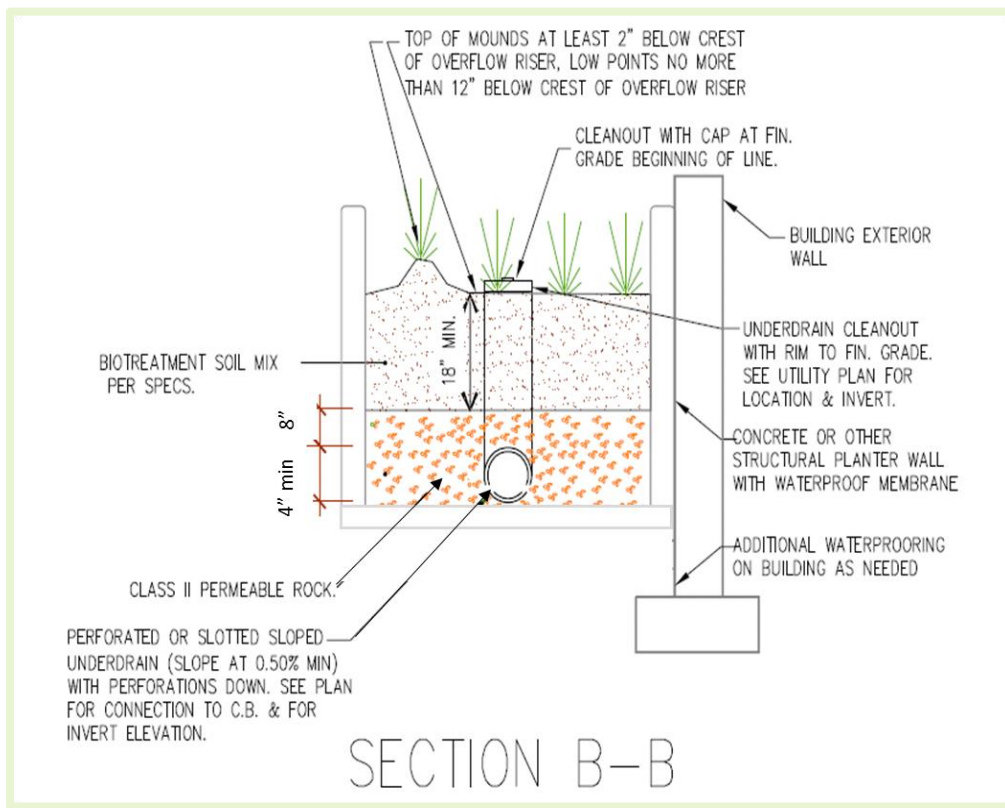


Figure 6-18: Cross section B-B of flow-through planter, shows cross section of underdrain

6.3 Tree Well Filter

Overview

Description



Best uses

- Plazas, parks, roadways and parking lots where trees are desired.

Advantages

- Aesthetic
- Small footprint (in some designs)
- Blends with the landscape

Limitations

- Larger trees need more soil volume
- Higher installation cost
- Systems with high flow rate media are allowed *only in Special Projects*

Figure 6-19: Tree Well Filter (Credit: City of Menlo Park)

Tree well filters come in several types. They can be in boxes or open areas, with underground suspended pavement systems, or with proprietary high-flow rate media. Some tree well filters are in open-bottom systems that promote infiltration or in closed-bottom systems where infiltration is undesirable or infeasible, such as sites near structures, groundwater contamination, or high groundwater levels. Tree well filters are often installed along urban sidewalks as part of an integrated street landscape, but they are highly adaptable and can be used in most development scenarios. The top of the soil and mulch is set low enough that runoff from adjacent pavement can flow into the system. Tree well filters can also be constructed using suspended pavement system products (see Chapter 4 and Figures 6-24, 6-25 and 6-26).

A tree well filter's basic design is similar to that of a bioretention area or flow-through planter. It consists of an excavated pit or vault filled with biotreatment soil media, planted with a tree and sometimes with additional small plants, with Class 2 Permeable material and an underdrain. A tree well filter that uses biotreatment soil media and is designed for a stormwater runoff surface loading rate of 5 inches per hour is considered a LID treatment measure (either an infiltration or biotreatment measure, depending on its design). Suspended pavement systems can provide additional uncompacted soil volume for tree root growth under adjacent pavement areas as well as allowing for "underground" bioretention. If used as part of the stormwater treatment system, the areas under the pavement should be installed with the required minimum 18-inch depth of biotreatment soil media and underdrains as necessary.

High flow-rate tree well filters containing manufactured media with design loading rates greater than 5 inches per hour do not qualify as LID treatment measures and are only allowed for use in Special Projects, as described in Appendix J.

Siting

For strategies and examples of how to retrofit sites and parcels to include tree well filters, *see sections 3.2 and 3.3 of the GI Design Guide.*

Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. Tree well filters should not be located on inaccessible private property such as residential backyards.

When paired with suspended pavement systems and BSM, tree well filters can be considered LID and can sometimes fit into constrained spaces. They can prevent pavement damage and heaving from tree roots, reducing trip and fall hazards. See discussion in Chapter 4 for more information on providing increased soil volumes. Figure 6-25 from the Ada County Highway District Stormwater Design Guidelines (from Boise, Idaho) shows a cross section detail for a street tree design with a suspended pavement system installed adjacent to the tree under a sidewalk, but the design can also be used in a parking lot or other paved areas on a private or public parcel.

Additional soil volumes can also be provided under pervious pavement systems. Pervious pavement allows the runoff to enter the suspended pavement system without a network of inlet pipes and can distribute the flow more evenly. The example in Figure 6-26 illustrates a location where a tree and a suspended pavement system is integrated into a project with pervious pavement. Three ways that trees, pervious pavement and suspended pavement systems can be integrated are:

1. Suspended pavement systems under pervious parking area pavement;
2. Suspended pavement systems under a pervious sidewalk adjacent to the tree planting areas; and/or
3. Suspended pavement systems under an adjacent roadway – typically a parking lane or gutter area.



Figure 6-20: A tree well filter along a roadway (top – Credit: City of Fremont); and high flow rate tree well filters in a parking lot (bottom - Credit: City of Emeryville)

Table 6-5: Recommended locations for tree well filters

| Recommended Locations | Tree Well Filter |
|-----------------------|------------------|
| Parking Lot | ● |
| Roof | |
| Driveway | ● |
| Podium-level | |
| Close to building | ● |
| Away from Buildings | ● |
| Underground | |

Design and Sizing Guidelines

Treatment Dimensions and Sizing

- Flows in excess of the treatment flow rate should bypass the tree well filter to a downstream inlet structure or other appropriate outfall.
- Tree well filters cannot be placed in sump condition; therefore, tree well filters should have flow directed along a flow line of curb and gutter or other lateral structure. Do not direct flows directly to a tree well filter.
- Tree well filters with BSM (LID):
 - It is recommended that a tree well filter with BSM be sized to be 4% of the contributing impervious surface area; i.e., the area of impervious surface multiplied by the 0.04 sizing factor will equal the required surface area of the tree well filter. This sizing factor is derived from the flow-based treatment standard (runoff from 0.2 in./hr. intensity rainfall) and a required surface loading rate of 5 in./hr. Alternatively, if there are site constraints, tree well filter sizing may be calculated using a volume-based treatment method or a combination flow- and volume-based treatment method. Larger sized systems will allow for a larger tree species.
 - The number of trees to be provided will vary with the size of the treatment area and the size of the canopy of the expected tree species at maturity. It is recommended that a minimum of one tree for each 100 square feet of surface area be provided for smaller trees with increased spacing for larger tree species so that branches do not overlap. Smaller understory plants can provide treatment between trees when spacing exceeds 10 feet.
- High flow rate tree well filters (non-LID):
 - The system should be reviewed by the manufacturer/local supplier before installation. High flow rate tree well filters should be sized based on the loading rate of the media. The manufacturer should certify the ratio of impervious area to treatment area for the project. For example, Filterra states that a tree well filter of 6 x 6-feet can treat 0.25 acres of impervious surface. However, a more conservative loading rate may be used.
 - The tree species will typically be of small stature due to the constrained box environment and lack of large volume of rootable soil. Larger boxes will allow for more soil volume and possibly increased tree health. Typically one to two trees per unit are used.
 - High flow rate tree well filters are available in multi-sized pre-cast concrete drop in boxes. Sizes range from 4 x 6-feet up to 6 x 12-feet boxes. The required size of the box is based on the size of the tributary impervious surface and the permeability of the filter media. The product must be certified by the Washington State Technical Assessment Protocol – Ecology (TAPE) program, General Use Level Designation (GULD) for Basic Treatment, and sized based on the certified design operating rate³².

Inlets to Treatment Measure

- Flow may enter the treatment measure (see example drawings in Section 5.13):

³² For more information, see: <https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies#tape>

- As overland flow from landscaping (no special requirements);
 - As overland flow from pavement (cutoff wall required);
 - Through a curb opening;
 - Through a curb drain;
 - With a drop structure through a stepped manhole (See Section 5.6);
 - Through a bubble-up manhole or storm drain emitter; and/or
 - Through a roof leader or other conveyance from building roof.
- Where flows enter the biotreatment measure, allow a change in elevation of 4 to 6 inches between the paved surface and biotreatment soil media elevation, so that vegetation or mulch build-up does not obstruct flow.
 - Splash block, concrete aprons, grouted rock cobble, pea gravel rock mulch, or plants should be installed to dissipate flow energy where runoff enters the treatment measure.
 - Curb openings should be a minimum width of 18 inches (or 12" if allowed by the municipality) with the number and locations designed so that runoff is dispersed throughout the bioretention area or through the use of a flow spreading system.
 - Bubble-up emitters and pipes to bubble-up emitters should have weep holes to avoid standing water inside after storm events.



Figure 6-21: Tree well filter with curb-cut inlet. This tree well filter also features an overflow bypass (Source: University of New Hampshire Environmental Research Group, 2006)

Vegetation

- Suitable tree species are identified in Appendix A planting guidance and general tree guidance is provided in Sections 4.1.3 and 5.7. Small-stature tree species are typically recommended for high flow rate tree well filters due to the small amount of soil volume available and the containerized system minimizing the connection to natural systems and stability. Larger-stature species can be used where increased soil volumes are provided.

- Use integrated pest management (IPM) principles in the landscape design to help avoid or minimize any use of synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction for any local policies regarding the use of pesticides and fertilizers.
- Irrigation should be provided, as needed, to maintain plant life. If irrigation cannot be provided, then watering by hand should be accommodated weekly through plant establishment – typically through the first six months depending on the season and levels of precipitation.
- Trees and vegetation do not block inflow, create traffic or safety issues, or obstruct utilities.

Soil and Drainage Requirements Specific to Tree Well Filters

- If the permeability of the media exceeds 5 inches per hour, use of the tree well filter is not considered LID and will not be allowed, except for Special Projects (see Appendix J).
- An underdrain system is required for tree well filters.

Soil and Drainage Considerations for All Biotreatment Systems

- Consideration of groundwater level and placement of the underdrain:
 - If there is less than a 5-foot separation between the bottom of the facility and the seasonal high groundwater level, or infiltration is not allowed due to other site constraints, an impermeable liner should be placed between the Class 2 Perm and the bottom of the facility and the underdrain placed on top of that liner.
 - If there is at least a 5-foot separation between the bottom of the facility and the seasonal high groundwater level, and geotechnical conditions allow infiltration, the facility should be unlined and the underdrain should be raised at least 6 inches above the bottom of the Class 2 Perm to allow storage and infiltration of treated water.
- To avoid excess hydraulic pressure on subsurface treatment system structures:
 - The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the structure.
- A geotechnical engineer should be consulted for situations where the bottom of the structure is less than 5 feet from the seasonal high groundwater level.
- Soil used in the tree well filter must meet the BASMAA biotreatment soil media (BSM) specification included in Appendix K if the project is a Regulated Project. Check with municipality for any additional requirements.
- An underdrain system is required where infiltration is not feasible or where it's limited.
- Filter fabric should not be used around the underdrain or between the BSM and the Class 2 Perm layer. Class 2 Perm performs the function of filter fabric (keeping the BSM from exiting the system through the underdrain) but is less prone to clogging.
- Install and maintain a 3-inch layer of composted arbor mulch (also called “aged mulch”) in areas between plantings. Rock mulches such as river cobble or pea gravel, or other mulches that resist floating may be used, but large rock mulch, such as cobble, should be used sparingly and only where absolutely necessary. Dyed, “micro-bark”, or “gorilla hair” mulches, as well as chipped wood mulch from recycled pallets and dimensional lumber, are not recommended. **See Sections 4.9 and 6.3 of the GI Design Guide** for more information on mulch.

- The underdrain should consist of a solid perforated or slotted HDPE or PVC pipe connected to a cleanout pipe(s) and to a storm drain or discharge point. Solid HDPE or triple-walled HDPE pipe, with smooth inner and outer layers and a corrugated middle layer, are recommended. The cleanout should consist of a vertical, rigid, non-perforated, non-corrugated PVC or HDPE pipe, with a minimum diameter of 4 inches and a watertight cap fit, raised or flush with the ground, or as required by municipality. There should be adequate fall (min. 0.5% slope) from the underdrain to the storm drain or discharge point. See Section 5.14 for more information on underdrains.
- The underdrain should be placed at the bottom of a 12-inch thick layer of Caltrans Class 2 permeable material, or similar municipality-approved material. See Section 5.14 for more information on Class 2 permeable material.

Construction and Maintenance Plans

Construction Requirements for All Biotreatment Systems

- Minimize compaction of existing soils if the system will be infiltrating water. Protect BSM and whole system from construction traffic and compaction.
- Protect the area from construction site runoff. Runoff from unstabilized areas should be diverted away from biotreatment facility.
- ***For additional construction guidelines, see Chapters 2, 4 and 5 of the GI Design Guide.*** Specifically, see **Sections 4.3 through 4.9** for construction strategies for dealing with slopes, overflows, poor soils, utilities, runoff capture, etc.

Remember

Maintenance Considerations for All Treatment Measures

- See Chapter 8 for specific maintenance guidance. Specifically, see Section 8.3.3 for maintenance concerns specific to tree well filters.
- A Maintenance Agreement should be provided and should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement. Maintenance plan templates are in Appendix G.

Typical Design Details

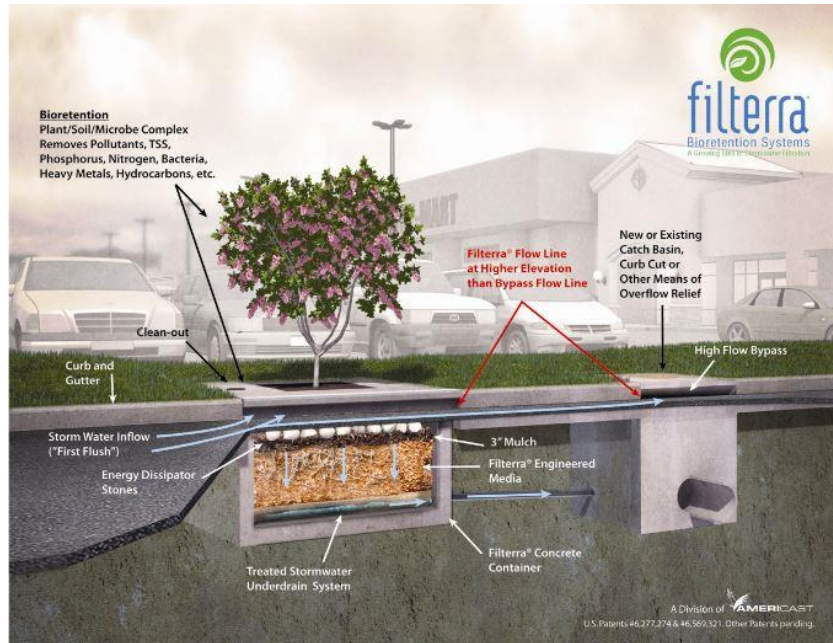


Figure 6-22: Cut Away View of a high-flow rate tree well filter- the use of this photo is for general information only and is not an endorsement of this or any other high flow rate stormwater treatment device. (Source: Contech Engineered Solutions, 2019).

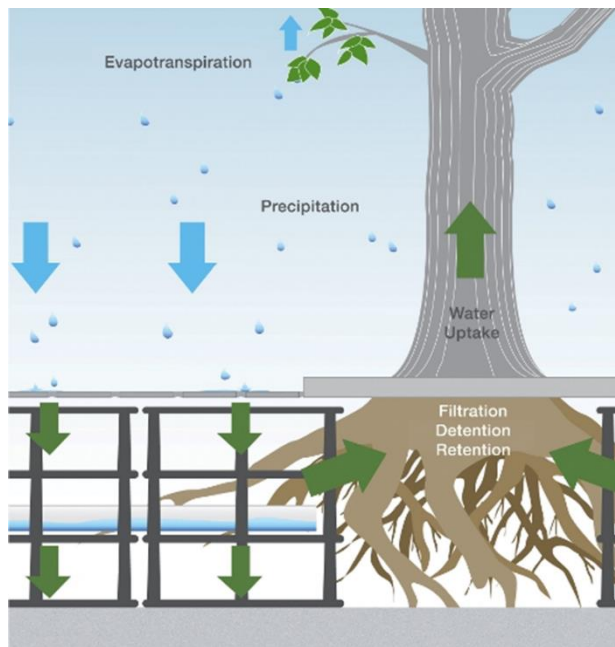


Figure 6-23: Schematic of modular suspended pavement system and a tree well filter. (Courtesy of: Deeproot Green Infrastructure, LLC).

6.3 Tree Well Filter

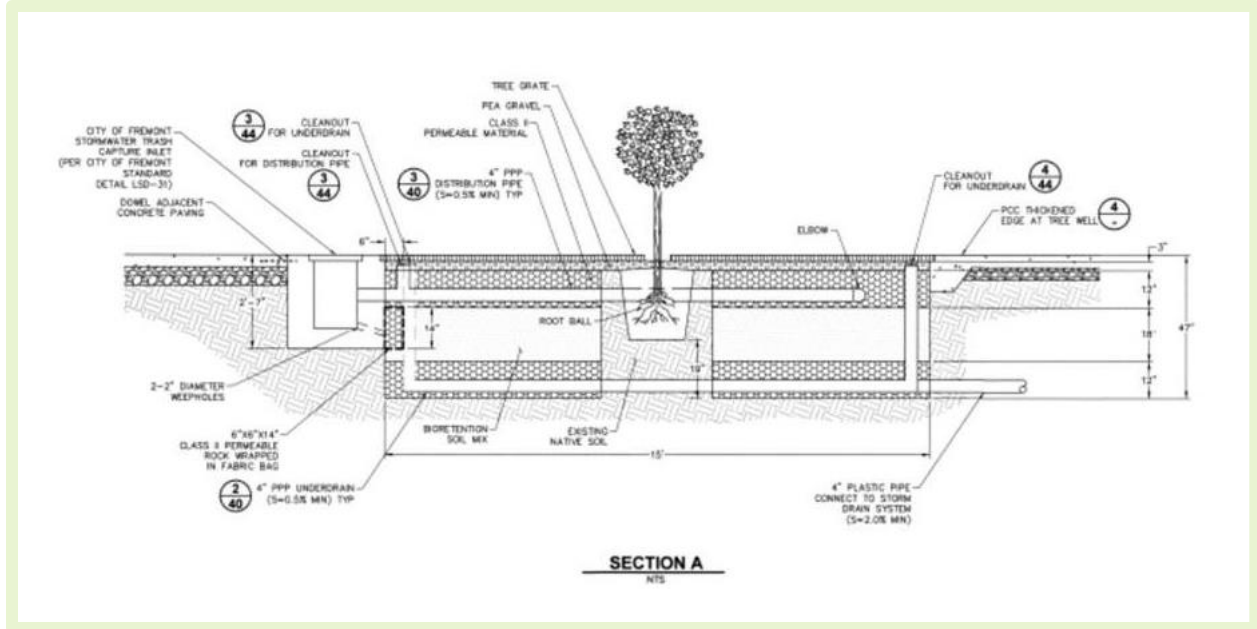


Figure 6-24: Cross Section Detail of a tree well filter with an integrated trash capture device (Credit: City of Fremont)

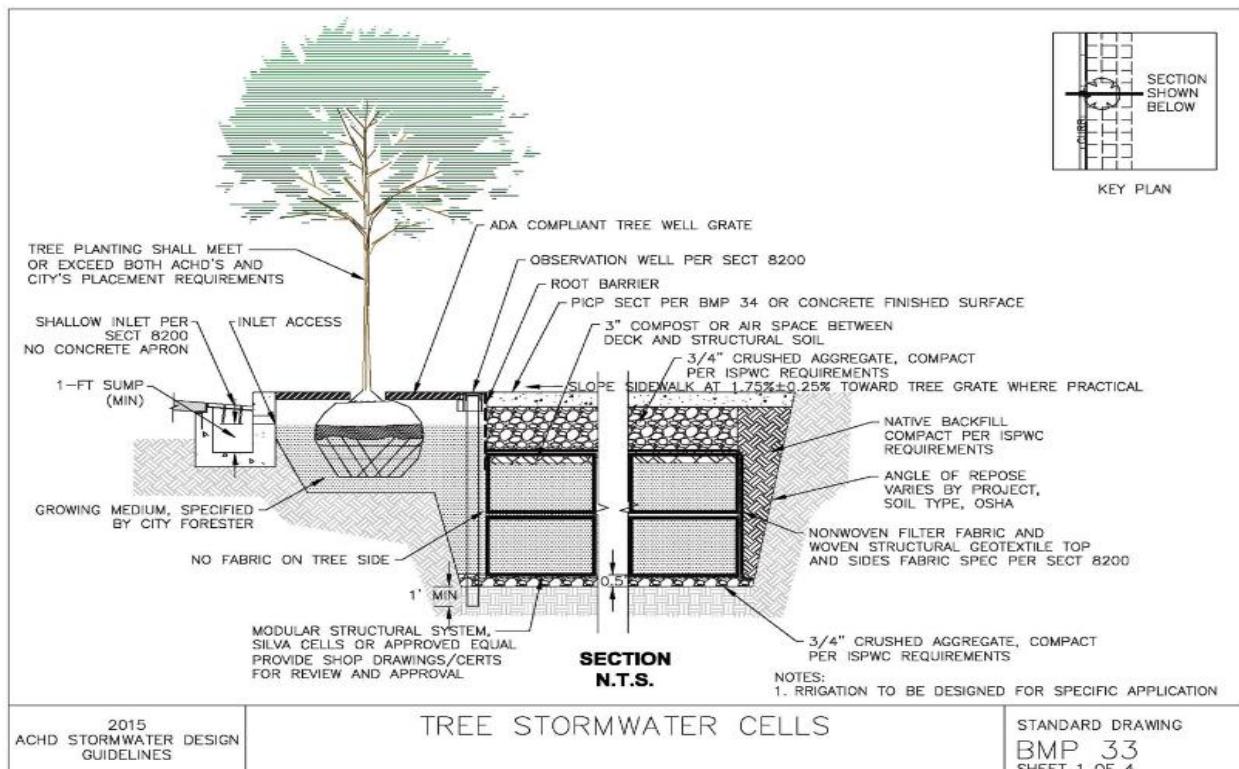


Figure 6-25: Cross Section Detail of a tree well filter with suspended pavement system installed under sidewalk (Credit: Ada County Highway District Stormwater Design Guidelines)

6.3 Tree Well Filter

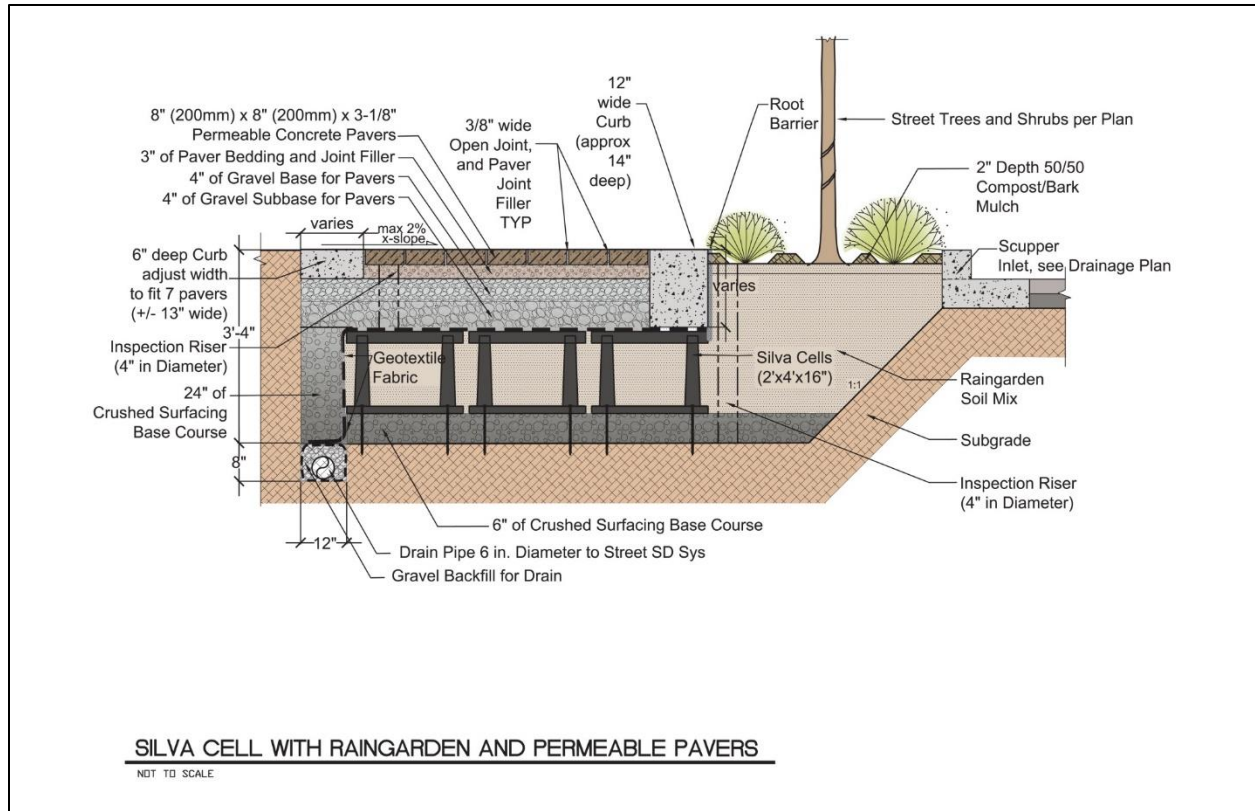


Figure 6-26: Cross Section detail of a tree well filter with Silva Cells under pervious pavement
 (Courtesy of: DeepRoot Green Infrastructure, www.deeproot.com)

6.4 Infiltration Trench

Overview

Description

Infiltration trenches are appropriate in areas with well-drained (Type A or B) native soils. An infiltration trench is a long, narrow excavation backfilled with stone aggregate and lined with filter fabric. Runoff is stored in the void space between the stones and infiltrates through the bottom and into the soil matrix.



Figure 6-27. Infiltration Trench (Source: CASQA, 2003)

Note that this section primarily applies to shallow infiltration systems (that are wider than they are deep); for systems that are deeper than they are wide (such as infiltration wells) and subsurface infiltration systems, additional requirements may apply (see Section 6.11). For both shallow and deep system guidance on infiltration, refer to Appendix E.

Infiltration trenches perform well for removal of fine sediment and associated pollutants. Pretreatment using swales, vegetated filter strips or detention basins is important for limiting amounts of coarse sediment entering the trench, which can clog and render the trench ineffective. Infiltration practices, such as infiltration trenches, remove suspended solids, particulate pollutants, coliform bacteria, organics, and some soluble forms of metals and nutrients from stormwater runoff. Pollutants are filtered out of the runoff as it infiltrates the surrounding soils. Infiltration trenches can also provide groundwater recharge and preserve base flow in nearby streams.

Best uses

- Limited space
- Adjacent to paved surfaces
- Landscape buffers

Advantages

- May increase groundwater recharge
- Achieves treatment via infiltration into existing soils
- No surface outfalls

Limitations

- Susceptible to clogging if not maintained
 - leading to system failure
- Infiltration of soils must exceed 0.5 in./hr.
- Cannot be used with certain site conditions (see Appendix E)

Siting

- Infiltration trenches should not be used where there are poorly draining soils, high groundwater tables, contaminated soils, fill soils, steep slopes, or in proximity to wells or septic systems.
- For strategies and examples of how to retrofit sites and parcels to include infiltration trenches, see **Sections 3.2 and 3.3 of the GI Design Guide**.
- Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. Infiltration trenches should not be located on inaccessible private property such as residential backyards.
- A permit may be required from San Mateo County Environmental Health if the system is more than 10 feet deep or if groundwater is encountered during excavation.³⁴

Table 6-6: Recommended locations for infiltration trenches

| Locations | Infiltration Trench |
|---------------------|---------------------|
| Parking Lot | ● |
| Roof | |
| Driveway | ● |
| Podium-level | |
| Close to building | |
| Away from Buildings | ● |
| Underground | 33 |

³³ Subsurface infiltration systems are covered in a separate section (see section 6.11)

³⁴ <https://www.smchealth.org/gpp>

Design and Sizing Guidelines

Drainage Area and Setback Considerations

- Infiltration trenches work best when the upgradient drainage area slope is less than 5 percent. The downgradient slope should be no greater than 20 percent to minimize slope failure and seepage.
- In-situ/undisturbed soils should have a low silt and clay content and have permeability greater than 0.5 inches per hour. In-situ testing is required to confirm permeability of trench site. Infiltration trenches are not recommended for use in Type C or D soils.
- A 10-foot separation between the bottom of the trench and the seasonal high groundwater level is required to prevent potential groundwater contamination.
- Trenches should also be located at least 100 feet upgradient from water supply wells.
- A setback of 18 feet from building foundations is recommended, or a 1:1 slope from the bottom of the foundation, unless a smaller setback is approved by geotechnical engineer and allowed by local standard.

Treatment Dimensions and Sizing

- The infiltration trench should be sized to store and infiltrate the water quality design volume.
- A site-specific trench depth can be calculated based on the soil permeability, aggregate void space, and the trench storage time. The stone aggregate used in the trench is normally 1.5 to 2.5 inches in diameter, which provides a void space of 35 to 40 percent. A minimum drain time of 6 hours should be provided to ensure satisfactory pollutant removal in the infiltration trench, and a maximum of 48-72 hours drain time is required to ensure capacity for runoff from successive storm events. Trench depths are usually between 3 and 8 feet, with a depth of 8 feet most commonly used.
- The trench surface may consist of stone or pervious pavement with inlets to evenly distribute the runoff entering the trench. The basic infiltration trench design utilizes stone aggregate in the top of the trench to promote filtration; however, this design can be modified by substituting pea gravel for stone aggregate in the top 1-foot of the trench. Typically, there is about 35 to 40% void space within the rock.
- Use trench rock that is 1.5 to 2.5 inches in diameter or pea gravel to improve sediment filtering and maximize the pollutant removal in the top 1 foot of the trench.
- Place permeable filter fabric around the walls and bottom of the trench and 1 foot below the trench surface. The filter fabric should overlap each side of the trench in order to cover the top of the stone aggregate layer. The filter fabric prevents sediment in the runoff and soil particles from the sides of the trench from clogging the aggregate.
- An observation well is recommended to monitor water levels in the trench. The well can be 4 to 6-inch diameter PVC pipe, which is anchored vertically to a foot plate at the bottom of the trench.

Inlet to the Treatment Measure

- Ideally runoff should enter the trench via sheet flow from the paved surface - spreading the flow. Runoff can be captured by depressing the trench surface or by placing a berm at the down gradient side of the trench. Underground inlets can also be used, but care must be taken to pretreat inflows to remove sediment to reduce the risk of clogging.
- To prevent clogging of the system with sediment, a vegetated buffer strip at least 5 feet wide, or other means of pretreatment, should be located adjacent to the infiltration trench to capture sediment particles in the runoff before runoff enters the trench. If a buffer strip or swale is used, installation should occur immediately after trench construction, using sod instead of hydroseeding to prevent erosion. The buffer strip should be graded with a slope between 0.5 and 1.5 percent so that runoff enters the trench as sheet flow.
- If runoff is piped or channeled to the trench, a level spreader should be installed to create sheet flow.

Vegetation

- Infiltration trenches should be kept free of vegetation. If vegetation on the surface is desired, a different treatment measure (e.g., linear bioretention area) should be selected.
- To avoid accumulation of leaves and other debris that can lead to sediment production and clogging, trees and other large vegetation should be planted away from trenches such that drip lines do not overhang infiltration beds.

Construction and Maintenance Plans

Construction Requirements

- If the area tributary to the infiltration trench contains disturbed soil or stockpiles, it must be fully developed, stabilized and protected from erosion with vegetation, temporary pavement, liners or rock mulch before constructing the infiltration trench. High sediment loads from unstabilized or protected areas will quickly clog the infiltration trench. During project construction, runoff from unstabilized or protected areas should be diverted away from the infiltration trench into a sedimentation control BMP until the final tributary area landscaping or other non-erosive surface is established.
- When excavating, avoid spreading fines of the soils on bottom and sides. Remove any smeared soiled surfaces and provide a natural soil interface into which water may percolate.
- Minimize compaction of existing soils. Protect from construction traffic.
- ***For additional construction guidelines, see Chapter 4 of the GI Design Guide.*** Specifically, see Sections 4.3 through 4.9 of the GI Design Guide for construction strategies for dealing with slopes, overflows, poor soils, utilities, runoff capture, etc.

Remember

Maintenance Considerations for All Treatment Measures

- See Chapter 8 for specific maintenance guidance. Specifically, see Section 8.3.4 for maintenance concerns specific to infiltration trenches.
- A Maintenance Agreement should be provided and should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement. Maintenance plan templates are in Appendix G.

Typical Design Details

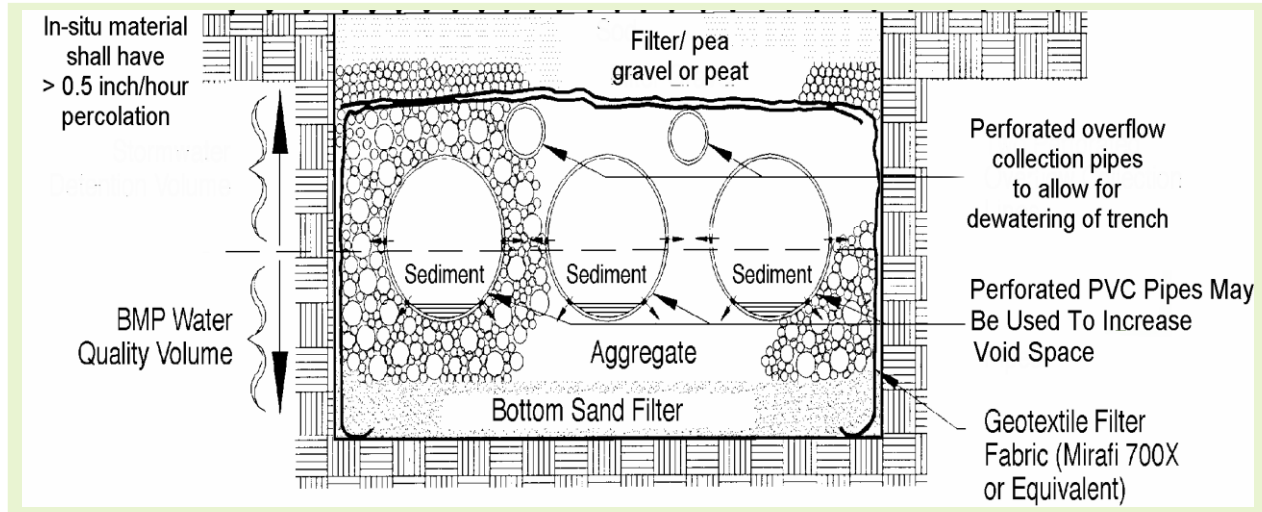


Figure 6-28: Infiltration trench cut-away view

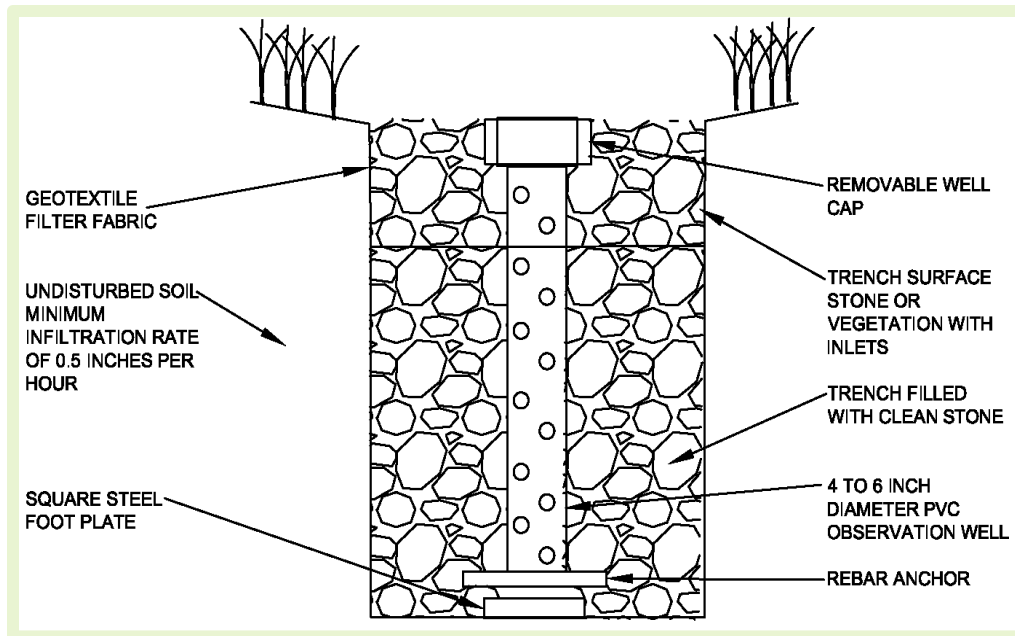


Figure 6-29: Cutaway view: Infiltration Trench with Observation Well

6.5 Extended Detention Basin

Overview

Description

Extended detention ponds (a.k.a. dry ponds, dry extended detention basins, detention ponds) are basins whose outlets have been designed to detain the stormwater runoff from a water quality design storm for some minimum time (e.g., 48 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a permanent pool. They can also be used to provide flood control by including additional flood detention storage above the treatment storage area.



Figure 6-30: Extended Detention Basin. (Courtesy of DES Architects and Engineers)

As of December 1, 2011, projects can no longer meet stormwater treatment requirements with stand-alone extended detention basins that are designed to treat stormwater through the settling of pollutants and gradual release of detained stormwater through an orifice. However, this type of extended detention basin could be used as part of a treatment train, in which the basin stores a large volume of water, which is gradually released to a bioretention area that meets the new MRP requirements for biotreatment soil media and surface loading area. Detention basins can also be used for hydromodification management.

Best uses

- Detain low flows
- Can be expanded to detain peak flows
- Sedimentation of suspended solids
- Pre-treatment

Advantages

- Easy to operate
- Inexpensive to construct
- Treatment of particulates
- Low maintenance

Limitations

- Storage area available
- Moderate pollutant removal
- Not considered LID treatment

Siting

Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections.

Table 6-7: Recommended locations for extended detention basins areas

| Recommended Locations | Extended Detention Basin |
|-----------------------|--------------------------|
| Parking Lot | |
| Roof | |
| Driveway | |
| Podium-level | |
| Close to building | |
| Away from Buildings | ● |
| Underground | |

Design and Sizing Guidelines

Treatment Dimensions and Sizing

- Extended detention basins should be sized to capture the required water quality volume and store and release it over a 48-hour period. At least 10 percent additional storage should be provided to account for storage lost to deposited sediment.
- Extended detention basins should have no greater than 3:1 side slope.
- The optimal basin depth is between 2 and 5 feet.
- A safety bench should be added to the perimeter of the basin wall for maintenance when basin is full.
- Extended detention basin should empty within five days to avoid vector generation.
- A 12-foot wide maintenance ramp leading to the bottom of the basin and a 12-foot wide perimeter access road should be provided. If not paved, the ramp should have a maximum slope of 5 percent. If paved, the ramp may slope 12 percent.
- The extended detention basin should have a length to width ratio of at least 1.5:1.
- A fixed vertical sediment depth marker should be installed in the sedimentation forebay. The depth marker should have a marking showing the depth where sediment removal is required. The marking should be at a depth where the remaining storage equals the design water quality volume.
- Extended detention basins are not designed to infiltrate the entire volume of water captured, but they may infiltrate some water if conditions allow.
- For sizing information relative to hydromodification management, refer to Chapter 7.

Inlets to Treatment Measure

- The inlet pipe should have at least 1 foot of clearance to the basin bottom.
- Piping into the extended detention basin should have erosion protection. As a minimum, a forebay with a 6-inch thick layer of Caltrans Section 72, Class 2 rock slope protection should be placed at and below the inlet to the extent necessary for erosion protection.
- Check with municipality regarding trash screen requirements. Trash screen installation may be required upstream of the pipe conveying water into the pond, in order to capture litter and trash in a central location where it can be kept out of the pond until it is removed.

Outlets and Orifices

- The outlet should be sized with a drawdown time of 48 hours for the design water quality volume. The outlet should have two orifices at the same elevation sized using the following equation:

$$a = (7 \times 10^{-5}) * A * (H - H_o)^5 / CT$$

Where:

a = area of each orifice in square feet

A = surface area of basin at mid-treatment storage elevation (square feet)

H = elevation of basin when filled by water treatment volume (feet)

H_o = final elevation of basin when empty (bottom of lowest orifice) (feet)

C = orifice coefficient (0.6 typical for drilled orifice)

T = drawdown time of full basin (hours)

(Caltrans Method, Appendix B, Stormwater Quality Handbook, September 2002)

- The orifices should each be a minimum diameter of 1 inch. Extended detention basins are not practical for small drainage areas because the minimum orifice diameter cannot be met.
- Each orifice should be protected from clogging using a screen with a minimum surface area of 50 times the surface area of the openings to a height of at least 6 times the diameter. The screen should protect the orifice openings from runoff on all exposed sides.
- For each outlet, documentation should be provided regarding adequacy of outlet protection. A larger stone size may be necessary depending on the slope and the diameter of the outfall.

Vegetation

- Plant species should be adapted to periods of inundation. See planting guidance in Appendix A.
- Use integrated pest management (IPM) principles in the landscape design to help avoid or minimize any use of synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction for any local policies regarding the use of pesticides and fertilizers.
- Irrigation should be provided as needed to maintain plant life.
- If vegetation is not established by October 1st, sod should be placed over loose soils. Above the area of inundation, a 1-year biodegradable loose weave geofabric may be used in place of sod.

Groundwater Separation Considerations

- Consideration of groundwater level:
 - If there is less than a 5-foot separation between the bottom of the facility and the seasonal high groundwater level, or infiltration is not allowed due to other site constraints, an impermeable liner should be placed at the bottom of the facility.
 - If there is at least a 5-foot separation between the bottom of the facility and the seasonal high groundwater level, and geotechnical conditions allow infiltration, the facility may be unlined.

Construction and Maintenance Plans

Construction Considerations

- The GI Design Guide does not cover extended detention basins. However, some construction guidelines developed for other infiltration measures might apply to detention basins.
- ***For general construction guidelines, see Chapter 4 the GI Design Guide.*** Specifically, see Sections 4.3 through 4.9 of the GI Design Guide for construction strategies for dealing with slopes, overflows, poor soils, utilities, runoff capture, etc.

Remember

Maintenance Considerations for All Treatment Measures

- See Chapter 8 for specific maintenance guidance. Specifically, see Section 8.3.5 for maintenance concerns specific to detention basins.
- A Maintenance Agreement should be provided and should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement. Maintenance plan templates are in Appendix G.

Typical Design Details

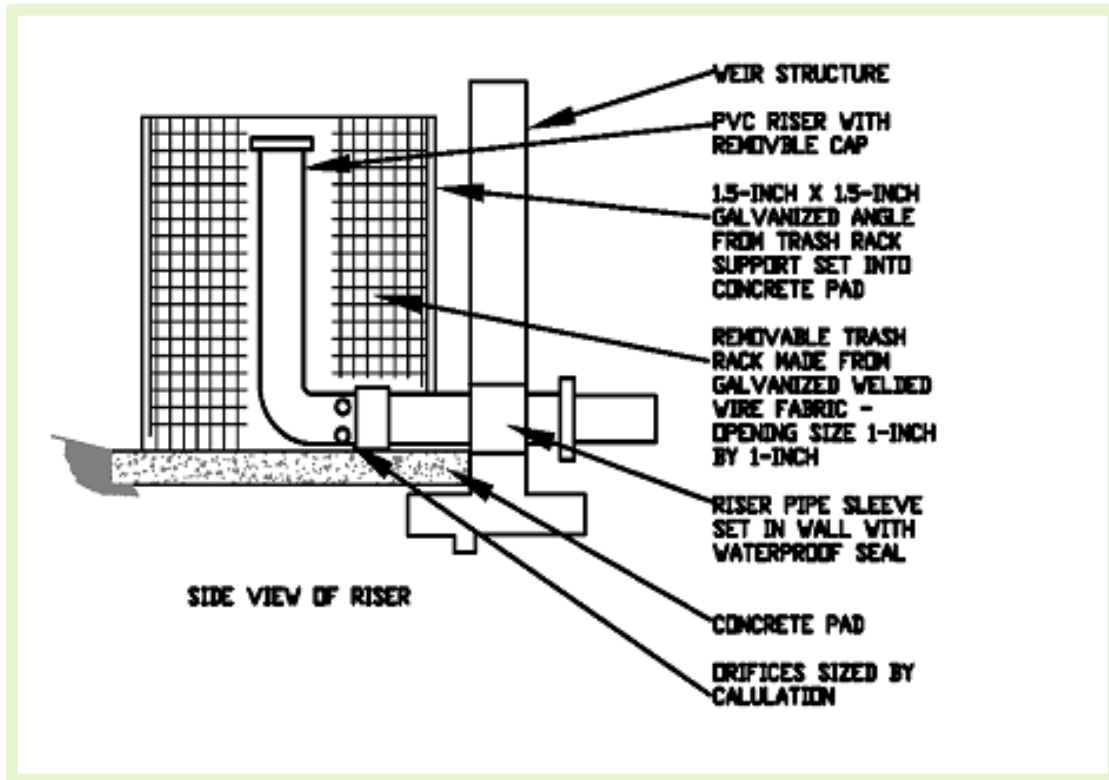


Figure 6-31. Side View of Riser

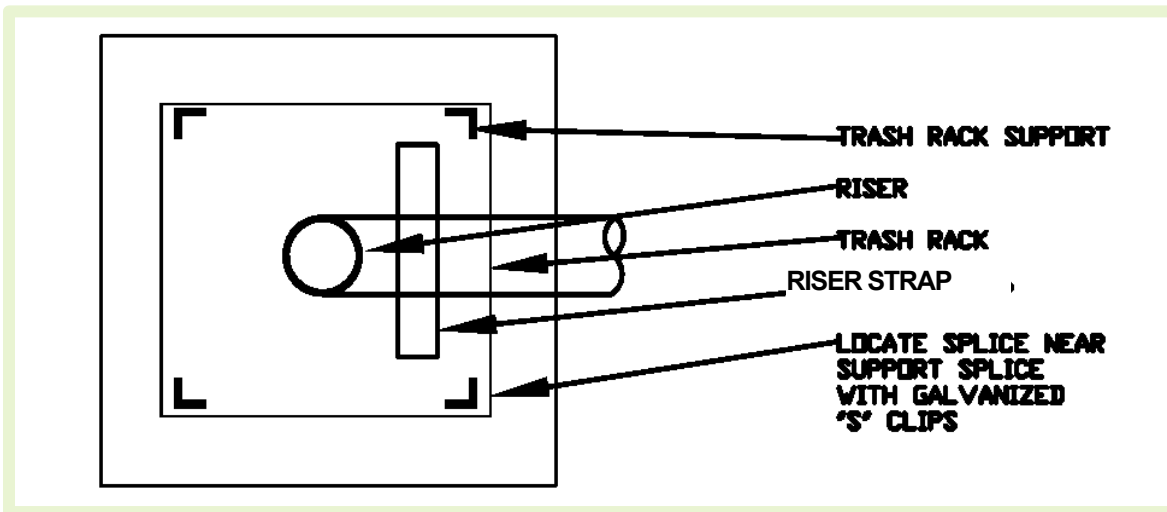


Figure 6-32. Top View of Riser (Square Design)

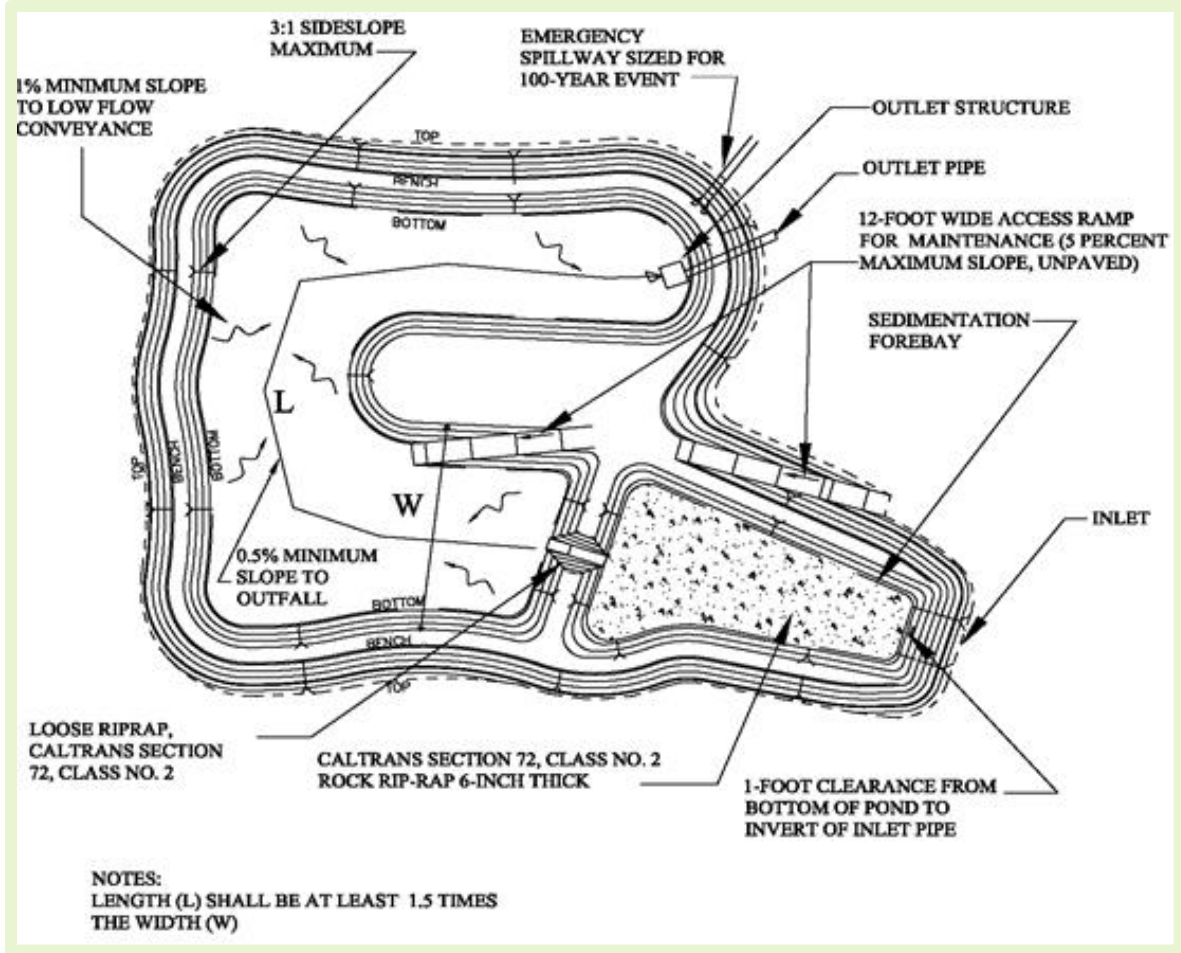


Figure 6-33. Plan View, Typical Extended Detention Basin

6.6 Pervious Pavement

Overview

Description



Figure 6-34: The City of Menlo Park used pervious concrete for parking stalls and standard paving in the drive aisles in this public parking lot. (Credit: City of Menlo Park)

Pervious pavement types include pervious concrete, porous asphalt, permeable pavers and pervious pavers. Pervious pavers allow infiltration through the paver while permeable pavers utilize the joint space between the pavers for infiltration. Except for permeable pavers, pervious pavement is generally used for areas with light vehicle loading, such as vehicle parking stalls and drive aisles, parking lanes on streets, access/maintenance roads, overflow parking lots, sidewalks, pedestrian plazas, cycling facilities and walking paths. Table 6-9 shows possible applications for different types of pervious pavement. Figures 6-35 through 6-40 provide more detailed design information as well as in the GI Design Guide. The term pervious pavement describes a system comprised of a load-bearing, durable surface constructed over a subbase of various layers of compacted, open-graded aggregates. The layers temporarily store water prior to infiltration or drainage to a controlled outlet. The surface must be porous and allow water to infiltrate through the material, or into the joints. ***If an area of pervious pavement is underlain with pervious storage material, such as a layer of aggregate sufficient to hold at least the C.3.d amount of runoff, and allows for infiltration into native soil, it is not considered an impervious surface and can function as a self-treating or self-retaining area, as described in Section 4.2.*** Note that this applies to projects that use pervious pavement to reduce the impervious surface area to below the C.3 Regulated Projects threshold. ***Pervious pavement treatment systems must include infiltration into native soil to be considered LID.***

Please note that the CALGreen Building Code does not define pervious pavement in the same way as the MRP. Projects that include pervious pavement per CALGreen requirements must also verify that the pervious pavement meets the MRP definition of pervious pavement.

Best uses

- Light traffic roads and alleys, parking lots, driveways, bike lanes, sidewalks, and plazas
- Where space is limited for Biotreatment

Advantages

- Flow/volume reduction
- Provides treatment via infiltration into soil
- Reduces need for other treatment measures

Limitations

- May clog without periodic cleaning
- Higher installation costs than conventional pavement

The Countywide Program gratefully acknowledges the contributions of Mr. David Smith, Technical Director of the Interlocking Concrete Pavement Institute, to this section of the Guide, including pavement sections, design details, and specifications.

Siting

For strategies and examples of how to retrofit streets and sites to include pervious pavement, *see Sections 3.2 and 3.3 of the GI Design Guide.*

Contrary to most other treatment measures, small areas of pervious pavement do not need as much maintenance so they can be located in remote sections of private property such as backyards and pathways. However, if the areas total 3,000 sq. ft. or more, they are considered regulated treatment systems (meaning they require an O&M agreement) and require municipal inspection at least once every five years. Therefore, they should only be constructed in front yards, driveways, parking lots and other areas visible from the public right of way so that municipal inspectors can see and verify the existence of the systems.

Table 6-8: Recommended locations for pervious pavement areas

| Recommended Locations | Pervious Pavement |
|-----------------------|-------------------|
| Parking Lot | ● |
| Roof | |
| Driveway | ● |
| Podium-level | |
| Close to building | |
| Away from Buildings | ● |
| Underground | |

Table 6-9: Types of Pervious Pavement and Possible Applications

| Paver Type | Description | Possible Applications |
|--|--|---|
| Porous Asphalt | Open-graded asphalt concrete over an open-graded aggregate base, over a draining soil. Contains very little fine aggregate (dust or sand) and is comprised almost entirely of stone aggregate and asphalt binder; surface void content of 12-20%. | Low traffic use, such as parking lots, travel lanes, parking stalls. Surface may be too rough for some applications. |
| Pervious Concrete | Typically a cast-in-place discontinuous mixture of coarse aggregate, hydraulic cement and other cementitious materials, admixtures, and water which have a surface void content of 15-25% allowing water to pass through. Also available in pre-cast units of variable sizes. | Sidewalks and patios; low traffic volume; low speed (less than 30 mph limit) and lighter load roadways; bikeways; parking stalls; gutters; and residential driveways. |
| Permeable Pavers | Discrete units set in a pattern on a prepared base. Typically made of precast concrete in shapes that form interlocking patterns. Solid unit pavers are made of impermeable materials but are spaced to expose a permeable joint filled with permeable aggregates and set on a permeable base. | All uses: parking lanes, stalls and lots, private driveways, bikeways, walkways, patios, alleys, public and private roadways. |
| Pervious Pavers | Discrete units set in a pattern on a prepared base. Constructed of permeable concrete to allow water to flow through the paver. Can be set adjacent to other pavers with no joint space required. | Lighter traffic areas such as walkways, bikeways and vehicle parking areas. |
| For more information on the use of pervious pavement in roadway projects, see Section 2.6 of the GI Design Guide. | | |

Design and Sizing Guidelines

The design of each layer of the pavement must be determined by the likely traffic loadings and the layer's required operational life. The thickness of the base layer is also affected by hydrologic sizing considerations. To provide satisfactory performance, the following criteria should be considered.

Subgrade and Site Requirements

- The soil sub-grade should be able to sustain anticipated traffic loading without excessive deformation while temporarily saturated.
- The sub-grade should be either ungraded in-situ material with a permeability that allows detained flows to infiltrate within 72 hours, or the pavement system can be installed with an underdrain that will remove detained flows within the pervious pavement and base.
- Depth to seasonal high groundwater level should be at least 5 feet from the bottom of the base of the pervious pavement system, unless a different separation is recommended by the geotechnical engineer.
- Pervious pavement systems should not be used where site conditions do not allow infiltration. Grading of the soil subgrade below the pervious pavement should be relatively flat (not to exceed 2% slope) to promote infiltration across the entire area.
- A slope of 1% is recommended for pervious pavement surfaces. Slopes of subgrades for pervious pavement should not exceed 5% but can be sloped up to 16%³⁵ when constructed with underdrains and check dams. Slopes of subgrades exceeding 3% typically require berms or check dams placed laterally over the soil subbase to slow the flow of water and provide some infiltration. Alternatively, pervious pavement systems can be terraced to step down a steep slope, maintaining level bed bottoms separated by berms. More details on subgrade slopes and check dams can be obtained by going to the Sustainable Street Typical GI Details in the GI Design Guide, or see Detail PC 2.2 in Figure 6-40 in the typical details section below.

Base Layer

- To allow for subsurface water storage, the base must be open graded, crushed stone (not pea gravel), meaning that the particles are of a limited size range, with no fines, so that small particles do not choke the voids between large particles.
- When subject to vehicular traffic, all open-graded aggregates should conform to the following or to similar specifications as directed by the municipality: crushed material, minimum 90% with at least 2 fractured faces conforming to Caltrans test method CT 205; have Los Angeles Rattler no greater than 40% loss at 500 revolutions per Caltrans test method CT 211; and a minimum Cleanness value of 75 per Caltrans test method CT 211. Sieve analysis should conform to Caltrans test method CT 202.
- If the subbase/base layer is sized to hold and infiltrate at least the C.3.d amount of runoff, the area of pervious pavement is not considered an impervious surface and can function as a self-treating area (see Section 4.2).

³⁵ <https://www.perviouspavement.org/design/hydrological.html>

- If the subbase/base layer has sufficient capacity in the void space to store the C.3.d amount of runoff (volume) for both the area of pervious pavement and the area that drains to it, it is not considered an impervious surface and can function as a self-retaining area, described in Section 4.2.
- Pervious pavement designed to function as a self-retaining area may accept runoff from an area of impervious surface that has a surface area of up to two times the surface area of the properly designed pervious pavement area.
- If an underdrain is used, position the perforated pipe within the subgrade enveloped on all sides by a least 4 inches of open-graded aggregate and provide a non-perforated, upturned elbow pipe for outflows (see Figures 6-26 and 6-27.) A cleanout with surface access is recommended at the upturn. To be considered a self-treating area or self-retaining area, the underdrain should be positioned above the portion of the base layer that is sized to meet the C.3.d sizing criteria.
- Design calculations for the base should quantify the following:
 - Soil type/classification and soil permeability rate; if subject to vehicular traffic, k-values (psi/cubic inch) or R-values characterizing soil strength when saturated;
 - Fill type if used, installation, and compaction methods plus target densities;
 - Lifetime expected vehicular traffic loading (in 18,000 lb. equivalent single axle loads or Caltrans Traffic Index); the maximum Traffic Index = 9.
 - Drainage routing of detained flows within the open graded subbase/base as well as expected infiltration into in-situ soils, or collection in a raised underdrain if the permeability cannot meet design criteria.

Pavement Materials

- The pavement materials should not crack or suffer excessive rutting under anticipated traffic loads. This is controlled by designing pervious concrete and porous asphalt surfacing materials and layer thicknesses that minimize the horizontal tensile stress at their base. All pervious pavements benefit from using open-graded aggregate base materials with sufficient thicknesses and compaction that spread and minimize applied vertical stresses from vehicles.
- Pervious concrete and porous asphalt materials require narrow aggregate grading to create open voids in their surfaces. Materials choice is therefore a balance between stiffness in the surface layer and permeability. Permeable pavers require similar types of aggregate (without cement or asphalt) placed in the joints, typically ASTM No. 8, 89, or 9 stone depending on the paver joint widths. Refer to industry association literature for grading recommendations for all surfaces.
- Permeable paver units should conform to the dimensional tolerances, compressive strengths and absorption requirements in ASTM C936. Paver units subject to vehicular traffic should be at least 3 1/8 in. thick and have a length to thickness ratio not exceeding 3.

Construction and Maintenance Plans

Design and Installation

- All designs should be reviewed and approved by a licensed civil or geotechnical engineer or as directed by the municipality.
- Design for pervious concrete should be reviewed by the concrete manufacturer or National Ready Mixed Concrete Association (NRMCA) (www.nrmca.org), or as directed, the municipality. Consult Portland Cement Association publication, *Hydrologic Design of Pervious Concrete* (2007) available from www.cement.org.
- Design for porous asphalt should be reviewed by the asphalt manufacturer, the National Asphalt Pavement Association (NAPA) (www.porousasphalt.net), or as directed by the municipality. Consult NAPA publication, *Porous Asphalt for Stormwater Management* (2008) for additional information on design, construction, and maintenance.
- Design for permeable pavers should be reviewed by the concrete paver manufacturer, the Interlocking Concrete Pavement Institute (ICPI) (www.icpi.org), or as directed by the municipality. Consult ICPI publication, *Permeable Interlocking Concrete Pavements* 4th Edition (2012) for additional information on design, construction and maintenance. www.icpi.org/node/2750
- Installation of pervious concrete, porous asphalt, pervious pavers and permeable pavers should be done by contractors who have constructed projects similar in size to that under consideration.
- For poured-in-place pervious concrete, only contractors with certification from NRMCA should be considered, and such contractors should have at least one foreman with this certification on the job site at all times. More information can be found at: www.concreteparking.org/pervious/index.html and www.bayareaperviousconcrete.com
- For permeable pavers, it is recommended that only contractors holding a record of completion in the Interlocking Concrete Pavement Institute's PICP Installer Technician Course should be considered and such contractors should have at least one foreman with this certificate on the job site at all times. More information can be found at www.icpi.org.
- All new pervious concrete and porous asphalt pavements should have a minimum surface permeability of 100 in./hr. when tested in accordance with ASTM C1701. Permeable pavers should have a minimum surface permeability of 100 in./hr. when tested in accordance with ASTM C1781. Test results using both methods are comparable.
- Protect excavated area from excessive compaction due to construction traffic and protect the finished pavement from construction traffic.
- Additional design resources can be found on: <https://dot.ca.gov/programs/design/hydraulics-stormwater>.
- **For additional construction guidelines, see Chapter 4 of the GI Design Guide.** See Section 4.10 of the GI Design Guide for construction strategies specific to pervious pavement.

Remember

Maintenance Considerations

- See Chapter 8 for specific maintenance guidance. Specifically, see Section 8.3.6 for maintenance concerns specific to pervious pavement.
- A Maintenance Agreement should be provided for Regulated Projects with installations totaling 3,000 square feet or more of pervious pavement.
- The Maintenance Agreement should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with the Maintenance Agreement. Maintenance plan templates are in Appendix G.

Typical Design Details

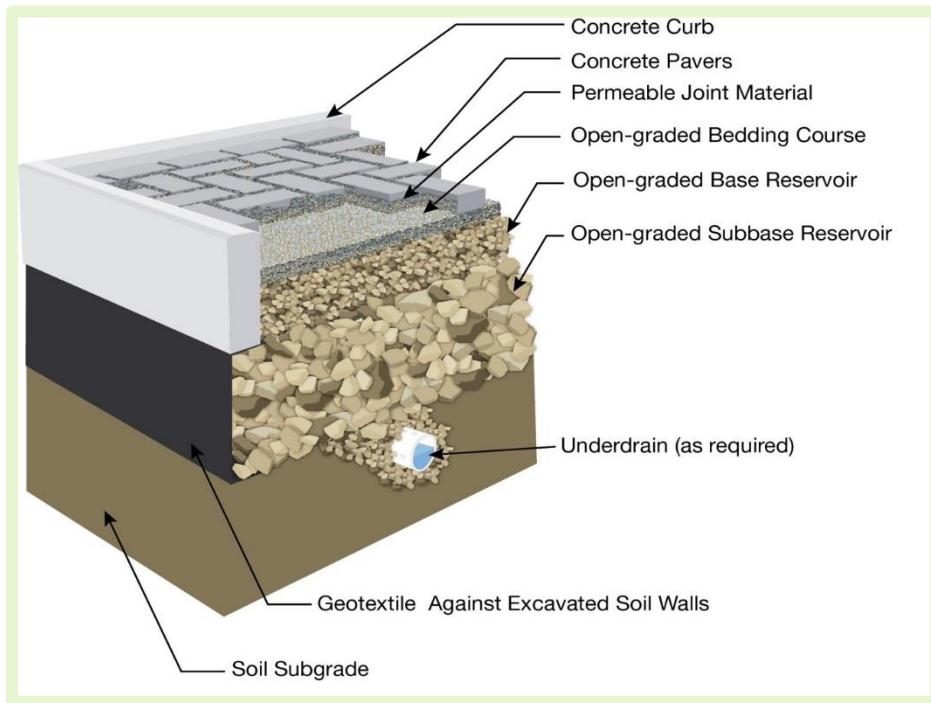


Figure 6-35. Permeable pavers designed for partial infiltration, with underdrain (Credit: Interlocking Concrete Pavement Institute)

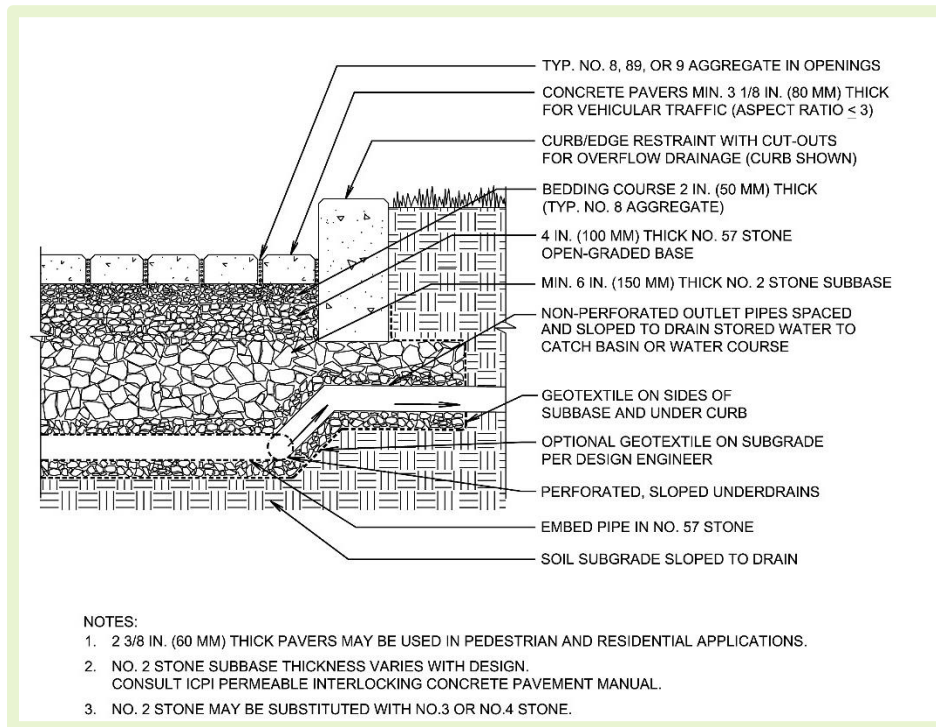


Figure 6-36. Permeable pavers with detail of underdrain in aggregate trench with upturned elbow (Credit: ICPI)

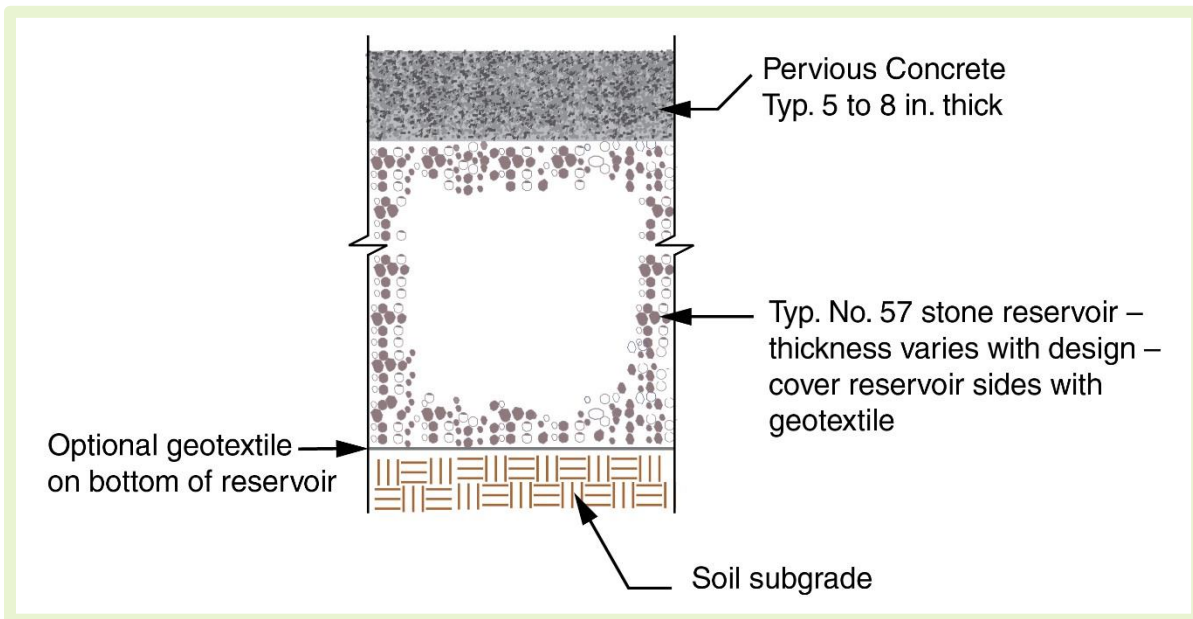


Figure 6-37. Typical Pervious Concrete Pavement (Credit: ICPI)

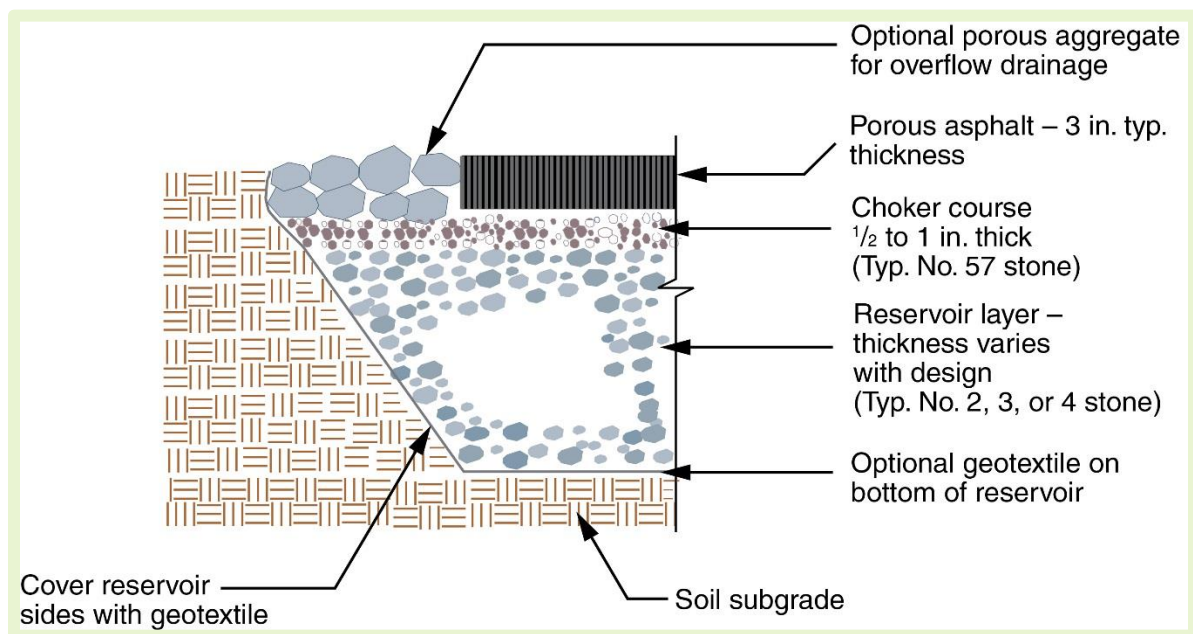


Figure 6-38. Typical Porous Asphalt Pavement Section (Credit: ICPI)

Note: ASTM No. 3 or 4 stone may be substituted for No. 2 stone.

6.6 Pervious Pavement

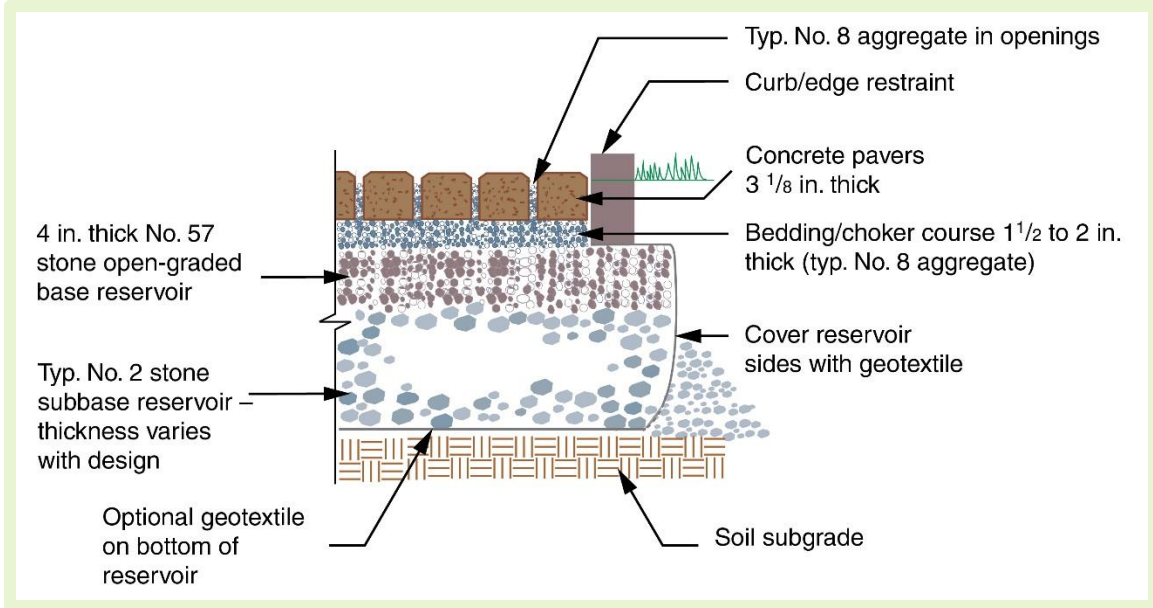


Figure 6-39. Typical Permeable Paver Section (Credit: ICPI)

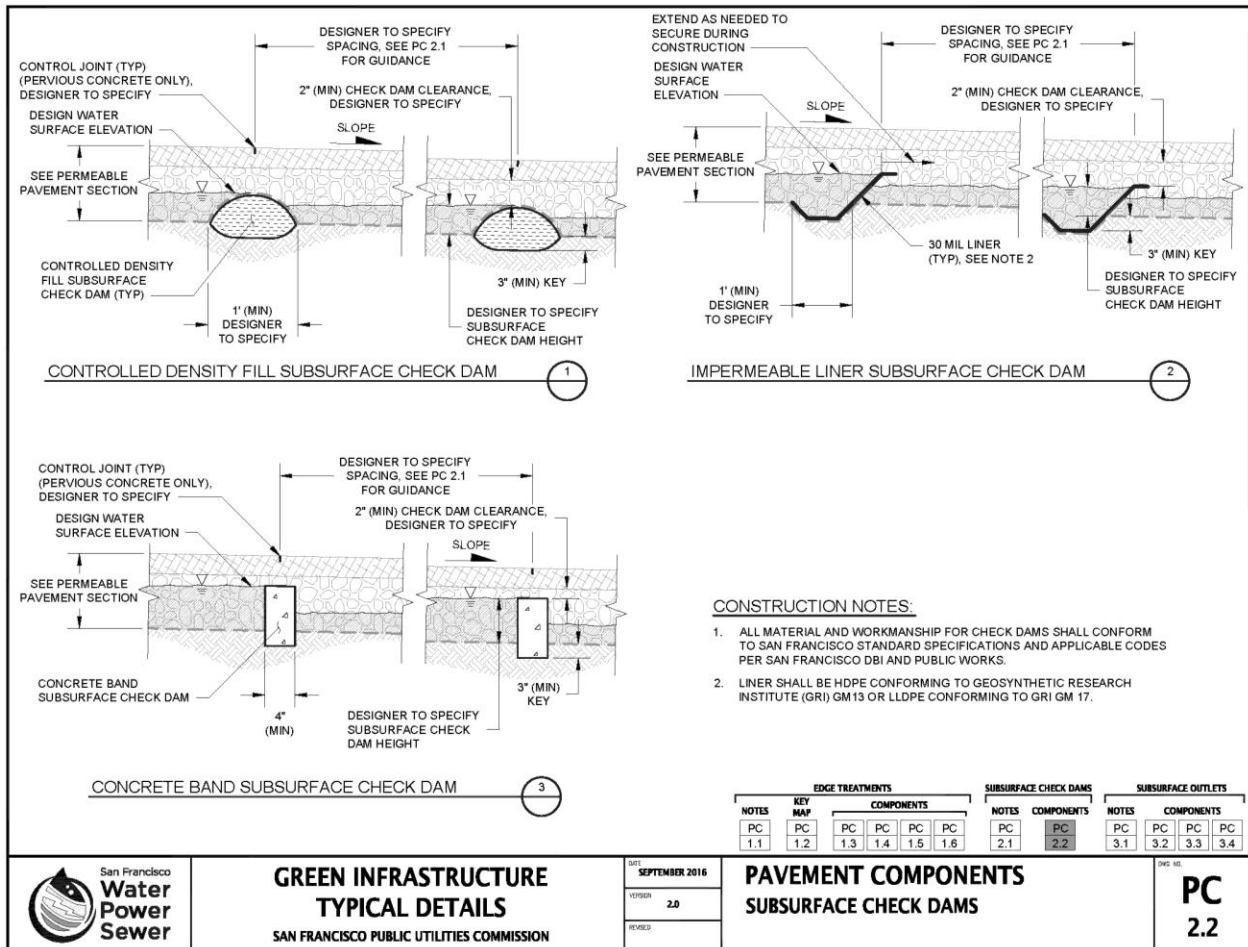


Figure 6-40. Subsurface Check Dam Details – PC 2.2 from the GI Design Guide (Credit: SMCWPPP Sustainable Streets Typical GI Details and SFPUC)

6.7 Reinforced Grid Paving

Overview

Description

Reinforced grid paving consists of concrete or plastic grids used in areas that receive occasional light traffic (i.e., < 7,500 lifetime 18,000-lb equivalent single axle loads or a Caltrans Traffic Index < 5), typically overflow parking or fire access lanes, when placed over compacted Caltrans Class 2 or Class 2 permeable base or similar materials. Class 2 permeable base should use an underdrain in silt and clay soils. The surfaces of these systems can include a layer of gravel as shown in Figure 6-41 below or be planted with topsoil and grass in their openings or installed over a bedding layer that rests over a compacted, dense-graded aggregate base (see Figure 6-42 and Figure 6-43). When planted with turf grass, they also assist in providing a cooler surface than conventional pavement. Some of these systems are also known as turf block or grasscrete. Reinforced grid paving can also be designed with aggregate in the openings.



Figure 6-41. Reinforced grid paving in an overflow parking lot in Napa. (Credit: EOA, Inc.)

Reinforced grid paving can be installed over open-graded aggregate bases for additional water storage, infiltration, and outflow via an underdrain in low permeability soils if needed. However, such designs should see limited automobile traffic and no truck traffic other than rarely occurring emergency vehicles. Reinforced grid pavings are not considered an impervious area and can function as “self-treating areas” when supported by an aggregate base sufficient to hold the C.3.d amount runoff. Reinforced grid pavings with dense-graded bases are not generally designed to accept runoff from adjacent areas.

Best uses

- Overflow parking areas
- Emergency access lanes
- Common areas
- Lawn/landscape buffers
- Pathways

Advantages

- Flow attenuation
- Removes fine particulates
- Reduces need for treatment

Limitations

- May clog without periodic cleaning
- May allow weed growth
- Lightly trafficked areas only
- Higher installation costs than conventional paving

The Countywide Program gratefully acknowledges the contributions of Mr. David Smith, Technical Director of the Interlocking Concrete Pavement Institute, to this section of the Guide, including pavement sections, design details, and specifications.

Siting

Contrary to most other treatment measures, small areas of reinforced grid paving do not need as much maintenance so they can be located in remote sections of private property such as backyards and pathways. However, if the areas total 3,000 sq. ft. or more, they are considered regulated treatment systems and they require an O&M agreement, with municipal inspections at least once every five years. Therefore, they should only be constructed in front yards, driveways, parking lots and other areas visible from the public right of way so that municipal inspectors can see and verify the existence of the systems.

Table 6-10: Recommended locations for reinforced grid paving

| Recommended Locations | Reinforced Grid Paving |
|-----------------------|------------------------|
| Parking Lot | ● |
| Roof | |
| Driveway | ● |
| Podium-level | |
| Close to building | |
| Away from Buildings | ● |
| Underground | |

Design and Sizing Guidelines

To provide satisfactory performance, the following criteria should be considered:

Subgrade and Site Requirements

- The soil subgrade should be able to sustain anticipated traffic loads without excessive deformation while temporarily saturated.
- The soil subgrade should have sufficient permeability to meet the requirements in this manual, or include an underdrain(s) to remove detained flows within the aggregate base. The surfacing and bedding materials are not used to store water.
- Depth to seasonal high groundwater level should be at least 5 feet from the bottom of the base of the reinforced grid paving system, unless a different separation is recommended by the geotechnical engineer.
- Reinforced grid paving systems should not be used where site conditions do not allow infiltration.
- Grading of the soil subgrade below the reinforced grid paving should be relatively flat to promote infiltration across the entire area or berms should be used. Underground slopes of reinforced grid paving should not exceed 5%. Slopes exceeding 3% typically require berms or check dams placed laterally over the soil subgrade to slow the flow of water and increase infiltration.
- A slope of 1% is recommended for the pavement surface.

Aggregates

- When subject to vehicular traffic, all dense-graded aggregate bases should conform to Caltrans Class 2 or similar specifications as directed by the municipality. All open-graded aggregates should be crushed material, minimum 50% with one or more fractured faces conforming to Caltrans test method CT 205; have Los Angeles Rattler no greater than 45% loss at 500 revolutions per Caltrans test method CT 211; and a minimum Cleanness value of 75 per Caltrans test method CT 211. Sieve analysis should conform to Caltrans test method CT 202.
- If the subbase/base layer is sized to hold at least the C.3.d amount of runoff, the area of reinforced grid paving is not considered an impervious surface and can function as a self-treating area as described in Section 4.1.
- If an underdrain is used, position the perforated pipe within the subgrade enveloped on all sides by at least 4 inches of open-graded aggregate and provide non-perforated, upturned elbow pipe for outflows. A cleanout with surface access is recommended at the upturn. To be considered a self-treating area or self-retaining area, the underdrain raised outlet should be positioned above the portion of the base layer that stores and infiltrates the C.3.d amount of rainfall onto the reinforced grid paving (and runoff from adjacent areas, if self-retaining).
- Design calculations for the base should describe and quantify the following:
 - Soil type/classification and soil permeability rate; for vehicular areas, k-values (psi/cubic inch) or R-values characterizing soil strength when saturated
 - Fill type if used, installation, and compaction methods plus target densities

- Lifetime expected traffic loading in 18,000 lb. equiv. single axle loads or Caltrans Traffic Index
- Drainage routing of detained flows within the aggregate base as well as expected infiltration into in-situ soils, or collection in underdrain if the permeability cannot meet design criteria

Reinforced Grid Paving Materials

- Concrete grids should conform to the dimensional tolerances, compressive strength, and absorption requirements in ASTM C1319 and should be a minimum of 3 1/8 in. thick.
- Aggregates used for bedding and filling the grid openings should be No. 8 stone or similar sized crushed materials.
- If topsoil and grass are used in the grids, they should be placed over a 1 in. thick layer of bedding sand and over Caltrans Class 2 base compacted to a minimum 95% standard Proctor density. Do not use topsoil, grass, sand bedding and geotextile over an open-graded aggregate base as the surface has a low permeability.
- Reinforced grid paving should have edge restraints to render them stationary when subject to pedestrian or vehicular traffic.

Construction and Maintenance Plans

Design and Installation Recommendations

- All designs should be reviewed and approved by a licensed civil or geotechnical engineer or as directed by the municipality.
- Design for plastic reinforced grid paving should be done per the manufacturer's recommendation. Such designs should be reviewed by the manufacturer or as directed by the municipality.
- Installation of reinforced grid paving should be done by contractors who have constructed projects similar in size to that under consideration.
- Protect excavated area from excessive compaction due to construction traffic and protect the finished pavement from construction traffic.
- ***For additional construction guidelines, see Chapter 4 of the GI Design Guide.*** Specifically, see Sections 4.3 through 4.9 of the GI Design Guide for construction strategies for dealing with slopes, overflows, poor soils, utilities, runoff capture, etc.

Remember

Maintenance Considerations

- See Chapter 8 for specific maintenance guidance. Specifically, see Section 8.3.6 for maintenance concerns specific to reinforced grid paving.
- A Maintenance Agreement should be provided for Regulated Projects with installations of 3,000 square feet or more of reinforced grid paving.
- The Maintenance Agreement should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with the Maintenance Agreement. Maintenance plan templates are in Appendix G.

Typical Design Details

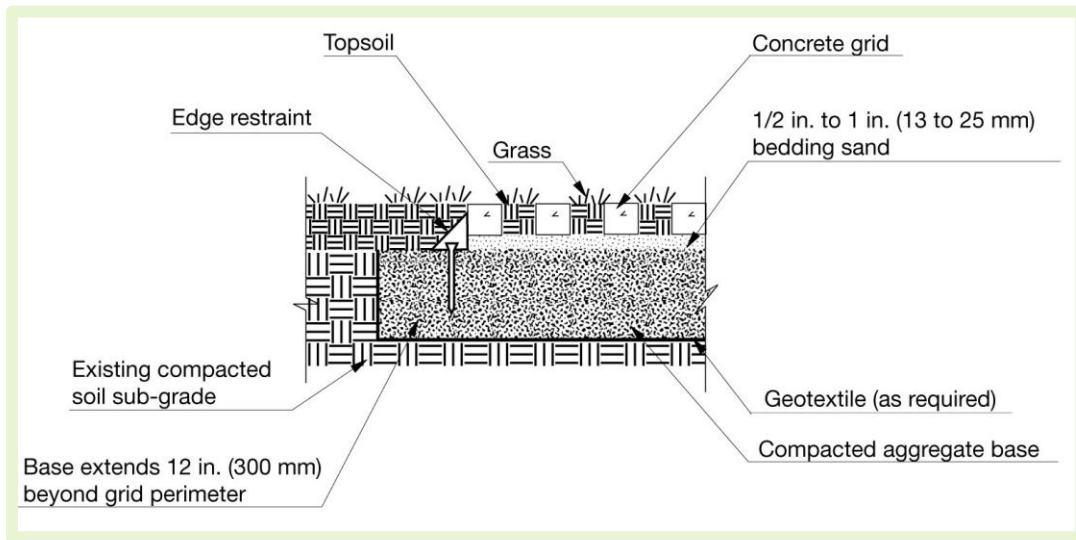


Figure 6-42: Concrete Reinforced Grid Paving for Occasional Vehicular Use or for Emergency Access Lanes. (Credit: Santa Clara Valley Urban Runoff Pollution Prevention Program)



Figure 6-43: Plastic Reinforced Grid Paving for Occasional Vehicular Use or for Emergency Access Lanes (Credit: Santa Clara Valley Urban Runoff Pollution Prevention Program). Note: Sand and turf grass can be replaced with ASTM No. 8 aggregate in cell openings.

6.8 Green Roof

Overview

Description



Figure 6-44: Parking Lot with Turf-Covered Intensive Green Roof, Google building, Mountain View; and Modular Extensive Green Roof installation, Emeryville. (Credit: EOA, Inc.)

A green roof can be either **extensive**, with 3 to 7 inches³⁶ of lightweight substrate and a few types of low-profile, low-maintenance plants, or **intensive** with a thicker (8 to 48 inches) substrate, more varied plantings, and a more garden-like appearance. The extensive installation at the Gap Headquarters in San Bruno (Figure 6-45) was installed in 1997. Green roofs provide energy savings, and native vegetation may be selected to provide habitat for endangered species of butterflies, as at the extensive green roof of the Academy of Sciences in San Francisco.

Best uses

- For innovative architecture
- Where limited space at grade is available

Advantages

- Minimizes roof runoff
- Reduces “heat island” effect
- Absorbs sound and saves energy
- Provides bird/insect habitat
- Longer “lifespan” than conventional roofs

Limitations

- Sloped roofs may require steps
- Non-traditional design
- Can increase structural costs

³⁶ www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/muni/mrp/05-02-2011/Green_Roof.pdf

Siting

- For strategies and examples of how to retrofit sites and parcels to include green roofs, *see Sections 3.2 and 3.3 of the GI Design Guide.*
- See www.greenroofs.com for information about and more examples of green roofs.
- Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections.
- Green roofs can be sited on podium levels, roof tops, garbage enclosures, parking garages, plazas over underground buildings etc. Example projects are shown in the pictures below.

Table 6-11: Recommended locations for green roofs

| Recommended Locations | Green Roof |
|-----------------------|------------|
| Parking Lot | |
| Roof | ● |
| Driveway | |
| Podium-level | ● |
| Close to building | |
| Away from Buildings | |
| Underground | |



Figure 6-45: Top: Extensive Green Roof at YouTube Headquarters, San Bruno (Courtesy of William McDonough & Partners); Bottom: Intensive Green Roof, Kaiser Center Parking Garage, Oakland. (Credit: Gene Anderson)

Design and Sizing Guidelines

Treatment Dimensions and Sizing

- Green roofs are considered “self-treating areas” or “self-retaining areas” and may drain directly to the storm drain, if they meet the following requirements specified in the MRP:
- The green roof system planting media should be sufficiently deep to provide capacity within the pore space of the media to capture 80 percent of the average annual runoff.
- Extensive green roof systems contain layers of protective materials to convey water away from roof deck. Starting from the bottom up, a waterproof membrane is installed, followed by a root barrier, a layer of insulation (optional), a drainage layer, a filter fabric for fine soils, engineered growing medium or soil substrate, and plant material.
- The components of intensive green roofs are generally the same as those used in extensive green roofs, with differences in depth and project-specific design application.
- Follow manufacturer recommendations for slope, treatment width, and maintenance.
- Green roof should be free of gullies or rills.

Vegetation

- The planting media should be sufficiently deep to support the long-term health of the vegetation selected for the green roof, as specified by the landscape architect or other knowledgeable professional.
- Either grass or a diverse selection of other low growing, drought tolerant, native vegetation should be specified. Vegetation whose growing season corresponds to the wet season is preferred. See Appendix A for planting guidance.
- Irrigation is typically required.



Figure 6-46: Plants selected to support endangered butterflies on the extensive Green Roof at the California Academy of Sciences, San Francisco (Credit: Tim Griffith)

Construction and Maintenance Plans

Design and Installation Recommendations

- Design and installation are typically completed by an established vendor.
- *For additional construction guidelines, see Chapter 4 of the GI Design Guide.* Even though the GI Design Guide does not include specific construction guidance for green roofs, general information on runoff capture and utility constraints can apply to green roofs.

Maintenance Recommendations

- Although green roofs are often categorized as “site design measures”, a Maintenance Agreement may be required by the municipality. The Maintenance Agreement should state the parties’ responsibility for maintenance and upkeep.
- Inspections should be conducted by the project owner at least semiannually. Confirm adequate irrigation for plant health.
- Care for plants and replenish growing media as specified by landscape designer and as needed for plant health. See Appendix A for IPM methods.

Typical Design Details



GREENGRID
The Smart Choice for Your Roof

TRELLEBORG

THE MODULAR GREEN ROOF SYSTEM

- Water reservoirs retain 99% of a 25mm rainfall
- Drainage holes allow water run-off to roof surface
- Non woven geotextile filtration layer
- Plants flourish in depth of growing media
- Wide variety of plant choice
- Recycled material content

ROOF BUILD UP EXAMPLE

- Protection Fleece
- Waterproofing Membrane
- Insulation
- Vapour Control Layer
- Concrete deck

MODULE BUILD UP EXAMPLE

| | | |
|--------------------------|---|-----------|
| Module Dimensions | 600mm (W) x 600mm (L) x 100mm (D) | Extensive |
| | 600mm (W) x 1200mm (L) x 100mm (D) | Extensive |
| | 600mm (W) x 1200mm (L) x 200mm (D) | Intensive |
| Saturated Weight | 75kg/m ² - 100mm depth module | |
| | 134kg/m ² - 200mm depth module | |

Trelleborg - Suite 3D, Willow House, Stratfields Business Park, Beckett, Leamington CV4 3PB Tel: +44 (0)1898 464620 Fax: +44 (0)1898 464623 Email: thecustomers@trelleborg.com
www.greengridroofs.co.uk

Figure 6-47: Green roof cross-sections (Credit: American Wick Drain Corp and GreenGrid)

6.9 Rainwater Harvesting and Use

Overview

Description

Rainwater harvesting systems are engineered to store a specified volume of water with no discharge until this volume is exceeded. Storage facilities that can be used to harvest rainwater include above-ground or below-ground cisterns, open storage reservoirs (e.g., ponds and lakes), and various underground storage devices (tanks, vaults, pipes, arch spans, and proprietary storage systems).



Figure 6-48: Rainwater is collected and used for flushing toilets at Mills College, Oakland. (Credit: EOA, Inc.)

Best uses

- High density residential or office towers with high toilet flushing demand
- Park or low density development with high irrigation demand.
- Industrial use with high non-potable water demand

Advantages

- Helps obtain LEED or other credits for green building

Limitations

- High installation and maintenance costs
- High toilet flushing or irrigation demand needed to use design volume

Rooftop runoff is the stormwater most often collected in harvesting/use system, because it often contains lower pollutant loads than surface runoff, and it provides accessible locations for collection. Rainwater can also be stored under hardscape elements, such as paths and walkways, by using structural plastic storage units, such as RainTank, or other proprietary storage products. Water stored in this way can be used to supplement onsite irrigation needs, typically requiring pumps to connect to the irrigation system. Rain barrels are often used in residential installations, but typically collect only 55 to 120 gallons per barrel; whereas systems that are sized to meet Provision C.3 stormwater treatment requirements typically require thousands of gallons of storage.

Uses of captured water may potentially include irrigation, indoor non-potable use such as toilet flushing, industrial processing, or other uses. In the Bay Area, toilet flushing is the use that is most likely to generate sufficient demand to use the C.3.d amount of runoff. The demand for indoor toilet flushing is most likely to equal to the C.3.d amount of stormwater in high rise residential or office projects, and in schools. Irrigation demand may equal the C.3.d amount of runoff in projects with a very high percentage of landscaping.

Siting

For strategies and examples of how to retrofit sites and parcels to include rainwater harvesting systems, *see Sections 3.2 and 3.3 of the GI Design Guide.*

Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. Rainwater harvesting units used to meet C.3.d treatment requirements should not be located on inaccessible private property such as residential backyards.

Table 6-12: Recommended locations for rainwater harvesting systems areas

| Recommended Locations | Rainwater Harvesting |
|-----------------------|----------------------|
| Parking Lot | |
| Roof | ● |
| Driveway | |
| Podium-level | ● |
| Close to building | ● |
| Away from Buildings | ● |
| Underground | ● |

Design and Sizing Guidelines

System Components

Rainwater harvesting systems typically include several components: (1) methods to divert stormwater runoff to the storage device, (2) an overflow for when the storage device is full, (3) a distribution system to get the water to where it is intended to be used, and (4) filtration and treatment systems (see Treatment Requirements below).

Leaf Screens, First-Flush Diverters, and Roof Washers

These features may be installed to remove debris and dust from the captured rainwater before it goes to the tank. The initial rainfall of any storm often picks up the most pollutants from dust, bird droppings and other particles that accumulate on the roof surface between rain events. Leaf screens remove larger debris, such as leaves, twigs, and blooms that fall on the roof. A first-flush diverter routes the first flow of water from the catchment surface away from the storage tank to remove accumulated smaller contaminants, such as dust, pollen, and bird and rodent droppings. A roof washer may be placed just ahead of the storage tank and filters small debris for systems using drip irrigation. Roof washers consist of a tank, usually between 30- and 50-gallon capacity, with leaf strainers and a filter.

Codes and Standards

The State of California added rainwater harvesting and graywater regulations into the State’s Plumbing Code on January 1, 2014. The code was updated in 2016 and 2019. Chapter 16 of the code, “Nonpotable Rainwater Catchment Systems”, allows rainwater to be harvested from roof tops for use in outdoor irrigation and some non-potable indoor uses. Rainwater collected from parking lots or other impervious surfaces at or below grade is considered graywater and subject to the water quality requirements for graywater in Chapter 15 of the code. Some small catchment systems (5,000 gallons or less) being used for non-spray irrigation do not require permits – see Chapter 16 for more details³⁷.

The Plumbing Code defines rainwater as “precipitation on any public or private parcel that has not entered an offsite storm drain system or channel, a flood control channel, or any other stream channel, and has not previously been put to beneficial use.”³⁸ The Rainwater Capture Act of 2012, which took effect January 1, 2012, specifically states that the use of rainwater collected from rooftops does not require a water right permit from the State Water Resources Control Board.

The ARCSA/ASPE Rainwater Catchment Design and Installation Standard³⁹ may also be used as a resource.

Treatment Requirements

Rainwater catchment system treatment requirements in the code vary depending on the use. Small systems described above are not required to treat rainwater. Other systems may be required to remove

³⁷ 2019 California Plumbing Code, <https://iapmo.org/publications/read-uniform-codes-online/>
Select CPC 2019 and click on Chapter 16

³⁸ <https://up.codes/viewer/california/ca-plumbing-code-2016/chapter/15/alternate-water-sources-for-nonpotable-applications#15>

³⁹ American Rainwater Catchment Systems Association (ARCSA) and American Society of Plumbing Engineers (ASPE), August 2009. Rainwater Catchment Design and Installation. See: www.harvesth2o.com/adobe_files/ARCSA_Rainwater%20Code.pdf.

turbidity, bacteria, particulates and/or debris. Uses of rainwater for car washing, drip irrigation and small volume spray irrigation require filtration, while uses for large volume spray irrigation, toilet flushing, ornamental water features and cooling tower makeup water require filtration and disinfection. More details are provided in Plumbing Code Chapter 16, Table 1602.9.6.

The 2019 California Plumbing Code contains minimum treatment and water quality standards for rainwater, which are summarized in Table 6-13 below.

*Table 6-13
Summary of Minimum Treatment and Water Quality Standards for Rainwater*

| Application | Minimum Treatment | Minimum Water Quality |
|--|--|---|
| Non-spray irrigation (less than 5,000 gallons of storage) | No treatment required if tank is supported directly on grade and height: width ratio < 2:1 | N/A |
| Spray irrigation (less than 360 gallons of storage); | Debris excluder or other approved means | N/A |
| Surface, subsurface, and drip irrigation; car washing | Debris excluder or other approved means; 100 micron filter for drip irrigation | N/A |
| Spray irrigation (360 gallons or more of storage); ornamental fountains and other water features | Debris excluder or other approved means | Turbidity < 10 NTU; Escherichia coli < 100 CFU/100 ml |
| Toilet flushing, clothes washing, and trap priming; cooling tower make-up water | Debris excluder or other approved means; 100 micron filter for drip irrigation | Turbidity < 10 NTU; Escherichia coli < 100 CFU/100 ml |
| Source: 2019 California Plumbing Code, Table 1602.9.6, Chapter 16 page 329. | | |

Hydraulic Sizing

- If a rainwater harvesting system will be designed to meet Provision C.3 stormwater requirements, there must be sufficient demand to use 80 percent of the average annual rainfall runoff, as specified in Provision C.3.d. Appendix I provides guidance on how to estimate the required landscaping or toilet flushing demand to meet C.3.d. requirements.
- If the project appears to have sufficient demand for rainwater, size the cistern (or other storage device) to achieve the appropriate combination of drawdown time and cistern volume indicated in the sizing curves in Appendix I.
- If a rainwater harvesting system is designed for less than the water quality design volume, the overflow must receive additional treatment, e.g., by infiltration in landscaping or by infiltration/biotreatment in a bioretention area.

Design Guidelines for All Systems

- Equip water storage facilities covers with tight seals, to reduce mosquito-breeding risk. Follow mosquito control guidance in Appendix F.
- Water storage systems in proximity to the building may be subject to approval by the building official. The use of waterproofing as defined in the building code may be required for some systems, and the municipality may require periodic inspection. Check with municipal staff for the local jurisdiction's requirements.
- Do not install rainwater storage devices in locations where geotechnical/stability concerns may prohibit the storage of large quantities of water. Above-ground cisterns should be located in a stable, flat area, and anchored for earthquake safety.
- To avoid excess hydraulic pressure on subsurface cisterns:
 - The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the cistern.
 - A geotechnical engineer should be consulted for situations where the bottom of the cistern is less than 5 feet from the seasonal high groundwater level.
- Provide separate piping without direct connection to potable water piping. Dedicated piping should be color coded and labeled as harvested rainwater, not for consumption. Faucets supplied with non-potable rainwater should include signage identifying the water source as non-potable and not for consumption.
- The harvesting system must not be directly connected to the potable water system at any time.
- When make-up water is provided to the harvest/reuse system from the municipal system, prevent cross contamination by providing a backflow prevention assembly on the potable water supply line, an air gap, or both, to prevent harvested water from entering the potable supply. Contact local water system authorities to determine specific requirements.
- The rainwater storage facility should be constructed using opaque, UV resistant materials, such as heavily tinted plastic, lined metal, concrete, or wood, or protected from sunlight by a structure or roof to prevent algae growth. Check with municipal staff for local building code requirements.
- Storage facilities should be provided with access for maintenance, and with a means of draining and cleaning.

Design Guidelines for Indoor Use

- Avoid harvesting water for indoor use from roofs with architectural copper, which may discolor porcelain plumbing fixtures.
- Provide filtration of rainwater harvested for indoor non-potable use, as required by the California Plumbing Code (Table 6-13) and any municipality-specific requirements.

Design Guidelines for Irrigation Use

- Water diverted by a first flush diverter may be routed to a landscaped area large enough to accommodate the volume, or a hydraulically-sized treatment measure.
- First flush diverters should be installed in such a way that they will be easily accessible for regular maintenance.
- When rainwater is harvested from roofs with wood shingles or shakes, asphalt shingles, tar, lead, etc., do not use to irrigate food-producing gardens as such materials may adversely affect food for human consumption.

Construction and Maintenance Plans

- Hire a contractor experienced with the installation of rainwater harvesting systems, and follow California Plumbing Code requirements.
- Do not allow sediment to get into the system during construction, and protect from construction traffic.

Although the GI Design Guide does not include specific construction and maintenance guidance for rainwater harvesting, it does include design and siting guidance for these systems.

Remember

Maintenance Considerations for All Treatment Measures

- See Chapter 8 for specific maintenance guidance. See Section 8.3.7 for common maintenance concerns specific to rainwater harvesting.
- A Maintenance Agreement should be provided and should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement. See Appendix G of this Guide for maintenance plan templates.

6.10 Media Filter⁴⁰

Overview

Description

Media filters are flow-through treatment systems that remove pollutants from runoff through screening and adsorptive media such as sand, peat, or manufactured media. Types of non-vegetated⁴¹ media filters include: 1) bed filters, such as Austin or Delaware sand filters; 2) proprietary modular cartridge filters; 3) powered filtration systems; and 4) catch basin inserts, also known as inlet filters.

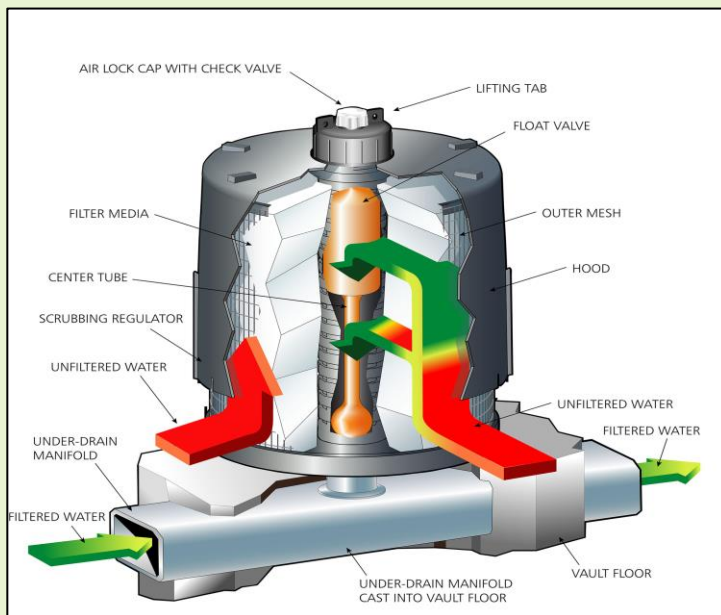


Figure 6-49. System C Filter Cartridge, Typically Used as Part of Treatment Train (Credit: CONTECH Engineered Solutions)

Under current Municipal Regional Permit (MRP) requirements, the use of media filters as a stand-alone treatment measure is no longer allowed, except at “Special Projects” that qualify for LID treatment reduction credits (see Appendix K). Media filters may also be used as part of a treatment train, for example, as pre-treatment for a subsurface infiltration system. Because Special Projects are typically dense urban infill projects where LID treatment is infeasible due to space constraints, this section focuses on proprietary cartridge filters, which are suitable for limited space and/or underground applications.

Cartridge filters use cartridges of a standard size that can be filled with various types of manufactured media, individually or in combination, including perlite (expanded volcanic ash), zeolite (natural mineral), granular activated carbon, and granular organic media (such as processed leaves). The media are designed to remove certain types of pollutants. The media cartridges are placed in vaults, manholes, or catch basins. In the unit shown in Figure 6-49, the water flows laterally (horizontally and upwards) into the cartridge,

Best uses

- Limited space
- Underground
- As part of a treatment train (pre-treatment)

Advantages

- Less area required
- Customized media
- Customized sizing

Limitations

- Not considered LID
- No removal of trash without pre-treatment
- High installation and maintenance costs
- Confined space entry may be required
- Media filtration is allowed only for qualifying “special projects”

⁴⁰ Note: The proprietary media filters shown are for general information only and are not endorsed by the Countywide Program. An equivalent media filter system may be used.

⁴¹ Vegetated media filters using biotreatment soil media are described in the bioretention, flow-through planter, and tree well filter sections of the C.3 Technical Guidance.

through the media to a center tube, then downward to an underdrain system. The number of cartridges required is a function of the water quality design flow rate and cartridge design operating rate (that is, the surface loading rate).

Siting

Media filters should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. Media filter access manholes should not be located in parking stalls because they can't be inspected if a car is parked in the spot. Media filters should also not be located in garages or other areas with limited overhead clearance as large vector trucks need access for cleaning.

Table 6-14: Recommended locations for media filters

| Recommended Locations | Media Filter |
|-----------------------|--------------|
| Parking Lot | • |
| Roof | |
| Driveway | • |
| Podium-level | |
| Close to building | • |
| Away from Buildings | • |
| Underground | • |

Design and Sizing Guidelines

- The selected media filter product must be certified by the Washington State Technical Assistance Protocol – Ecology (TAPE) program under the General Use Level Designation (GULD) for Basic Treatment⁴². A list of proprietary media filters currently holding this certification can be obtained from the Department of Ecology’s website⁴³.
- The treatment measure should be sized based on the water quality design flow specified in MRP Provision C.3.d and the cartridge design operating rate for which the product received TAPE GULD certification.
- Consult the manufacturer to determine the proper type of media for the project site and pollutants of concern. Some use combinations of media to address a wide range of pollutants.
- Pretreatment to remove debris and coarse sediment upstream of the media filter is highly recommended. Pretreatment can be provided in a separate upstream unit and/or within the vault containing the cartridges (see Figures 6-48 and 6-49).
- Consider filter head loss when selecting a media filter product. Options may be limited if the site has limited available head or if trying to match up with existing storm drain invert elevations.
- Include provisions for bypassing high flows, either an internal bypass within the treatment measure or an external bypass using a piping configuration with a flow splitter (see Figure 6-51 for an example).
- Inform the contractor that, if there is a product substitution prior to or during construction, he/she must obtain approval from the local jurisdiction for any changes in the selected treatment product or design. The substituted produce must have TAPE GULD certification, and the design calculations must be revised if the design operating rate of the substituted product is different than the originally specified product.

⁴² “General Use” is distinguished from pilot or conditional use designation, and “Basic Treatment” is distinguished from treatment effectiveness for phosphorus removal. Basic treatment is intended to achieve 80% removal of total suspended solids (TSS) for influent concentrations from 100 mg/l to 200 mg/l and achieve 20 mg/l TSS for less heavily loaded influents.

⁴³ See: <https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Stormwater-permittee-guidance-resources/Emerging-stormwater-treatment-technologies#tape>

Construction and Maintenance Plans

- Consult the manufacturer for construction and maintenance requirements.
- Additional guidance is included in Chapter 8 and Appendix G of this Guide.

Installation Requirements

- Consult the manufacturer to determine the installation requirements for a specific product.
- For vault-based media filters, base preparation will be required. Typically, the soil subbase will need to be compacted and a minimum 6-inch layer of crushed rock base material provided. See manufacturer's specifications.
- To avoid excess hydraulic pressure on subsurface treatment system structures:
 - The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the structure.
 - A geotechnical engineer should be consulted for situations where the bottom of the structure is less than 5 feet from the seasonal high groundwater level.

Remember

Maintenance Considerations for All Treatment Measures

- See Chapter 8 for specific maintenance guidance. Specifically, see Section 8.3.8 for common maintenance concerns.
- A Maintenance Agreement should be provided and should state the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement. Maintenance plan templates are in Appendix G.

Typical Design Details

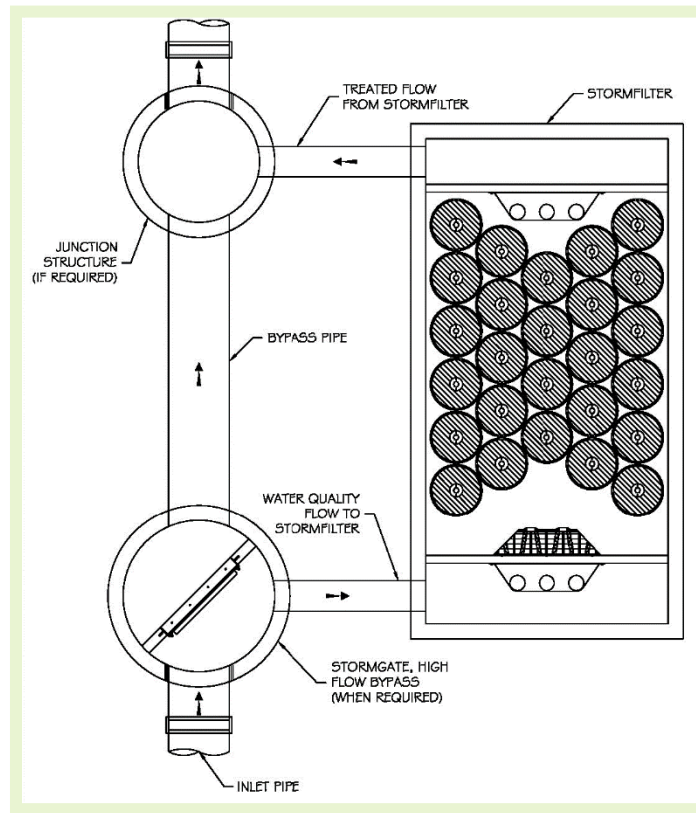


Figure 6-50. Profile View, Typical Cartridge System Filter Array (Credit: CONTECH Engineered Solutions). Note: The proprietary media filters shown are for general information only and are not endorsed by the Countywide Program.

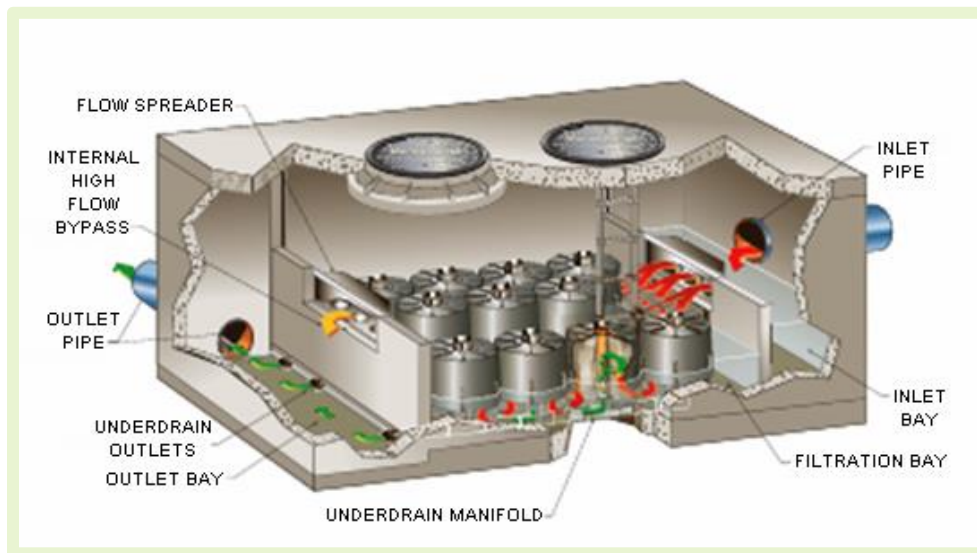


Figure 6-51. Plan View, Typical Cartridge System Filter Array (Credit: CONTECH Engineered Solutions). Note: The proprietary media filters shown are for general information only and are not endorsed by the Countywide Program.

6.11 Subsurface Infiltration System

Overview



Figure 6-52: Photo of subsurface retention/infiltration system installation under a parking lot (Credit: CONTECH Engineered Solutions)

Description

Subsurface infiltration systems, also known as infiltration galleries, are underground vaults or pipes that store and infiltrate stormwater. Storage can take the form of large-diameter perforated metal or plastic pipe, or concrete arches, concrete vaults, plastic chambers or crates.

These systems allow infiltration into surrounding soil while preserving the land surface above for parking lots, parks or playing fields. A number of vendors offer prefabricated, modular infiltration galleries in a variety of material types, shapes and sizes. Many of these options can be made strong enough for heavy vehicle loads, if needed.

Another type of subsurface infiltration system is an exfiltration basin or trench, which consists of a perforated or slotted pipe laid in a bed of gravel. It is similar to an infiltration basin or trench with the exception that it can be placed below paved surfaces such as parking lots and streets. Stormwater runoff is temporarily stored in perforated pipe or coarse aggregate and allowed to infiltrate into the trench walls bottom for disposal and treatment.

Subsurface infiltration systems are appropriate for residential and commercial sites where soil conditions and groundwater depths allow for safe infiltration of stormwater into the ground and no risk of groundwater contamination exists. These systems are not appropriate for industrial sites, locations where chemical spills may occur, fill sites or steep slopes. Pretreatment of runoff to remove sediment and other pollutants is typically required to maintain the infiltration capacity of the facility, reduce the cost and frequency of maintenance, and protect groundwater quality. A “subsurface fluid distribution system” is considered a Class V injection well that is regulated by EPA’s Underground Injection Control Program⁴⁴

Best uses

- Residential or commercial projects with large parking lots or common areas
- Large drainage areas

Advantages

- Can be located beneath at grade features
- Systems are modular, allowing flexible design
- Multi-benefit attributes: groundwater recharge, flood mitigation, pollutant load reduction

Limitations

- Not recommended for poorly infiltrating soils or highly polluted runoff with potential for groundwater contamination
- Requires pretreatment
- Can be high cost
- Potential for standing water and mosquito production

⁴⁴ See EPA Region 9’s website: <https://www.epa.gov/uic/underground-injection-control-regulations-and-safe-drinking-water-act-provisions>

These systems are “authorized by rule” and do not require a permit if they do not endanger underground sources of drinking water and comply with federal UIC requirements (see Appendix E of this Guide).

Siting

For strategies and examples of how to retrofit sites and parcels to include subsurface infiltration systems, *see Sections 3.2 and 3.3 of the GI Design Guide.*

Remember that stormwater control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections.

A permit may be required from San Mateo County Environmental Health if the system is more than 10 feet deep or if groundwater is encountered during excavation.⁴⁵

Table 6-15: Recommended locations for subsurface infiltration systems

| Recommended Locations | Subsurface Infiltration System |
|-----------------------|--------------------------------|
| Parking Lot | ● |
| Roof | |
| Driveway | ● |
| Podium-level | |
| Close to building | |
| Away from Buildings | ● |
| Underground | ● |

⁴⁵ <https://www.smchealth.org/gpp>

Design and Sizing Guidelines

Drainage Area and Setback Requirements

- In-situ/undisturbed soils should have a low silt and clay content and have permeability greater than 0.5 inches per hour. Hydrologic soil groups C and D are generally not suitable. Soil testing should be performed to confirm the permeability, and an appropriate safety factor (minimum of 2) applied as directed by the municipality.
- A 10-foot separation between the bottom of the Class 2 Perm and seasonal high groundwater levels is required to avoid the risk of groundwater contamination.
- A setback of 18 feet from building foundations is recommended, or a 1:1 slope from the bottom of the foundation, unless a different setback is allowed by a geotechnical engineer or local standard, or a cutoff wall is provided.
- Refer to Infiltration Guidelines (Appendix E) for additional setback and separation requirements.

Treatment Measure Dimensions and Sizing (Infiltration Galleries)

- The subsurface infiltration system should be sized to store and infiltrate the water quality design volume per MRP Provision C.3.d. The system may also be sized to store a larger volume for hydromodification management, if site conditions allow.
- Design the system to drain down (infiltrate) within 48-72 hours.
- The maximum allowable effective depth of water (inches) stored in the system can be calculated by multiplying the drawdown time (hours) by the design permeability of the native soils adjusted by the safety factor (in./hr.) The required footprint of the system can then be calculated by dividing the storage volume by the effective depth. Consult with the manufacturer for sizing of various components to achieve storage and infiltration of the water quality design volume.
- One or more observation wells should be installed to monitor water levels (drain time) in the facility. The well should be a minimum 6-inch diameter perforated PVC pipe, which is anchored vertically to a foot plate at the bottom of the facility.
- Maintenance access to the underground galleries must be provided, as periodic cleaning may be necessary to maintain performance. Open systems such as large diameter pipe or concrete structures can more easily be inspected and entered for maintenance if necessary than low profile or crate-type systems. The access should be large enough to allow equipment to be lowered into each gallery.
- Provide a layer of aggregate between the subsurface storage component or galleries and native soils to prevent migration of native soils into the storage component.

Treatment measure Dimensions and Sizing (exfiltration trenches)

- The exfiltration trench should be sized to store and infiltrate the water quality design volume per MRP Provision C.3.d. It is designed similar to an infiltration trench.
- A site-specific trench depth can be calculated based on the soil permeability, aggregate void space, and the trench storage time. The stone aggregate used in the trench is typically 1.5 to 2.5 inches in

diameter, which provides a void space of approximately 35 percent. Trenches may be designed to provide temporary storage of storm water, but should drain within 72 hours.

- The trench depth should maintain the required separation from seasonal high groundwater, and the depth should be less than the widest surface dimension.
- The invert of the trench should be flat (no slope).
- Place permeable filter fabric around the walls and bottom of the trench and top of the aggregate layer. The filter fabric should overlap each side of the trench in order to cover the top of the aggregate. The filter fabric prevents sediment in the runoff and soil particles from the sides of the trench from clogging the aggregate.
- A layer of filter fabric or sand should be placed at the bottom of the trench to keep the rock matrix from settling into the subgrade over time.
- An observation well should be installed to monitor water levels (drain time) in the trench. The well should be a minimum 6-inch diameter perforated PVC pipe, which is anchored vertically to a foot plate at the bottom of the trench.

Inlets to Treatment Measure

- Flow may enter the treatment measure in the following ways:
 - Through a pipe
 - Through a drop inlet or catch basin
 - Through roof leader or other conveyance from building roof

Pre-Treatment Measures

- The pretreatment measure(s) should be selected based on the expected pollutants on site and the infiltration system's susceptibility to clogging. Sediment removal is important for maintaining the long-term infiltration capability of the system.
- Hydrodynamic separators or media filters are most commonly used for subsurface systems, and are allowed as part of a treatment train with the infiltration system. Landscaped-based treatment, such as swales or bioretention areas may also be used upstream of subsurface systems if appropriate and if space allows.
- If a media filter is selected, refer to the discussion of media filter design in Section 6.10.

Construction and Maintenance Plans

Construction Considerations

- The drainage area must be fully developed and stabilized with vegetation before constructing an infiltration trench. High sediment loads from unstabilized areas will quickly clog the infiltration trench. During project construction, runoff from unstabilized areas should be diverted away from the trench into a sedimentation control BMP until vegetation is established.
- Avoid spreading fines of the soils on bottom and side slopes while excavating. Loosen soils at the bottom of the excavation prior to constructing the infiltration trench.
- Avoid compaction of existing soils in the area of the infiltration. Protect from construction traffic.

Remember

Maintenance Considerations

- Provide a Maintenance Agreement (or other document or mechanism) that states the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit with Maintenance Agreement.