Chapter

5

General Technical Guidance for Treatment Measures

The technical guidance in this Chapter will help you with proper sizing and design concepts for various types of stormwater treatment measures.

This chapter contains general technical information regarding stormwater treatment measures for all types of new development and redevelopment projects. It includes the following topics:

- Hydraulic sizing criteria;
- Getting runoff into stormwater treatment measures;
- Infiltration guidelines;
- Underdrains;
- Bypassing high flows;
- Using “treatment trains”;
- Mosquito control;
- Plant selection and maintenance;
- Integrating trees and stormwater treatment.

5.1 Hydraulic Sizing Criteria

The stormwater treatment measures must be sized to treat stormwater runoff from ***relatively small sized storms*** (storms with frequent recurrence intervals) that comprise the great majority of all storms. The intent is to treat most of the stormwater runoff on an average annual basis while recognizing that it would be infeasible to size stormwater treatment measures to treat runoff from very large storms that occur only every few years. (See Section 5.5 for more information on how stormwater treatment measures that are sized to treat runoff from small, frequent storms can also be designed to handle flows from large, infrequent storms.)

How Much of a Project Site Needs Stormwater Treatment?

The Municipal Regional Stormwater Permit requires that, for all "Regulated Projects"[1], runoff from the project site must be treated. Exceptions to the stormwater treatment requirement for Regulated Projects are pervious areas that are "self-treating" (including areas of pervious pavement with a hydraulically-sized aggregate base layer) as described in Section 4.1, and "self-retaining areas" designed to store and infiltrate runoff from rooftops or paved areas as described in Section 4.2. Other than "self-treating areas" and "self-retaining areas," runoff from ***all areas of a project site*** must receive stormwater treatment.

For redevelopment projects and road reconstruction projects, the ***"50% Rule"*** applies. Projects that alter or replace less than 50 percent of existing impervious surface need to treat stormwater runoff only from the portion of the site that is redeveloped. Projects that alter or replace 50 percent or more of the existing impervious surface are required to treat runoff from the entire site. Calculations of the altered portion should include portions of the public right of way that are altered as part of the redevelopment project.

Flow-Based Versus Volume-Based Treatment Measures

For hydraulic sizing purposes, stormwater treatment measures can be divided generally into three groups: flow-based, volume-based, and treatment measures that use a combination of flow and volume capacity. ***Flow-based treatment measures*** remove pollutants from a moving stream of stormwater through filtration, infiltration or biological processes, and the treatment measures are sized based on hourly or peak flow rates. Examples of flow-based treatment measures include tree well filters and most proprietary media filters. ***Volume-based treatment measures*** detain stormwater for periods of time and treat primarily through settling and/or infiltration processes. Examples of volume-based stormwater treatment measures include infiltration basins and infiltration trenches. Flow-through planters and bioretention areas can use a sizing method based on a ***combination of flow and volume*** for stormwater treatment. Table 5-1 shows which hydraulic sizing method is appropriate for commonly used stormwater treatment measures.

[1] "Regulated Projects" are projects that create and/or replace 5,000 square feet or more of impervious surface, detached single-family home projects that create and/or replace 10,000 square feet or more of impervious surface, and road reconstruction projects that create and/or replace 1 acre or more of impervious surface.

Table 5-1 Flow and Volume Based Treatment Measure Sizing Criteria		
Type of Treatment Measure	**LID?**	**Hydraulic Sizing Criteria**
Bioretention area	Yes	Flow- or volume-based or combination
Flow-through planter box	Yes	Flow- or volume-based or combination
Tree well filter	Yes[2]	Flow-based
Infiltration trench	Yes	Volume-based
Subsurface infiltration system	Yes	Volume-based
Rainwater harvesting and reuse	Yes	Volume-based
Media filter	No	Flow-based (most)
Extended detention basin	No	Volume-based

Note that this section does not address the sizing of a treatment system that will be used for both volume and flow duration control, as may be required if the project is subject to hydromodification management (HM) requirements.

Volume-Based Sizing Criteria

The Municipal Regional Stormwater Permit specifies two alternative methods for hydraulically sizing volume-based stormwater treatment measures:

- Determine the stormwater quality volume for the area, based on historical rainfall records, using the formula and volume capture coefficients in "Urban Runoff Quality Management (URQM), WEF Manual of Practice No. 23/ASCE Manual and Report on Engineering Practice No. 87 (1998), pages 175-178 (known as the "URQM Approach"); or
- Determine the stormwater quality volume equal to 80% of the annual runoff, in accordance with the methodology in Appendix D of the California Stormwater Best Management Practices Handbook (2003) using local rainfall data (known as the California BMP Handbook Approach").

The URQM approach is based on modeling and regression analysis using long-term rainfall records from six U.S. cities, including San Francisco, but the coefficients are based on average storm event size and do not represent local rainfall patterns. The California BMP Handbook Approach incorporates sizing curves that were developed using continuous simulation modeling based on local rainfall data. For these reasons, SCVURPPP recommends the use of the "California Stormwater BMP Handbook Approach." This approach was adapted for Santa Clara Valley using continuous simulation modeling to generate sizing curves based on rainfall records from four rain gages in Santa Clara County (see Table 5-2) for various soil types

> ***Recommended Volume-Based Sizing Approach***
>
> Volume-based treatment measures should be designed to treat the stormwater quality volume equal to 80% of the annual runoff from the site, using the sizing curves in Appendix B specific to Santa Clara Valley conditions.

[2] A tree well filter is considered LID treatment if biotreatment soil is used as the filter media and the unit is sized based on a 5 in/hr surface loading rate.

and site slopes. These curves are provided in Appendix B.

SCVURPPP has developed a Worksheet for Sizing Volume-Based Treatment Controls, which is included in Appendix B. Completing this worksheet will walk you through the following steps to size your volume-based treatment measure.

1. Determine the treatment measure ***drainage area***. This includes all areas that will contribute runoff to the stormwater treatment measure, including pervious and impervious areas. The drainage areas of the site should be laid out such that any self-treating areas (described in Section 4.1) or impervious surfaces that drain to self-retaining areas (described in Section 4.2) do NOT drain to the treatment measure.
2. Determine the ***percent imperviousness*** of the drainage area for the stormwater treatment measure.
3. Determine the ***mean annual precipitation*** for the project site (MAP_{site}) using the map in Appendix B.
4. Identify the ***reference rain gage*** that is closest to your project site from the list of rain gages in Table 5-2, and the mean annual precipitation for the reference gage (MAP_{gage}).
5. Determine the ***rain gage correction factor*** for the precipitation at your site using the information from Step 3 and Step 4.

$$\text{Correction Factor} = MAP_{site}/MAP_{gage}$$

6. Identify the general ***soil type*** for the treatment measure drainage area, using the map in Appendix B or site soils information.
7. Determine the ***average slope*** for the drainage area of the treatment measure.
8. Determine the ***unit basin storage volume*** using the sizing curves provided in Appendix B. The worksheet in Appendix B will help you identify which curve to use for the applicable rain gage, depending on the average slope and soil type. You may need to interpolate between the curves for your site's average slope.
9. Size the stormwater treatment measure using the following equation:

Water quality design volume = Rain gage correction factor X Unit Basin Storage Volume X Drainage area

Table 5-2
Reference Rain Gages

Rain Gage	Mean Annual Precipitation (MAP_{gage})
San Jose Airport	13.9
Palo Alto	13.7
Gilroy	18.2
Morgan Hill	19.5

Appendix B includes examples of sizing volume-based treatment measures using the worksheet. Stormwater treatment measure sizing worksheets (in Excel format) are also available on the Program website at this link: https://scvurppp.org/newdev/

Flow-Based Sizing Criteria

The Municipal Regional Stormwater Permit specifies three alternative methods for hydraulically sizing flow-based stormwater treatment control measures, such as bioretention areas, flow through planters, and media filters. These three methods are described in Table 5-3.

Table 5-3
Flow-based Sizing Criteria Included in MRP Provision C.3.d

Flow-based Sizing Criteria	Description	Practice Tips
Percentile Rainfall Intensity	The flow of runoff produced by a rain event equal to at least two times the 85th percentile hourly rainfall intensity, using local rainfall data.	Curves providing the 85^{th} percentile rainfall intensity for the four rain gages in Santa Clara Valley are provided in Appendix B.
0.2 Inch-per-Hour Intensity (Uniform Intensity Approach)	Simplification of the Percentile Rainfall Intensity Method: The flow of runoff resulting from a rain event equal to at least 0.2 inches per hour intensity.	This simplified approach is most commonly used. In the Bay Area, calculating the percentile rainfall intensity has generally resulted in a value of 0.2 in/hr or greater. However, in some areas of the Santa Clara Valley, the percentile rainfall intensity is less than 0.2 in/hr, which may result in a smaller treatment facility.
10% of the 50-year peak flow rate (Factored Flood Flow Approach)	The design flow rate is determined using Intensity-Duration-Frequency curves published by the local flood control agency or climactic data center.	This approach may be used if the 50-year peak flow has been determined. This approach has not been used locally.

The percentile rainfall intensity method is based on ranking the hourly depth of rainfall from storms over a long period, determining the 85^{th} percentile hourly rainfall depth and multiplying this value by two. The permit also allows the use of 0.2 inches/hour as one of the three alternative methods regardless of the results from calculating values from local rainfall depths.

Because two of the permit allowed methods yield similar results and the third method requires data that may not be readily available, SCVURPPP recommends the use of a ***rainfall intensity of 0.2 inches/hour*** or two times the 85^{th} percentile rainfall intensity at a local rain gage (adjusted based on MAP) to design flow-based treatment systems.

The Sizing for Flow-Based Treatment Controls Worksheet in Appendix B provides the procedures to size the stormwater treatment measure using the Rational Method, which computes the runoff resulting from the design rainfall intensity.

The Rational Method formula is:

$$Q = CiA$$

Where

Q = flow in cubic feet/second

i = rainfall intensity in inches/hour

C = composite runoff coefficient (unitless – see Table 5-4)

A = drainage area in acres

To accomplish this, the worksheet uses the following steps:

1. Determine the ***drainage area***, "A," for the stormwater treatment measure.
2. Determine the ***runoff coefficient,*** "C," from Table 5-4. Note that it is more accurate to compute an area-weighted "C-factor" based on the surfaces in the drainage area, if possible, than to assume a composite C-factor.
3. Use a design intensity of ***0.2 inches/hour*** for "i" in the Q=CiA equation.
4. Determine the design flow (Q) using Q = CiA:

   Q = [Step 2] × 0.2 in/hr × [Step 1] = _____ cubic ft/sec [3]

Table 5-4
Estimated Runoff Coefficients for Various Surfaces During Small Storms[4]

Type of Surface	Runoff Coefficients "C" factor
Roofs	0.90
Concrete	0.90
Stone, brick, or concrete pavers with mortared joints and bedding	0.90
Asphalt	0.90
Stone, brick, or concrete pavers with sand joints and bedding	0.90
Pervious concrete	0.10
Porous asphalt	0.10
Permeable interlocking concrete pavement	0.10
Grid pavements with grass or aggregate surface	0.10
Crushed aggregate	0.10
Grass	0.10

The runoff coefficients in Table 5-4 are for use only in stormwater treatment designs based on ***small, frequent storms***. These runoff coefficients are not for sizing conveyance or flood control facilities.

[3] Note that the Rational Method formula produces a result with units of "acre-in/hour"; however, the conversion factor from acre-in/hour to cubic feet/second is approximately 1.0.

[4] Note: These C-factors are only appropriate for small storm treatment design and should not be used for flood control sizing. When available, locally developed small storm C-factors for various surfaces may be used.

Appendix B includes examples of sizing flow-based treatment measures using the worksheet. Stormwater treatment measure sizing worksheets (in Excel format) are also available on the Program website at this link: https://scvurppp.org/newdev/

Simplified Sizing Method

A biotreatment measure (e.g., bioretention area *or* flow-through planter) can be sized by calculating a surface area equal to 4 percent of the contributing impervious area. This is a flow-based sizing method, assuming a runoff inflow of 0.2 inches per hour (equal to the rainfall intensity), with an infiltration rate of 5 inches per hour (0.2 in/hr divided by 5 in/hr = 0.04). This "4 percent method" is conservative as it does not take into consideration the volume of water that is temporarily detained in the surface ponding area; however, it is the recommended method to design bioretention areas, because it maximizes the amount of infiltration that can be achieved at a given location. If there are site constraints or infiltration is not allowed, then the combination flow and volume method may be used.

The 4 percent method requires the surface area of the treatment measure to be 4 percent of the impervious area that drains to it (1,750 square feet of bioretention area per impervious acre). If areas of landscaping or pervious paving are within the drainage area that will contribute runoff to the treatment measure, the area of these pervious surfaces is multiplied by a factor of 0.1 and added to the area of impervious surface, to obtain the amount of "equivalent impervious surface". To apply the 4 percent method, the worksheet uses the following steps:

1. Based on the topography of the site and configuration of buildings, divide the site into drainage areas, each of which will drain to one LID treatment measure. Implement Steps 2 through 5 for each drainage area.
2. Minimize the amount of landscaping or pervious pavement that will contribute runoff to the LID treatment measures. Refer to Sections 4.2 and 4.3 to design areas of landscaping or pervious pavement as "self-treating areas" or "self-retaining areas," so that they do not contribute runoff to the LID treatment measure and may be excluded from the drainage areas for the treatment measures.
3. For each drainage area in which a portion of the area that will contribute runoff to the treatment measure consists of pervious surfaces (landscaping or pervious paving), multiply the area of pervious surface by a factor of 0.1.
4. For applicable drainage areas, add the product obtained in Step 3 to the area of impervious surface, to obtain the area of "equivalent impervious surface."
5. Multiply the impervious surface (or equivalent impervious surface in applicable drainage areas) by a factor of 0.04. This is the required surface area of the LID treatment measure.

Combination Flow and Volume Design Basis

Some stormwater treatment measures, such as bioretention areas and flow-through planters, include some design elements that provide flow-based treatment and some that provide volume-based treatment. For example, flow-based treatment occurs in a biotreatment area with an underdrain as stormwater filters through the soil and flows out the underdrain. Volume-based treatment is provided when stormwater is stored in the surface ponding area and the pore spaces of the soil media. The ponding area may be sized so that it retains a certain volume of runoff prior to it entering the soil at the required 5 inch per hour surface loading rate.

The "simplified approach" for sizing bioretention areas and flow-through planters, in which the surface area of the treatment measure is designed to be 4 percent of the impervious area that drains to the treatment measure, is a flow-based sizing approach. This approach tends to result in the design of a conservatively large treatment measure because it does not account for any storage provided by the surface ponding area or media pore volume. A volume-based sizing approach for bioretention areas, in which the surface ponding area and depth are sized to contain the entire water quality design volume, is also conservative because it does not take into account the emptying of this ponding area into the soil media during the storm event.

Provision C.3.d of the MRP specifies that treatment measures that use a combination of flow and volume capacity shall be sized to treat at least 80 percent of the total runoff over the life of the project, using local rainfall data. This sizing criteria is best applied when using a continuous simulation hydrologic model to demonstrate that a treatment system is in compliance with C.3.d. However, when doing sizing calculations by hand, compliance with C.3.d. can be demonstrated by showing how the treatment system design meets both the flow-based and volume-based criteria.

For bioretention areas and flow-through planters, the following approach may be used to take into consideration both the flow of stormwater through the planting media and the volume of stormwater in the surface ponding area. Note that the approach assumes that all of the design rainfall becomes runoff, and thus ***it is only appropriate for use where the drainage area to the bioretention area is mostly impervious*** (small amounts of contributing pervious area can be converted to equivalent impervious areas using the factors in Table 5-4).

1. Determine the required treatment volume using the ***recommended volume-based sizing approach*** described earlier in Section 5.1. As part of this method, you will calculate the ***unit basin storage volume*** in inches using the sizing curves provided in Appendix B (adjusted for the mean annual precipitation of the project site) and the ***water quality design volume*** in cubic feet (the unit basin storage volume multiplied by the drainage area to the treatment measure, converted to units of cubic feet). For example, say you determined the adjusted unit basin storage volume to be 0.5 inches, and the drainage area to the bioretention facility is 7,000 square feet. Then the water quality design volume would be 0.5 inches × (1 foot/12 inches) × 7,000 square feet = 292 cubic feet.

2. Assume that a ***rainfall intensity of 0.2 inches/hour*** will be used as the flow based sizing criteria (as recommended by the Urban Runoff Program).

3. Assume that the rain event that generates the required capture volume of runoff determined in Step 1 occurs at a constant intensity of 0.2 inches/hour from the start of the storm (i.e., assume a rectangular hydrograph). Calculate the ***duration of the rain event*** by dividing the unit basin storage volume by the intensity. In other words, determine the amount of time required for the unit basin storage volume to be achieved at a rate of 0.2 inches/hour. For example, if the unit basin storage volume is 0.5 inches, the rain event duration is 0.5 inches ÷ 0.2 inches/hour = 2.5 hours.

4. Make a ***preliminary estimate of the surface area*** of the bioretention facility by multiplying the equivalent impervious surface area to be treated by a sizing factor of 0.04. For example, a drainage area of 7,000 square feet × 0.04 = 280 square feet of bioretention treatment area.

5. Assume a bioretention area that is about 25% smaller than the bioretention area calculated in Step 4. Using the example above, 280 – (0.25 × 280) = 210 square feet. ***Calculate the volume of runoff that filters through the treatment soil*** at a rate of 5 inches per hour (the design surface loading rate for bioretention facilities), for the duration of the rain event calculated in Step 3. For example, for a bioretention treatment area of 210 square feet, with an infiltration rate of 5 inches per hour for a duration of 2.5 hours, the volume of treated runoff = 210 square feet × 5 inches/hour × (1 foot/12 inches) × 2.5 hours = 219 cubic feet.
6. Calculate the portion of the water quality design volume ***remaining after treatment is accomplished by filtering*** through the treatment soil. The result is the amount that must be stored in the ponding area above the reduced bioretention area assumed in Step 5. For example, the amount remaining to be stored comparing Step 1 and Step 5 is 292 cubic feet – 219 cubic feet = 73 cubic feet. If this volume is stored over a surface area of 210 square feet, the average ponding depth would be 73 cubic feet ÷210 square feet = 0.35 feet or 4.2 inches.
7. Check to see if the ***average ponding depth is approximately 6 inches*** *(or up to a maximum of 12 inches if allowed by the municipality)*, which is the recommended ponding depth in a bioretention facility or flow-through planter. If the ponding depth is less than 6 inches, the bioretention design can be optimized with a smaller surface area (i.e., repeat Steps 5 and 6 with a smaller area). If the ponding depth is greater than 6 inches (or the depth allowed by the municipality), a larger surface area will be required. (In the above example, the optimal size of the bioretention area is 190 square feet with a ponding depth of 6 inches.)

Appendix B includes examples of sizing bioretention areas using this combination flow- and volume-based method. Stormwater treatment measure sizing worksheets (in Excel format) are also available on the Program website at this link: https://scvurppp.org/newdev/

5.2 Getting Runoff into Treatment Measures

Stormwater may be routed into stormwater treatment measures using ***sheet flow or curb cuts.*** The following guidance on common curb cut types is taken from the San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook.

Figure 5-1: Cobbles in this stormwater treatment measure in San José help prevent erosion.

A minimum 18-inch width is recommended for curb cuts, to avoid clogging. A minimum 2-inch drop in grade between the impervious surface and the finish grade of the stormwater treatment facility is required; a 4- to 6-inch drop is recommended so that vegetation or mulch build-up does not obstruct flow. To avoid erosion, cobbles or other energy dissipater materials are recommended below the drop for a distance of at least 4 feet. The overflow drain for the treatment measure should not be located directly in line with or next to the curb cut.

Standard Curb Cut: Design Guidance

- Opening should be at least 18 inches wide; for smaller facilities, 12" width may be allowed at more frequent intervals subject to municipal approval.[5]
- Curb cut can have vertical sides or have chamfered sides at 45 degrees (as shown).
- Need to slope the bottom of the concrete curb toward the stormwater facility.
- Allow a drop in elevation of 4 to 6 inches between the paved inlet surface and biotreatment soil elevation.
- Provide cobbles or other energy dissipater to prevent erosion below the drop, for 4 ft.

Figure 5-2: This standard curb cut at parking lot rain garden has 45 degree chamfered sides.

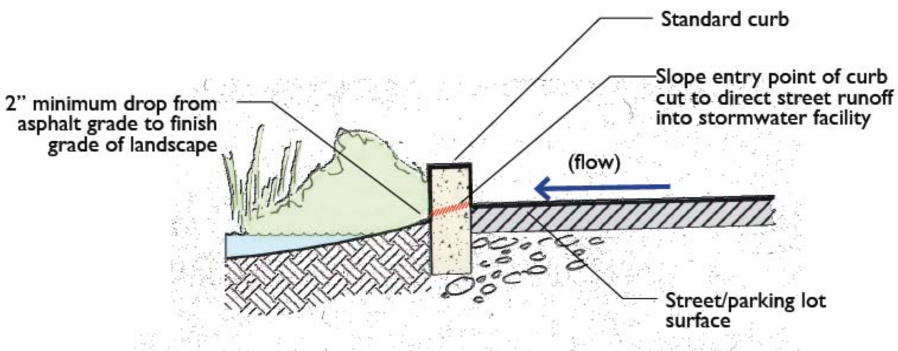

Figure 5-3: Standard curb cut: section view (Source: San Mateo Countywide Water Pollution Prevention Program [SMCWPPP] 2009)

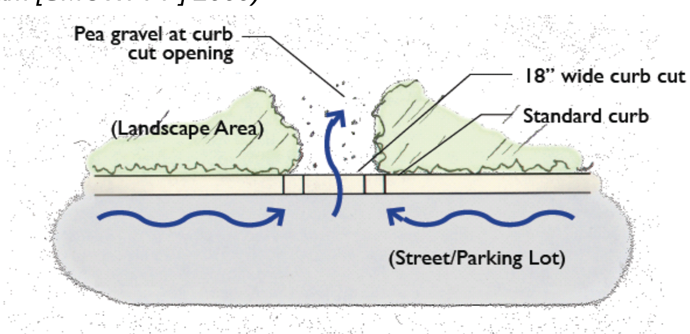

Figure 5-4: Standard curb cut: plan view (Source: SMCWPPP 2009)

[5] For on-grade openings, it is recommended that the designer calculate the required opening width to account for the approach velocity, so that the design flow does not bypass the opening. The opening to the treatment measure should be sized similar to an on-grade storm drain inlet. The flow rate, approach depth and flow cross section dictate the length of the curb opening needed. See Orange County Local Drainage Manual, 1996: http://www.ocflood.com/Documents/pdf/Local_Drainage_Manual_1996.pdf

Standard Curb Cut with Side Wings: Design Guidance

- Opening should be at least 18 inches wide; for smaller facilities, a 12" width may be allowed subject to municipal approval.
- Works well with stormwater facilities that have steeper side slope conditions.
- Need to slope the bottom of the concrete curb toward the stormwater facility.
- 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. Provide a 2" drop from the inlet to the splash apron or energy dissipater.
- Provide cobbles or other energy dissipater to prevent erosion below the drop.

Figure 5-5: The side wings of this standard curb cut help retain the side slope grade on each side of the curb cut opening.

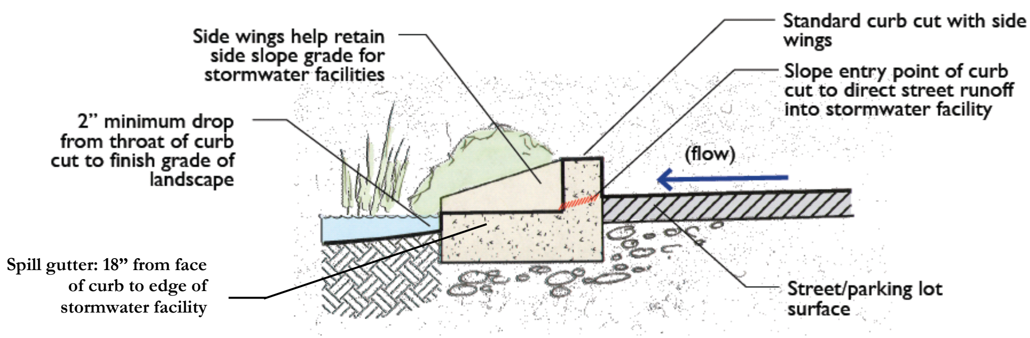

Figure 5-6: Standard curb cut with side wings: cut section view (Source: SMCWPPP 2009)

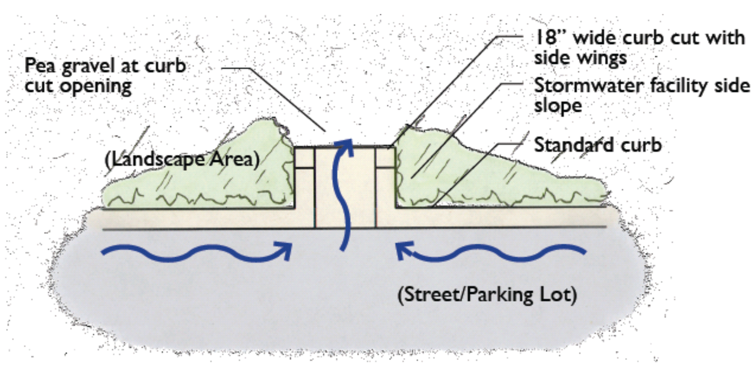

Figure 5-7: Standard curb cut with side wings: plan view (Source: SMCWPPP 2009)

Wheelstop Curbs: Design Guidance

- Wheelstops allow water to flow through frequently spaced openings.
- Wheelstops are most common in parking lot applications, but they may also be applied to certain street conditions.
- Need to provide a minimum of 6 inches of space between the wheelstop edge and edge of paving. This is to provide structural support for the wheelstop.
- 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.
- Provide cobbles or other energy dissipater at wheel stop opening to prevent erosion.

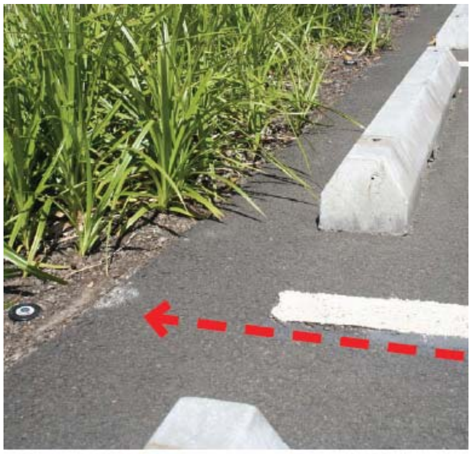

Figure 5-8: Stormwater runoff enters the stormwater facility through the 3-foot space between these wheelstops. The design could be improved by providing more of a drop in grade between the asphalt and landscape area.

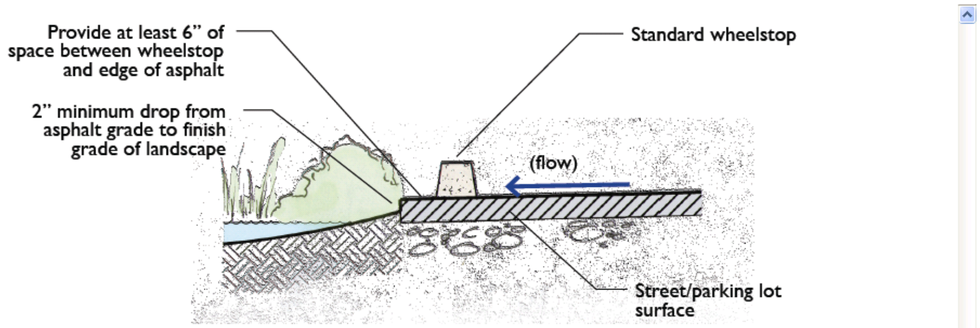

Figure 5-9: Opening between wheelstop curbs: section view (Source: SMCWPPP 2009)

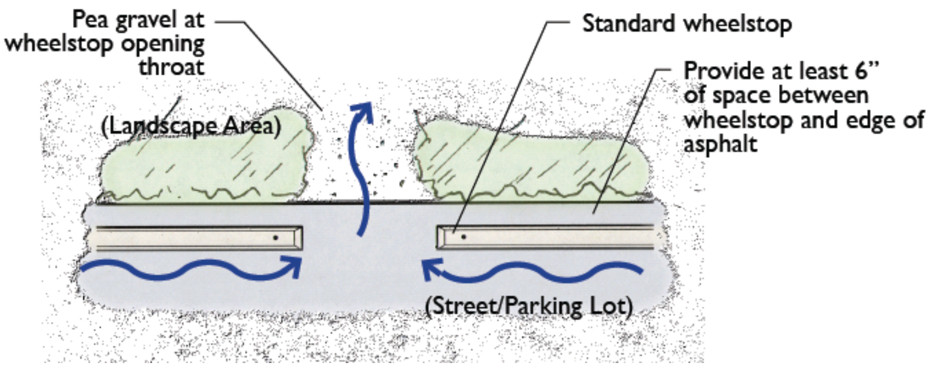

Figure 5-10: Opening between wheelstop curbs: plan view (Source: SMCWPPP 2009)

Grated Curb Cut: Design Guidance

- Grated curb cuts allow stormwater to be conveyed under a pedestrian walkway. The curb cut opening should be at least 18 inches wide; 12” may be allowed for smaller facilities subject to municipal approval. (See footnote under standard curb cut for design of on-grade opening.)
- Grates need to be ADA compliant and have sufficient slip resistance.
- 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.

Figure 5-11: A grated curb cut allows stormwater to pass under a pedestrian walkway to the stormwater facility.

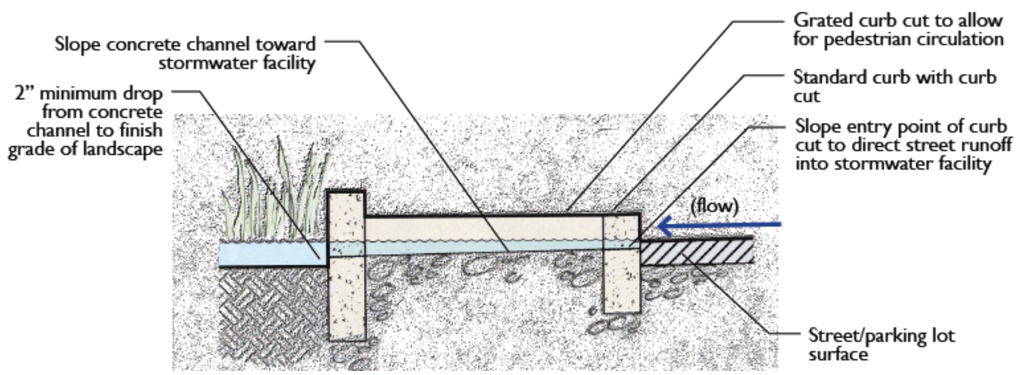

Figure 5-12: Grated curb cut: section view (Source: SMCWPPP 2009)

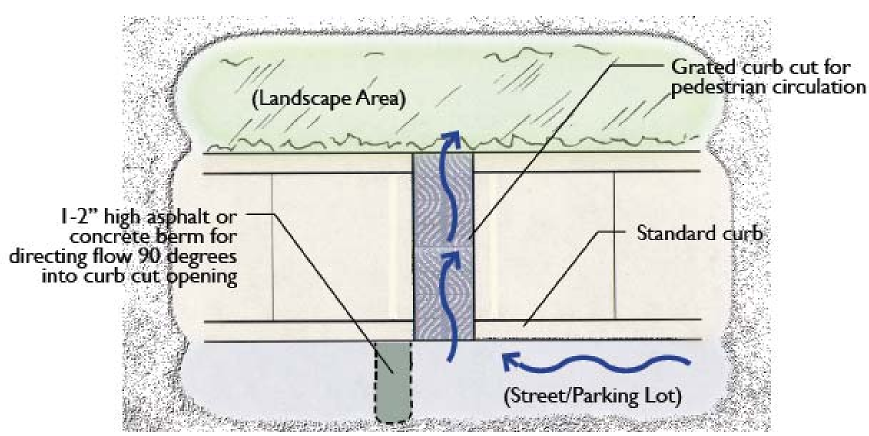

Figure 5-13: Grated curb cut: plan view (Source: SMCWPPP 2009)

5.3 Infiltration Guidelines

Infiltration is a preferred LID treatment measure and a cost-effective method to manage stormwater – if the conditions on the site allow. Site design and treatment measures that accomplish stormwater infiltration can be categorized as follows:

- ***Site design measures*** -- clustering development or otherwise laying out the site to reduce the overall impervious area, routing drainage from building roofs to landscaped areas for infiltration, and using pervious pavement.
- ***Indirect infiltration*** – methods which allow stormwater runoff to percolate ***through surface soils***. Runoff may reach groundwater indirectly, following treatment by surface soils. Bioretention is an example of an indirect infiltration method.
- ***Direct infiltration*** methods*,* which are designed to ***bypass surface soils*** and transmit runoff directly to subsurface soils, which allows infiltration to groundwater. These types of devices must be located and designed to limit the potential for stormwater pollutants to reach groundwater. Infiltration basins and trenches are examples of a direct infiltration method.

The local jurisdiction may require a geotechnical review for your project. When selecting site design and stormwater treatment measures that promote on-site infiltration, be sure to ***follow the geotechnical engineer's recommendations*** based on soil boring data, percolation tests, drainage patterns, and conditions needed for slope stability. The geotechnical engineer's input will be critical to prevent infiltrating water from damaging building foundations, surrounding properties, public improvements, and sloped banks.

Appendix A provides guidelines to help you determine whether your project site is suitable for infiltration measures or devices and regulatory requirements that apply to infiltration devices.

5.4 Underdrains

Where the existing soils have a lower infiltration rate than soils specified for a landscape-based stormwater treatment measure, it may be necessary to install an underdrain to allow the treatment measure to function as designed and ***prevent the accumulation of standing water.*** In most of Santa Clara Valley, underdrains will be required.

Underdrains are perforated pipes that allow water to enter the pipe and flow to the storm drain system. To help prevent clogging, two rows of perforations or slots should be cut along the underside of the pipe, so that water enters the pipe primarily from the bottom and lower sides to allow for more water storage within the system. Slots are considered less open to root intrusion than round perforations. Cleanouts should be installed to allow access to underdrains to remove debris. ***Underdrains should NOT be wrapped in filter fabric,*** to avoid clogging. Underdrains are typically installed in a layer of washed drain rock or Class 2 permeable aggregate, beneath more permeable stormwater biotreatment soils. The nominal rock diameter size used in the rock layer should be larger than the diameter of the perforations in the subdrain to prohibit drain rock from entering the subdrain pipe.

When designing a bioretention facility and infiltration is permitted onsite, the underdrain should be placed near the top of the drain rock layer to allow as much water to infiltrate into native soils as possible before entering the underdrain and discharging to a storm drain. If infiltration is not permitted due to site conditions such as high groundwater, contaminated soils, proximity to structures, etc., the bioretention facility should be lined and the underdrain placed near the bottom of the drain rock layer. Refer to the technical guidance for specific stormwater treatment measures in Chapter 6 for more details.

5.5 Bypassing High Flows

Although stormwater treatment measures are sized to remove pollutants from flows resulting from frequent, small storms, projects must also be designed to bypass drainage from large infrequent flows to ***prevent flooding and potential damage*** to the treatment measure. The safe conveyance of high flows through or around the treatment measure may be accomplished in one of two ways, which are described below.

One option is to have the flows that are larger than those required by the hydraulic sizing criteria (given in Section 5.1) handled ***within the stormwater treatment measure.*** This includes making sure that landscape-based stormwater treatment measures do not erode during flows that will be experienced during larger storms. Infiltrating vegetated swales and extended detention basins can be designed to handle higher flows, although they would not be providing much treatment during these flows.

Bioretention areas, flow-through planter boxes, and other treatment systems that rely on filtering or infiltrating stormwater through soils must have ***overflow systems*** that allow high flows larger than the water quality design flow or volume to bypass the stormwater treatment measure. These systems have to include an alternative flow path for high flows, otherwise stormwater would back up and flood the project area. The technical guidance in Chapter 6 for treatment measures that operate in this manner includes design standards for high-flow bypasses.

The second option for stormwater treatment measures designed as low-flow systems is to restrict stormwater flows to the treatment measure and ***bypass excess flows around the facility.*** Bypassing larger flows helps prevent hydraulic overload and resuspension of sediment, and it can protect stormwater treatment measures from erosion. In some designs, the ponding depth in the bioretention facility may prevent the excess runoff from entering the facility, causing it to flow to a separate grate system or downstream inlet.

Flow splitter devices may be used to direct the initial flows of runoff, or "first flush," into a stormwater treatment measure, and bypass excess flows from larger storm events around the facility into a bypass pipe or channel. The bypass may connect directly to the storm drain system, or to another stormwater control measure that is designed to handle high flows. This can be accomplished using a stepped manhole (Figure 5-14) or a proprietary flow splitter (Figure 5-15). The proprietary flow splitter works in the following manner: runoff enters the device by way of the inlet at the left side of the figure; low flows are conveyed to the stormwater treatment measure by way of the outlet pipe at the lower right. Once the treatment measure reaches its design capacity, water backs up in the low-flow outlet pipe and into the flow splitter. When the water level in the flow splitter reaches the bypass weir elevation, stormwater begins to flow out the overflow pipe, shown at the upper right of the figure, bypassing the stormwater treatment measure.

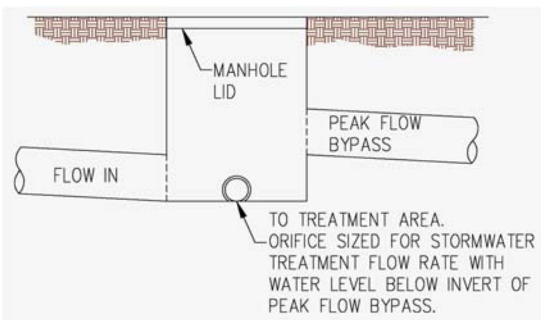

Figure 5-14: Stepped manhole design directs low-flows to treatment measure and diverts high flows to storm drain system. (BKF Engineers)

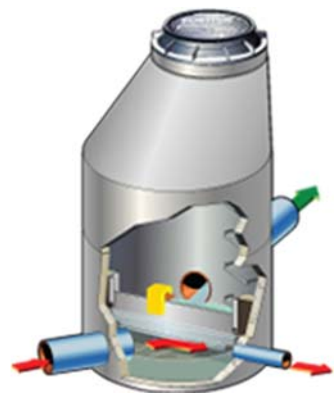

Figure 5-15: StormGate[TM] flow splitter structure. Source: Contech Construction Products
Use of this illustration is for general information only and is not an endorsement of this or any other proprietary device.

5.6 Using Treatment Trains

What is a treatment train?
A treatment train is a multiple treatment system that uses two or more stormwater treatment measures in series, for example, a settling basin/ infiltration trench combination.

Stormwater can be directed to flow through a series of different types of stormwater treatment measures that are each designed to treat different broad categories of stormwater pollutants. These groupings of stormwater treatment measures have been called "stormwater treatment trains" or a "multiple treatment system." The use of a ***series of treatment measures*** is most effective where each treatment measure optimizes the removal of a particular type of pollutant, such as coarse solids and debris, pollutants associated with fine solids, and dissolved pollutants. Targeting specific treatment processes by constituent is referred to as "unit process" design. ***Each stormwater treatment measure in a treatment train should be sized using the Provision C.3 numeric sizing criteria.***

The simplest version and most common use of a treatment train consists of ***pretreatment*** prior to the stormwater reaching the main treatment system. For example, bioretention areas may use vegetated buffer strips to pretreat stormwater to settle out sediment before the stormwater enters the bioretention area. This type of pretreatment helps prevent sediment from clogging the bioretention area, which maximizes its life. Another example is when a hydrodynamic separator is used to remove trash and coarse sediment upstream of a media filter or subsurface infiltration system. ***Note that non-LID treatment measures may be used in the treatment train as long as the last measure in the train is an LID treatment measure.***

Another option for a treatment train is to provide ***upstream storage*** for a treatment measure, which may allow the treatment measure to be reduced in size. For example, a rainwater cistern may be used to store and slowly release water to a bioretention facility. Conversely, the bioretention facility can be used to treat the overflow from the cistern if there is insufficient irrigation or toilet flushing demand to empty the cistern prior to the next rain event.

Figure 5-16: Detention pond at a retirement center in Saratoga

5.7 Mosquito Control

Treatment measure designs and maintenance plans must include the mosquito control ***design and maintenance strategies*** in Appendix F if applicable.

Some types of stormwater treatment measures are designed to detain water, and other treatment measures may have the potential to ***retain standing water*** if they are not properly designed, constructed and maintained. The surface of standing water provides habitat for mosquitoes. Local agencies annually provide information to the Santa Clara County Vector Control District (SCCVCD) on the locations of newly installed stormwater treatment measures, to assist the District with addressing potential vector control issues.

SCCVCD staff has identified a ***five-day maximum*** allowable water retention time, based on actual incubation periods of mosquito species in this area. With the exception of certain stormwater treatment measures designed to hold permanent water (e.g., wet ponds), all treatment measures should drain completely within five days to effectively suppress vector production. *Please note that the design of stormwater treatment measures* ***does not require*** *that water be retained for five days.* Treatment measure designs and maintenance plans must include mosquito control ***design and maintenance strategies*** included in Appendix F.

5.8 Plant Selection and Maintenance

Selecting the appropriate plants and using sustainable, horticulturally sound landscape design and maintenance practices are essential components of a successful landscape-based stormwater treatment measure. Appendix D provides a list of plants that can be used for stormwater treatment and Chapter 6 includes guidance in selecting the best plants for the specific stormwater treatment measures.

Plant Selection Guidance

Plant selection must consider the type of development and location, uses on the site and an appropriate design aesthetic. Ideally, a Landscape Architect will be involved as an active member of the design team ***early in the site design phase*** to review proposed stormwater measures and coordinate development of an integrated solution that responds to all of the various site goals and constraints. In some cases, one professional will design a stormwater control, while another designs the rest of the landscaping. In these situations it is critical for the professionals to work together very early in the process to integrate their designs. Appendix D provides guidance for selecting plants appropriate to the vegetated stormwater treatment measures included in Chapter 6 and the site design measures in Chapter 4.

Water Efficient Landscaping Requirements

The California Water Conservation in Landscaping Act of 2006 requires municipalities to adopt, by January 1, 2010, landscape water conservation ordinances that are at least as effective in conserving water as the Model Water Efficient Landscape Ordinance (MWELO) prepared by the Department of Water Resources (DWR). The MWELO automatically went into effect, on January 1, 2010, in municipalities that had not adopted a local Water Efficient Landscape Ordinance (WELO).

The California Water Commission approved the revised MWELO on July 15, 2015. The deadline for local agencies to adopt the MWELO or adopt their own WELO, which must be at least as effective in conserving water, was December 1, 2015. The deadline for local agencies creating a regional ordinance was February 1, 2016.

Most new and rehabilitated landscapes are subject to a WELO. The MWELO applies to the following public and private development projects:

(1) new construction projects with an aggregate landscape area equal to or greater than 500 square feet requiring a building or landscape permit, plan check or design review;

(2) rehabilitated landscape projects with an aggregate landscape area equal to or greater than 2,500 square feet requiring a building or landscape permit, plan check, or design review.

Contact the municipality to ***determine whether your project is subject to the MWELO*** or a comparable local WELO. Water conserving, drought tolerant plants that are suitable for use in stormwater treatment measures are listed in Table D-1 in Appendix D.

Bay Friendly Landscaping (ReScape)

Bay-Friendly landscaping is a whole systems approach to the ***design, construction and maintenance*** of landscapes in order to protect the San Francisco Bay watershed. Project sponsors are encouraged to use landscape professionals who are familiar with and committed to implementing Bay-Friendly landscaping practices from the initial plant selection through the long-term maintenance of the site. Appendix D summarizes Bay-Friendly Landscaping Practices that may be implemented to benefit water quality of the Bay and local creeks, based on the Bay-Friendly Landscaping Guidelines (available at www.rescapeca.org)[6].

Integrated Pest Management

Integrated pest management (IPM) is a holistic approach to mitigating insects, plant diseases, weeds, and other pests. Projects that require a landscaping plan as part of a development project application will be required to use IPM practices, as indicated in each agency's source control measures list. ***Avoiding pesticides and quick release synthetic fertilizers***, covering exposed earth with appropriate mulch material, and nourishing the soil with compost are particularly important when maintaining stormwater treatment measures to protect water quality.

IPM encourages the use of many strategies for preventing and controlling pests. It places a priority on fostering a healthy environment in which plants have the strength to resist diseases and insect infestations, and out-compete weeds. Using IPM requires an understanding of the life cycles of pests and beneficial organisms, as well as regular monitoring of their populations. When pest problems are identified, IPM considers all viable solutions and uses a combination of strategies to control pests, rather than relying on pesticides alone. The least toxic pesticides are used only as a last resort. More information on IPM is included in Appendix D.

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[6] The Bay-Friendly Landscaping Coalition is now known as ReScape (www.rescapeca.org).

5.9 Integrating Trees and Stormwater Treatment

As discussed in Chapter 4, trees provide a variety of functions that can benefit water quality. Despite these benefits, trees that are simply planted or maintained near impervious surfaces ("interceptor trees") cannot be credited toward treatment of those areas. However, trees can be integrated into biotreatment systems that are sized and designed to provide stormwater treatment. The types of biotreatment systems that can incorporate trees include bioretention, tree well filters, and bioretention in combination with suspended pavement systems.

In general, trees should only be ***planted in bioretention systems*** when the tree species is appropriate for sandy soils (or where adjacent loamy/clayey soils can be utilized and accessed by tree roots) and sufficient soil volumes and space are provided for the tree to reach mature size without causing problems with surrounding infrastructure, pavement, and buildings. Overhead infrastructure, such as lighting, awnings, and utilities can also reduce space for trees or limit the list of tree species for selection to smaller stature types. The design of the system and tree species selected should also be carefully considered for future irrigation needs (especially with large tree species, as irrigation demand may increase as the tree grows, possibly causing problems in a future drought scenario.) Hybrid systems that are able to use different soil types in different sectors of the landscape can also assist in providing water retaining soils for large trees.

Retrofitting or modifying an existing planting area with a tree into a bioretention area with that tree can be done, but there are many design and construction issues. An arborist or landscape architect should be consulted before attempting that advanced strategy. Similarly, if a stormwater treatment measure is proposed for a location adjacent to an existing tree of value, then the impacts to and protection measures for the tree should be discussed with an arborist. The design of the measure might also have to be modified to protect the tree. Trees that have not previously been inundated with water during the rainy season and become inundated after modification into a bioretention area can experience health impacts. This can occur when pavement surrounds the tree and that pavement is removed as part of the retrofit.

High volumes of leaf drop in a short period of time can create inlet blockages in stormwater treatment measures, so leaf collection or accommodation of degradation of leaves within the stormwater landscape needs to be assessed and/or incorporated into the design before large broadleaf deciduous trees (such as the London Plane or Sycamore) are selected.

Soil volume, soil compaction, structural trimming, and compost, along with appropriate irrigation during the first three years, are important to long-term tree health. Where limited open space is available for planting trees and roots may damage hardscape, consider the use of ***suspended pavement systems***. One type of suspended pavement system is ***structural soil,*** an engineered planting medium that consists of a stone or aggregate skeleton structure for strength, planting soil, and in some cases a hydrogel to adhere the two materials together, which allows urban trees to grow under pavement. The structural soil system creates a load-bearing matrix with voids filled with soil and air, which allows for greater tree growth, better overall health of trees, and reduced pavement uplifting by tree roots. The voids that benefit the tree roots also provide some stormwater storage capacity. However, structural soils provide minimal (approximately 20%) amounts of soil because the majority of the space is taken up by the rock and void space. In addition, structural soil does not meet the specification for biotreatment soil media, so it cannot be used in a treatment measure.

Modular suspended pavement systems (also known as load-bearing modular grid products) have also been developed to allow the planting of trees in uncompacted native soils, fill soils, or stormwater treatment soils, extending under sidewalks and other areas of pavement. These products provide similar benefits in terms of pavement support and tree health as structural soil. When filled with biotreatment soil, modular products can be used to increase the surface area of a tree well filter and provide more capacity for stormwater treatment. Having these systems set up for a tree ensures the long-term health and growth by providing rootable soil volumes without destroying urban features, such as lifting sidewalks.

Modular products, such as the Silva Cell, are typically composed of a frame (or frames) and a deck. The frames can be stacked one, two, or three units high before they are topped with a deck to create a maximum amount of soil volume for tree root growth and stormwater infiltration. Newer versions can also be modified to different heights without stacking. Cells can be installed laterally as wide as necessary. Void space within the cells may accommodate the surrounding utilities. More information on the use of these systems is provided in Section 6.3. Check with the local jurisdiction to confirm that they accept the use of Silva Cells or other suspended pavement systems as options for stormwater treatment systems in their plan review process.

An additional strategy used to provide trees with adequate soil volumes is related to the ***planting of trees in places where there is an adjacent landscaped area***. If the adjacent area is separated from the tree planting location by impervious surfaces such as sidewalks or parking areas, then suspended pavement systems can be used to provide an uncompacted soil "bridge" or "root channel" between the two landscaped areas allowing roots to grow through and under that pavement to the adjacent landscaped area without heaving of the pavement over time. This strategy can be even more important if the adjacent landscaped area contains a clayey/loamy soil with good water retention compared to the sandy biotreatment soil media used in bioretention areas. With the expectation of recurrent droughts in the future, loamy soils are a good option for retaining water for trees during the dry season, thereby reducing the need for irrigation. For more information on how to integrate trees and bioretention, refer to Section 6.3.