Chapter

6

Technical Guidance for Stormwater Treatment and Site Design Measures

In this Chapter, technical guidance is provided for the stormwater treatment measures allowed by permit requirements as well as selected site design measures.

Table 6-1: Treatment and Site Design Measures Addressed in Chapter 6			
Treatment Measures		**LID?**	**Design Basis**
6.1	Bioretention area	Yes	Flow, Volume, Both
6.2	Flow-through planter	Yes	Flow, Volume, Both
6.3	Tree well filter	Yes[1]	Flow, Volume, Both
6.4	Infiltration trench	Yes	Volume
6.5	Subsurface infiltration system	Yes	Volume
6.6	Rainwater harvesting and use	Yes	Volume
6.7	Media filter	No	Flow[2]
6.8	Extended detention basin	No	Volume
Site Design Measures			
6.9	Green roof	Yes	Volume
6.10	Pervious pavement	Yes	Volume
6.11	Grid pavements	Yes	Volume

[1] A tree well filter meets LID requirements for a biotreatment measure if biotreatment soil is used as the filter media in the unit, and the unit is sized based on a 5 in/hr surface loading rate. A proprietary tree well filter that contains manufactured media with a higher flow rate is not considered LID treatment and may only be used at qualifying Special Projects. See Section 6.3 for more details.

[2]While some non-proprietary media filters are sized using a volume-based approach, this section focuses on proprietary systems that may be used at qualifying Special Projects or as part of a treatment train.

The technical guidance in this chapter is intended to assist you in preparing permit application submittals for your project. The guidance is in the form of fact sheets on specific treatment or site design measures that provide information on advantages and limitations of each measure, design and sizing considerations, construction guidelines, siting considerations and maintenance requirements. Municipalities will require you to prepare more specific drawings taking into consideration project site conditions, materials, plumbing connections, etc., when you submit your application.

Control measures should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections. Ensure requirements needed for access are in place (e.g., easements, permission to access in maintenance agreements).

Table 6-1 presents a list of the treatment and site design measures covered in this chapter. The table also indicates whether the measures meet the definition of low impact development site design or treatment, and whether the measures should be hydraulically sized on a flow or volume basis or both.

This technical guidance was developed based on a review of existing documents on design and maintenance of treatment and site design measures (specific to California), local experience, and best engineering judgment. Fact sheets will be updated as new information is gained through experience with stormwater treatment or site design measure design and installation.

6.1 Bioretention Area

Figure 6-1: Bioretention area in office building parking lot in San José. Source: City of San José.

Best uses

- Any type of development
- Any size drainage area
- Landscape design element

Advantages

- Landscape feature of any shape that works with a variety of plants
- Low maintenance
- Reliable once established

Limitations

- Geotechnical conditions must be suitable if runoff is infiltrated
- May require irrigation
- Susceptible to clogging – especially if installed prior to construction site soil stabilization.

Bioretention areas, or "rain gardens," function as soil and plant-based filtration measures that remove pollutants through a variety of physical, biological, and chemical treatment processes. These facilities normally consist of a ponding area, a mulch layer, plants, and biotreatment soil mix, underlain by drain rock and an underdrain (if required). Bioretention areas are designed to distribute stormwater runoff evenly across the surface ponding area. Water stored in the ponding area percolates through the biotreatment soil mix to the drain rock layer and then either infiltrates into native soil or flows out through the underdrain to the storm drain system.

Bioretention areas can be any shape, including linear. Bioretention areas with underdrains should be designed to maximize infiltration to native soils by placing the underdrain near the top of the drain rock layer unless infiltration is not permitted due to site conditions (e.g., high groundwater table, steep slopes, proximity to structures, presence of contaminated soil or groundwater, etc.). Bioretention areas without underdrains are sometimes referred to as "bioinfiltration" measures. All bioretention areas should include an overflow/bypass system to convey runoff volumes that are greater than the water quality design volume.

Design and Sizing Guidelines

DRAINAGE AREA AND SETBACK REQUIREMENTS

- The area draining to the bioretention area is limited by available surface area for the unit, and maintenance considerations. Multiple units can be installed to serve any size area.
- Units 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.
- The drainage area should not contain a significant source of sediment, such as unstabilized and unvegetated areas.
- The bioretention area should be set back from structures at least 10 feet or as required by the structural or geotechnical engineer or local jurisdiction, unless it has a waterproof lining.

- If the bioretention area is designed to infiltrate stormwater to underlying soils and the site includes a septic system leach field, a 100-foot setback is required from the leach field.

TREATMENT MEASURE DIMENSIONS AND SIZING

- It is recommended that the bioretention area be sized to be 4% of the impervious surface area on the project site. The area of tributary impervious surface multiplied by the 0.04 sizing factor will equal the required surface area of the bioretention area. This sizing factor is derived from the flow-based treatment standard (runoff from 0.2 in/hr intensity rainfall) and a desired surface loading rate of 5 in/hr through the biotreatment soil mix. Alternatively, if there are site or infiltration constraints, bioretention sizing may be calculated using a volume-based sizing method or a combination flow- and volume-based sizing method described in Section 5.1 of the C.3 Handbook.
- The surface of the bioretention area should be primarily flat, but elevations may vary as needed to distribute stormwater flows throughout the surface area. Edges may slope up to meet surrounding grade. Side slopes 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, 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 shoulders[1]. The slope within cells should not exceed 2%. Bioretention cells are not recommended if overall slope exceeds 8%.
- Surface ponding depths may vary, with a recommended 6-inch depth, and a maximum 12-inch depth if allowed by the municipality. The depth is measured from the surface of the biotreatment soil and not adjusted for the application of mulch. If ponding depths exceed 6 inches, the landscape architect should approve the planting palette for desired depth.
- The inlet to the overflow pipe or catch basin should be at least 6 inches above the flat surface of the bioretention planting area and at least 2 inches above the high point of the bioretention area (i.e., the top of planting mounds). Additional freeboard requirements may apply to protect nearby structures from flooding; check with the local jurisdiction.

INLETS TO TREATMENT MEASURE

Flow may enter the treatment measure in the following way(s):

  - As overland flow from landscaping
  - As overland flow from pavement
  - Through a curb opening (minimum 18 inches wide, with the number and locations designed so that runoff is dispersed throughout the bioretention area)
  - Through a curb drain
  - With drop structure through a stepped manhole
  - Through a pop-up or bubble-up emitter
  - Through roof leader or other conveyance from building roof
- Where flows enter the bioretention area, allow a change in elevation of 4 to 6 inches between the paved surface and biotreatment soil elevation, so that vegetation or mulch build-up does not obstruct flow.

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[1] 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)

- Install cobbles or rocks, underlain by geotextile fabric, to dissipate flow energy and avoid erosion at the point where runoff enters the bioretention area.
- Bioretention areas should be designed so that drainage into and out of the treatment measure is by gravity flow. This promotes effective, low-maintenance operation and helps avoid mosquito problems. Pumped systems should only be used on retrofit projects, as a last resort.

See Section 5.2 of the SCVURPPP C.3 Handbook for example inlets and additional guidance.

UNDERDRAIN AND OVERFLOW STRUCTURES

- An underdrain system is generally required for installations in slow-draining native soils. If the water quality design volume will infiltrate into native soils in 72 hours or less, based on local percolation tests, and the local jurisdiction allows, then no underdrain is required.
- The underdrain should consist of a minimum 4-inch diameter perforated pipe with cleanouts and connection to a storm drain or discharge point. To help prevent clogging, two rows of perforation may be used.
- The underdrain trench should include a minimum 12-inch thick layer of drain rock, such as Caltrans Standard Section 68-1.025 Class 2 permeable material or equivalent. At least two inches of drain rock should cover the underdrain. The underdrain should be placed with perforations facing downward, at a minimum 0.5% slope to the storm drain or discharge point (unless a flatter slope is allowed by the municipality based on site-specific conditions).
- To avoid clogging, filter fabric should not be used in or around the underdrain or between the biotreatment soil mix and the drain rock. If desired, a 2-inch pea gravel layer may be used between the biotreatment soil mix and the drain rock.
- If there is 5 feet or more separation between the base of the bioretention facility and the groundwater table and infiltration is permitted on site, the underdrain should be installed at least 6 inches above the base of the trench to maximize infiltration into native soils.
- If there is less than 5 feet separation to the groundwater table, or infiltration is not permitted due to site-specific conditions, the facility should be lined with a waterproof fabric and the underdrain should be placed just above the waterproof fabric (see Figure 6-6).
- A cleanout for the underdrain should be provided, consisting of a vertical, rigid, non-perforated PVC pipe, with a minimum diameter of 4 inches and a watertight cap fit flush with the biotreatment soil surface.
- The design should include an overflow or bypass system, with the overflow inlet elevation set to achieve the design ponding depth, to convey the runoff volume that exceeds the water quality design volume.

PLANTING SOIL REQUIREMENTS

- Soil used in the bioretention area should meet the biotreatment soil mix specifications included in Appendix C of this Handbook. A minimum long term infiltration rate of 5 inches per hour is required (initial infiltration rate may exceed this to allow for tendency of infiltration rate to reduce over time).
- Bioretention areas should have a minimum biotreatment soil mix depth of 18 inches.

VEGETATION

- Plant species selected should be suitable for the location of the bioretention area, biotreatment soils and occasional inundation. A variety of plants, including ground cover, shrubs and small trees, helps maintain a healthy soil environment and pollutant removal capabilities. See planting guidance in Appendix D.

- Plants within the bioretention area need to be spaced closely enough to ensure substantial plant coverage to prevent scour, keep mulch in place and provide pleasing aesthetics. The local jurisdiction may have landscaping guidelines that specify plant spacing.
- Trees may be planted in the bioretention area as allowed by the municipality (see Appendix D for recommended tree species). If larger trees are selected, plant them at the periphery of bioretention area. No trees should be planted within 20 feet of an overflow inlet. Biotreatment soil mix depth may need to be increased to accommodate tree root systems. (For more biotreatment options that utilize trees, see Section 6.3)
- Install and maintain a 3-inch layer of composted arbor mulch (also called "aged mulch") in areas between plantings. Pea gravel, or large bark mulches that resist floating may also be used. "Micro-bark" and "gorilla hair" mulches are not recommended. Cobbles should only be used for erosion protection at inlets. Large boulders should not be placed in the bioretention area.
- The underdrain trench should be offset from the edge of tree planting zone, as needed, to maximize distance between tree roots and the underdrain. The underdrain should be solid pipe for a distance 10 feet upstream and downstream of any tree.
- Drought tolerant plants are preferred, and may be required by the local municipality. Provide sufficient irrigation for the initial establishment period as well as long term maintenance of plant life.
- Use integrated pest management (IPM) principles in the landscape design to help avoid the need for synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction regarding local IPM policies.
- Trees and vegetation should not block inflow, create traffic or safety issues, or obstruct utilities.

Construction Requirements

- Bioretention areas are not intended to work as construction-phase BMPs. Protect the area from construction site runoff; divert runoff from unstabilized areas away from completed bioretention areas.
- If the bioretention area will be used for infiltration, 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 bioretention area.
- Minimize compaction of existing soils in the location of bioretention areas; protect from construction traffic.

Maintenance Requirements

- Provide a Maintenance Agreement (or other document or mechanism) that states the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit it with the Maintenance Agreement. Refer to Chapter 8 and Appendix G for specific maintenance requirements.

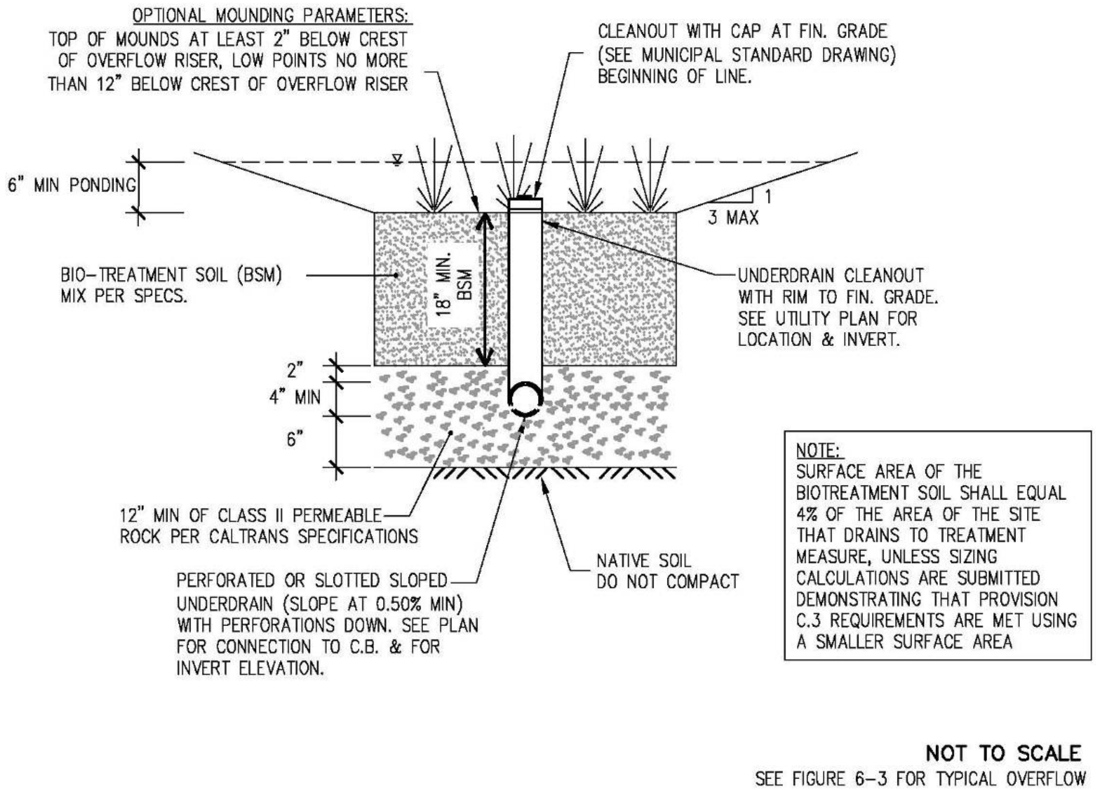

Figure 6-2: Cross Section of a Bioretention Area (with Maximized Infiltration)

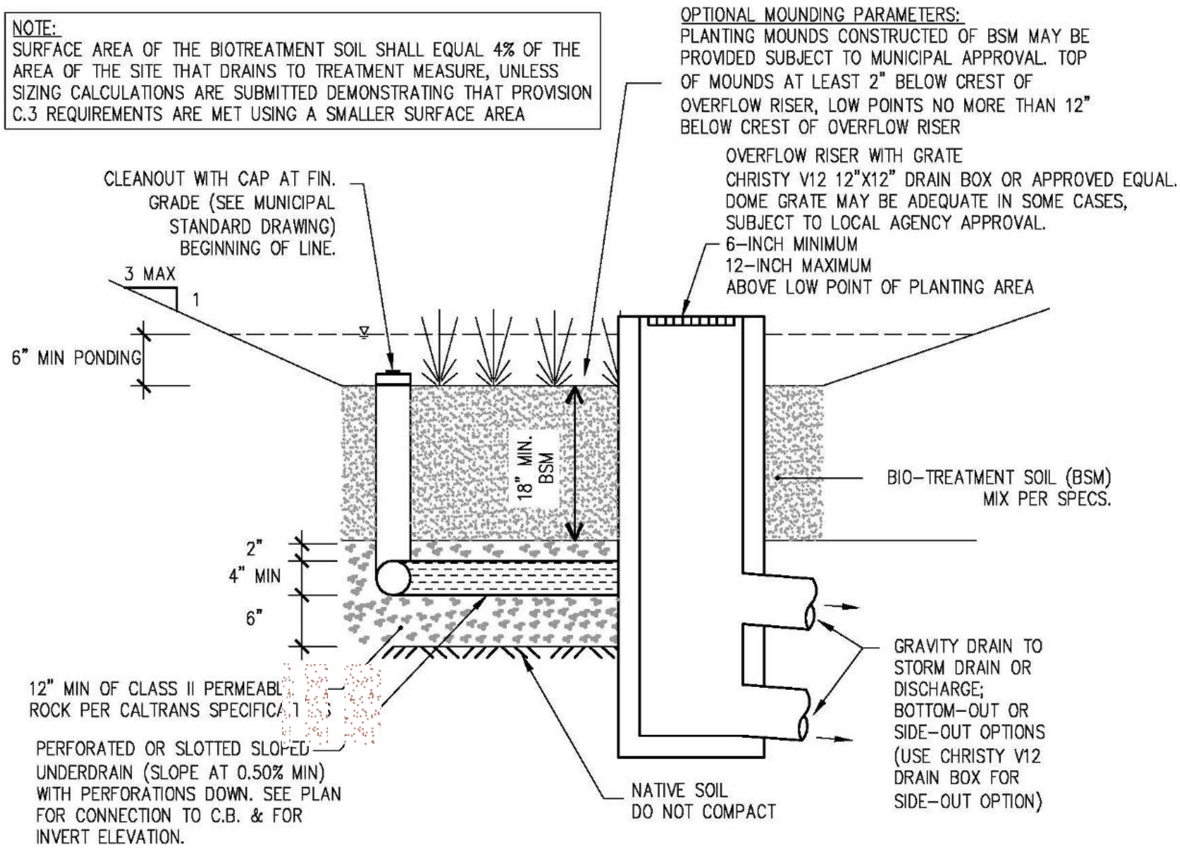

Figure 6-3: Cross Section of a Bioretention Area (Side View)

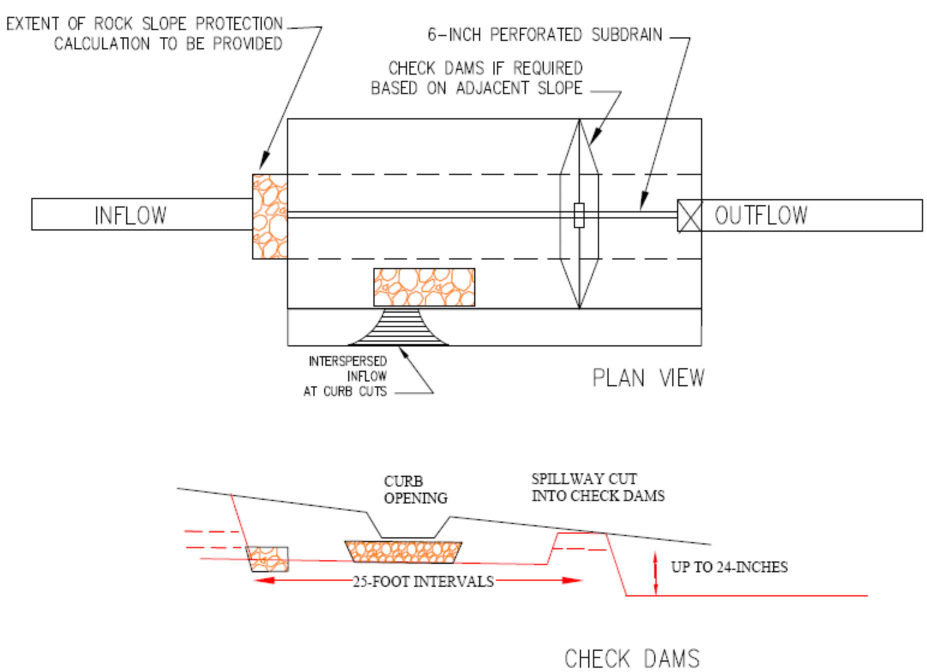

Figure 6-4: Check Dam (plan view and profile) for installing a series of linear treatment measures (bioretention cells) in sloped area

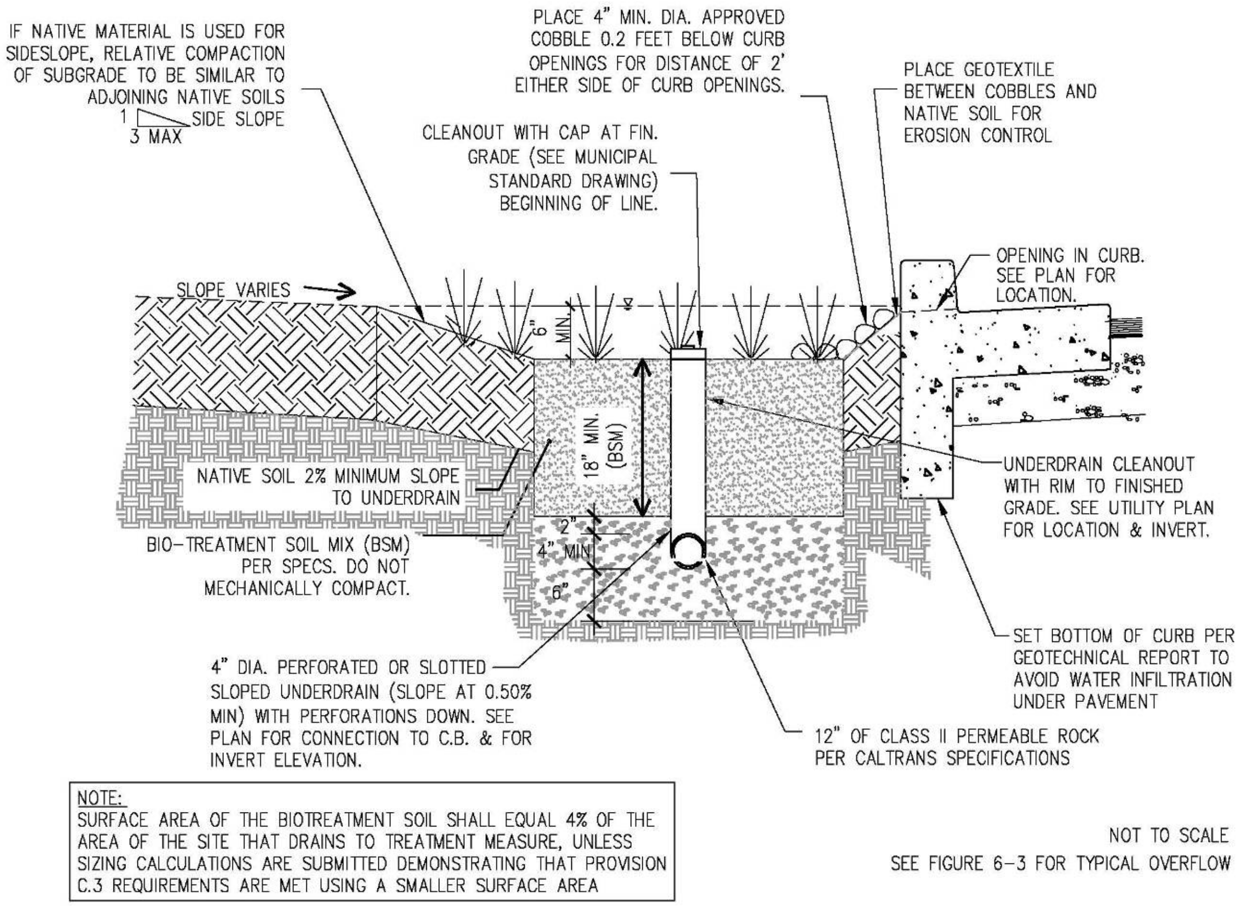

Figure 6-5: Cross Section of a Linear Bioretention Area (with Maximized Infiltration)

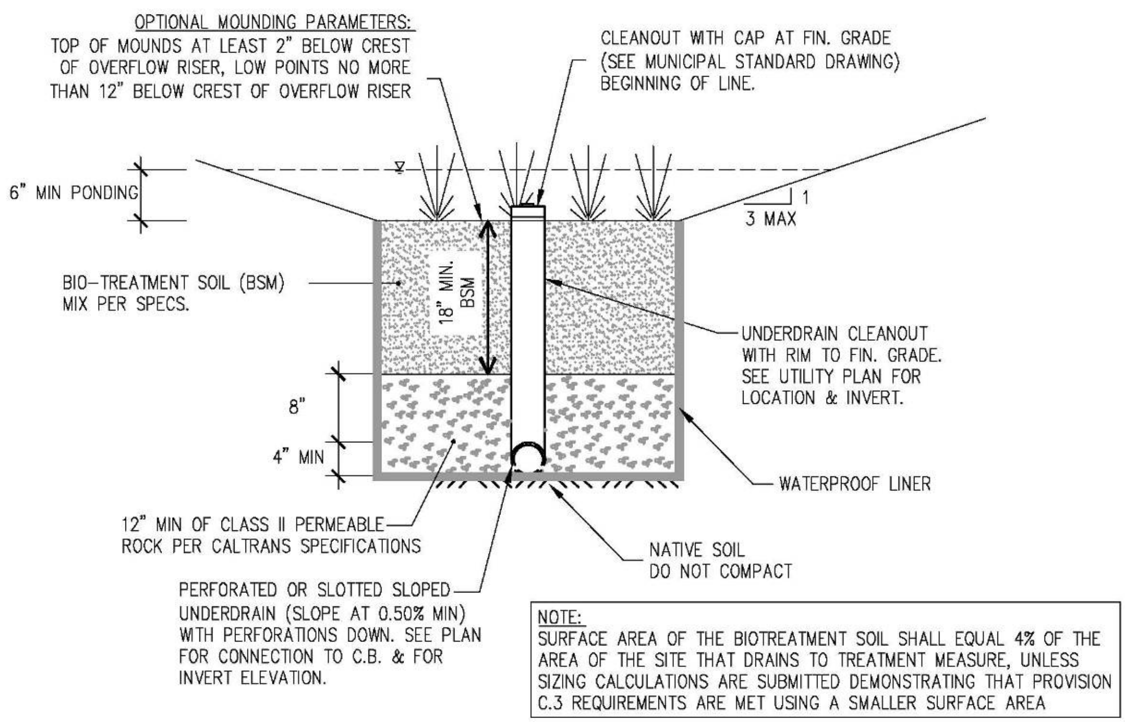

Figure 6-6: Cross Section of Lined Bioretention Area (Infiltration Not Allowed)

6.2 Flow-Through Planter

Figure 6-7: Flow-through planters at Hampton Park residences in San Jose. Photo: EOA, Inc.

Best uses

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

Advantages

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

Limitations

- Requires sufficient head
- Careful selection of plants
- Requires level installation
- Susceptible to clogging

Flow-through planters function similar to bioretention areas but are designed to detain and treat runoff without allowing seepage into the underlying soil. They are a type of biotreatment facility that is completely lined and surrounded with concrete or other structural planter box walls with waterproof membranes. They can be used next to buildings and other locations where soil moisture is a potential concern. Flow-through planters typically receive runoff via downspouts leading from the roofs of adjacent buildings. However, flow-through planters can also be set level with the surrounding grade and receive runoff as sheet flow. Pollutants are removed as the runoff passes through the biotreatment soil mix and is collected in an underlying drain rock layer and perforated underdrain. The underdrain must be directed to a storm drain or other discharge point. An overflow inlet conveys flows that exceed the capacity of the planter.

Design and Sizing Guidelines

TREATMENT MEASURE DIMENSIONS AND SIZING

- It is recommended that flow-through planters be designed with a surface area that is 4% of the impervious area draining to it. This sizing factor is derived from the flow-based treatment standard (runoff from 0.2 in/hr intensity rainfall) and a desired surface loading rate of 5 in/hr. Alternatively, if there are site constraints, planter size may be calculated using a volume-based treatment method or a combination flow- and volume-based treatment method described in Appendix B.
- The surface of the planting bed should be relatively level but may have a slight slope if needed to distribute stormwater flows throughout the surface area.
- Surface ponding depths may vary, with a recommended 6-inch depth and a maximum 12-inch depth if allowed by the municipality. The depth is measured from the surface of the biotreatment soil and not adjusted for the application of mulch. If the design ponding depth exceeds 6 inches, the landscape architect should approve the planting palette for the desired depth.

- The inlet elevation of the overflow drain should be at least 6 inches above the low point of the planting area and at least 2 inches above the high point of the planting area (i.e., the top of planting mounds). Planter box walls should be higher than overflow elevation. The maximum head requirements should be checked using the maximum flow and planter outlet configuration. Four inches of freeboard should be provided, and an overflow point away from structures should be designed. Additional freeboard requirements may apply to protect nearby structures from flooding; check with the local jurisdiction.
- Waterproofing should be installed as required to protect adjacent building walls.
- Units should be located in areas that can be accessible at any given time for the purpose of operation and maintenance and inspections.

INLETS TO TREATMENT MEASURE

Flows may enter the planter in the following ways:

- As overland flow from landscaping or pavement
- Through a curb opening (minimum 18 inches with the number and locations designed so that runoff is dispersed throughout the bioretention area)
- Through a curb drain
- Through a pop-up or bubble-up emitter
- Through roof leader or other conveyance from building roof
- 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 planting soil elevation, so that vegetation or mulch build-up does not obstruct flow.
- Install splash blocks, cobbles or rocks, underlain by geotextile fabric as needed, to dissipate flow energy and avoid erosion where runoff enters the planter.
- For long linear planters, space inlets to the planter at 10-foot intervals or install a flow spreader (see Figures 6-12 and 6-13).
- Flow-through planters should be designed so that drainage into and out of the treatment measure is by gravity flow. This promotes effective, low-maintenance operation and helps avoid mosquito problems. Pumped systems should only be used on retrofit projects, as a last resort.

See Section 5.2 of the SCVURPPP C.3 Handbook for example inlets and additional guidance.

UNDERDRAIN AND OVERFLOW STRUCTURES

- An underdrain system is required for flow-through planters.
- The underdrain should consist of a minimum 4-inch diameter perforated pipe with cleanouts and connection to a storm drain or discharge point. To help prevent clogging, two rows of perforation may be used.
- The underdrain trench should include a minimum 12-inch thick layer of drain rock, such as Caltrans Standard Section 68-1.025 permeable material Class 2 or equivalent. The underdrain should be placed near the bottom of the drain rock layer, with perforations facing downward, at a minimum 0.5% slope (unless a flatter slope is allowed by the municipality based on site-specific conditions).
- A cleanout for the underdrain should be provided, consisting of a vertical, rigid, non-perforated PVC pipe, with a minimum diameter of 4 inches and a watertight cap fit flush with the planter bed surface.
- To avoid clogging, filter fabric should not be used in or around the underdrain or between the biotreatment soil mix and the drain rock. If desired, a 2-inch pea gravel layer may be used between the biotreatment soil mix and the drain rock.
- To avoid excess hydraulic pressure on subsurface concrete treatment system structures:

1. The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the structure.
2. A geo technical engineer should be consulted for situations where the bottom of the structure is less than 5 feet from the seasonal high groundwater level.

PLANTING SOIL REQUIREMENTS

- Soils used in the planter should meet the biotreatment soil mix specifications included in Appendix C of this Handbook. A minimum long term infiltration rate of 5 inches per hour is required (initial infiltration rate may exceed this to allow for tendency of infiltration rate to reduce over time).
- Flow-through planters should have a minimum biotreatment soil mix depth of 18 inches.

VEGETATION

- Plant species selected should be suitable for the flow-through planter location, biotreatment soils and occasional inundation. A variety of plants, including ground cover, grasses, and shrubs, helps maintain a healthy soil environment and pollutant removal capabilities. See planting guidance in Appendix D.
- Plants within the planter area need to be spaced closely enough to ensure substantial plant coverage to prevent scour, keep mulch in place and provide pleasing aesthetics. The local jurisdiction may have landscaping guidelines that specify plant spacing.
- Use integrated pest management (IPM) principles in the landscape design, i.e., select native and/or pest resistant plants, to avoid the need for synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction regarding local IPM policies.
- Drought tolerant plants are preferred and may be required by the local municipality. Provide sufficient irrigation for the initial establishment period as well as long term maintenance of plant life.
- Install and maintain a 3-inch layer of composted arbor mulch (also called "aged mulch") in areas between plantings. Pea gravel or large bark mulches that resist floating may also be used. "Micro-bark" and "gorilla hair" mulches are not recommended. Cobbles should only be used for erosion protection at inlets. Large boulders should not be placed in the bioretention area.
- Vegetation should not block inflow, create safety issues, or obstruct utilities.

Construction Requirements

- At-grade planters are not intended to work as construction-phase BMPs. Protect the area from construction site runoff; divert runoff from unstabilized areas away from completed planter areas.

Maintenance Requirements

- Provide a Maintenance Agreement (or other document or mechanism) that states the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit it with the Maintenance Agreement. Refer to Chapter 8 and Appendix G for specific maintenance requirements.

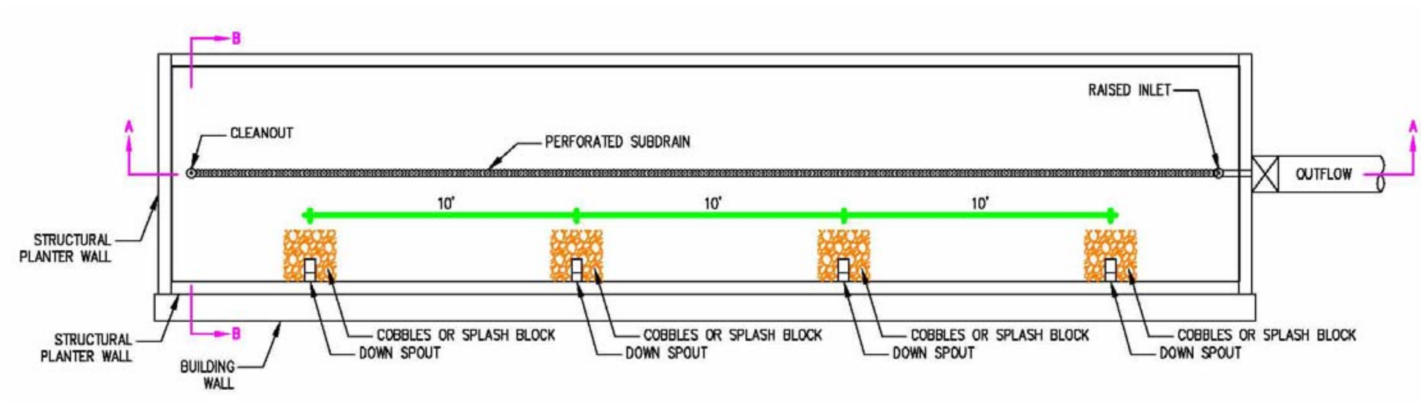

Figure 6-8: Plan view of long, linear planter, with inlets to the planter distributed along its length at 10' intervals.

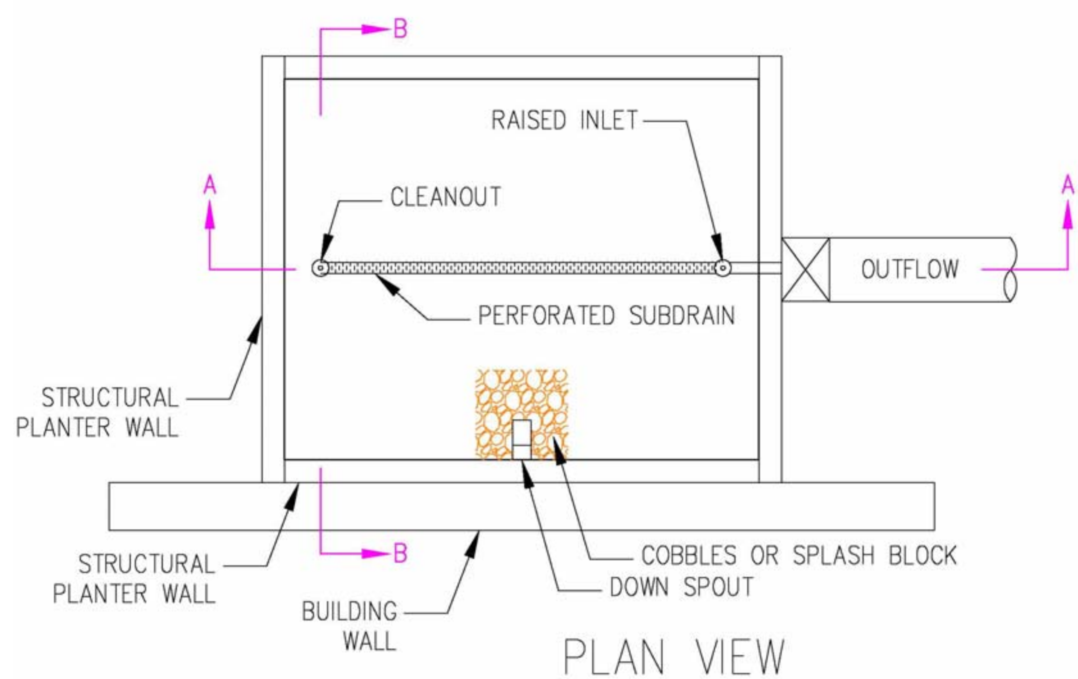

Figure 6-9: Plan view of planter designed to disperse flows adequately with only one inlet to planter

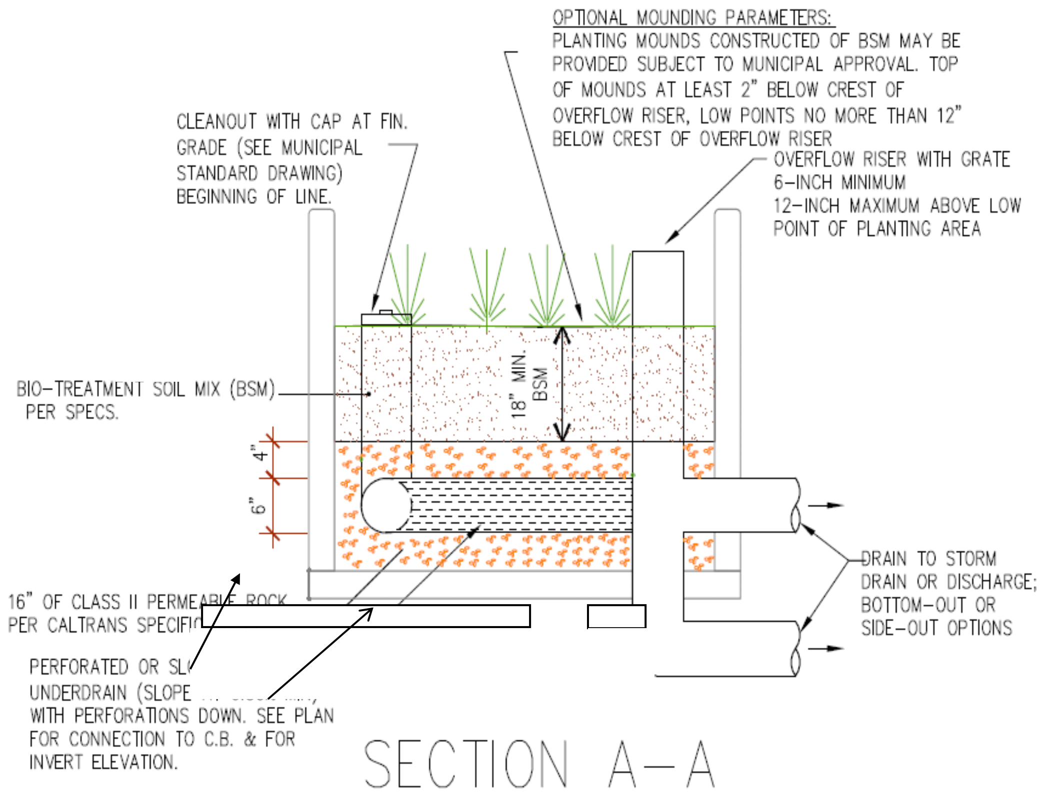

Figure 6-10: Cross section A-A of flow-through planter, shows side view of underdrain

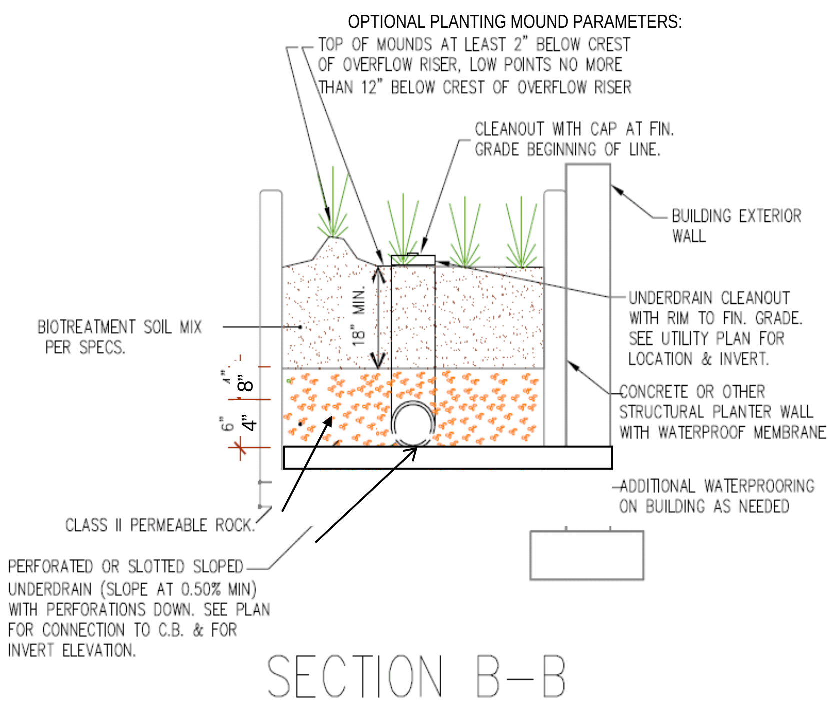

Figure 6-11: Cross section B-B of flow-through planter, shows cross section of underdrain

Figure 6-12: Half-buried, perforated flexible pipe serves as a flow spreader to distribute stormwater evenly throughout a long flow-through planter in Emeryville (Source: GreenGrid/ Weston Solutions).

Figure 6-13: The same planter as shown in Figure 6-12, after vegetation has matured and partially conceals the half-buried pipe from view (Source: San Francisco Estuary Partnership).

6.3 Tree Well Filter

Figure 6-14: Non-proprietary tree well filters in San José. Photo: City of San José.

Best Uses

- Sites with limited space
- Street improvement projects
- Sidewalks, urban plazas
- Special Projects

Advantages

- Aesthetic feature
- Occupies small footprint
- Integrates with landscape plan

Limitations

- Can clog without maintenance
- Higher installation cost
- Proprietary systems containing media with high infiltration rates are only allowed for Special Projects

Tree well filters are especially useful in settings where available space is at a premium. They can be installed as open-bottom systems that promote infiltration or in closed-bottom systems where infiltration is undesirable or infeasible, such as sites with tight clay soils, 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. Tree well filters can also be constructed using modular suspended pavement system products such as Silva Cells (see Chapter 4 and Figure 6-18 below).

The 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 mix or other filtration media, planted with a tree and/or other vegetation, and underlain with drain rock and an underdrain. A tree well filter that uses a biotreatment soil mix 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). Silva Cells and other modular suspended pavement system products 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 mix and underdrains as necessary.

Proprietary tree well filters containing manufactured media with design loading rates that exceed 5S inches per hour do not qualify as LID treatment measures and will only be allowed for use in Special Projects, as described in Appendix I.

Design and Sizing Guidelines

TREATMENT MEASURE DIMENSIONS AND SIZING

- It is recommended that a non-proprietary tree well filter (with biotreatment soil mix) 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 described in Appendix B.
- The allowable ponding depth for the type of tree selected should be determined by the landscape architect, and should not exceed 6 inches. The inlet to the overflow pipe should be at least 2 inches above the high point of the treatment area.
- 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.
- Proprietary tree filters are available in pre-cast concrete boxes. The required size of the box is based on the size of the tributary impervious surface and the infiltration rate 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 rate[1].

INLETS TO TREATMENT MEASURE

Flow may enter the tree well filter in the following ways:

- As overland flow from landscaping or pavement
- Through a curb opening (minimum 18 inches)
- Through a curb drain
- Through a bubble-up manhole or storm drain emitter
- Through roof leader or other conveyance from building roof
- Where flows enter the tree well filter, allow a change in elevation of 4 to 6 inches between the paved surface and biotreatment soil elevation, so that vegetation or mulch build-up does not obstruct flow.
- Install cobbles or rocks as needed to dissipate flow energy where runoff enters the treatment measure.

UNDERDRAIN AND OVERFLOW STRUCTURES

- An underdrain system is required for installations in slow-draining native soils. If the water quality design volume will infiltrate into native soils in 72 hours or less, based on local percolation tests, and the local jurisdiction allows, then no underdrain is required.
- The underdrain should consist of a minimum 4-inch diameter perforated pipe with cleanouts and connection to a storm drain or discharge point. To help prevent clogging, two rows of perforation may be used.
- The underdrain trench should include a minimum 12-inch thick layer of drain rock such as Caltrans Standard Section 68-1.025 permeable material Class 2 or equivalent. The

[1] For more information, see: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html

underdrain should be placed at least 2 inches below the top of the drain rock layer, with perforations facing downward.

- The underdrain should have a 2% minimum slope to the storm drain or discharge point.
- To avoid clogging, filter fabric should not be used in or around the underdrain or between the biotreatment soil mix and the drain rock. If desired, a 2-inch pea gravel layer may be used between the biotreatment soil mix and the drain rock.
- If there is 5 feet or more separation between the base of the tree well and the groundwater table and infiltration is permitted on site, the underdrain should be installed at least 6 inches above the base of the trench to allow infiltration into native soils.
- If there is less than 5 feet separation to the groundwater table, or infiltration is not permitted due to site-specific conditions, the facility should be lined with an impermeable fabric and the underdrain should be placed just above the impermeable fabric.
- To avoid excess hydraulic pressure on subsurface concrete treatment system structures:
  1. The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the structure.
  2. 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.

PLANTING SOIL REQUIREMENTS

- Soils used in the tree well filter should meet the biotreatment soil mix specifications included in Appendix C of this Handbook. A minimum long term infiltration rate of 5 inches per hour is required (initial infiltration rate may exceed this to allow for tendency of infiltration rate to reduce over time).
- Tree well filters should have a minimum biotreatment soil mix depth of 18 inches. This depth may need to be increased to accommodate large tree root systems.
- For proprietary tree well filters (to be used in Special Projects only), follow the media recommendations from the manufacturer.

VEGETATION

- Suitable tree and plant species are identified in the planting guidance in Appendix D.
- Install and maintain a 3-inch layer of composted arbor mulch (composted tree trimmings also called “aged arbor mulch”) around the tree as appropriate or as recommended by the landscape architect. Rock, cobble, or pea gravel may also be used. “Micro-bark” and “gorilla hair” mulches are not recommended.
- Use integrated pest management (IPM) principles to help avoid the need for synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction regarding local IPM policies.
- Trees should not block inflow, create traffic or safety issues, or obstruct utilities.

Construction Requirements

- When excavating a tree pit, avoid spreading fines of the soils on bottom and side slopes. Loosen soils at the bottom of the excavation prior to constructing the tree well filter.
- Minimize compaction of existing soils in the location of tree wells; protect from construction traffic.
- Protect the area from construction site runoff; divert runoff from unstabilized areas away from completed tree wells.

Maintenance Requirements

- Provide a Maintenance Agreement (or other document or mechanism) that states the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit it with the Maintenance Agreement. Refer to Chapter 8 and Appendix G for specific maintenance requirements.

Figure 6-15: Non-proprietary Tree Filter with Overflow Bypass. Source: University of New Hampshire Environmental Research Group, 2006

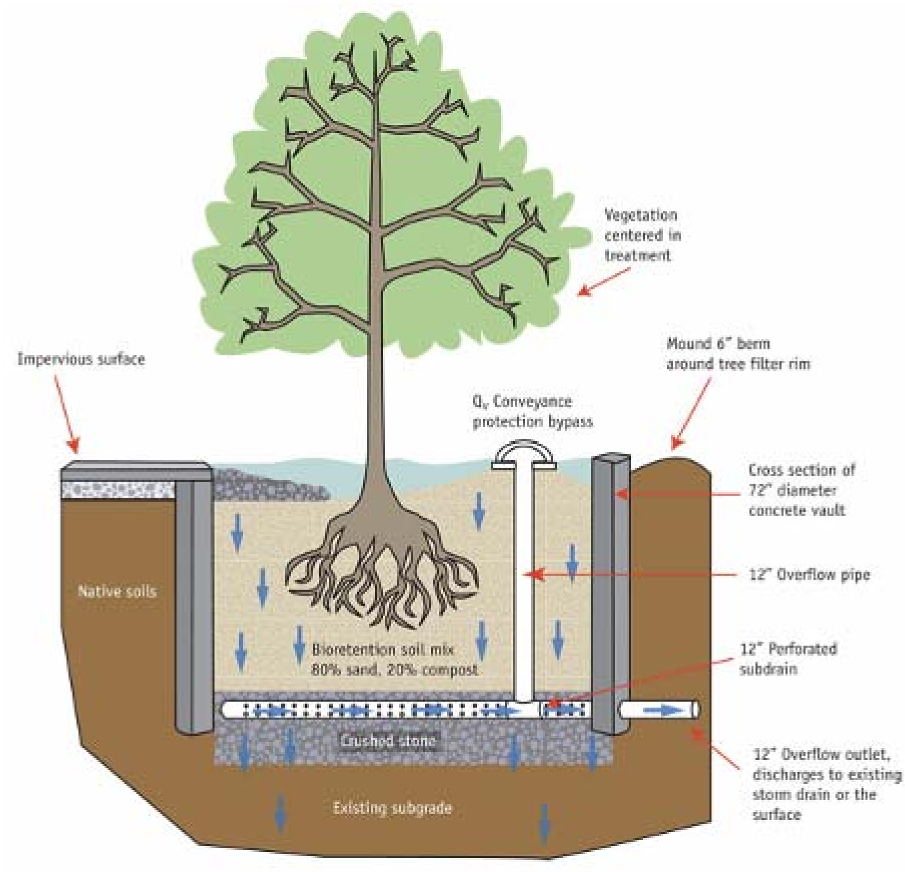

Figure 6-16: Schematic of a non-proprietary tree well filter (note that bioretention soil mix and other components vary from Bay area requirements). Source: UNH Stormwater Center 2007 Annual Report.

Figure 6-17: Proprietary tree well filter at an office building in San José. Photo: City of San José.

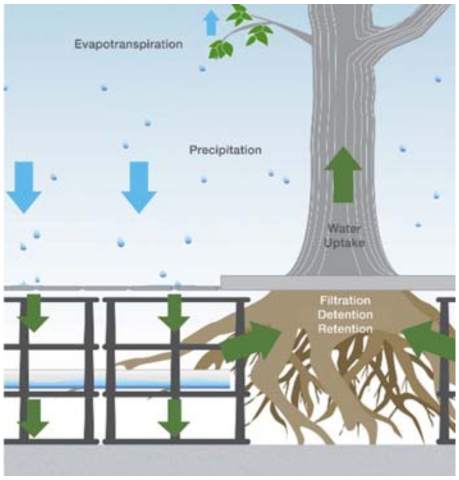

Figure 6-18: Schematic of modular suspended pavement system. Image: deeproot Inc.

6.4 Infiltration Trench

Figure 6-19: Infiltration trench next to parking structure, Palo Alto. Photo: EOA, Inc.

Best Uses

- Limited space
- Adjacent to paved surfaces
- Landscape buffers

Advantages

- Meets LID requirements
- Achieves treatment via infiltration into existing soils
- No surface outfalls

Limitations

- Susceptible to clogging if not maintained
- Infiltration rate of site soils must exceed 0.5 in/hr (i.e., not suitable for Type C or Type D soils)
- Cannot be used with certain site conditions, e.g., high groundwater table, contaminated soils, proximity to wells or septic systems.
- Not for use on steep slopes or in fill soils
- Not for use at industrial sites

An infiltration trench is an excavated trench backfilled with a stone aggregate, and lined with a filter fabric. Infiltration trenches remove suspended solids, particulate pollutants, coliform bacteria, organics, and some soluble forms of metals and nutrients from stormwater runoff by detaining the runoff, storing it in the void spaces of the aggregate, and allowing it to infiltrate into the underlying soil. An underdrain may be provided if the drain is placed above the void space needed to store and infiltrate the water quality design runoff volume. Infiltration trenches are prone to clogging with sediment and require pretreatment using buffer strips or swales as well as regular observation and maintenance to ensure proper functioning.

If an infiltration trench is deeper that it is wide, it will be considered a Class V injection well that is regulated by EPA's Underground Injection Control Program[1]. Care should be taken to design the trench such that its depth does not exceed its largest horizontal dimension. This is usually not an issue with a long, narrow trench. However, note that Santa Clara Valley Water District guidelines for stormwater infiltration devices (Appendix A) will apply when siting any infiltration trenches.

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[1] See EPA Region 9's website: https://www.epa.gov/uic/underground-injection-control-regulations-and-safe-drinking-water-act-provisions

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 infiltration rates greater than 0.5 inches per hour. Soil testing near the trench location is highly recommended to confirm infiltration rates.
- A 10-foot separation between the bottom of the trench 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 Santa Clara Valley Water District Infiltration Guidelines (Appendix A) for additional setback and separation requirements.

TREATMENT MEASURE 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 infiltration rate, 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. Trench depths are usually between 3 and 8 feet.
- The trench surface may consist of large stone or pea gravel.
- 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.
- 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 can be 4 to 6-inch diameter perforated PVC pipe, which is anchored vertically to a foot plate at the bottom of the trench.

INLET TO THE TREATMENT MEASURE

- Runoff should enter the trench via sheet flow from the paved surface. Runoff can be captured by depressing the trench surface or by placing a berm on the downgradient side.
- 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.

VEGETATION

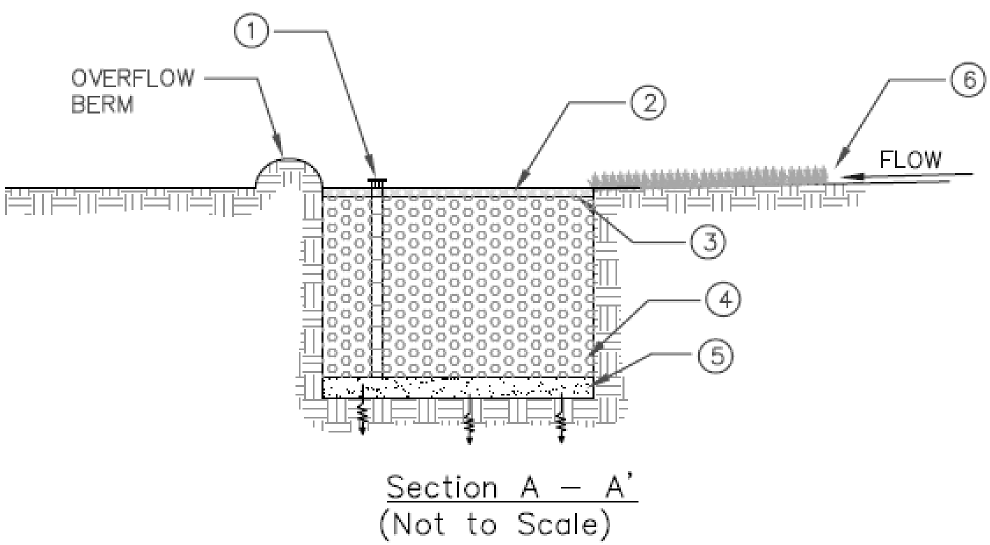
- Infiltration trenches should be kept free of vegetation. If vegetation on the surface is desired, a different treatment measure (e.g., a linear bioretention area) should be selected.
- Trees and other large vegetation should be planted away from trenches such that drip lines do not overhang infiltration beds.

Construction Requirements

- 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.
- Minimize compaction of existing soils in the area of the trench. Protect from construction traffic.

Maintenance Requirements

- Provide a Maintenance Agreement (or other document or mechanism) that states the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit it with the Maintenance Agreement. Refer to Chapter 8 and Appendix G for specific maintenance requirements.



Notes:
1. Observation well with lockable above-ground cap
2. 2" pea gravel filter layer
3. Provide filter fabric if no pretreatment is provided
4. 3' – 5' deep trench filled with 1.5" – 2.5" diameter clean stone with approximately 35% voids
5. 6" deep sand filter layer (or fabric equivalent)
6. Runoff filters through grass filter strip or vegetated swale
7. Optional flow control device for off-line configurations

Figure 6-20: Infiltration Trench Section. Source: County of Los Angeles, 2010.

6.5 Subsurface Infiltration System

Figure 6-21: Photo of subsurface retention/infiltration system installation under a parking lot. Source: Contech.

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

Limitations

- Not recommended for poorly infiltrating soils or highly polluted runoff
- Requires pretreatment
- Potential for standing water and mosquito production

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 with open bottoms. These systems allow infiltration into surrounding soil while preserving the land surface above parking lots, parks and playing fields. A number of vendors offer prefabricated, modular infiltration galleries in a variety of material types, shapes and sizes. Most of these options are strong enough for heavy vehicle loads and can be reinforced 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 Program[1]. 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 the link below and Appendix A). The Santa Clara Valley Water District guidelines for stormwater infiltration devices (Appendix A) also apply when siting any subsurface infiltration system.

[1] See EPA Region 9's website: https://www.epa.gov/uic/underground-injection-control-regulations-and-safe-drinking-water-act-provisions

Design and Sizing Guidelines

DRAINAGE AREA AND SETBACK REQUIREMENTS

- In-situ/undisturbed soils should have a low silt and clay content and have infiltration rates greater than 0.5 inches per hour. Hydrologic soil groups C and D are generally not suitable. Soil testing should be performed to confirm infiltration rates, and an appropriate safety factor (minimum of 2) applied as directed by the municipality.
- A 10-foot separation between the bottom of the drain rock 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 Santa Clara Valley Water District Infiltration Guidelines (Appendix A) 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 infiltration rate 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 infiltration rate, 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

PRETREATMENT 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, buffer strips, or bioretention 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 Requirements

- 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.

Maintenance Requirements

- 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. Refer to Chapter 8 and Appendix G for specific maintenance requirements.

6.6 Rainwater Harvesting and Use

Figure 6-22: Rainwater is collected and used for flushing toilets at Mills College, Oakland.

Best Uses

- High density residential or office buildings 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

- Higher installation and maintenance costs than other LID treatment measures.
- High toilet flushing or irrigation demand needed to use design volume Municipal permitting requirements are not standardized.

Rainwater harvesting is the process of collecting rainwater from impervious surfaces and storing it for later use. Rainwater harvesting systems are designed 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 rain barrels, above-ground or below-ground cisterns, open storage reservoirs (e.g., ponds), and various underground storage devices (tanks, vaults, pipes, and proprietary storage systems). The harvested water is then fed into irrigation systems or non-potable water plumbing systems, either by pumping or by gravity flow. Rooftop runoff is the source of stormwater most often collected in a harvesting/use system, because it often contains lower pollutant loads than at-grade surface runoff, and it provides accessible locations for collection in storage facilities via gravity flow. Rainwater storage systems designed for stormwater management are usually much larger than rain barrel systems (typically 100 gallons or less) used for supplemental landscape irrigation on small sites.

Uses of Harvested Water

Uses of captured water may include irrigation, vehicle washing, and indoor non-potable use such as toilet flushing, heating and cooling, or industrial processing[1]. In the Bay Area, toilet flushing in high density residential or office projects and schools is the use that most commonly generates sufficient demand to use the water quality design volume of runoff. In projects with a

[1] Rainwater harvesting for potable use has special requirements and is not covered by this guidance.

very large landscaped areas, irrigation demand may be sufficient to utilize the required amount of runoff; however, in these types of projects, it is generally more cost-effective to disperse runoff from impervious areas directly onto surrounding landscaping, rather than collecting it in large cisterns for distribution later.

Codes and Standards

The 2013 California Plumbing Code adopted on January 1, 2014 includes rainwater harvesting and graywater requirements, codes, and treatment standards. Chapter 17 of the Plumbing Code, which contains the rainwater harvesting requirements, allows rainwater to be harvested from rooftops 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 16 of the Code. Some small catchment systems (5,000 gallons or less) being used for non-spray irrigation do not require permits – see Chapter 17 for more details[2].

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."[3] The Rainwater Capture Act of 2013, which took effect January 1, 2013, 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 Standard* [4] may also be used as a resource.

System Components

Rainwater harvesting systems typically include the following components: (1) methods to divert stormwater runoff to the cistern or other storage facility; (2) an overflow for releasing water when the cistern is full; (3) a distribution system to get the water to where it is intended to be used; and 4) filtration and treatment systems. Treatment is required for indoor uses of harvested rainwater (see Table 6-2).

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 cistern. The initial rainfall of any storm usually picks up pollutants from dust, bird droppings, and debris 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 collection surface away from the cistern (typically to landscaping) to remove accumulated smaller contaminants, such as dust, pollen, and bird and rodent droppings. Roof washers are commonly used to waste the initial water coming off the collection surface before being allowed to fill the cistern. The simplest version is a standpipe connected to the downspout that fills before rainwater can flow into piping leading to the cistern.

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[2] www.iapmo.org/Pages/2013CaliforniaPlumbingCode.aspx click on Chapter 17

[3] www.iapmo.org/Pages/2013CaliforniaPlumbingCode.aspx click on Chapter 2

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

TREATMENT METHODS

Harvested rainwater typically requires filtration prior to any use, and disinfection for indoor non-potable use. As a general reference, the Texas Manual on Rainwater Harvesting (3rd Edition, 2006) identifies two methods of disinfection used in rainwater harvesting systems for indoor use: chlorine and ultraviolet (UV) light. Compared to chlorination, UV light is often preferred because it is safer to use, does not create harmful disinfection by-products, and uses minimal power for operation. However, filtration before the UV light treatment is required because pathogens can be shadowed from the UV light by suspended particles in the water. Disinfection using ozone may also be an option for larger systems. Check with local health officials for acceptable methods of disinfection.

The 2013 California Plumbing Code contains minimum treatment and water quality standards for rainwater, which are summarized in Table 6-2 below.

Table 6-2
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: 2013 California Plumbing Code, Table 1702.9.4, Chapter 17, page 329.		

Design and Sizing Guidelines

HYDRAULIC SIZING

- If a rainwater harvesting system will be designed to fully meet Provision C.3.d stormwater requirements, there must be sufficient demand to use the water quality design volume, i.e., 80 percent of the average annual rainfall runoff, from the collection area. Appendix I provides guidance on how the 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 facility) to achieve the appropriate combination of drawdown time and cistern volume indicated in the sizing curves included 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

- Provide separate piping without direct connection to potable water piping. Dedicated piping should be color coded and labeled as harvested rainwater, not for consumption. Fixtures supplied with non-potable rainwater should include signage identifying the water source as non-potable and not for consumption.
- The rainwater harvesting system must not be connected to the potable water system in any way.
- When make-up water is provided to the rainwater harvesting 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 buildling code requirements.
- Equip rainwater storage facilities covers with tight seals and/or screens, to reduce risk of mosquito production. Follow mosquito control guidance in Appendix F.
- Do not install rainwater storage facilities 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:
  1. The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the cistern.
  2. 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.
- Storage facilities should be provided with access for maintenance, and with a means of draining and cleaning.

DESIGN GUIDELINES FOR INDOOR USE

- Provide filtration and disinfection of harvested rainwater for indoor non-potable use, as required by the California Plumbing Code (Table 6-2) and any municipality-specific requirements.
- Avoid harvesting water for indoor non-potable use from roofs with architectural copper, which may discolor porcelain plumbing fixtures.

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 to a hydraulically-sized treatment measure.
- First flush diverters should be installed in such a way that they will be easily accessible for regular maintenance.
- Do not direct any rainwater from roofs with wood shingles, asphalt shinges, tar, lead, etc. to food-producing gardens due to the leaching of compounds that may adversely affect food for human consumption.

Construction Requirements

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

Maintenance Requirements

- Provide a Maintenance Agreement (or other document or mechanism) that states the parties' responsibility for maintenance and upkeep.
- Prepare a maintenance plan and submit it with the Maintenance Agreement. See Chapter 8 and Appendix G for guidance on maintenance requirements, and discuss maintenance requirements with your contractor or supplier.

6.7 Media Filter

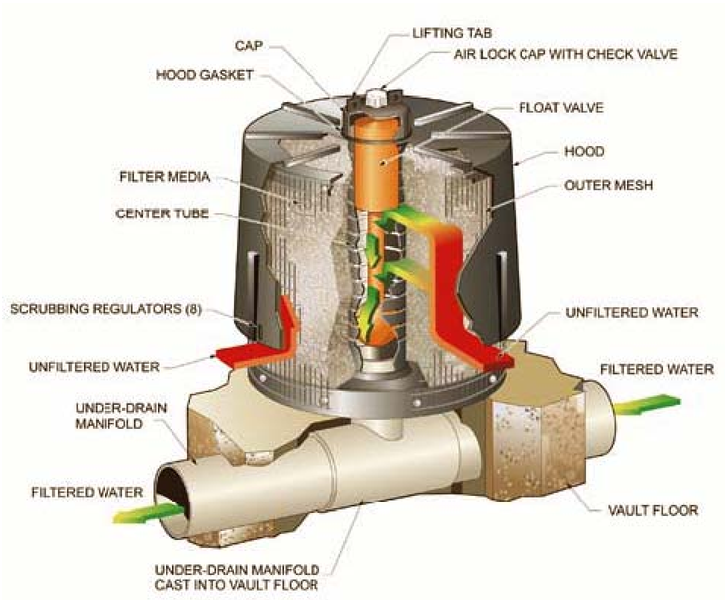

Figure 6-23: Filter Cartridge, Typically Used as Part of Array. Source: CONTECH Stormwater Solutions, 2006. (Note: This photo is for general information only and is not an endorsement of this or any other proprietary product.)

Best Uses

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

Advantages

- Less area required
- Customized media
- Customized sizing

Limitations

- Not considered LID
- High installation and maintenance costs; rely on manufacturer
- Confined space entry may be required
- Media filtration is only allowed at qualifying Special Projects

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-vegetated[1] 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.

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 J). Media filters may also be used as part of a treatment train, e.g., 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 6-23, the

[1] Vegetated media filters using soil as the media are described in the bioretention, flow-through planter, and tree well filter sections of the C.3 Handbook.

water flows laterally (horizontally) into the cartridge 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 (i.e., surface loading rate).

Design and Sizing Guidelines

- For Special Projects, 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 Treatment[2]. A list of proprietary media filters currently holding this certification can be obtained from the Department of Ecology's website[3].
- 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 Figure 6-24 for an example).
- Consider filter head loss when selecting a media filter product. Your options may be limited if the site has limited available head or if you are 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 6-25 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.
- Units 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 as vactor trucks need access for cleaning.

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:

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[2] "General Use" is distinguished from pilot or conditional use designation, and "Basic Treatment" is distinguished from treatment effectiveness for phosphorus removal. Basis 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.

[3] See: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html

1. The depth to seasonal high groundwater level should be at least 5 feet from the bottom of the structure.
2. 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.

Maintenance Requirements

- 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. Refer to Chapter 8 and Appendix G, or check with the manufacturer for maintenance requirements.

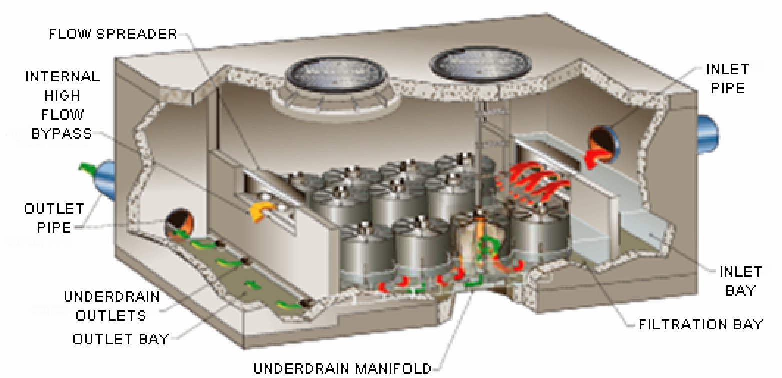

Figure 6-24: Plan View, Filter Array in a Vault. Source: CONTECH, 2006. (Note: This photo is for general information only and is not an endorsement of this or any other proprietary product.)

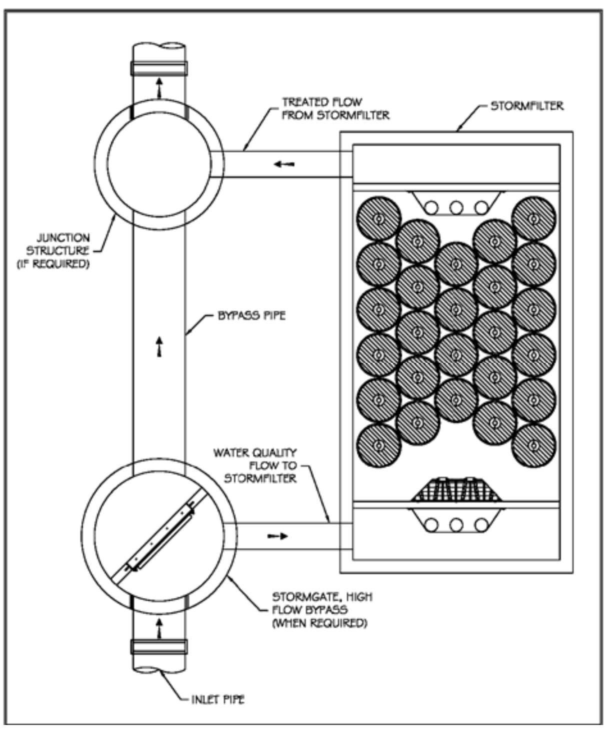

Figure 6-25: Profile View, Filter Array in a Vault with a High Flow Bypass. Source: CONTECH Stormwater Solutions, 2006. (Note: This photo is for general information only and is not an endorsement of this or any other proprietary product.)

6.8 Extended Detention Basin

Figure 6-26: Extended detention pond. Source: City of Saratoga

Best uses

- Detain low flows and peak flows
- Settling of suspended solids
- Sites larger than 5 acres
- Hydromodification management

Advantages

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

Limitations

- Land requirements
- Not a stand-alone treatment measure after 12/1/11

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

Starting December 1, 2011, projects are not allowed to 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, an extended detention basin could be used as part of a treatment train, in which the basin stores a large volume of water and gradually releases it to an LID treatment measure, such as a bioretention area.

Design and Sizing Guidelines

TREATMENT DIMENSIONS AND SIZING

- Extended detention basins used as part of a treatment train should be sized to capture the required water quality volume with a 48-hour detention time.
- Extended detention basins should have no greater than 3:1 side slopes (2:1 side slopes may be allowed if fenced).
- 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.
- The extended detention basin should empty within five days to avoid mosquito production.

- The extended detention basin should have a length to width ratio of at least 1.5:1.
- 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.
- 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.

INLETS TO TREATMENT MEASURE

- The inlet pipe should enter the basin at the invert, and have engineered energy dissipation.
- 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 outlet pipe or as part of the outlet riser.

OUTLETS AND ORIFICES

- If the detention basin is to be used as part of a treatment train, the outlet should be sized with a drawdown time of 48 hours for the design water quality volume.
- If the detention basin is to be used for hydromodification management, see Chapter 7 and Appendix E of the SCVURPPP C.3 Handbook for outlet and orifice sizing guidelines.
- Orifices should each be a minimum diameter of 0.5 inch. Extended detention basins are not practical for small drainage areas because the criteria for the minimum orifice diameter cannot be met.
- Each orifice should be protected from clogging using a welded stainless steel wire mesh screen. The screen should protect the orifice openings from runoff on all exposed sides. For example, see Caltrans standard detail for Water Quality Outlet Riser Type 1.

VEGETATION

- Plant species should be adapted to periods of inundation. See planting guidance in Appendix D.
- Use integrated pest management (IPM) principles in the landscape design to avoid the need for synthetic pesticides and quick-release fertilizer. Check with the local jurisdiction regarding local IPM policies.
- 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

- 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 Requirements

- Minimize compaction of existing soils. Protect from construction traffic.
- Protect the area from construction site runoff. Runoff from un-stabilized areas should be diverted away from the detention basin.

Maintenance Requirements

- 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. Refer to Chapter 8 and Appendix G for specific maintenance requirements.

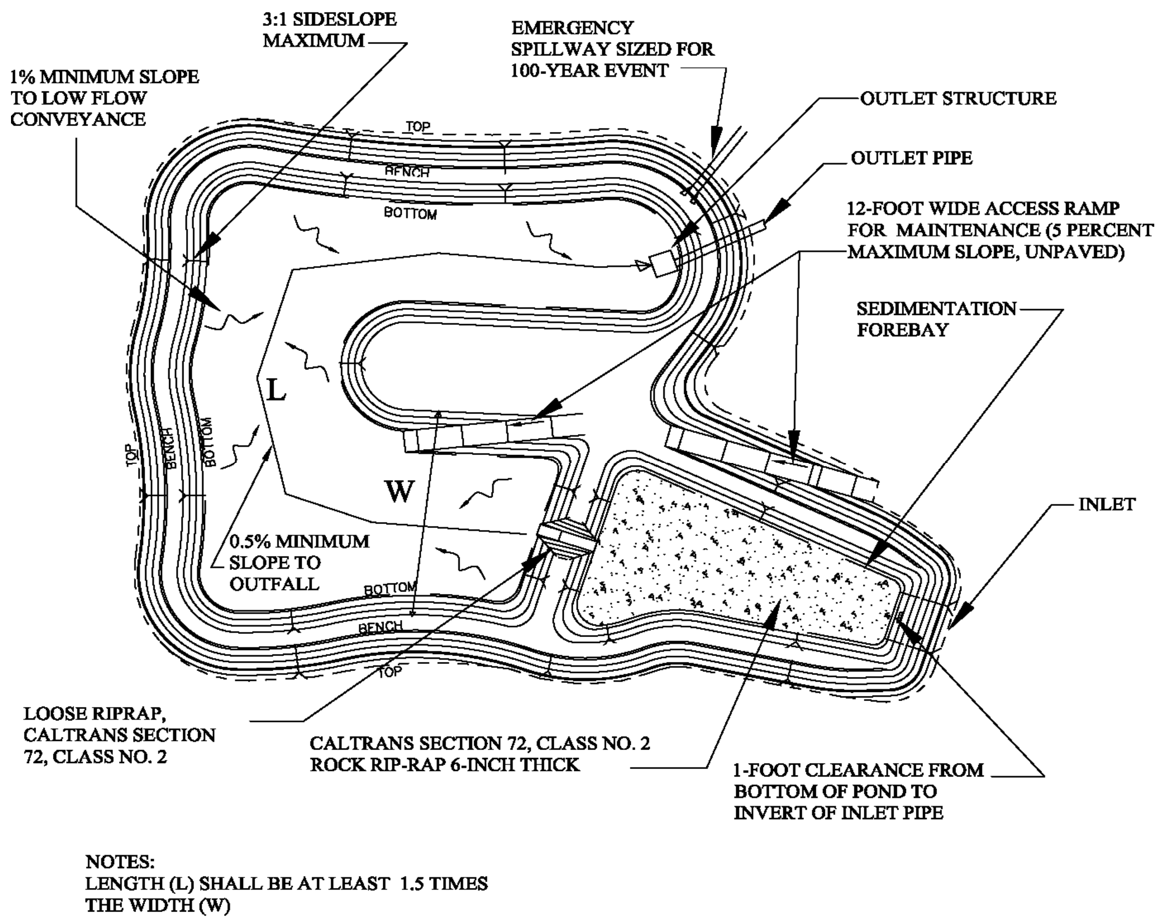

Figure 6-27: Plan View, Typical Extended Detention Basin

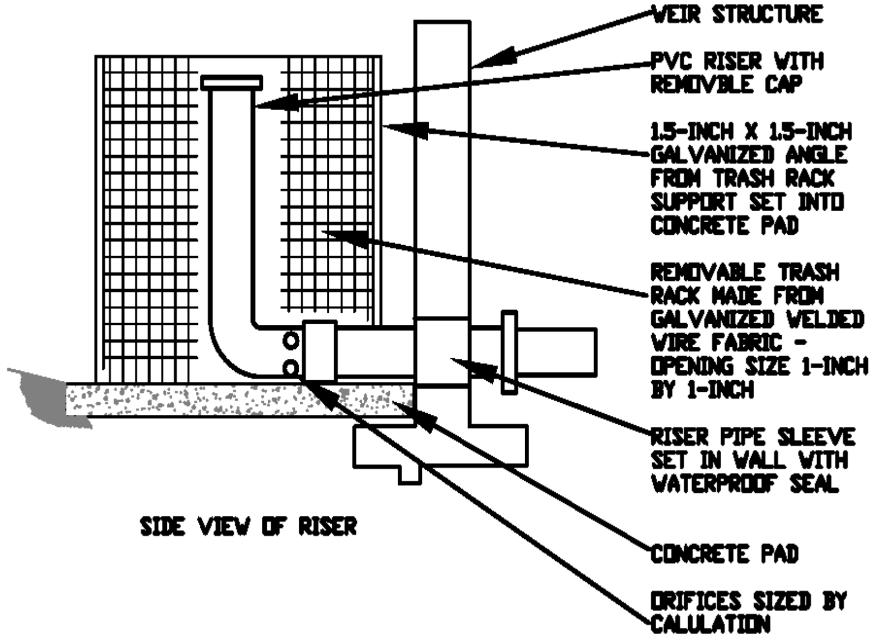

Figure 6-28: Side view of riser, extended detention basin

6.9 Green Roofs

Figure 6-29: Extensive green roof at the Casa Feliz Studios in San José.

Best Uses

- Urban infill sites with limited room for stormwater treatment

Advantages

- Minimizes roof runoff
- Insulates and reduces "heat island" effect
- Earns LEED credits
- Vegetation can provide habitat
- Longer "lifespan" than conventional roofs

Limitations

- Sloped roofs require stepped surfaces
- Non-traditional design
- Higher installation costs

Green roofs are vegetated roof systems that filter, absorb, and retain or detain the rain that falls upon them. Green roof systems are comprised of a layer of planting media planted with vegetation, underlain by other structural components including waterproof membranes, synthetic insulation and geofabrics. A green roof can be either ***extensive***, with 3 to 7 inches of lightweight planting media and low-profile, low-maintenance plants, or ***intensive*** with a thicker (8 to 48 inches) media, more varied plantings, and a more garden-like appearance. Green roofs can provide high rates of rainfall retention and decrease the peak flow rate because of the storage that occurs in the media during rain events.

Design and Sizing Guidelines

- Green roofs may be considered "self-treating areas" or "self-retaining areas" and may drain directly to the storm drain, as allowed by the local municipality, if they meet the following requirements:

  The green roof system planting media must be sufficiently deep to provide capacity within the pore space of the planting media for the water quality design volume (i.e., 80 percent of the average annual runoff).

  If the green roof system receives runoff from other areas of the roof, such as mechanical/HVAC equipment areas or impervious walkways, the media must be sufficiently deep to provide capacity for the additional runoff.

  The planting media must 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.
- Extensive green roof systems contain layers of protective materials to convey water away from the roof deck. Starting from the bottom up, typical construction consists of a waterproof membrane, followed by a root barrier, a layer of insulation (optional), a drainage

layer, a filter fabric for fine soils, the engineered growing medium or soil mix, and the plant material (see Figure 6-33).

- 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.
- Design and installation should be completed by an established vendor or certified green roof professional.
- Plants should be selected to create a healthy, drought-tolerant roof cover. In general, selected plants should:
    - Be native or adapted species tolerant of extreme climate conditions (e.g., heat, drought, and wind);
    - Be low-growing, with a range of growth forms (e.g., spreading evergreen shrubs, succulents, perennials, or self-seeding annuals);
    - Have shallow root systems without the chance of developing a deep taproot; and
    - Be long-lived or self-propagating, with low maintenance and fertilizer needs.

  See Appendix D for planting guidance.
- Green roofs should drain to landscaping or to bioretention facilities where feasible to do so.
- Irrigation systems are typically required to establish and/or maintain selected plants. In addition, local fire codes may require irrigation systems to prevent a fire hazard or for emergency fire suppression.
- Buildings with green roofs should provide the required facilities (e.g., ladders, guard rails, and anchors) to ensure safe access by maintenance workers in compliance with OSHA regulations.

Maintenance

- Vegetation must be maintained in a healthy state for the life of the project.
- Inspections should be conducted at least semi-annually to confirm adequate irrigation and plant health.
- Fertilize and replenish growing media as specified by landscape designer and as needed for plant health. Avoid the use of pesticides or quick release fertilizers.

See www.greenroofs.com for information about and more examples of green roofs.

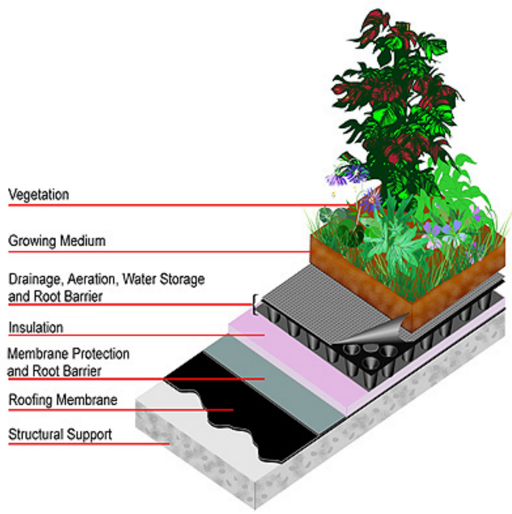

Figure 6-30: Green roof cross-section. Source: American Wick Drain Corp.

Figure 6-31: Intensive Green Roof at Google, Mountain View.

6.10 Pervious Pavement

Figure 6-32: Parking Lot with Pervious Concrete, San José

Figure 6-33 Porous Asphalt Parking Lot, Stanford

BEST USES

- Low-speed residential roads
- Alleys
- Parking lots
- Driveways
- Sidewalks & plazas

ADVANTAGES

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

LIMITATIONS

- May clog without periodic vacuum cleaning
- Low-speed areas only
- Higher installation costs than conventional paving

Figure 6-34: Permeable Pavers, Palo Alto

Pervious pavement describes a system comprised of a load-bearing, durable surface constructed over a subbase/base structure typically consisting of compacted, open-graded aggregate. This layer or layers temporarily stores water prior to infiltration or drainage to a controlled outlet. The surface allows water to infiltrate at a high rate. Pervious pavement is well suited for automobile parking lots, alleys, walking paths and sidewalks, plazas, and driveways. It can also be used for low-speed residential roads receiving occasional truck traffic.

The types of pervious pavement include pervious concrete, porous asphalt, pervious concrete pavers, and permeable interlocking concrete pavement (PICP). Pervious pavers allow infiltration across the entire surface of the paver while permeable pavers utilize the joint space between the pavers for infiltration. Figures 6-35 to 6-37 illustrate pavement cross sections typically under vehicular traffic. These cross sections may include underdrains. Crushed aggregate is sometimes used as pervious pavement as well. Pervious pavement is not considered an impervious area and can function as a self-treating area when underlain with pervious soil or pervious storage material sufficient to hold the volume of rainfall runoff in the Municipal Stormwater Regional Permit (MRP) Provision C.3.d.

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

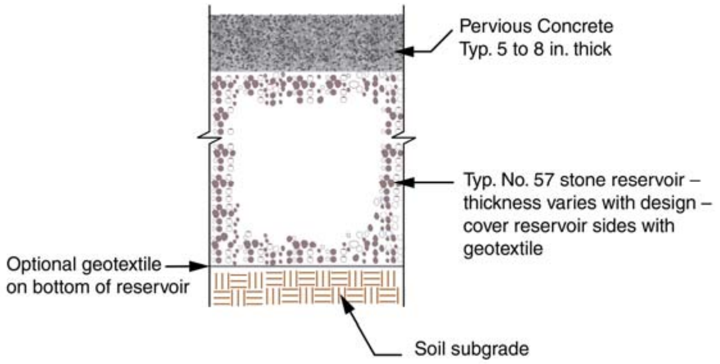

Figure 6-35. Typical Pervious Concrete Pavement
(Source: Interlocking Concrete Pavement Institute)

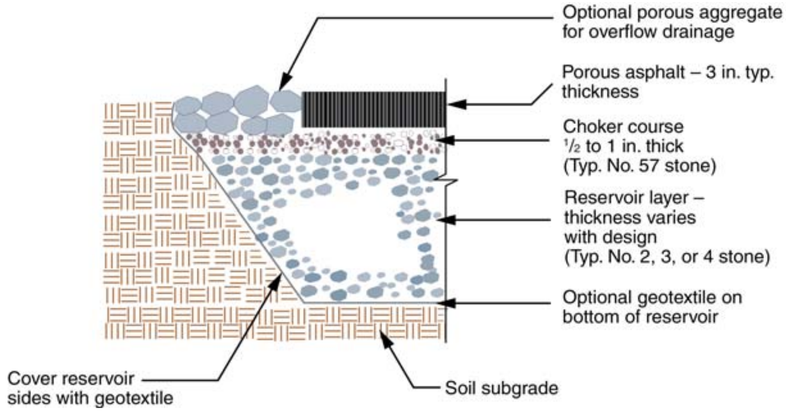

Figure 6-36. Typical Porous Asphalt Pavement
Note: ASTM No. 3 or 4 stone may be substituted for No. 2 stone.
(Source: Interlocking Concrete Pavement Institute)

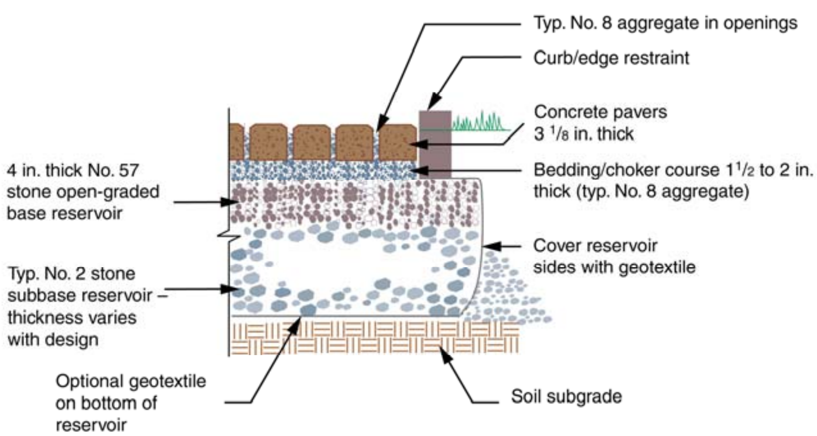

Figure 6-37. Typical Permeable Interlocking Concrete Pavement
Note: ASTM No. 3 or 4 stone may be substituted for No. 2 stone.
Note: ASTM No. 89 or 9 stone may be used in the paver openings.
(Source: Interlocking Concrete Pavement Institute)

Design and Sizing Guidelines

The base thickness design of pervious pavement is determined by the expected traffic loadings on the pavement and hydrologic sizing considerations. The thicker of the two base designs is used for the project. The following design 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 infiltration rate to meet the requirements in this Handbook, or include an underdrain(s) to remove detained flows stored within the aggregate base. The surfacing and bedding materials (where applicable) are not used to store water.
- Depth to seasonal high groundwater from the soil subgrade should be at least 5 feet from the bottom of the subbase of the pervious pavement system, unless a different separation is recommended by the geotechnical engineer.
- Slopes of pervious pavement surface should not exceed 5% or up to 16% with underdrains. Slopes exceeding 3% typically require berms or check dams placed laterally over the soil subgrade 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 earthen berms.

AGGREGATES AND UNDERDRAINS

- 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 has sufficient capacity in its void spaces to store and infiltrate the MRP Provision C.3.d volume of rainfall runoff, the area of pervious paving is not considered an impervious surface and can function as a self-treating area per Section 4.1 of the C.3 Handbook.
- Pervious pavements may be designed to accept runoff from adjacent areas. If the subbase/base layer has sufficient capacity in its void spaces to store and infiltrate the C.3.d volume of rainfall falling onto the pervious paving and runoff from adjacent areas, the pervious paving is not considered an impervious surface and can function as a self-retaining area per Section 4.2 of the C.3 Handbook.
- 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 non-perforated, upturned elbow pipe for outflows (see Figures 6-38 and 6-39. 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 volume of rainfall falling onto the pervious 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; 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 or deflections;
  - Lifetime expected vehicular traffic loading in 18,000 lb. equivalent single axle loads or Caltrans Traffic Index;

- Drainage routing of detained flows within the open-graded aggregate subbase/base as well as expected infiltration into in-situ soils, or collection in an underdrain if infiltration rate cannot meet design criteria.

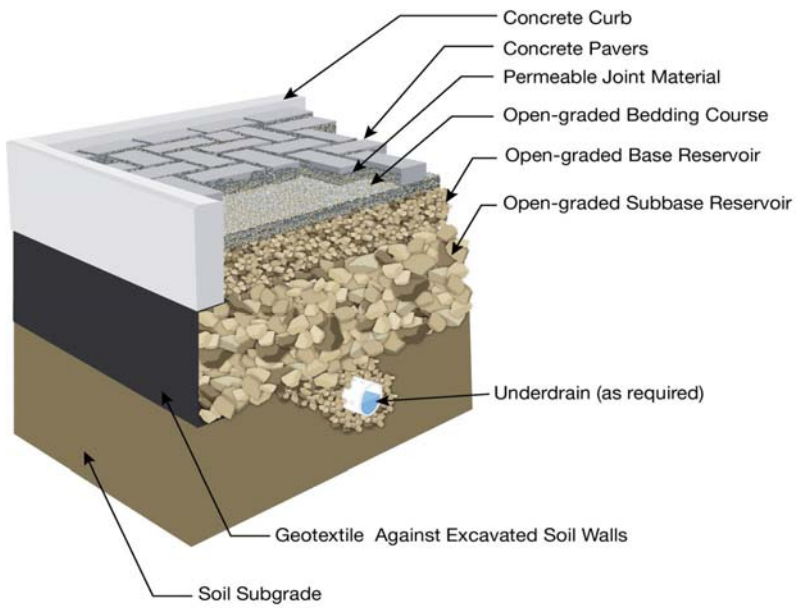

Figure 6-38. PICP designed for partial infiltration, with underdrain.
(Source: Interlocking Concrete Pavement Institute)

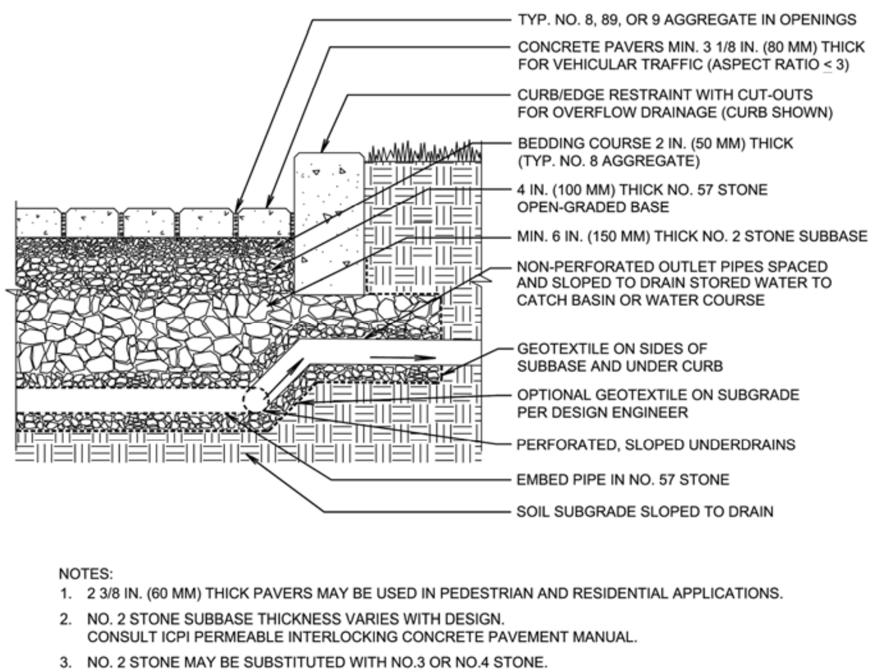

Figure 6-39. Detail of underdrain in aggregate trench with upturned elbow.
(Source: Interlocking Concrete Pavement Institute)

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. Material choice is therefore a balance between stiffness in the surface layer and permeability. PICP requires 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.
- Paving units for PICP should conform to the dimensional tolerances, compressive strengths and absorption requirements in ASTM C936. Paving units subject to vehicular traffic should be at least 3 1/8 in. thick and have a length to thickness ratio not exceeding 3.

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 pervious concrete pavement should be reviewed by the concrete manufacturer, the National Ready Mixed Concrete Association (NRMCA) (www.nrmca.org), or as directed by 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 PICP 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 (2011) for additional information on design, construction and maintenance.
- Installation of pervious concrete, porous asphalt and PICP should be done by contractors who have constructed projects similar in size to that under consideration.
- For 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.
- For PICP, 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 infiltration rate of 100 in./hr when tested in accordance with ASTM C1701. PICP should have a minimum surface infiltration rate 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 www.dot.ca.gov/hq/oppd/stormwtr/pervious.htm.

Maintenance

- A maintenance plan should be provided. Typical requirements are described in Chapter 8. An essential requirement is periodic surface vacuuming to remove accumulated debris and sediment.

6.11 Grid Pavements

Figure 6-40: *Turf block fire access at the Residence Inn in Los Altos*

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
- Weeds
- Lightly-trafficked areas only
- Higher installation costs than conventional paving

Grid pavements consist 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 be planted with topsoil and grass in their openings and installed over a sand bedding layer that rests over a compacted, dense-graded aggregate base (see Figures 6-35 and 6-36). When planted with turf grass, they also assist in providing a cooler surface than conventional pavement. Grid pavements can also be designed with aggregates in the openings.

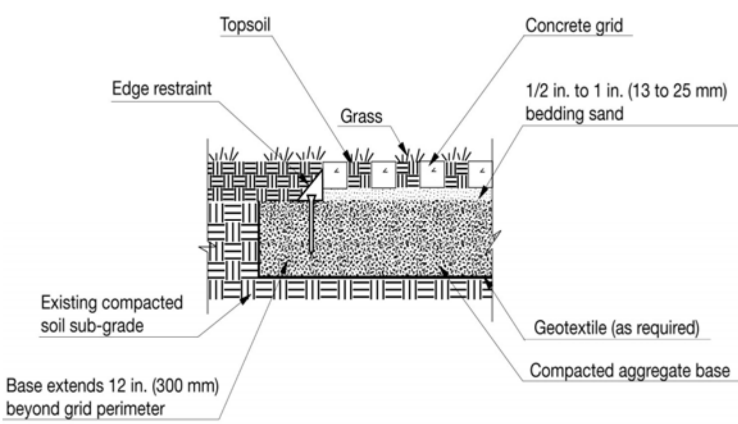

Figure 6-41: Concrete Grid Pavement for Occasional Vehicular Use or for Emergency Access Lanes

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

Figure 6-42: Plastic Grid Pavement for Occasional Vehicular Use or for Emergency Access Lanes
Note: Sand and turf grass can be replaced with ASTM No. 8 aggregate in cell openings.

Grid pavements 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. Grid pavements are not considered an impervious area and can function as "self-treating areas" when supported by an aggregate base sufficient to hold the volume of rainfall runoff specified in the Municipal Stormwater Regional Permit Provision C.3.d. Grid pavements with dense-graded bases are not generally designed to accept runoff from adjacent areas.

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 infiltration rate 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 from the soil subgrade should be at least 5 ft. from the bottom of the subbase of the grid pavement system, unless a different separation is recommended by the geotechnical engineer.
- Slopes of grid pavements 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 provide some infiltration.

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 volume of runoff, the area of pervious 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 a 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 volume of rainfall falling onto the pervious 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 infiltration rate cannot meet design criteria

GRID PAVEMENT 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 infiltration rate.
- Grid pavements should have edge restraints to render them stationary when subject to pedestrian or vehicular traffic.

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 grid pavements should be done per the manufacturer's recommendation. Such designs should be reviewed by the manufacturer or as directed by the municipality.
- Design for concrete grid pavements 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 *Tech Spec 8 Concrete Grid Pavements* available at www.icpi.org for additional design information and guide specifications.
- Installation of grid pavements should be done by contractors who have constructed projects similar in size to that under consideration. Only contractors holding a certificate of completion in the Interlocking Concrete Pavement Institute's Commercial Paver Technician Course should be considered for concrete grid pavement construction, 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.
- Protect excavated area from excessive compaction due to construction traffic and protect the finished pavement from construction traffic.

Maintenance

- A maintenance plan should be provided. Maintenance of grassed grid surfaces will require watering and mowing. Typical maintenance requirements are described in Chapter 8.