CITY OF SANTA CLARITA, CALIFORNIA

GREEN STREET LID

LOW IMPACT DEVELOPMENT SELECTION GUIDANCE MANUAL

The City of Santa Clarita Green Streets Selection Guidance Manual provides a general overview of effective low impact development practices when Green Streets are required. All site-specific plans are to be designed and approved in coordination with the appropriate City division.

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01 INTRODUCTION

The City of Santa Clarita, CA is required to comply with the requirements of the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit for stormwater and non-stormwater discharges from the MS4 within the coastal watersheds of Los Angeles County. In order to practically meet the standards created by the MS4 permit, there are a variety of stormwater quality control measures that can be implemented. One such implementation is Green Street Low Impact Development (LID) practices within transportation corridors, such as city streets, roadways and parking areas.

While LID is an umbrella term that covers a large number of techniques used to minimize the negative impacts of urbanization, Green Street LIDs are much more focused on intercepting and treating stormwater flow in and around streets, using as little area as possible. City streets, parking lots and other public transportation corridors are designed to connect people and places, but at the same time are a major source of site imperviousness and serve as "conduits" for stormwater runoff. The Green Street LID approach uses ***hydrologically-functional site design techniques or practices*** that store, retain, infiltrate, and treat stormwater and dry-weather runoff from local, individualized watersheds or sites that drain onto street corridors. Due to their localized scale, Green Street LIDs allow the site planner to use a wide array of simple, site-level, hydrological practices that are proven and cost-effective. These practices include rain gardens, vegetative swales, porous pavements, infiltration trenches, etc. By treating at the source, Green Street LID practices reduce the amount of runoff reaching receiving waters, thus providing one type of mitigation measure required as part of the 2012 MS4 Permit.

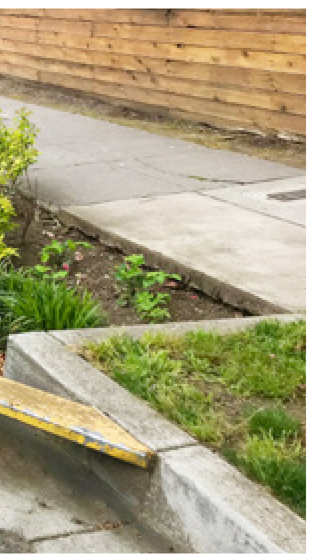
Bump out rain garden with curb slot inlet

The City of Santa Clarita Green Streets LID Selection Guidance Manual identifies effective Green Street LID practices, specifically for new and existing City-owned transportation corridors. This manual helps simplify the selection process of Green Street LID applications by pre-selecting Green Street LID practices that are proven effective for street corridors and provides design standards that ensure a uniform implementation of the Green Street LIDs. This manual has a screening tool that allows the user to quickly and effectively evaluate specific site considerations leading to the selection of appropriate Green Street LID applications that will help meet the requirements of the MS4 Permit ranging from detention, retention, filtration, and infiltration to bioretention and biotreatment.

Intended Audience

The intended audience for this manual includes City staff involved in street development and redevelopment, including engineers, planners, and construction / maintenance staff.

Disclaimer: Any Green Street LID applications, which will be maintained and operated by the City Landscape Maintenance District, will need to also reference the LMD Guidelines.

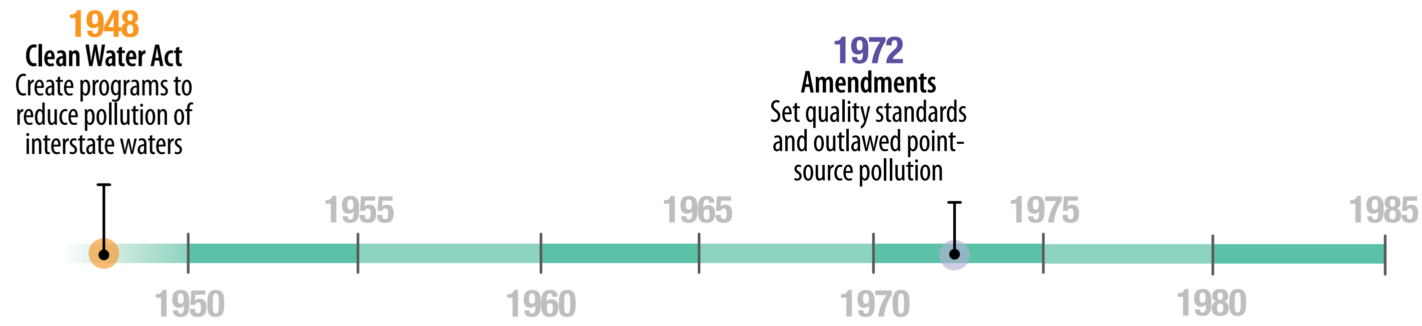


Vegetated swale between a street and parking lot

Permeable pavers in a parking area

Regulatory Background

In 1972, the Federal Water Pollution Control Act (Clean Water Act [CWA]) was updated so that any discharge of pollutants to waters of the United States from any point source would require an NPDES permit. Later on, in 1987, the CWA was amended so that the NPDES permitting program would regulate stormwater discharges coming from municipal, industrial, or construction sources, in Section 402(p). Since then, the United States Environmental Protection Agency (USEPA) has sought to guide the permitting of these discharges by creating various regulations.



Low Impact Development Ordinance

The LID Ordinance adopted by LA County in October 2008 (Title 12, Chapter 84) requires LID principles to be used in all development projects with exception to road and flood infrastructure projects. After the 2012 MS4 Permit, the County had to update this ordinance to reflect the new requirements. It was updated November 2013 so that all Designated, Non-Designated, street and road construction, and single-family hillside home projects comply with the LID Ordinance. The LID Standards Manual of February 2014 complements the November 2013 LID Ordinances, requiring project applicants to submit a comprehensive LID plan and analysis which demonstrates compliance with the LID Standards Manual for review and approval by the Director of Public Works.

1987
Amendments
Regulate point and non-point discharges. EPA create NPDES requirements for SW discharge

1990
MS4 Permit
Required implementation of SW pollution controls

2001
MS4 Permit
Required development of program addressing SW pollution in planning for private projects

2002
SUSMP
Created design standards for structural or treatment control BMPs in designated projects

2004
Technical Manual for Stormwater Best Management Practices in the County of Los Angeles

2008
LA County LID Ordinance
Requires use of LID principles in all development projects except road and flood infrastructure

2009
LA County LID Standards Manual
BMP design and techniques

2010
SW BMP DESIGN AND MAINTENANCE MANUAL:
Provides guidance on BMP sizing, design specifications, and maintenance requirements, and flood infrastructure

2012
MS4 PERMIT
Expands water quality monitoring requirements and adopted TMDL provisions

2013
LA County LID Ordinance
Incorporated requirements of 2012 MS4 Permit

2014
LA County LID Standards Manual
LID design and requirements complementing and consistent with NPDES MS4 Permit and 2013 LID Ordinance

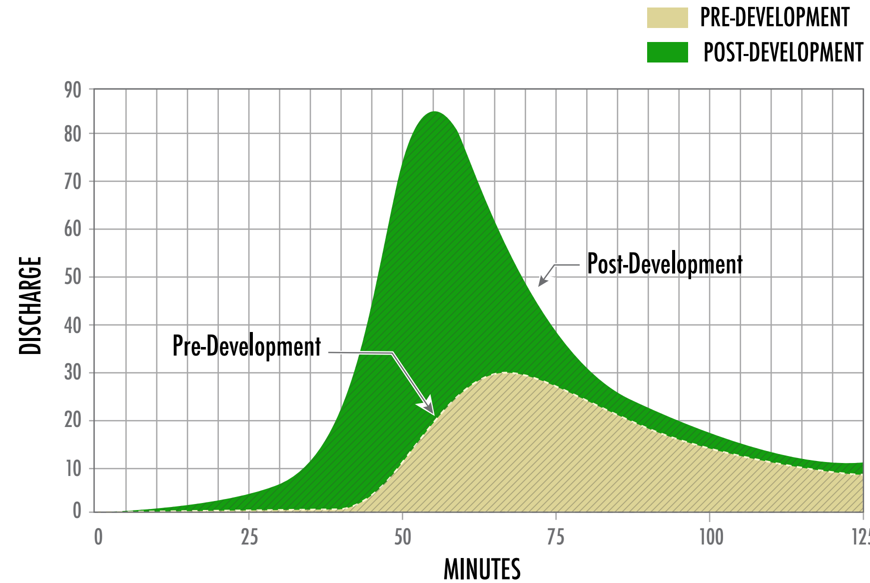
2019
Santa Clarita LID Guidance Manual

1995 2000 2005 2015 2020

Urbanization Impacts

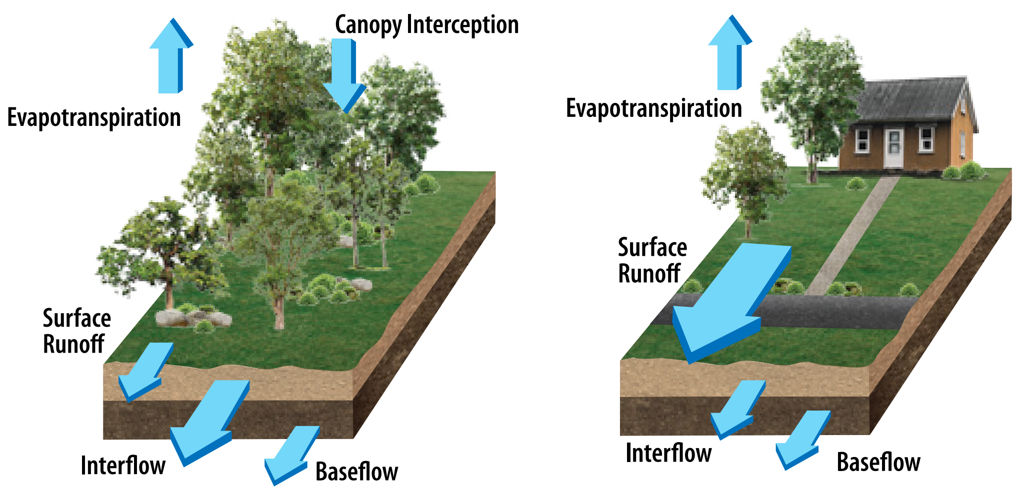
Hydrology/Hydraulics

Due to increases in impervious area and changes in topography, urbanization significantly increases the volume and velocity of stormwater runoff from the pre-development condition. The volume of stormwater runoff increases when previously open spaces with potential to infiltrate into the ground are covered by impervious surfaces, such as roofs, asphalt and concrete. These impervious surfaces cause water to pond up and begin draining to the downstream terminus sooner than it otherwise would have. This occurrence can be seen in pre- and post-development hydrographs, shown on the right. Essentially, urbanizing a watershed means more water moving faster to the downstream terminus, causing erosion, and collecting more pollutants on its way.



Pre-Development vs. Post-Development Hydrograph

Traditional methods of avoiding flooding to urbanized areas involve implementing stormwater conveyance techniques (i.e. curbs, concrete drainage channels, storm drains, pipes, etc.) that are very efficient in transporting runoff from a site, but discharge rapidly to the downstream terminus. This typical "end-of-pipe" approach furthers amplifies the stormwater runoff problem and severely impacts receiving streams / water bodies or requires large capital infrastructure to control water quality and flooding.



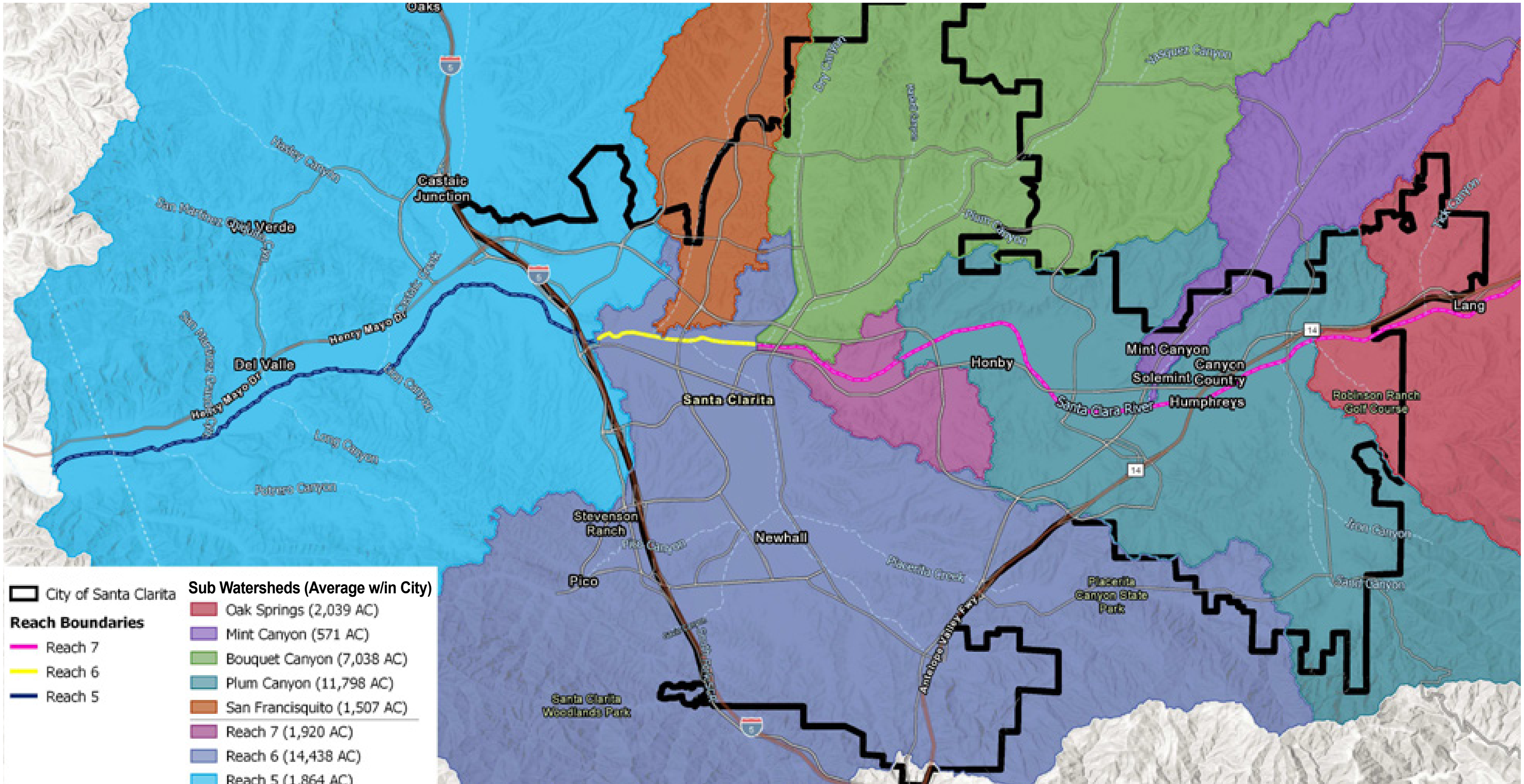
Left: before construction // Right: after construction

Effects of urbanization on watershed hydrology include:

- Increased runoff volumes
- Increased peak flowrate
- Reduced time of concentration
- Increased flow frequency
- Reduced infiltration (groundwater recharge)
- Loss of surface storage
- Increased erosion
- Increased non-stormwater discharges

Effects of urbanization on the ecosystem include:

- Increased stormwater pollutants / bacteria
- Modified flow pattern (base flow)
- Habitat destruction
- Thermal fluxes (change in water temperature)



Pollutants of Concern

Stormwater runoff naturally transports constituents, such as sediment; however, urbanization increases constituent concentration and introduces contaminants that harm water quality.

The following is a list of common pollutants associated with stormwater runoff:

- Bacteria
- Nutrients
- Trash and Debris
- Pesticides
- Metals
- Solvents and Cleaners
- Sediment
- Oil and Grease

The City of Santa Clarita's pollutants of concern for ***"wet-weather" flows are Zinc and E. Coli***, and is ***E. Coli for "dry-weather" flows***.

The City of Santa Clarita is a part of multiple watersheds that drain to three reaches of the Santa Clara River: Reaches 5, 6, and 7. Pollutants carried by stormwater flows that are not currently filtered out by any LID, BMP, or other system, can be tracked into whatever reach they enter, depending on the source location. The watershed map above shows the tributary watersheds draining to the three reaches of the Santa Clara River.

LID Solutions

6 Green Street LID Practices Presented in this Manual

Benefits of implementing LID strategies include:

Pollution Reduction
Pollutant removal through settling, filtration, absorption, and biological uptake.

Groundwater Recharge
LID can help recharge the groundwater through infiltration, something becoming increasingly necessary in Southern California. Groundwater levels are very low in times of drought, and traditional stormwater control methods redirect flows to the ocean, instead of infiltrating into the ground. When groundwater levels become too low, seawater intrusion and subsidence become very real threats.

Aesthetic Value
LID systems typically add a visually appealing landscaping component as an integral part of their design, such as trees, shrubs, and flowering plants. The use of these designs may increase property values and/or result in faster sale of the property due to the perceived value of the extra landscaping.

Protecting Downstream Water Resources
By reducing erosion and sediment aggradation, improving water quality, and enhancing recreational and aesthetic value of natural resources, LID practices eliminate and/or mitigate hydrologic impacts on receiving waters.

Habitat Improvement
When LID practices improve the quality of downstream water resources, they also improve wildlife habitat, and maintain or increase land value.

Quality of Life/Public Participation
Homeowners have the unique opportunity of participating in stormwater management when LID features are placed on or adjacent to individual lots. It also provides an educating opportunity by raising public awareness of stormwater runoff water quality issues.

Bioretention

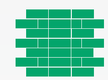
Rain Garden

Tree Box Filter

Infiltration

Rock Garden
Infiltration Trench

Permeable Pavements



Permeable Pavers
Permeable Concrete
Permeable Asphalt

Green Space Vegetated Buffers

Enhanced Open Swales

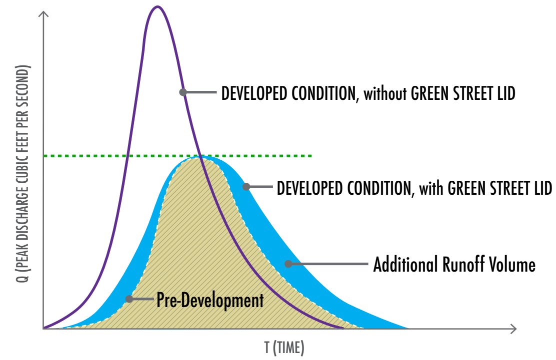
Disclaimer This manual's purpose is to assist in selection of Green Street LID practices based on typical constraints with different types of projects and lessons learned from Green Street LID practices used in the past. This manual does not, however, attempt to supply an exhaustive list of Green Street LID practices. The Green Street approaches presented in this manual are some of the most common and effective practices used, but there are many variations and innovative designs in existence or which could be created that are not listed here. Although any Green Street LID approaches not listed in this manual will not have City standard drawings or specifications, non-standard Green Street LID's may be used in a project pending the review and approval of the City's Planning Department. There is, however, less scrutiny and time required in the approval process for Green Street LID approaches that follow the standard design.

Additionally, this manual is not intended to be regulatory. Project proponents are encouraged to follow the procedures and designs shown here to streamline the design process, but there is a degree of flexibility associated with Green Street LID design in finding what works best in the context of individual projects. The regulation part of the design process is left to the City Planning Department during the project's review phase.

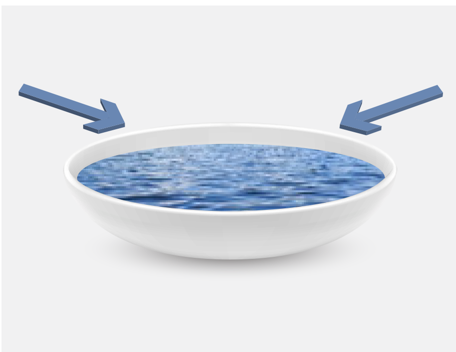
Green Street LIDs

The main goals of Green Street LID are to reduce, minimize, and disconnect the total impervious area of a site. Traffic corridors are one of the main sources of surface imperviousness in urban development and the implementation of Green Street LID practices converts as much of the impervious areas into pervious areas as possible. Bioretention areas, increased flow paths, infiltration devices, drainage swales, retention areas, and many other practices can be used to control and break up these impervious areas within the public right-of-way. The transformation of existing paved streets into Green Streets can help mitigate stormwater flooding and pollution issues while producing environmentally-friendly streets and a sustainable urban environment.

Green Street LID practices accomplish this through detention, retention, filtration, and infiltration (illustrated below).

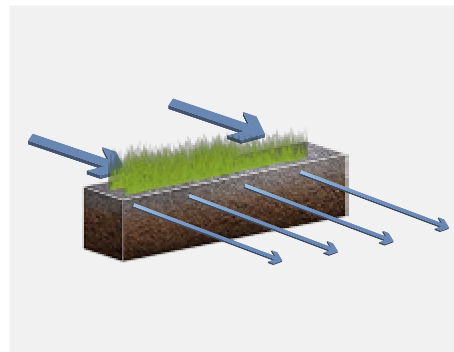


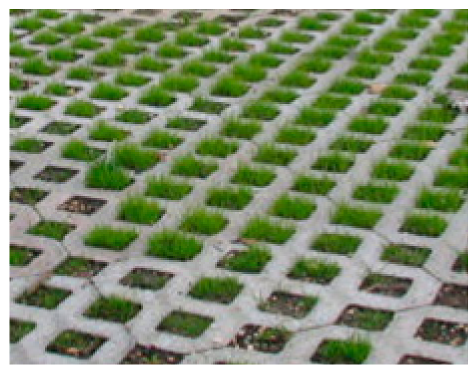
Hydrologic Response of Conventional Green Street LIDs



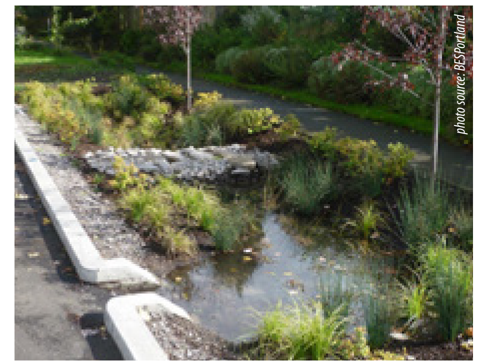
Detention
Capture of storm flows in a permanent holding site that allows for long-term infiltration or evaporation to occur.

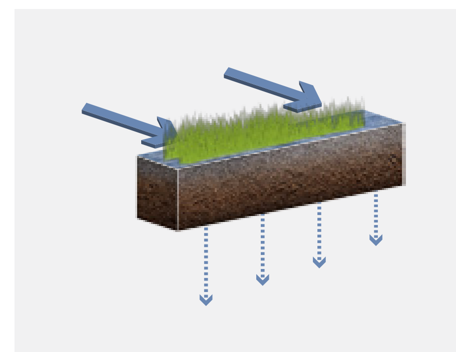
Retention
Capture of storm flows in a temporary holding site that releases flows after a certain amount of time at a design flow rate in order to reduce peak runoff volume and velocity.



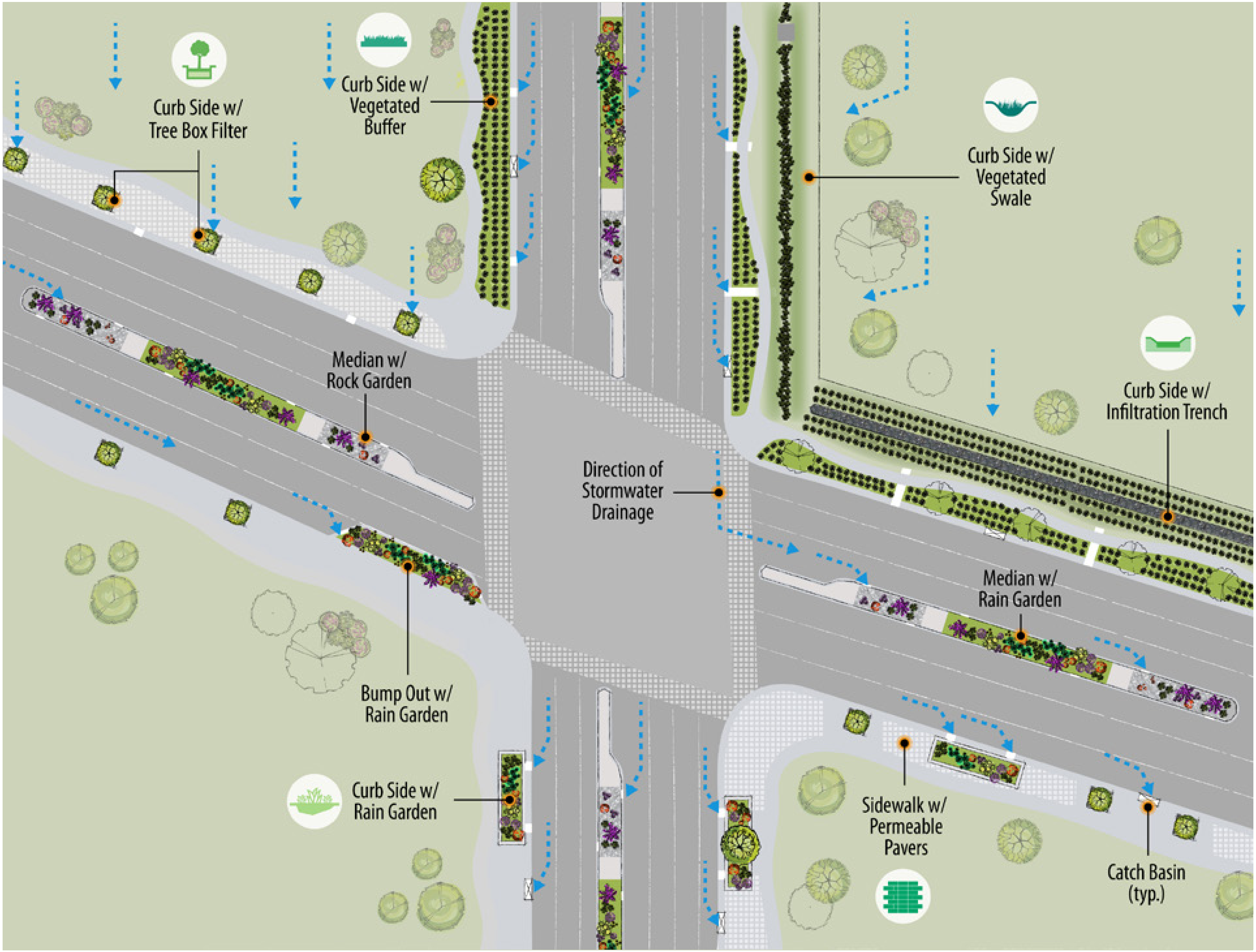


Filtration
Removing sediment, pollutants, bacteria, and other substances from water through physical, chemical, and biological processes.





Infiltration
Releasing storm flows into the groundwater table over time through direct interaction between the water and soil.


Curb Side w/
Tree Box Filter
Curb Side w/
Vegetated
Buffer
Curb Side w/
Vegetated
Swale
Median w/
Rock Garden
Curb Side w/
Infiltration Trench
Direction of
Stormwater
Drainage
Median w/
Rain Garden
Bump Out w/
Rain Garden
Curb Side w/
Rain Garden
Sidewalk w/
Permeable
Pavers
Catch Basin
(typ.)

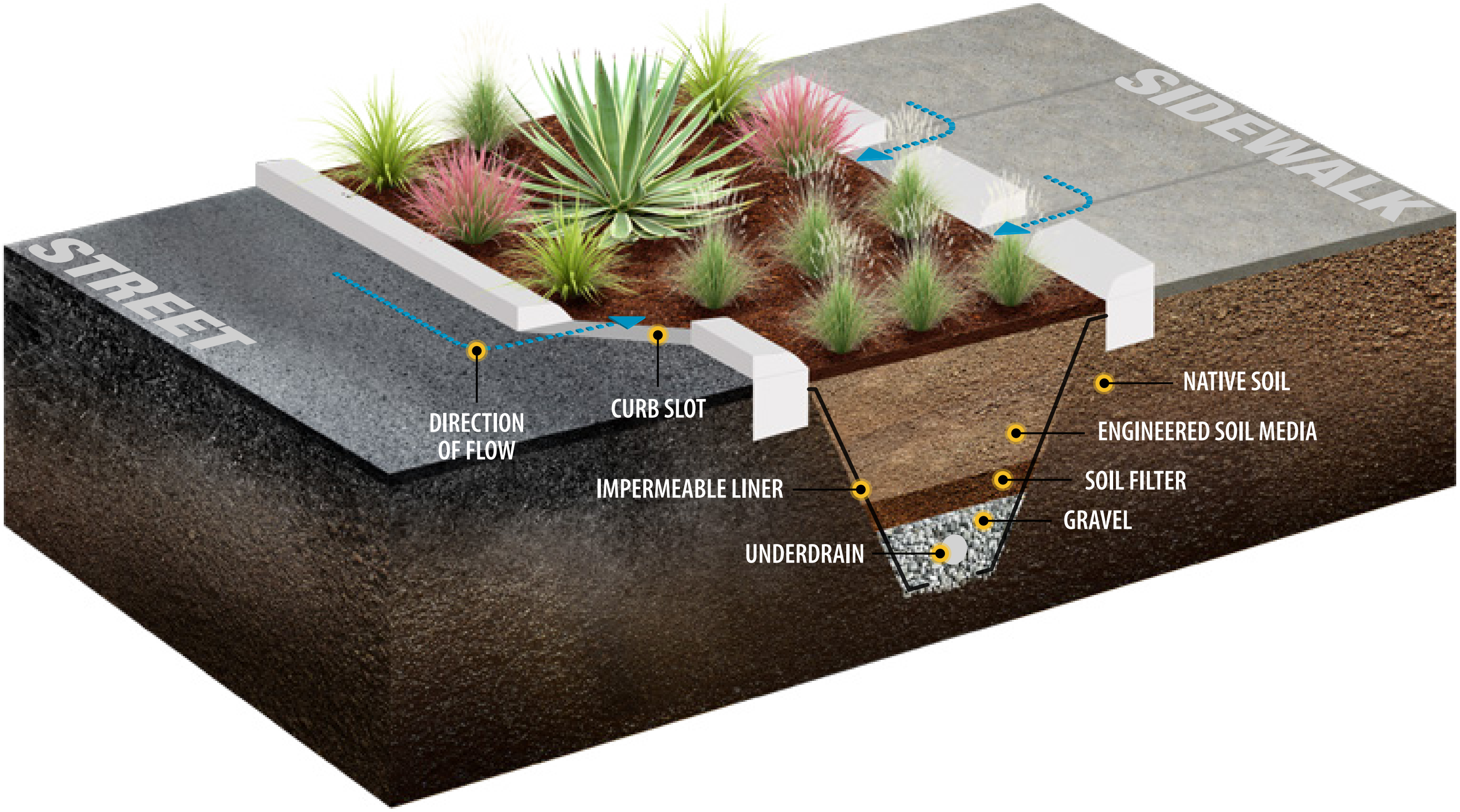
Bioretention

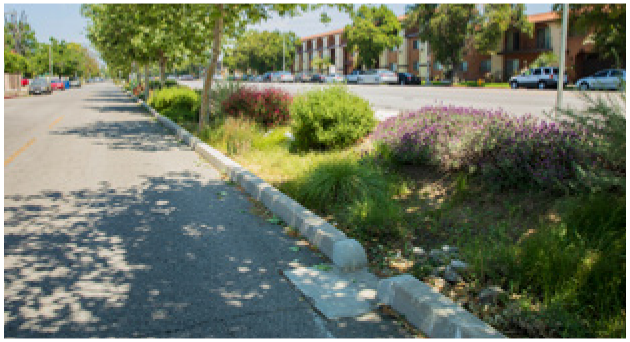
Rain Garden

Landscaped depressions that may incorporate soil amendments to promote stormwater retention and infiltration, providing the added benefit of a beautiful ornamental garden.

BENEFITS

- Retention
- Infiltration
- Pollutant Removal
- Aesthetically pleasing





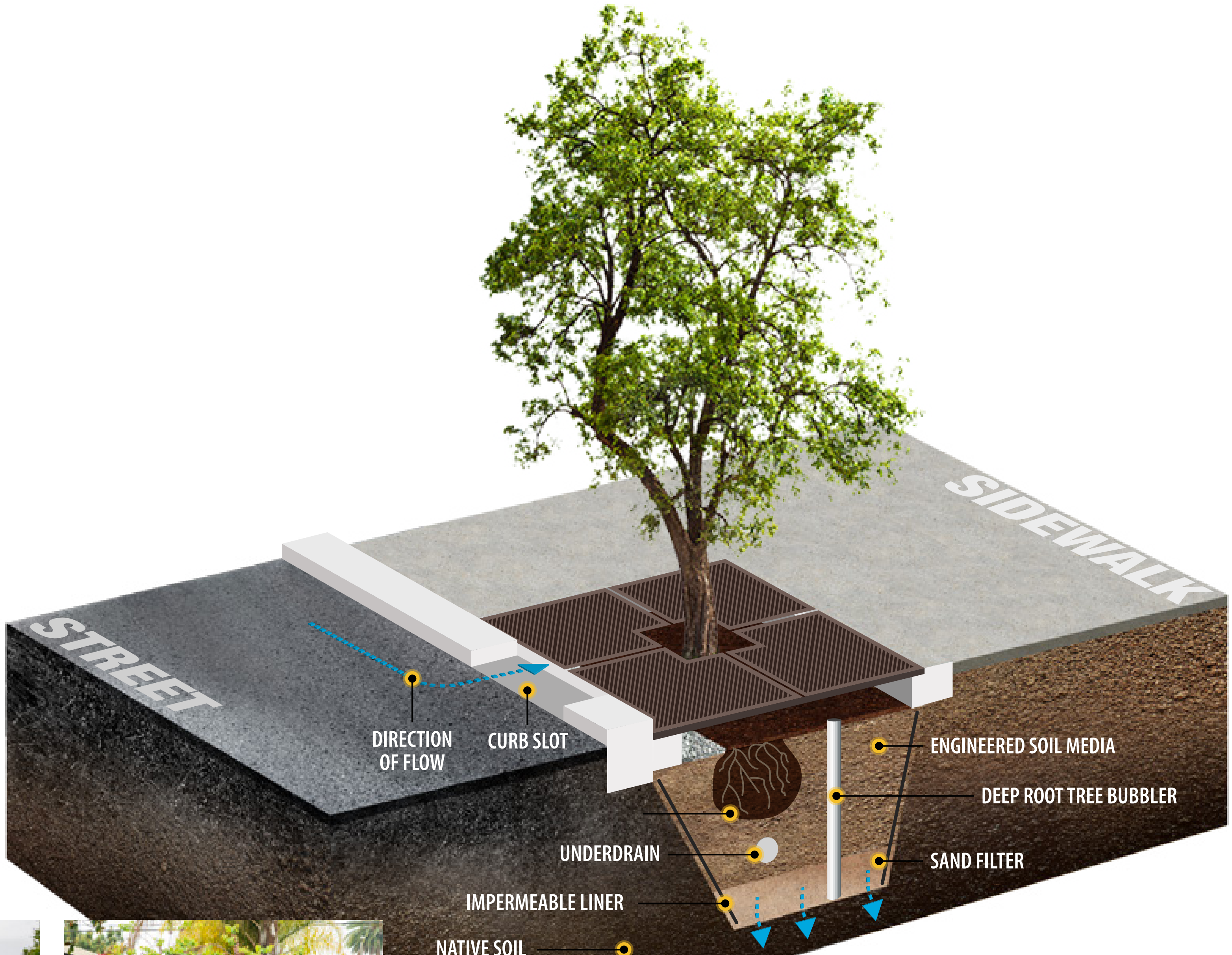
Left: Median rain garden with curb slot inlet
Middle: Curb side rain garden with step out zone
Right: Median rain garden on a high traffic street

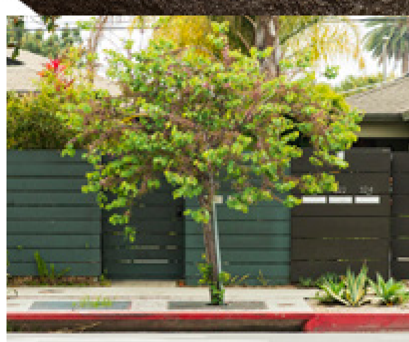
Tree Box Filter

Tree and vault system where the underground vault provides planting space for the tree and captures stormwater runoff. Water that enters the vault is simultaneously infiltrated and treated.

BENEFITS

- Infiltration
- Pollutant Removal
- Aesthetically Pleasing
- Minimal use of sidewalk space





Left: Curb side double tree box filter
Right: Curb side tree box filter in residential neighborhood

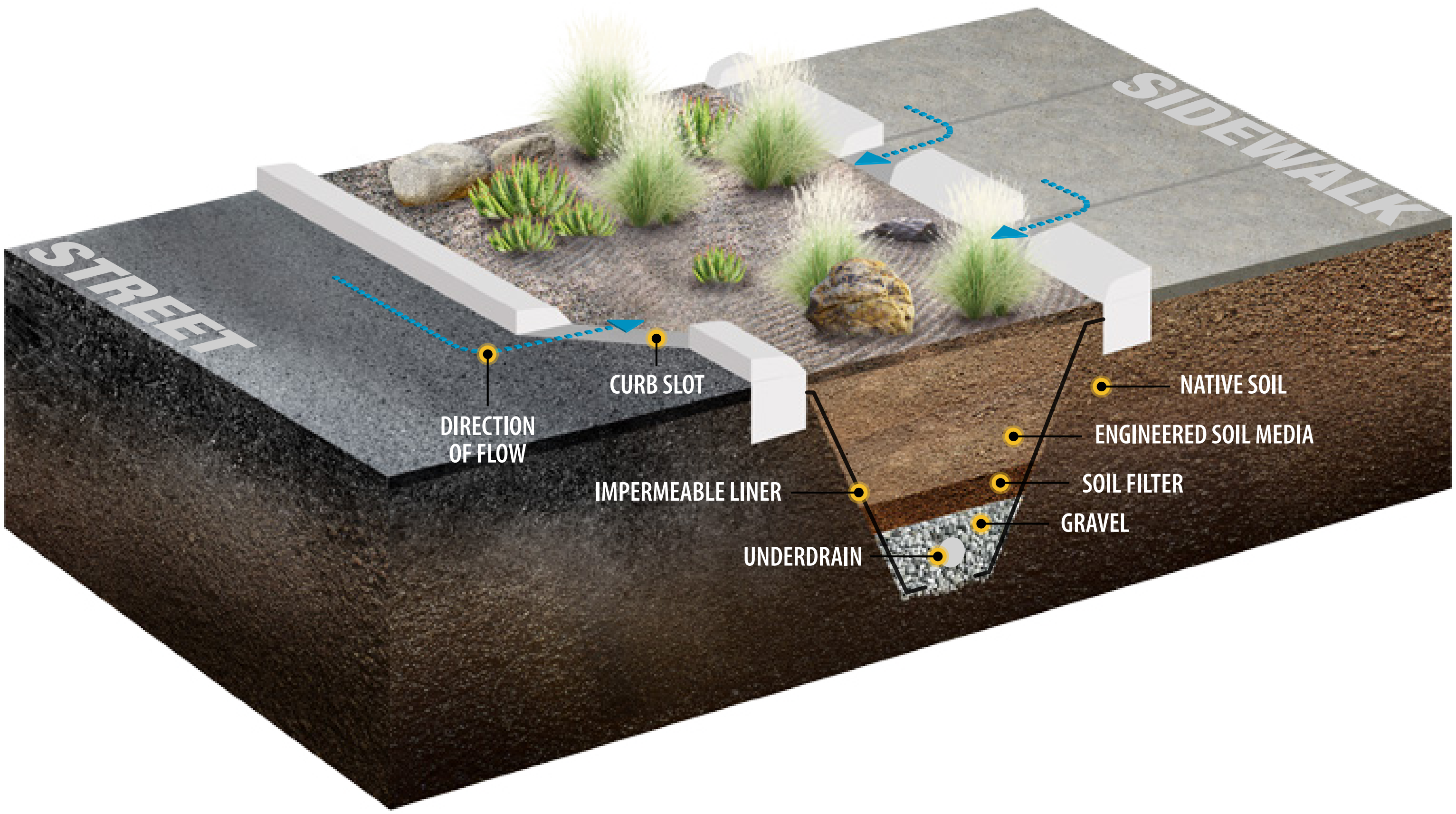
Infiltration

Rock Garden

Similar to a Rain Garden but with fewer plants and different sized / shaped rocks in place of mulch or soil. Infiltrates much faster than a rain garden.

BENEFITS

- Retention
- High Infiltration
- Pollutant Removal
- Low Water Usage in Dry Season



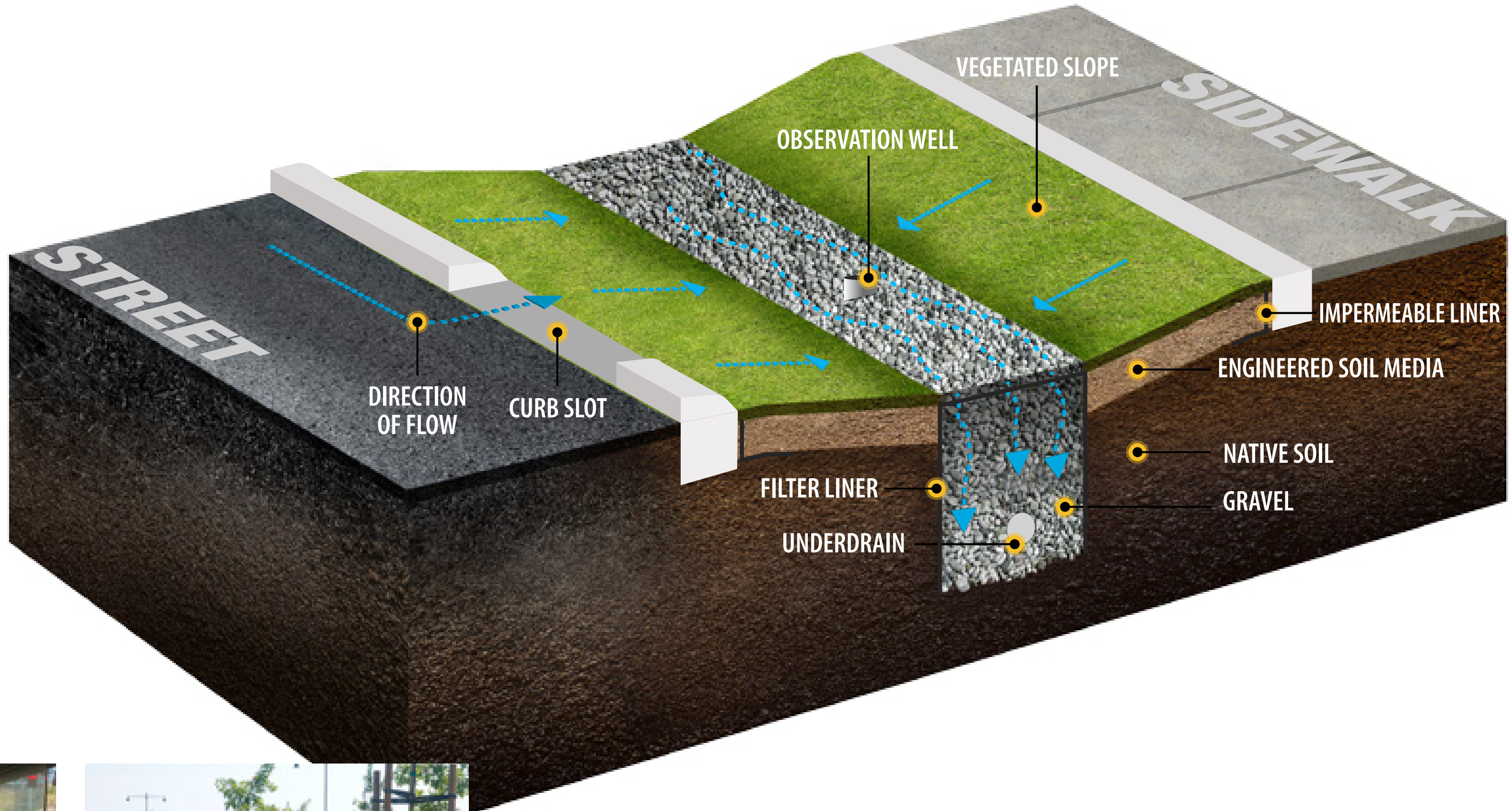
Left: California State University, Fullerton rock garden
Middle: Curb side rock garden with variation of rock sizes
Right: Curbside rock garden with scattered vegetation

Infiltration Trench

Excavated trench backfilled with stone that collects, infiltrates, and conveys stormwater runoff over an extended period of time. Side slopes of the trench can be vegetated for a more aesthetically appealing look

BENEFITS

- High Infiltration
- Pollutant Removal
- Low water use in dry season



Left: Curb side infiltration trench between sidewalk and building
Right: Median infiltration trench with meandering flow line

Permeable Pavements

Permeable Pavers

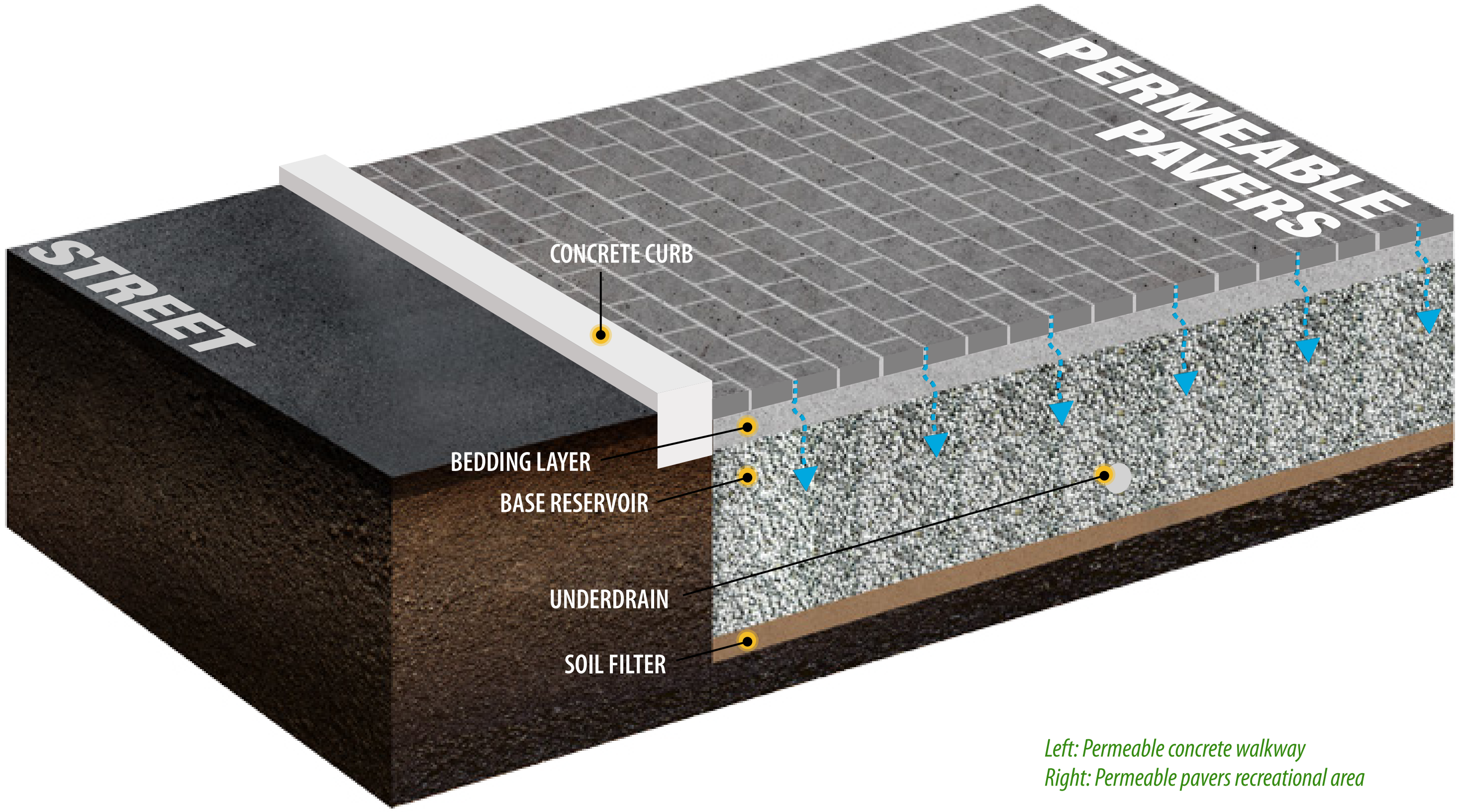
Pre-manufactured units that can be designed in an interlocking pattern. The pavers are impervious and the space between pavers is usually filled with a high porosity stone to encourage infiltration into the underlying soil.

Permeable Concrete

Similar to traditional concrete but with a larger aggregate size and less cement, to create more voids and allow infiltration into the underlying soil.

Permeable Asphalt

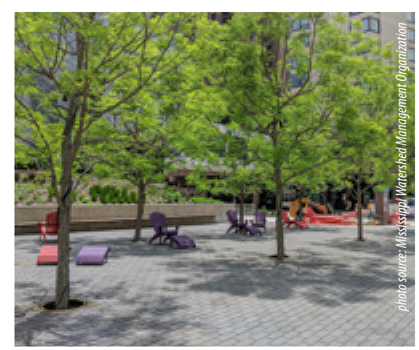
Similar to traditional asphalt but with a larger aggregate size and less cement, to create more voids and allow infiltration into the underlying soil.



BENEFITS

- Infiltration
- Pollutant Removal
- Does Not Require Extra Space Within the Right-of-Way

Left: Permeable concrete walkway
Right: Permeable pavers recreational area

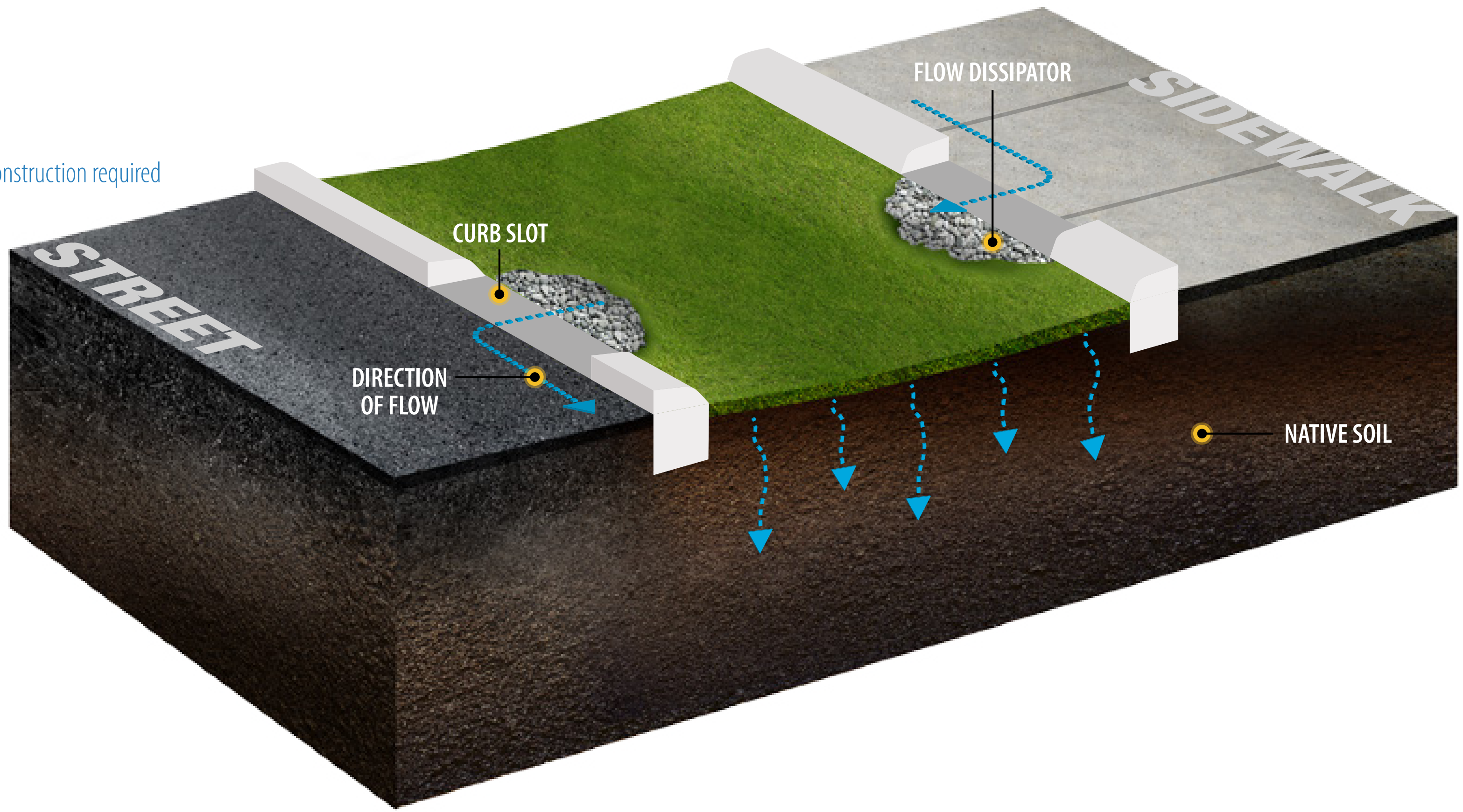


Green Space Vegetated Buffers

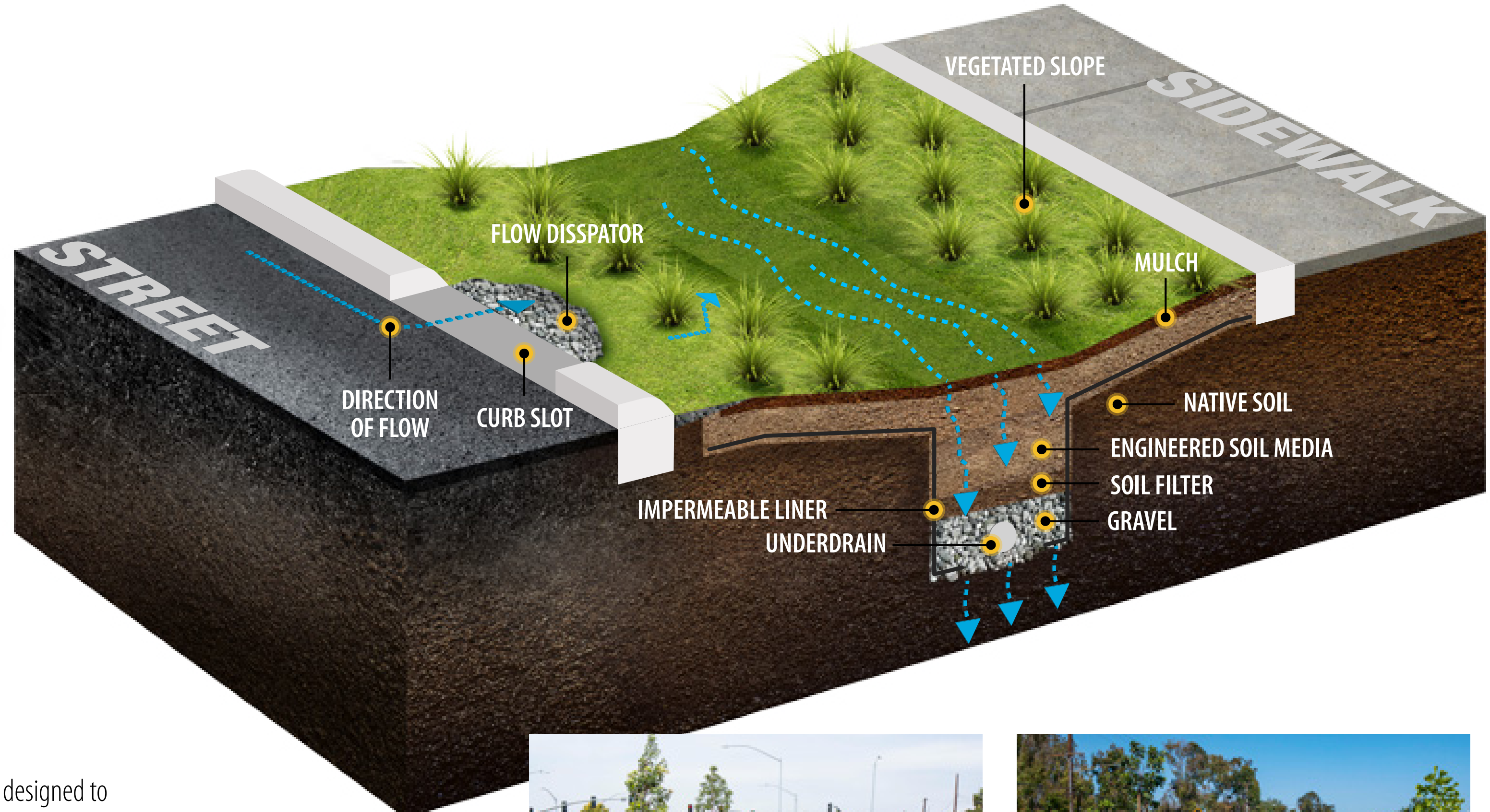
Extended vegetated areas (typically short grasses) that remove pollutants from and promote infiltration of sheet flow stormwater runoff.

BENEFITS

- Infiltration
- Pollutant Removal
- Minimal excavation / construction required



Enhanced Open Swales



Specialized vegetated channels designed to slow stormwater runoff, promote infiltration, trap sediment, and treat pollutants.

BENEFITS

- Infiltration
- Pollutant Removal
- Aesthetically Pleasing

Left: Curb side vegetated swale with tall grasses
Right: Curb side vegetated swale with varying grass species

Comparison of Solutions

Constraints

There are a variety of constraints associated with different Green Street LID Applications, making some more suitable for a site than others. The conditions that make one LID Application more favorable than another for a site are shown in the site constraints comparison table to the right. Depending on parameters such as space required, native soil condition, natural site slope, proximity to groundwater and nearby structure foundations, and maintenance requirements, the inventory of suitable LID Applications can be narrowed down.

Site Constraints							
Green Street LID Application	Space Required	Soils	Slopes	Water Table / Bedrock	Proximity to Building Foundations	Max. Depth	Maintenance
Rain Garden	SA_{min}= 50-200 SF W_{min}= 5-10 ft L_{min}= 10-20 ft D_{min}= 2-4 ft	I_{min}= 0.3 in/hr I_{max}= 12 in/hr	Z= 3H :1V max	Min. 10 ft clearance	Min. 10 ft	6-10 ft	High
Tree Box Filter	Varies by manufacturer	I_{min}= 0.3 in/hr I_{max}= 12 in/hr	Not Applicable	Min. 10 ft clearance	Min. 10 ft	Varies by site manufacturer	Low
Infiltration Trench	SA_{min}= 8-20 SF W_{min}= 2-4 ft L_{min}= 4-8 ft	I_{min}= 0.5 in/hr I_{max}= 12 in/hr	Z= 3H:1V max	Min. 10 ft clearance	Min. 10 ft	6-10 ft	Medium
Permeable Pavements	Not Applicable	I_{min}= 0.3 in/hr I_{max}= 12 in/hr	S_{max} = 10%	Min. 10 ft clearance	Min. 10 ft	Varies by site conditions	Low
Green Space Vegetated Buffers	L_{min}= 15-25 ft	I_{min}= 0.3 in/hr I_{max}= 12 in/hr	S_{min} = 2% S_{max} = 6% (in direction of flow)	Min. 10 ft clearance	Min. 10 ft	Not Applicable	Low
Enhanced Open Swales	Wb_{min}= 2 ft. Wb_{max}= 6 ft.	I_{min}= 0.3 in/ hrI_{max}= 12 in/hr	Z= 2H:1V max S_{min}= 2% S_{max} = 6%	Min. 10 ft clearance	Min. 10 ft	6-10 ft	Low

*SA = Surface Area
SF = Square Feet
W = Width
Wb = Base Width
L = Length
D = Depth
I = Infiltration Rate
Min = Minimum
Max = Maximum
Z = Slope perpendicular to flow
S = Slope parallel to flow

Source: 1

Hydrologic Functions

If the desired hydrologic function of a site utilizing a Green Street LID Application is already known, it may be helpful to consider which of these applications performs the best. Data pertaining to the effectiveness of Green Street LID Applications and specific hydrologic functions is presented in the Hydrologic Functions comparison table to the right.

Hydrologic Functions								
Green Street LID Application	Storage	Infiltration	GW Recharge	Runoff Volume Control	Peak Discharge Control	Runoff Frequency	Water Quality	Base Flow
Rain Garden	●●	●●●	●●●	●●●	●●	●●●	●●●	●●
Tree Box Filter	●●	●●●	●●●	●●●	●●	●●	●●●	●●
Infiltration Trench	●●	●●●	●●●	●●●	●●	●●	●●●	●
Permeable Pavements	–	●●●	●●●	●●	●●	●●	●●●	●
Green Space Vegetated Buffers	●	●●	●●	●●	●	●●	●●●	●●●
Enhanced Open Swales	●●●	●●	●●	●●	●●	●●	●●●	●●●

*High = ●●● Medium = ●● Low = ● None = – Source: 1

Pollutant Removal Efficiency

If a specific pollutant is desired to be targeted before the implementation of a Green Street LID application, it may be helpful to consider which of the available Applications is most effective at removing that pollutant. The Pollutant Removal Efficiency comparison table to the right presents seven types of pollutants and the efficiency of each of the Green Street LID Applications in removing them.

*TSS = Total Suspended Solids
Total P = Total Phosphorous
Total N = Total Nitrogen
BOD = Biological Oxygen Demand

Source: 6, 8, 10, 11

Pollutant Removal Efficiency %***

Green Street LID Application	TSS	Total P	Total N	Zinc	Lead	BOD	Bacteria
Rain Garden	●●●	●●	●●	●●●	●●●	●●●	●●●
Tree Box Filter	●●●	●●	●●	●	●	–	●●●
Infiltration Trench	●●●	●●	●●	●●●	●●●	●●	●●
Permeable Pavements	●●●	●●	●●●	●●●	●●●	●●●	–
Green Space Vegetated Buffers**	●●	●●	●	●●	●●●	–	–
Enhanced Open Swales	●●	●	●	●	●	–	●

High = ●●● (80-100 % Removal) Medium = ●● (40-80 % Removal) Low = ● (<40 % Removal) None = Data Unavailable

**Removal efficiencies for Green Space Vegetated Buffer are highly dependent on length of buffer strip in direction of flow. Longer buffer strip lengths produce higher pollutant removal efficiencies.
***All removal efficiencies provided are based on limited available data from field monitoring programs. This data relies on the specific design conditions at those monitoring sites and not all of the same pollutants were monitored between the six Green Street LID Application types.

Cost Ranking

Each of the Green Street LID Application types have different costs associated with them and can be broken down into construction costs, maintenance costs, and total cost. It is difficult to equate the unit costs for each of the Application types due to their varying size, components, and available data from existing projects. While the total cost of the project in $/SF may vary from the values shown in the table to the right, the ranking of the costs through relative comparison will generally hold constant.

LID Cost Comparison

Green Street LID Application	Materials & Installation Costs	Maintenance Costs	Ranking
Rain Garden	$35 / SF	$2,606 / YR	3
Tree Box Filter	$429 / SF	$1,646 / YR	6
Infiltration Trench	$42 / SF	$2,293 / YR	5
Permeable Pavements	$31 / SF	$1,542 / YR	2
Green Space Vegetated Buffers	$11 / SF	$1,666 / YR	1
Enhanced Open Swales	$47 / SF	$1,666 / YR	4

*SF = square feet EA = each YR = year M&I = Materials and Installation
Costs are provided only as a relative reference. Estimates are based on 2020 cost.

Maintenance Ranking

All Green Street LID applications require some level of maintenance, which varies between types. Maintaining Green Street LID applications plays a large role in extending their operational lives. Failure to provide the maintenance necessary for any of these applications will increase a project's long-term cost. The table to the right provides a basis for comparison of the levels of maintenance required for each Green Street LID Application, but further details about the maintenance routines are included in Section 5 - Maintenance Requirements.

LID Maintenance Comparison

Green Street LID Application	Irrigation?	Maintenance Costs	Maintenance Frequency
Rain Garden	Yes	$2,606 / YR	●●
Tree Box Filter	Yes	$1,646 / YR	●●
Infiltration Trench	No	$2,293 / YR	●●●
Permeable Pavements	No	$1,542 / YR	●
Green Space Vegetated Buffers	Yes	$1,666 / YR	●●●
Enhanced Open Swales	Yes	$1,666 / YR	●●●

*High = ●●● Medium = ●● Low = ● None = O Source: 1

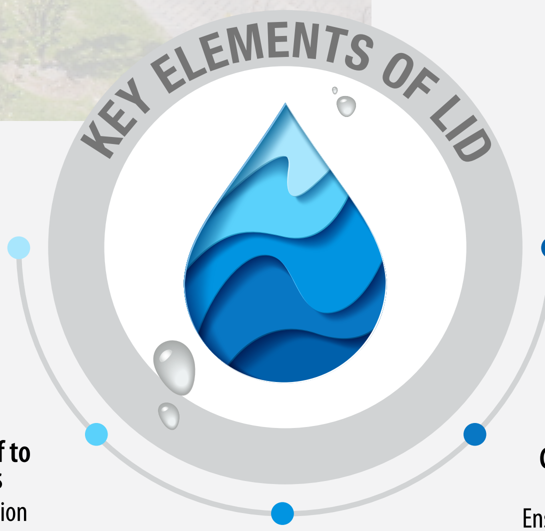
Hydraulically connected curb side rain gardens placed in series

02

GREEN STREET LID

PROJECT TYPES & SELECTION

Top: Series of rain gardens placed between walkways
Bottom: Curb side rain gardens in commercial area



Conservation
Preserves native trees, vegetation and soils. Maintains natural drainage patterns.

Small-scale Controls
Mimics natural hydrology and processes.

Directing Runoff to Natural Areas
Encourage infiltration and recharge of streams, wetlands and aquifers.

Customized Site Design
Ensures each site helps protect the entire watershed.

Maintenance, Pollution Prevention & Education
Reduces pollutant loads and increases efficiency and longevity.
Educates and involves the public.

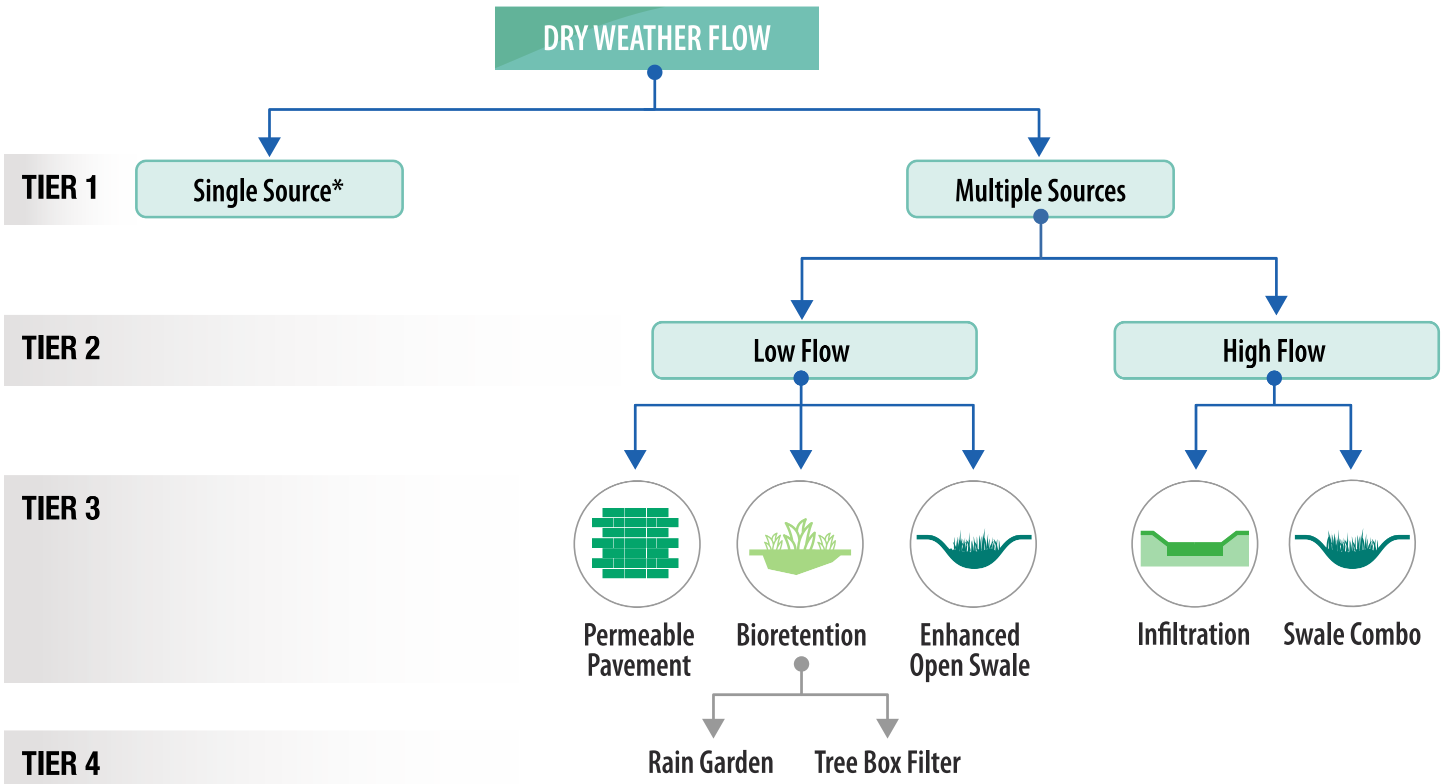
Types of Projects FOR GREEN STREET LID APPLICATION

This manual focuses on three project opportunity types where Green Street LID Applications can be implemented: Dry Weather Flow, Ponding, and General Application.

Dry Weather Flow

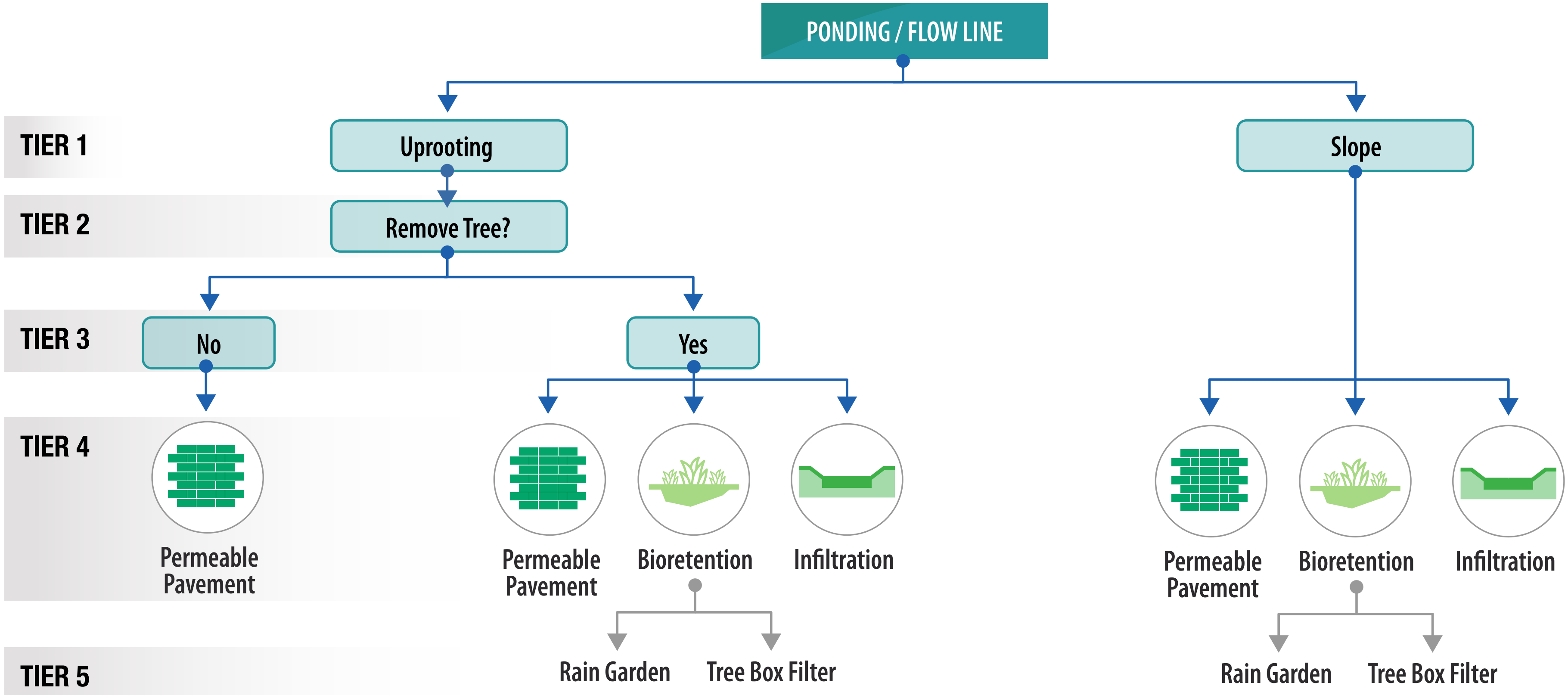
Even during dry seasons, storm drain infrastructure still handles accumulated runoff from urban areas that is made up of industrial wastewater, irrigation runoff, and domestic sewage. This accumulated flow is not usually high in volume but often carries a higher concentration of pollutants than typical stormwater runoff. Green Street LID practices create an opportunity to intercept these low flows and filter out the pollutants before they reach a major water body (in this case, the Santa Clara River).

**Single Source should be removed/mitigated if possible. If not possible, follow the matrix steps for the "Multiple Sources" branch.*



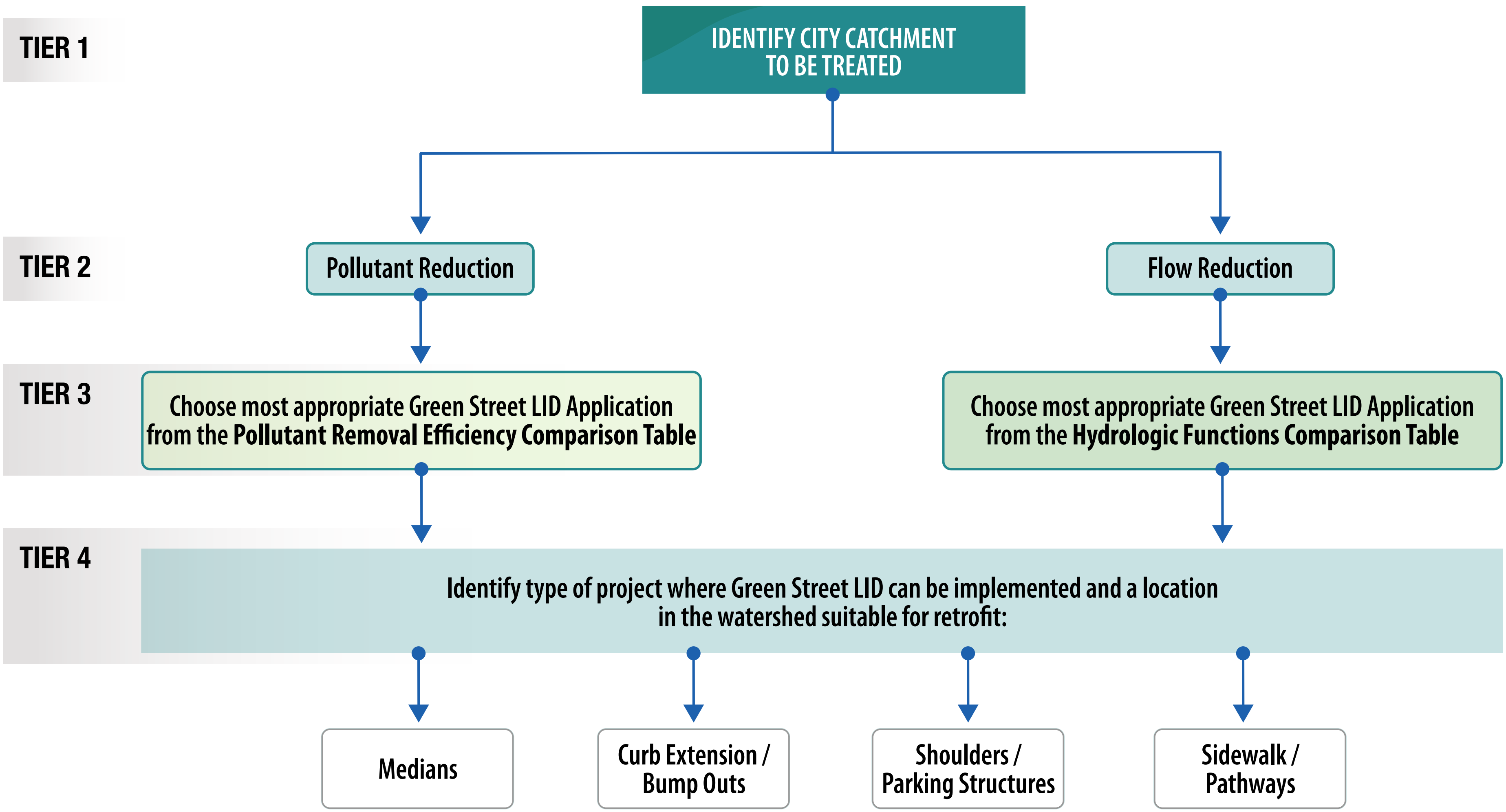
Ponding

Where slope isn't sufficient, ponding in the street flow lines will occur. As streets age and trees adjacent to the sidewalk grow larger, cracks and shifts in the asphalt and sidewalk often appear, altering the design path of stormwater flows. Settlement and accumulated sediment can also have the same result. These factors create an incorrect slope in the street, contributing to ponding. When these incorrect slopes appear in a gutter, stormwater has the potential to pond and can sit stagnant for days before it evaporates or slowly infiltrates into the ground. Green Street LIDs provide an excellent opportunity to direct flows from a ponded area into an adjacent planter, where the LID can not only reduce the volume of flow entering storm drain facilities during a rain event, but also allow residual water to infiltrate quickly into the ground, eradicating ponding areas and potential vector breeding.



General Application

The City may want to implement Green Street LID practices to reduce pollutants and peak runoff to meet the requirements of the MS4 permit without there being a preeminent goal, such as collecting dry weather flow or fixing a ponding area. In this case, it is best to select the LID site and type based on the tributary watershed map (on page 6) presented in the introduction to this manual or with the reduction of a specific pollutant of concern in mind.



LID Selection Process Follow the steps below to come up with an appropriate Green Street LID design:

Step 1 - Determine the project opportunity: Dry Weather, Ponding, or General Application.

Step 2 - Use the decision matrix corresponding to the project opportunity selected in **Step 1**.

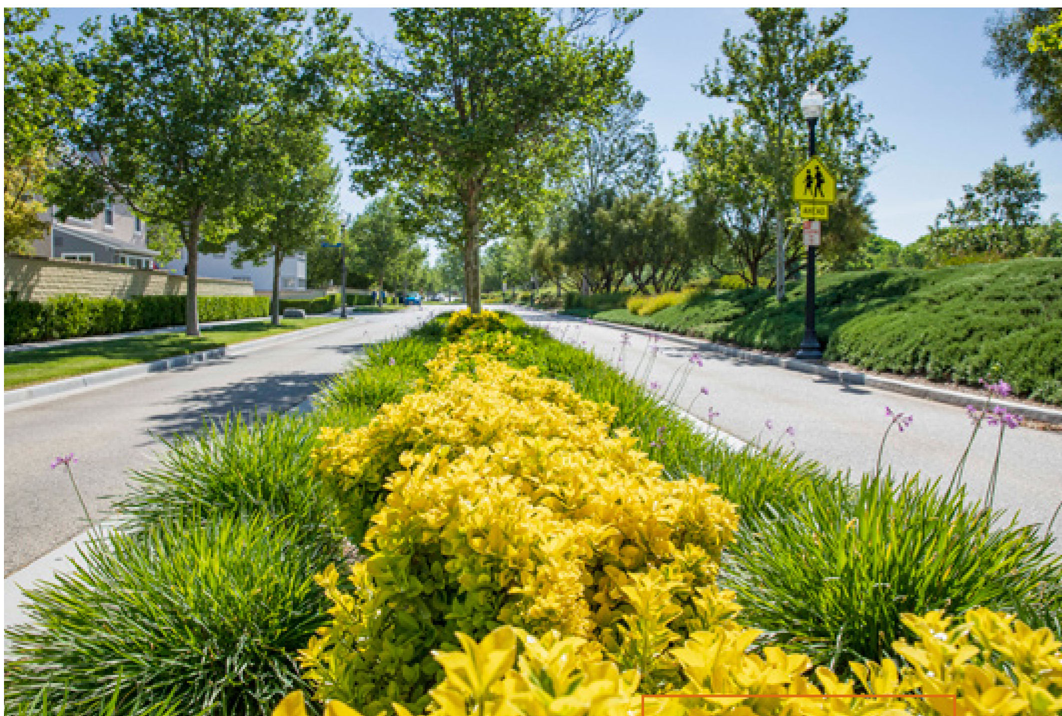
Step 3 - Out of the choices given by the matrix, further refine your options using tables for comparative cost, pollutant removal, constraints, and hydrological functions (see Comparison of Solutions in Chapter 1).

Step 4 - Go to the fact sheet for the selected Green Street LID for sizing and design in Section 3.

Step 5 - Use design standards where applicable in construction documents from Section 4.

Step 6 - Verify maintenance requirements in Section 5.

Step 7 - Select appropriate plants. See current City Landscape Maintenance District Guidelines.



Left: Median rain garden at a community entrance
Right: Curb side vegetated swale with meandering walkways

LID Selection Example

Example: General Application

The City wants to implement a Green Street LID in a strategic location where it can reduce zinc levels polluting Reach 6 of the Santa Clara River.

01 Determine the project opportunity

In this case, it would be General Application.

02 Use the decision matrix corresponding to the project opportunity selected in Step 1

TIER 1

Identify City catchment to be treated - Through water quality sampling of various areas draining to Reach 6 of the Santa Clara River, it is determined that high amounts of zinc originate from the San Francisquito Watershed, specifically at a sampling point along McBean Parkway*, between Decoro Drive and Summerhill Lane. The most downstream point of this length of street is used to determine the contributing catchment area.

**Note: No sampling data was used to create this example problem. Levels of zinc and other pollutants along McBean Parkkway are not known. This manual does not suggest McBean Parkway as a suitable location to construct a Green Street LID.*

TIER 2

Pollutant Reduction or Flow Reduction

⇣ ⇣ ⇣ ⇣ ⇣ ⇣ ⇣ ⇣ ⇣ ⇣

POLLUTANT REDUCTION

In order to reduce levels of Zinc.

TIER 3

Choose the most appropriate Green Street LID Application from the Pollutant Removal Efficiency Comparison Table

Based on the Pollutant Removal Efficiency Table, Rain Gardens, Infiltration Trenches, and Permeable Pavement are all highly effective at removing Zinc.

Pollutant Removal Efficiency %							
Green Street LID Application	TSS	Total P	Total N	Zinc	Lead	BOD	Bacteria
Rain Garden	●●●	●●	●●	●●●	●●●	●●●	●●●
Tree Box Filter	●●●	●●	●●	●	●	–	●●●
Infiltration	●●●	●●	●●	●●●	●●●	●●	●●
Permeable Pavement	●●●	●●	●●●	●●●	●●●	●●●	–
Green Space Vegetated Buffer**	●●	●●	●	●●	●●●	–	–
Enhanced Open Swale	●●	●	●	●	●	–	●

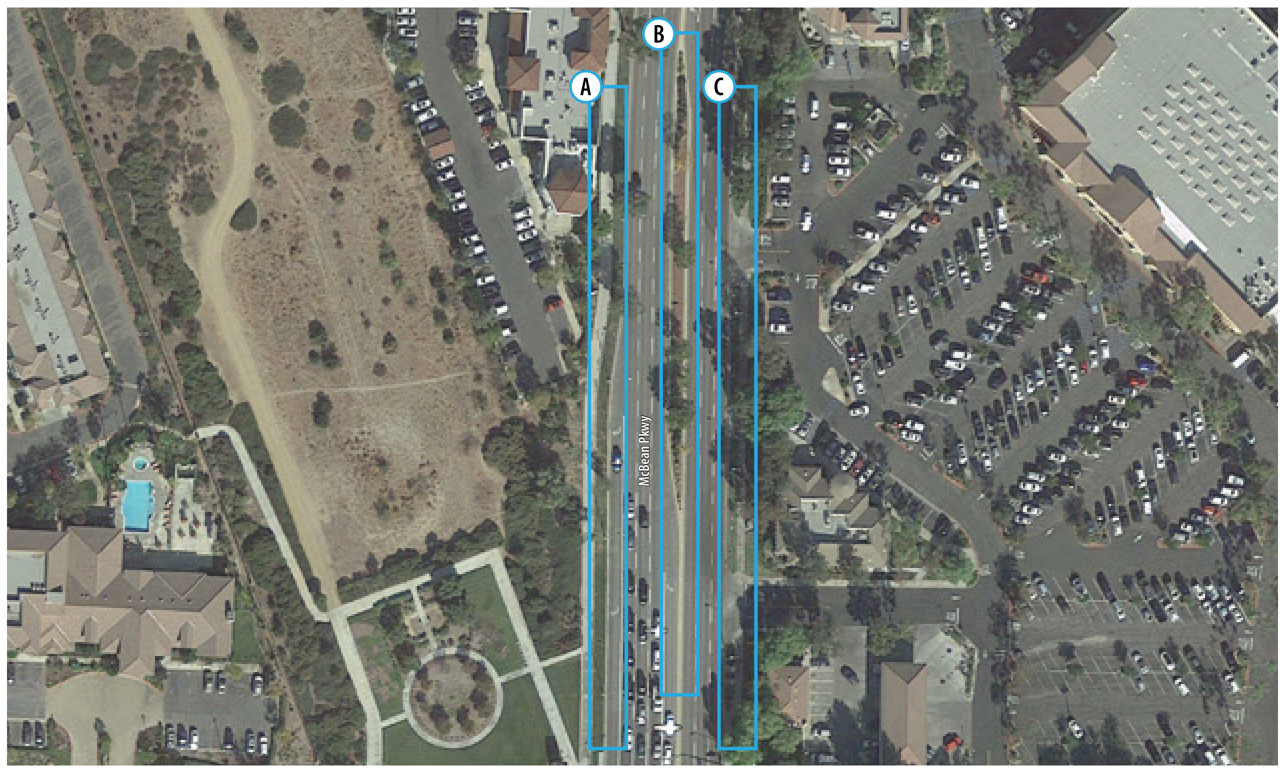
High = ●●● (80-100 % Removal) Medium = ●● (40-80 % Removal) Low = ● (<40 % Removal) None = –

TIER 4

Identify type of project where Green Street LID can be implemented and a location in the watershed suitable for retrofit Looking at the catchment drainage point location, there are a few project types that would be suitable to retrofit the existing McBean Parkway:

- Ⓐ Street Median along McBean Parkway
- Ⓑ Sidewalks on east and west edges of McBean Parkway
- Ⓒ Curb side on east and west edges of McBean Parkway

Out of these options, the sidewalk / curb side on the west edge of McBean Pkwy is the best location to install a Green Street LID. The current street grade directs more runoff to the east / west edges of McBean Parkway than to the center, so an LID in the median would not be as effective. Additionally, the east edge of McBean Parkway includes a driveway entrance to the shopping area, which decreases the total area the LID can be implemented. Driveways also present interruptions to the LID layout, increasing project cost to hydraulically connect separated LID segments.

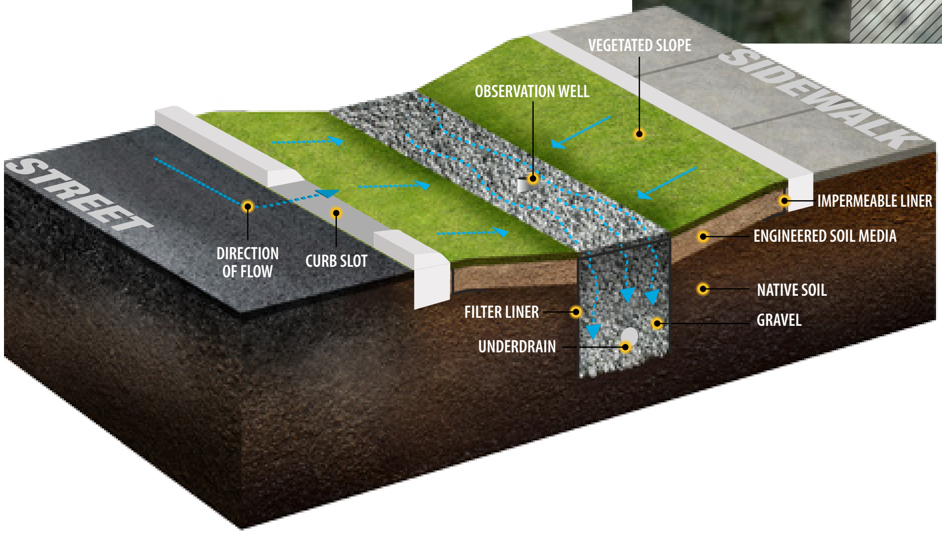


03 Out of the choices given by the matrix, further refine your options using tables for comparative cost, pollutant removal, constraints, and hydrological functions

Out of the three Green Street LID options (Rain Garden, Infiltration Trench, and Permeable Pavement), Permeable Pavement can be a combined installation with either Rain Gardens or Infiltration Trenches, but there is not sufficient room for both a Rain Garden and an Infiltration Trench.

According to the Cost Comparison Table, Infiltration Trenches are less expensive than Rain Gardens and, according to the Hydrologic Functions Table, Infiltration Trenches can infiltrate a greater amount of runoff than a Rain Garden for the same area used. This is especially an advantage since the catchment drainage area is rather large, at 2 acres.

Based on these facts, the most appropriate Green Street LID Application is curb side ***Infiltration Trench and Permeable Pavement sidewalk.***



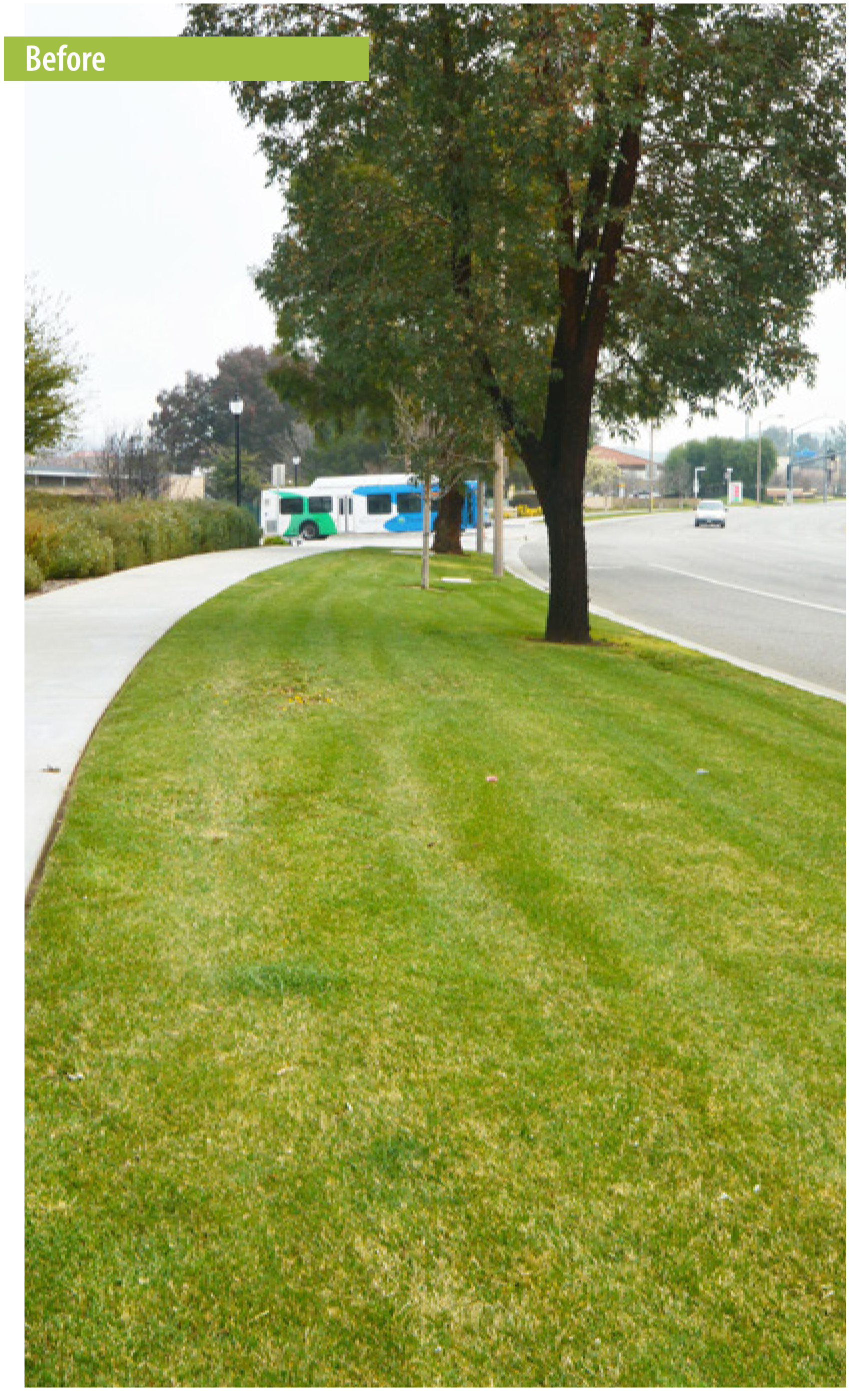
04 Go to the fact sheet for the selected Green Street LID for sizing and design

05 Use design standards where applicable in construction documents

06 Verify maintenance requirements in the maintenance section

07 Select appropriate plants from the plant palette section

Before



After

03 FACT SHEETS

Rain Garden

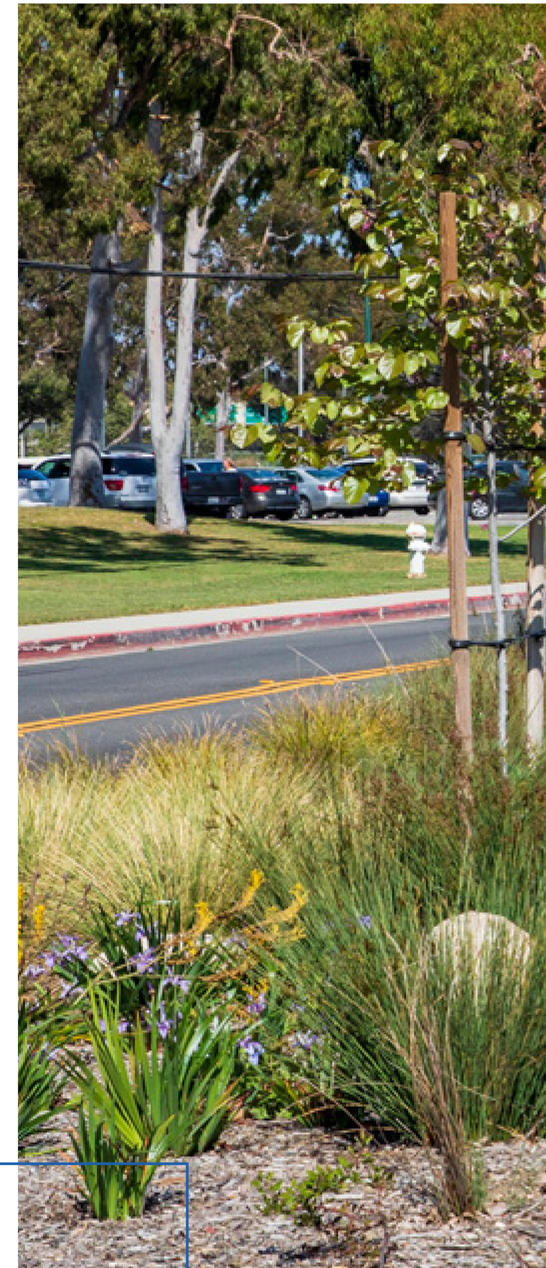
Tree Box Filter

Infiltration
(Rock Garden / Infiltration Trench)

Permeable Pavements
(Pavers / Concrete / Asphalt)

Green Space Vegetated Buffers

Enhanced Open Swales



Curb side vegetated swale with meandering walking/biking trail

Rain Garden

Rain gardens are vegetated areas depressed below the surrounding ground surface and surrounded by an impermeable barrier, such as a curb, with open slots that allow flow to enter. Water that enters the rain garden ponds up and slowly filters into the underlying soil, both reducing stormwater runoff volume and removing contaminants through physical and biological processes.

Flows in excess of the rain garden's designed capacity simply bypass the entrance slots and enter nearby storm drain lines or enter some sort of overflow structure. Features include:

- Sediment and contaminant removal
- Volume and flow rate reduction of storm flows
- Groundwater recharge
- Capture of dry-weather flows
- Visually appealing

Top: Curb side rain garden with check dams
Bottom: Bump out rain garden as a traffic calming strategy

Objectives

Retention | Filtration | Infiltration

- Water Quality Improvement Objectives
- Suitable Applications
- Design Principles
- Limitations and Constraints
- Pollutant Removal Efficiency
- Cost Estimation
- Design Procedure
- Example Scenario

A visually appealing way to reduce stormwater runoff volume, velocity, and contaminant transport.

Suitable Applications

Rain gardens can be applied in almost any scenario where there is sufficient room to designate as green space, but are most ideally placed along the edges of roads and in medians. Drought tolerant plants and Southern California native plants are encouraged but still require irrigation and maintenance.

In areas that don't receive regular rainfall, a combination of drought tolerant plants and irrigation lines will keep the garden green year-round.

Design Principles

a Bowl Shaped

- The surface of the garden should be bowl shaped, allowing water to pond. Recommended depth of excavation is 4 ft Minimum planting soil depth is 2 ft, although 3 ft is preferred.
- Size according to the design inflow rate.

b Slow the Flow

- Dissipate the energy of flows entering the rain garden by
  - » Creating a sheet flow condition or
  - » Providing energy dissipation devices at the inlet (i.e. large cobbles)
- Slopes may erode when velocities exceed 5 ft/s.

c Maximize Infiltration

- Rain gardens should infiltrate well enough to avoid vector breeding and drain the captured flow below the planting soil depth in less than 48 hours and completely drain in less than 96 hours.
- An underdrain must be installed for biofiltration LID applications. Preferably placed near the top of the gravel storage area, it promotes infiltration and enhances nitrogen removal. Native soils with low infiltration rates may require the underdrain to be placed deeper in the gravel soil layer, with the underdrain invert up to 6" from the layer bottom.
- A gravel storage layer below the soil media is required as necessary to provide adequate temporary storage to retain the Stormwater Quality Design Volume and to promote infiltration.
- Long term in-place infiltration of the planting media placed in the cell should achieve a minimum infiltration rate of 0.3 in/hr and a maximum infiltration rate of 12 in/hr.

d Slope Stability

- Slopes used to create the bowl shaped depression should be gradual to ensure slope stability (max. 33%).

e Vegetative Cover

- Vegetation promotes pollutant removal, increases infiltration rates, and provides an aesthetic appeal.
- Cover the area with 2-3 inches of mulch to promote vegetative growth.
- Plant about 1 tree or shrub per 50 ft^2 of rain garden area.

f Overflow Precautions

- The rain garden should be designed with an overflow control structure or system that directs flows in excess of the design flow rate out of the rain garden and onto an alternate flow path.
- The device is required at the 18-inch maximum ponding depth.

Top: Curb side rain garden with check dams and an overflow grate inlet
Bottom: Curb side rain garden with step out zone.

Limitations and Constraints

a Sizing

- Sites should have a drainage area between 0.25 and 1 acres, unless the design includes multiple rain gardens.
- The rain garden should drain the 85th percentile volume at a minimum rate of 0.3 inches per hour and a maximum of 12 inches per hour.

b Water Table

- The water table must be more than 10 ft below the invert of the rain garden to ensure adequate infiltration.

c Vegetation / Soil Requirements

- For the Arid-Mediterranean environment, the planting media should consist of 60% to 80% fine sand and 20% to 40% compost. Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc. or any other deleterious material. Compost should be a well decomposed, stable, weed-free organic matter source not including manure or biosolids.
- Plants selected should be able to withstand both short periods of submergence (18-inches) and extended periods of minimal irrigation.
- Soils should have a pH between 6.5 and 8, an organic content of 35% to 75% on a dry weight basis, and a salinity of <6.0 mmhos/cm.

d Standing Water

- A certain amount of ponding is expected, but low infiltration rates can result in standing water with the potential for vector breeding.
- Infiltration rates 0.3 to 1 inch per hour require replacing existing soil with a soil mix. The in-situ or amended soil must have an infiltration rate under saturated conditions of no less than 0.3 inches per hour.
- Existing soils with infiltration rates > 1 inch per hour are adequate.

e Slopes

- The initial slope of the site being considered for a rain garden should not be greater than 20%.

f Infiltration

- Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mm. Generally, waterproof barriers should not be placed at the bottom of the biofiltration unit, as this would prevent incidental infiltration, which is important to meeting the required pollutant load reduction.

Top: Ponding in a rain garden
Bottom: Rain garden with flowering vegetation

Pollutant Removal Efficiency

Rain Garden Pollutant Removal Efficiency Data	
Pollutant of Concern	Removal Rate
Total Phosphorous	70 – 83%
Metals (Cu, Zn, Pb)	93 – 98%
TKN	68 – 80%
Total Suspended Solids	90%
Organics	90%
Bacteria	90%

TKN = Total Kjeldahl Nitrogen
Cu = Copper
Zn = Zinc
Pb = Lead

Source : 3 & 4

Cost Estimation

Costs are provided only as a relative reference. Estimates are based on 2020 cost.

a Capital Cost

Materials / Installation Cost

Item	Unit Cost	Cost / SF
Mobilization	$3,452 LS	$1.45
Clearing & Grubbing	$6 SY	$0.65
Soil Media	$43 CY	$2.40
Pea Gravel	$129 CY	$0.92
Gravel	$27 CY	$0.76
Mulch	$80 CY	$0.57
Underdrain Pipe (PVC)	$8 LF	$0.07
Excavation / Grading	$18 CY	$3.49
Haul Away Material	$10 CY	$1.94
Finished Grading	$2 SY	$0.22
Vegetation	$4 SF	$3.03
18" x 18" Trench	$1 LF	$0.01
Irrigation	$9 SF	$9.00
Inflow Structures (concrete / riprap)	$2,200 LS	$0.92
Overflow Structure (concrete / riprap)	$125 CY	$0.37
Metal Beam Guard Rail	$58 LF	$1.02
	Subtotal/SF =	$27

Design Costs

Item	Unit Cost	Cost / SF
Project Management	$1,899 LS	$0.80
Preliminary Engineering	$3,798 LS	$1.60
Final Design Engineering	$1,899 LS	$0.80
Topographic Survey	$949 LS	$0.40
Landscape Design	$760 LS	$0.32
Legal Services	$380 LS	$0.16
Permitting & Construction Inspection	$380 LS	$0.16
Sales Tax	$2,374 LS	$1.00
Contingency	$7,596 LS	$3.19
	Subtotal/SF =	$8

Total Capital Cost/SF= $35

Source: 5

b Maintenance Cost

Item	Months Between Events	Hours Per Event	Average Labor Team Size	Average Labor Rate/Hr (pro-rated) ($)	Machinery Cost/Hr ($)	Materials & Incidentals Cost/Event ($)	Total Cost Per Visit ($)
Routine Maintenance							
Inspection, Reporting & Info Mgmt	12	2	2	$50.00	$40.00	$ –	$280.00
Vegetation Mgmt & Trash / Debris Removal	12	8	2	$50.00	$60.00	$100.00	$1,380.00
Infrequent / Corrective Maintenance (>3 yrs between events)							
Corrective Maintenance	96	24	4	$50.00	$60.00	$500.00	$6,740.00
Sediment Management	300	8	4	$50.00	$60.00	$500.00	$2,580.00
						Total Maintenance Cost =	$2,606/ yr

Source: 5

Design Procedure

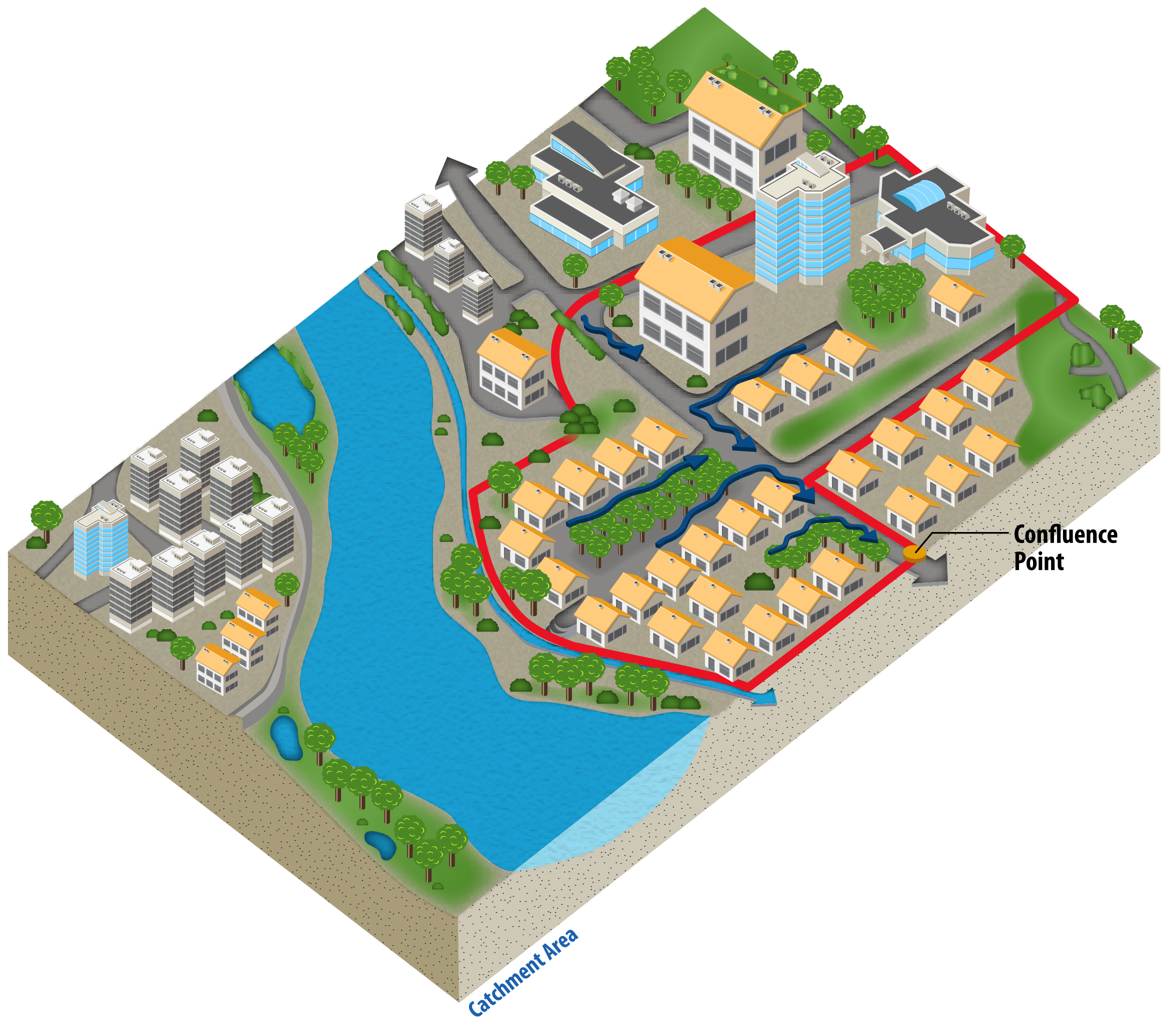
01 Identify Project Location → **02** Determine Design Volume → **03** Determine Design Infiltration Rate → **04** Calculate Bioretention Area → **05** Check Ponding Depth Drains

01 Identify Project Location

02 Determine Design Volume

In new development, rain gardens should be sized to capture the 85th percentile runoff volume for their contributing catchment. For redevelopment or retrofit projects, however, **the rain garden can either be sized to capture the 85th percentile runoff volume or the design volume will be based on the maximum size the rain garden can be**. For example, in a retrofit project, the available area and depth that can be used for design may not be enough to completely capture the 85th percentile runoff volume. The design volume, in this case, would be the maximum volume of runoff the proposed rain garden can hold. This volume would correspond to some "percentile" volume lower than 85th.

If the 85th percentile runoff volume can be designed for, it should. Otherwise, the rain garden will not be able to capitalize on a majority of storms. Alternatively, the rain garden should not be designed for a volume greater than the 85th percentile, even if there is sufficient room. Storm events producing runoff greater than the 85th percentile are not as common, so a larger rain garden will cost more money to infiltrate and treat an insignificant increase in runoff volume.



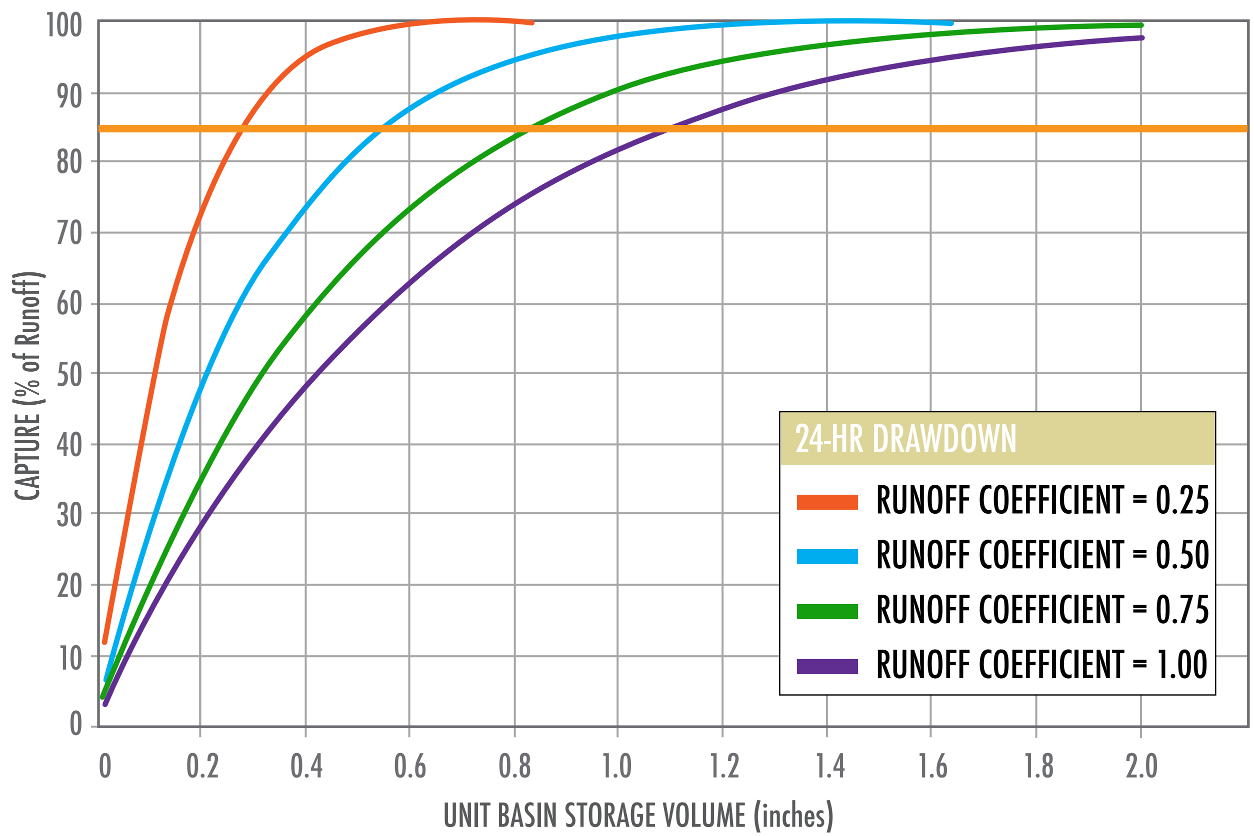
85[th] Percentile Design Volume Approach

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil. Catchment areas should be between 0.25 and 1 acres.
- Determine the runoff coefficient. The runoff coefficient is an indicator of how much pervious / impervious surface makes up the watershed draining to the Green Street LID project location (0.25, 0.5, 0.75, or 1.00). A runoff coefficient of 0.25 is used for watersheds with almost 0% impervious area while a coefficient of 1.00 is used for watersheds with almost 100% impervious areas. Analyzing the watershed area, determine the runoff coefficient to be used for design. A higher, conservative estimate is always better to use.
- Using the Sizing Curves graph below, find the "Unit Basin Storage Volume" (inches), corresponding to the intersection of the 85% runoff capture and the selected runoff coefficient curve.
- Multiply the contributing watershed drainage area, DA (units of ft^2), by the unit basin storage volume (units of feet), to obtain the 85[th] percentile volume, V (units of ft^3), the rain garden must hold.

$$V\ (ft^3) = DA\ (ft^2) \times \text{Unit Basin Storage Volume (ft)}$$

Maximum Runoff Volume Design Approach

- Determine the maximum volume, V_{max} (units of ft^3), that can be contained in the rain garden at the selected site. This will be the maximum area available, A_{max} (units of ft^2, bottom of the rain garden area), with a maximum ponding depth, d_{max}, of 1.5 ft (assume 3H : 1V side slopes).
- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil.
- Divide the maximum rain garden volume, V_{max} (ft^3), by the total catchment drainage area, DA (ft^2) to obtain the equivalent Unit Basin Storage Volume (ft). Convert this to inches.
- Analyzing the watershed area, determine the runoff coefficient to be used for design.
- Using the Sizing Curves graph to the right, find the "Capture (% Runoff)", corresponding to the intersection of the Unit Basin Storage Volume (inches) and the selected runoff coefficient curve. This is the "percentile" stormwater runoff that the Green Street LID Application can capture.



Sizing Curves Source: 4

03 Determine the Design Infiltration Rate

Use the procedures outlined in the most recent GMED Policy GS 200.1 to determine the corrected in-situ infiltration rate, f_{design} (units of in/hr) of the native soil at the project site.

Acceptable infiltration tests include:

1. **Double-ring Infiltrometer Test**
2. **Well Permeameter Test**
3. Boring Percolation Test Procedure
4. Excavation Percolation Test Procedure
5. High Flowrate Percolation Test Procedures
6. Policy for New Percolation Basin Testing, Design and Maintenance

The double-ring Infiltrometer and well permeameter tests are preferred, but whatever test is used must be performed at each location and elevation where the Green Street LID Application is proposed. Multiple tests at each site are recommended.

Procedures and example data forms for Double-Ring Infiltrometer tests are laid out in ASTM D3385. Details for the Well Permeameter Test can be found in the Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89).

In-situ infiltration rates should be between 0.3 in/hr and 12 in/hr. Anything above 12 in/hr or below 0.3 in/hr must have amended soil to achieve an adequate infiltration rate.

double ring infiltrometer test

04 Calculate the Bioretention Area *(85th Percentile Design Volume Approach Only)*

Assume the design volume, V (units of ft^3), will fill the available ponding depth, d_p (units of ft, 1.5 ft max). The surface area, A (units of ft^2, bottom of the rain garden area), required to accommodate the design volume at a ponding depth of 1.5 ft is:

$$A = V / d_p$$

Where: A = design surface area (ft^2)
V = design volume (ft^3)
d_p = ponding depth (1.5 ft max) (ft)

05 Check that Ponding Depth Drains within 96 hrs

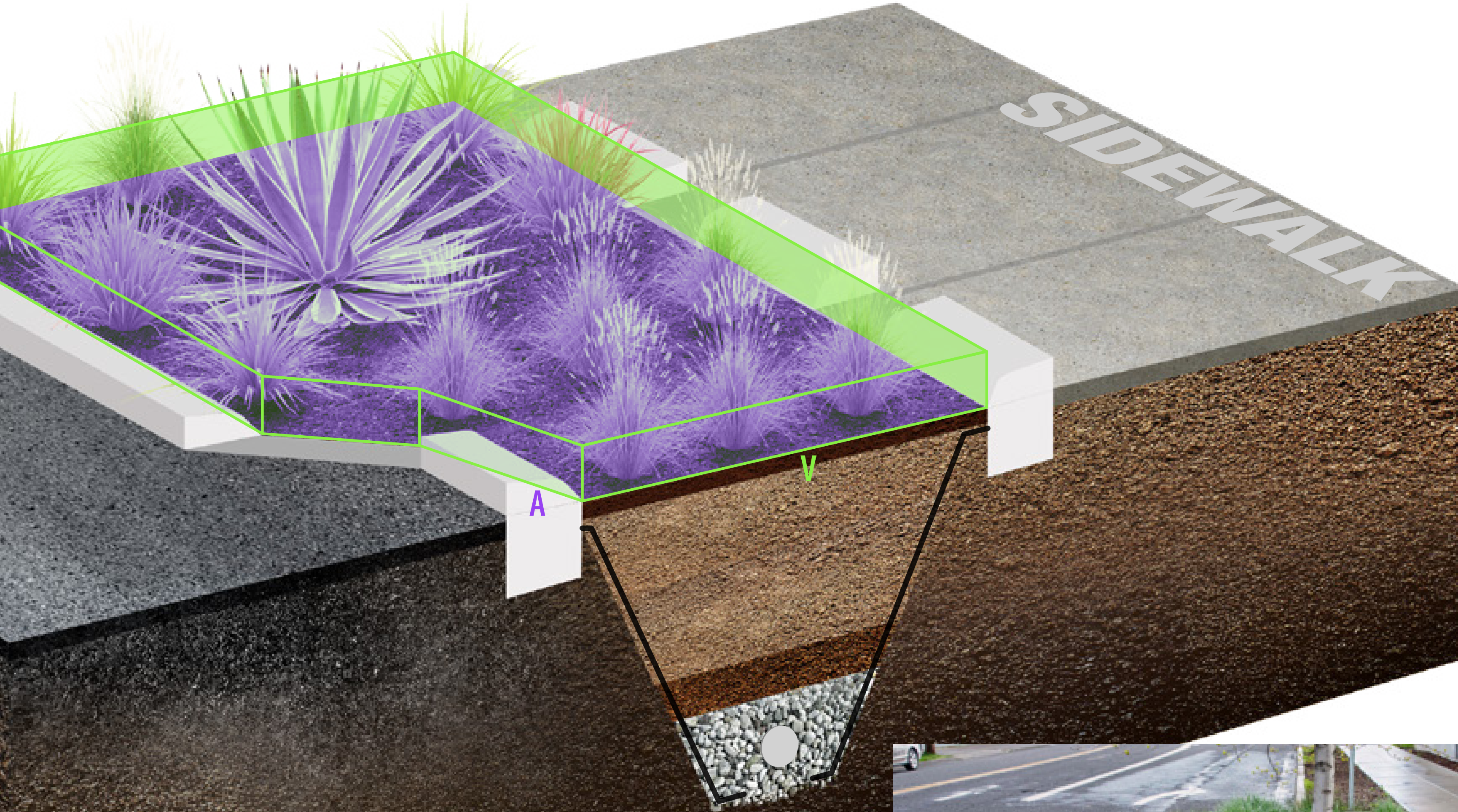
The rain garden needs to be able to drain within 96 hours. Check that the design volume can infiltrate with the following equation:

$$t = d_p / (f_{design} / 12)$$

Where: t = time to infiltrate (hrs)
d_p = ponding depth (1.5 ft max) (ft)
f_{design} = design infiltration rate (in/hr)

If $t \leq 96$ hrs then the design area, depth, and infiltration rate are adequate. If $t > 96$ hrs, the area needs to be expanded or the soil can be amended to drain in the required amount of time.

Isometric illustration of rain garden dimension and variables



Curb side rain garden with bench seating area

Example Scenario

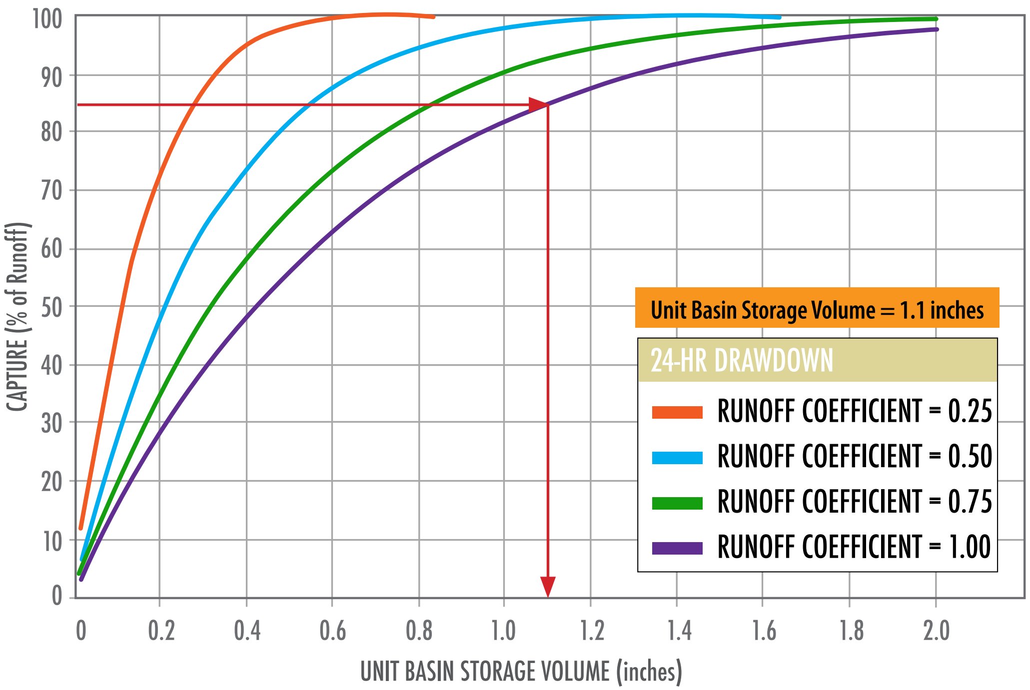
01 Identify Project Location

Looking back at the General Application example that was previously shown, suppose the rain garden turned out to be the most suitable application, instead of an infiltration trench. We will use a slightly smaller area from that problem to size a hypothetical rain garden. The drainage area is 1 acres:

02 Determine Design Volume

85th Percentile Design Volume Approach:

- Determine Total Catchment area: 2 acres
- Determine the Runoff Coefficient: 1.00 (almost 100% impervious)
- Use the Sizing Curves graph to determine the Unit Basin Storage Volume (inches)



- Calculate the design Volume necessary to capture the 85th percentile runoff:

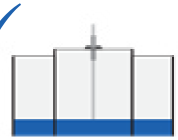
$$V = (\text{Unit Basin Storage Volume ft}) \times (\text{Drainage Area ft}^2)$$

$$V = (1.1 \text{ inches} / 12 \text{ in/ft}) \times (1 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre})$$

$$\mathbf{V = 3{,}993\ ft^3}$$

03 Determine the Design Infiltration Rate

- Choose a type of infiltration test to perform: Double-ring Infiltrometer
- Follow the procedures laid out in ASTM D-3385
- $f_{design} = 0.8$ in/hr
- 12 in/hr > 0.8 in/hr > 0.3 in/hr ✓



04 Calculate the Bioretention Area

(85th Percentile Design Volume Approach Only)

$$A = V / d_p$$
$$A = (3{,}993\ ft^3) / (1.5\ ft)$$
$$A = 2{,}662\ ft^2$$

05 Check that the Ponding Depth Drains within 96 hours

$$t = d_p / (f_{design} / 12\ in/ft)$$
$$t = (1.5\ ft) / (0.8\ in/hr / 12\ in/ft)$$
$$t = 16.36\ hours < 96\ hrs$$ ✓

SUMMARY OF SIZING

- $V = 3{,}993\ ft^3$
- $A = 2{,}662\ ft^2$
- $D = 1.5$ ft
- $f_{design} = 0.8$ in/hr
- $t = 16.4$ hrs

Curb side rain garden with curb slot inlets and check dams

Tree Box Filter

Curb side tree box filter amidst a drought-tolerant landscape

Tree box filters look like a standard street tree planted on the roadside edge of a sidewalk in an otherwise paved area. However, tree box filters differ from the traditional "sidewalk tree" design in that the soil surface is depressed below the sidewalk and an inlet exists in the adjacent curb / gutter to allow flow to enter the depression. Water intercepted by the tree box filter infiltrates into the underlying soil, only ponding up when inflow rates exceed infiltration rates. The tree and soil media are contained in a pre-cast concrete box on all sides with the option to leave the bottom open. Water captured by the system infiltrates through the soil, and undergoes contaminant removal via biological uptake through the tree and soil. Any water that reaches the bottom of the system is captured in a perforated underdrain pipe leading to an outlet or infiltrates into the surrounding native soil.

Flows in excess of the tree box filter's designed capacity either enter a riser that funnels flow into the underdrain pipe outlet, or will bypass the entrance slot entirely and continue flowing through the curb / gutter system to the nearest storm drain inlet. Features include:

- Sediment and contaminant removal
- Volume and flow rate reduction of storm flows
- Capture of dry-weather flows
- Visually appealing
- Use little to no right-of-way
- Easy to tie in to existing storm drain

Objectives

Detention | Filtration | Infiltration

- Water Quality Improvement Objectives
- Suitable Applications
- Design Principles
- Limitations and Constraints
- Pollutant Removal Efficiency
- Cost Estimation
- Design Procedure
- Example Scenario

A functional urban landscape feature that reduces stormwater runoff volume and contaminant transport, requiring no additional right-of-way.

Suitable Applications

Tree box filters are ideally suited for sites that are hard-pressed to find right-of-way area that can be dedicated to green space. The only component of a tree box filter that is above ground is the tree itself, which takes up the same amount of space as a traditional "street tree". Tree box filters intercept flow running past their inlet, much like a catch basin, and are therefore ideally placed along the gutter flow-line of a street.

Drought tolerant and / or California native trees are encouraged, but still require irrigation and maintenance.

Design Principles

a Depress Below Surrounding Surface

- The soil surface of the tree box should be depressed below the surrounding impervious grade to allow water to flow to and pond up within the tree box. Maximum ponding depth is 18-inches, but the depth of the tree box depression can be slightly greater than this, depending on the type of overflow precaution used.
- As a general rule, the surface area of a tree box filter should be approximately 5% of the drainage area in order to capture the 85th percentile volume.
- Size according to the design inflow rate.

b Energy Dissipation

- Flow entering the tree box filter depression must be slowed down using some sort of energy dissipation device, in order to protect against erosion. Such energy dissipating devices can be level spreaders, slotted curbs, gravel / rock pads, splash blocks, or other similar devices.
- Slopes may erode when velocities exceed 5 ft/s.

c Maximize Infiltration

- In order to keep the tree healthy, as well as prevent vector production, tree box filters should infiltrate well enough to avoid vector breeding and drain the captured flow below the planting soil depth in less than 48 hours and completely drain in less than 96 hours. This also ensures the tree box filter has capacity for back-to-back storms.
- For soils with low infiltration rates, or in order to maximize infiltration, native soils can be replaced with engineered soil media.
- Long term in-place infiltration of the planting media placed in the cell should achieve a minimum infiltration rate of 0.3 in/hr and a maximum infiltration rate of 12 in/hr.

d Underdrain Design

- Underdrain should be blanketed in gravel.
- Underdrain and gravel blanket should be covered with a geomembrane liner to prevent clogging. Geomembrane liner should have a permeability greater than or equal to the infiltration rate of the soil.
- Minimum underdrain slope is 0.5%.
- Clean-out points (non-perforated) of the same diameter of the underdrain should be installed for easy maintenance.

e Vegetation

- Cover the area with 2-3 inches of mulch to promote vegetative growth.

f Overflow precautions

- The tree box should be designed with adequate precautions in case of overflow. The most common methods are:
  - » Overflow riser
  - » Curb / gutter bypass
- Discharge excess waters to an appropriate location, such as another Green Street LID area, storm drain, or water body.
- The overflow device is required at the 18-inch maximum ponding depth.

Curb side tree box filter separated from walkway.

Curb side tree box filter placed in series.

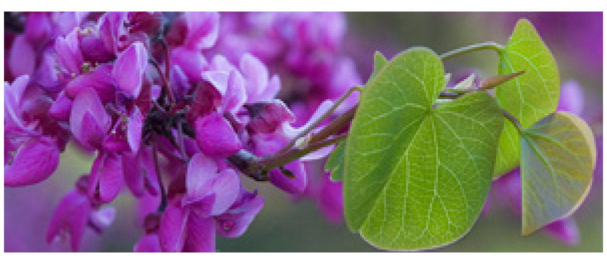
Limitations and Constraints

a Sizing

- Tree box filters should be designed to capture and infiltrate their drainage watershed's 85th percentile runoff volume in 96 hours or less. If the inflow rate is greater than the long-term infiltration rate, the depression should be sized to hold the excess storage (18-inch depth maximum).
- If the 18-inch ponding depth is not adequate to hold the excess storage, either the surface area of the tree box filter must be increased or the infiltration rate of the soil within the tree box must be increased through soil amendment. If neither of these things can be performed, the tree box filter will be designed for the maximum volume of runoff it can hold.
- The tree box filter should drain the minimum design flow at a minimum rate of 0.3 inches per hour and a maximum rate of 12 inches per hour.

b Placement

- Tree box filters function best in series. Multiple tree box filter installations upstream of a catch basin or other storm drain inlet will be far more effective than a single installation.
- Should be placed where site topography is relatively flat to allow stormwater runoff to drain to it.
- Never design the tree box filter to operate in a sump condition.



Flowering tree used in tree box filter.

c Vegetation / Soil Requirements

- For the Arid-Mediterranean environment, the planting media should consist of 60% to 80% fine sand and 20% to 40% compost. Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc. or any other deleterious material. Compost should be a well decomposed, stable, weed free organic matter source not including manure or biosolids.
- Plants selected should be able to withstand both short periods of submergence (18-inches) and extended periods of minimal irrigation.
- Soils should have a pH between 6.5 and 8, an organic content of 35% to 75% on a dry weight basis, and a salinity of < 6.0 mmhos/cm.
- The tree should be well-suited to the following conditions:
    - » Meets current City Urban Forestry Standards
    - » Planted in well-drained soils
    - » Remain upright, even in flowing water
    - » Minimal reliance on fertilizers
    - » Not pest-prone
    - » Can withstand periods of inundation
    - » Meets water conservancy standards *(see current City Landscape Maintenance District Guidelines)*

d Standing Water

- A certain amount of ponding is expected and acceptable; however, ponding that does not drain in 96 hours or less is not acceptable.
- Infiltration rates 0.3 to 1 in/hr require replacing existing soil with a soil mix.
- In-situ or amended soils must have an infiltration rate under saturated conditions of no less than 0.3 inches per hour.
- Soils with infiltration rates > 1 in/hr are typically adequate, unless the inflow rate greatly exceeds this and there is not enough capacity within the 18-inch ponding depth to store the excess water.

Curb side tree box filter with a grate covering.

e Slopes

- Tree box filters are not suitable applications in hillside areas or where areas are subject to slides.
- Tree box filters should never be placed in a sump position (i.e. low flow point), since they are intended to collect runoff flowing across the inlet.

f Infiltration

- Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mm. Generally, waterproof barriers should not be placed at the bottom of the biofiltration unit, as this would prevent incidental infiltration, which is important to meeting the required pollutant load reduction.

Pollutant Removal Efficiency

Pollutant Removal Efficiency of Tree Box Filters	
Pollutant of Concern	Removal Rate
Suspended Solids	85%
Total Phosphorous	44%
BOD	50%
Bacteria	Data Unavailable
Cadmium, Total	95%
Copper, Total	35%
Lead, Total	35%
Zinc, Total	35%

Source: 15

Cost Estimation

Costs are provided only as a relative reference. Estimates are based on 2020 cost.

a Capital Cost

Materials / Installation Cost		
Item	Unit Cost	Cost / SF
Mobilization	$1,800 LS	$50.00
Clearing & Grubbing	$3 SY	$0.65
Soil Media	$43 CY	$4.78
Pea Gravel	$129 CY	$ –
Gravel	$27 CY	$0.60
Mulch	$80 CY	$0.99
Underdrain Pipe (PVC)	$8 LF	$4.44
Excavation / Grading	$18 CY	$4.00
Haul Away Material	$10 CY	$1.48
Finished Grading	$2 SY	$ –
Vegetation	$250 LS	$6.94
18" x 18" Trench	$1 LF	$ –
Irrigation	$9 SF	$ 9.00
Inflow Structures (concrete / riprap)	$1,500 LS	$41.67
Overflow Structure (concrete / riprap)	$125 CY	$ –
Metal Beam Guard Rail	$58 LF	$ –
	Subtotal/SF =	$125

Design Costs		
Item	Unit Cost	Cost / SF
Project Management	$1,200 LS	$33.33
Preliminary Engineering	$2,500 LS	$69.44
Final Design Engineering	$900 LS	$25.00
Topographic Survey	$900 LS	$25.00
Landscape Design	$360 LS	$10.00
Legal Services	$360 LS	$10.00
Permitting & Construction Inspection	$340 LS	$9.44
Sales Tax	$2,000 LS	$55.56
Contingency	$2,400 LS	$66.67
	Subtotal/SF =	$304

Total Capital Cost/SF= $429

Soure: 7

b Maintenance Cost

Item	Months Between Events	Hours per Event	Average Labor Team Size	Average Labor Rate/Hr (pro-rated) ($)	Machinery Cost/Hr ($)	Materials & Incidentals Cost/Event ($)	Total Cost Per Visit ($)
Routine Maintenance							
Inspection, Reporting & Info Mgmt	12	2	2	$50.00	$40.00	$ –	$280.00
Vegetation Mgmt & Trash / Debris Removal	12	2	2	$50.00	$60.00	$100.00	$420.00
Infrequent / Corrective Maintenance (>3 yrs between events)							
Corrective Maintenance	96	24	4	$50.00	$60.00	$500.00	$6,740.00
Sediment Management	300	8	4	$50.00	$60.00	$500.00	$2,580.00
						Total Maintenance Cost =	$1,646 / yr

Soure: 7

Design Procedure

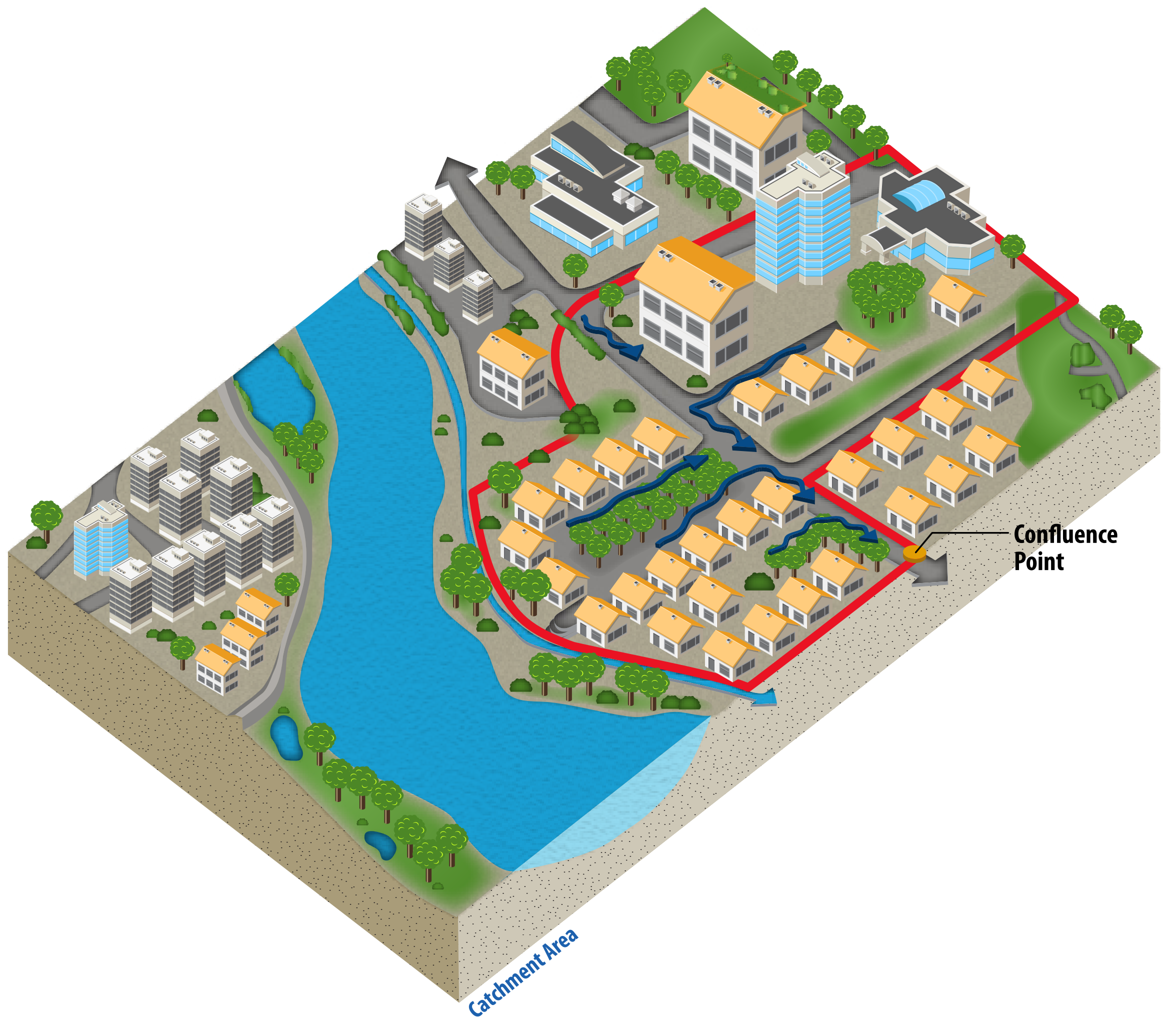
01 Identify Project Location	**02** Determine Design Volume	**03** Determine Design Infiltration Rate	**04** Calculate Bioretention Area	**05** Check Ponding Depth Drains

01 Identify Project Location

02 Determine Design Volume

In new development, tree box filters should be sized to capture the 85th percentile runoff volume for their contributing catchment. For redevelopment or retrofit projects, however, **the tree box filter can either be sized to capture the 85th percentile runoff volume or the design volume will be based on the maximum size the tree box filter can be**. For example, in a retrofit project, the available area and depth that can be used for design may not be enough to completely capture the 85th percentile runoff volume. The design volume, in this case, would be the maximum volume of runoff the proposed tree box filter can hold. This volume would correspond to some "percentile" volume lower than 85th.

If the 85th percentile runoff volume can be designed for, it should. Otherwise, the tree box filter will not be able to capitalize on a majority of storms. Alternatively, the tree box filter should not be designed for a volume greater than the 85th percentile, even if there is sufficient room. Storm events producing runoff greater than the 85th percentile are not as common, so a larger tree box filter will cost more money to infiltrate and treat an insignificant increase in runoff volume.



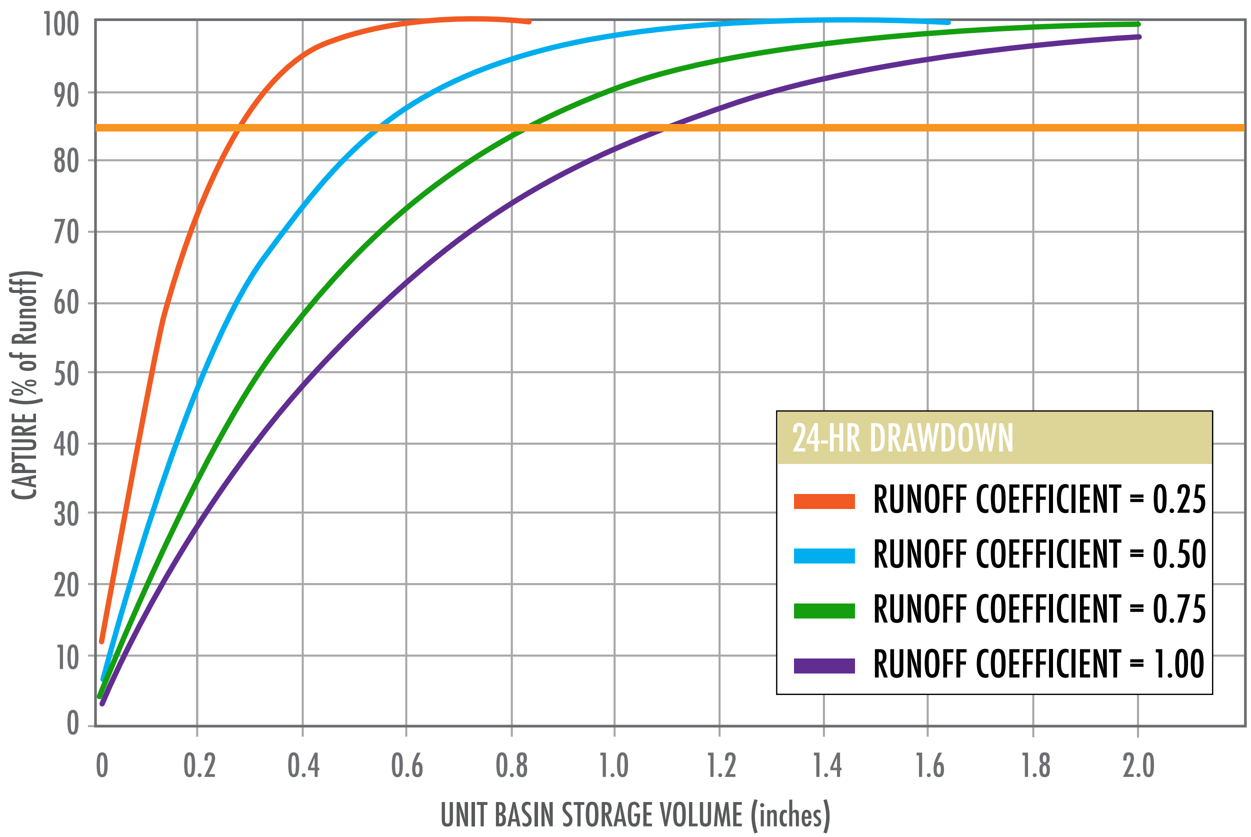
85th Percentile Design Volume Approach

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil. Catchment areas should be less than 1 acre.
- Determine the runoff coefficient. The runoff coefficient is an indicator of how much pervious / impervious surface makes up the watershed draining to the Green Street LID project location (0.25, 0.5, 0.75, or 1.00). A runoff coefficient of 0.25 is used for watersheds with almost 0% impervious area while a coefficient of 1.00 is used for watersheds with almost 100% impervious areas. Analyzing the watershed area, determine the runoff coefficient to be used for design. A higher, conservative estimate is always better to use.
- Using the Sizing Curves graph below, find the "Unit Basin Storage Volume" (inches), corresponding to the intersection of the 85% runoff capture and the selected runoff coefficient curve.
- Multiply the contributing watershed drainage area, DA (units of ft^2), by the unit basin storage volume (units of feet), to obtain the 85th percentile volume, V (units of ft^3), the tree box filter must hold.

$$V\ (ft^3) = DA\ (ft^2) \times \text{Unit Basin Storage Volume (ft)}$$

Maximum Runoff Volume Design Approach

- Determine the maximum volume, V_{max} (units of ft^3), that can be contained in the tree box filter at the selected site. This will be the maximum area available, A_{max} (units of ft^2), with a maximum ponding depth, d_{max}, of 1.5 ft (assume 3H : 1V side slopes).
- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil.
- Divide the maximum tree box filter volume, V_{max} (ft^3), by the total catchment drainage area, DA (ft^2), to obtain the equivalent Unit Basin Storage Volume (ft). Convert this to inches.
- Analyzing the watershed area, determine the runoff coefficient to be used for design.
- Using the Sizing Curves graph to the right, find the "Capture (% Runoff)" corresponding to the intersection of the Unit Basin Storage Volume (inches) and the selected runoff coefficient curve. This is the "percentile" stormwater runoff that the Green Street LID Application can capture.



Sizing Curves Source: 4

03 Determine the Design Infiltration Rate

Use the procedures outlined in the most recent GMED Policy GS 200.1 to determine the corrected in-situ infiltration rate, f_{design} (units of in/hr), of the native soil at the project site.

Acceptable infiltration tests include:

1. **Double-ring Infiltrometer Test**
2. **Well Permeameter Test**
3. Boring Percolation Test Procedure
4. Excavation Percolation Test Procedure
5. High Flowrate Percolation Test Procedures
6. Policy for New Percolation Basin Testing, Design and Maintenance

The double-ring Infiltrometer and well permeameter tests are preferred, but whatever test is used must be performed at each location and elevation where the Green Street LID Application is proposed. Multiple tests at each site are recommended.

Procedures and example data forms for Double-Ring Infiltrometer tests are laid out in ASTM D3385. Details for the Well Permeameter Test can be found in the Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89).

In-situ infiltration rates should be between 0.3 in/hr and 12 in/hr. Anything above 12 in/hr or below 0.3 in/hr must have amended soil to achieve an adequate infiltration rate.

double ring infiltrometer test

04 Calculate the Bioretention Area *(85th Percentile Design Volume Approach Only)*

Assume the design volume, V (units of ft^3), will fill the available ponding depth, d_p (units of ft, 1.5 ft max). The surface area, A (units of ft^2), required to accommodate the design volume at a ponding depth of 1.5 ft is:

$$A = V / d_p$$

Where: A = design surface area (ft^2)
V = design volume (ft^3)
d_p = ponding depth (1.5 ft max) (ft)

The pre-cast concrete vault structure the tree box filter is contained in is typically a standard, square size. If the area of one of these pre-cast vaults is less than the area calculated above, multiple tree box filters will need to be installed such that the cumulative areas of the tree box filters is greater than or equal to the area calculated.

Impermeable liners are typically installed between the soil media within the concrete vault and the concrete vault itself, in order to prevent water from infiltrating laterally through the box. The area of impermeable liner used in the tree box design will be equal to the perimeter of the standard box size multiplied by the standard depth of the box.

05 Check that Ponding Depth Drains within 96 hrs

The tree box filter needs to be able to drain within 96 hours. Check that the design volume can infiltrate with the following equation:

$$t = d_p / (f_{design} / 12)$$

Where: t = time to infiltrate (hrs)
d_p = ponding depth (1.5 ft max) (ft)
f_{design} = design infiltration rate (in/hr)

If $t \leq 96$ hrs then the design area, depth, and infiltration rate are adequate. If $t > 96$ hrs, the area needs to be expanded or the soil can be amended to drain in the required amount of time.

Curb side double tree box filter at the OC Great Park.

Isometric illustration of tree box filter dimension and variables.

Example Scenario

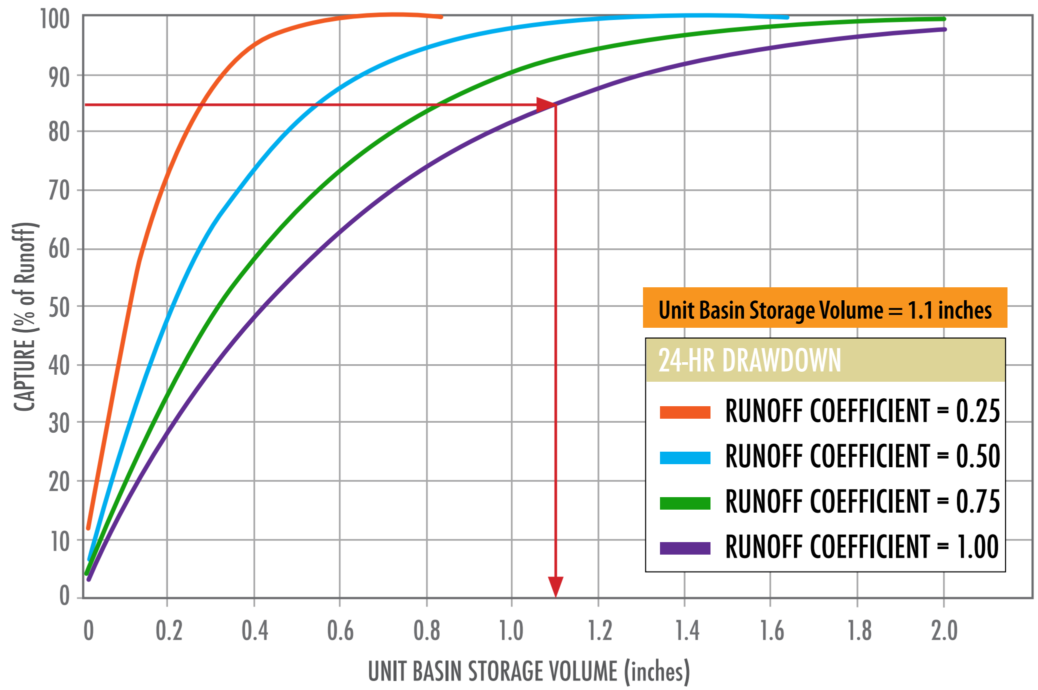
01 Identify Project Location

Looking back at the General Application example that was previously shown, suppose the tree box filter turned out to be the most suitable application, instead of an infiltration trench. We will use a smaller area from that problem to size a hypothetical tree box filter. The drainage area is 0.1 acres:

02 Determine Design Volume

85th Percentile Design Volume Approach:

- Determine Total Catchment area: 0.1 acres
- Determine the Runoff Coefficient: 1.00 (almost 100% impervious)
- Use the Sizing Curves graph to determine the Unit Basin Storage Volume (inches)



- Calculate the design Volume necessary to capture the 85th percentile runoff:

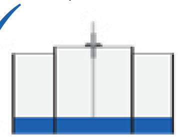
$$V = (\text{Unit Basin Storage Volume ft}) \times (\text{Drainage Area ft}^2)$$

$$V = (1.1 \text{ inches} / 12 \text{ in/ft}) \times (0.1 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre})$$

$$\mathbf{V = 3{,}99.3\ ft^3}$$

03 Determine the Design Infiltration Rate

- Choose a type of infiltration test to perform: Double-ring Infiltrometer
- Follow the procedures laid out in ASTM D-3385
- Assume the procedures were followed correctly and resulted in an infiltration rate $f_{design} = 0.8$ in/hr
- 12 in/hr > 0.8 in/hr > 0.3 in/hr ✓



04 Calculate the Bioretention Area

(85th Percentile Design Volume Approach Only)

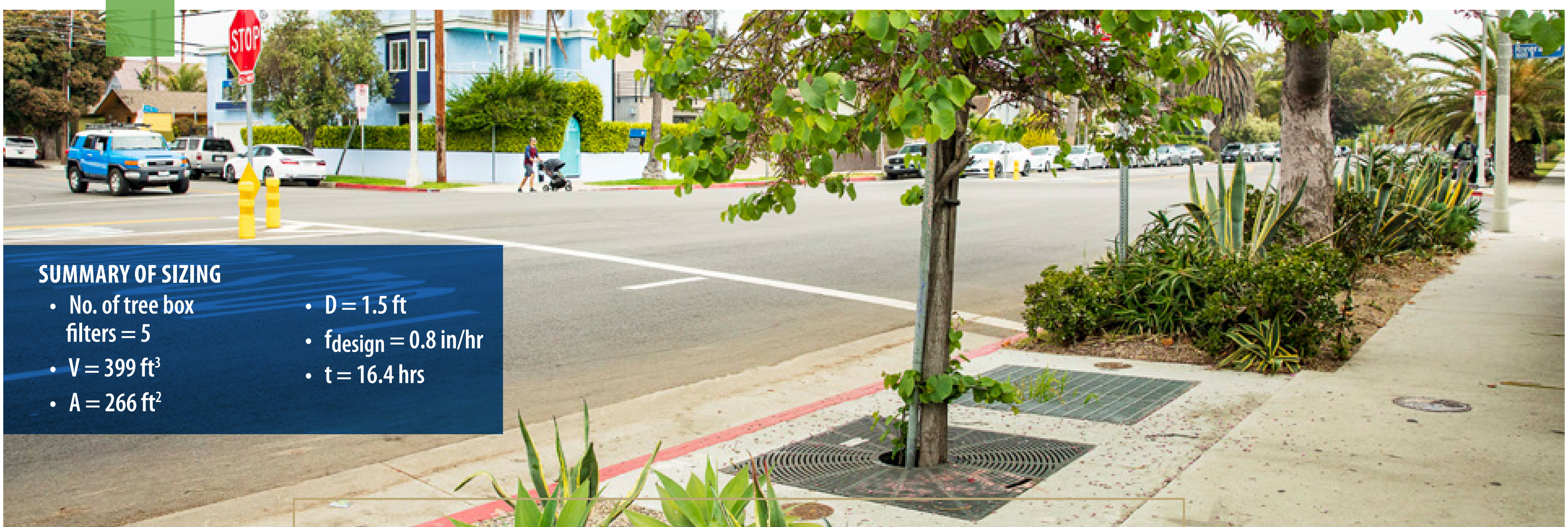
- Assume a maximum ponding depth of 1.5 ft

$$A = V / d_p$$
$$A = (399.3\ ft^3) / (1.5\ ft)$$
$$A = 266\ ft^2$$

Suppose the vendor of pre-cast concrete tree box filter encasements sells units that are 8' wide x 8' long x 6' tall. Each unit provides 64 ft^2 of area. In order to provide the area calculated above, 5 tree box filter units would need to be installed.

05 Check that the Ponding Depth Drains within 96 hours

$$t = d_p / (f_{design} / 12\ in/ft)$$
$$t = (1.5\ ft) / (0.8\ in/hr / 12\ in/ft)$$
$$t = 16.36\ hours < 96\ hrs$$ ✓



SUMMARY OF SIZING

- No. of tree box filters = 5
- $V = 399\ ft^3$
- $A = 266\ ft^2$
- D = 1.5 ft
- $f_{design} = 0.8$ in/hr
- t = 16.4 hrs

Curb side tree box filter at an intersection

Infiltration Trench

- Water Quality Improvement Objectives
- Suitable Applications
- Design Principles
- Limitations and Constraints
- Pollutant Removal Efficiency
- Cost Estimation
- Design Procedure
- Example Scenario

Left: Curb side infiltration trench between street and parking lot
Right: Typical example of vegetation and boulders in an infiltration trench

Infiltration trenches are elongated areas with a gravel bottom, depressed below the surrounding ground surface. They collect surface runoff and quickly infiltrate it into the underlying soil through the highly pervious gravel bottom. The water infiltrated through the trench is filtered through physical and chemical processes whether or not it enters the perforated underground pipe.

Flows in excess of the maximum infiltration capacity are typically transported to the nearest stormwater conveyance system through a perforated underground pipe. Features include:

- Sediment and contaminant removal
- Volume reduction of storm flows
- Groundwater recharge
- Capture of dry-weather flows

Objectives

Detention | Infiltration

A highly effective landscaping feature that promotes infiltration and groundwater recharge while reducing stormwater runoff volumes and pollutant loads.

Suitable Applications

Infiltration trenches are ideally placed along roadsides and curbs where there is frequent dry-weather flow or high storm flows. They typically take up less right-of-way area than a rain garden but still utilize a portion of this space. Since rocks make up a majority of the installation material, it is encouraged to use a variety of rock colors and sizes for a more visually appealing feature. Plants can be used in infiltration trenches, but are spaced farther apart to maximize infiltration. Any vegetation used in the trench should be drought tolerant and / or California native plant species, but will still require irrigation and maintenance.

Design Principles

a Pretreatment

- Grassed swales, vegetated filter strips, detention, or a plunge pool series can be used as pretreatment for an infiltration trench. Pretreatment is necessary to filter out as many sediment particles as possible before they can reach the gravel and clog up the pores. As the pores fill up with fine sediment, infiltration rates in the trench decrease and the effectiveness of this Green Street LID is lowered.

b Gravel Bottom

- The bottom of the infiltration trench should be filled with gravelly material that facilitates infiltration. Locally available trench rock that is 1.5-2.5 inches in diameter will be adequate.

c Size for 85th Percentile Runoff Volume

- The infiltration trench should be sized to treat the 85th Percentile Runoff Volume of its contributing watershed. The total trench volume will be the 85th Percentile Volume plus the volume of gravel if all of the water is contained within the voids (assume 35% voids).
- The trench bottom surface area necessary to drain the 85th Percentile Volume within 96 hours is the 85th Percentile volume divided by the infiltration rate.
- The trench depth is the total trench volume divided by the surface area.

d Maximize Infiltration

- For soils with low infiltration rates, or in order to maximize infiltration, native soils can be replaced with engineered soil media.

e Observation Well

- An observation well should be installed for monitoring of drain time.

f Filter Fabric

- A layer of filter fabric should be installed just below the trench surface to catch sediment and reduce the potential for clogging.
- Filter fabric should have an infiltration rate greater than or equal to the infiltration rate of the soil.

g Underdrain

- An underdrain is a design feature that can be used to decrease drain time and provide an outlet to a nearby storm drain when storm flows exceed the design flow of the trench.
- Minimum underdrain slope is 0.5%.
- Clean-out points (non-perforated) of the same diameter of the underdrain should be installed for easy maintenance.

h Overflow Precautions

- The infiltration trench should be designed with adequate precautions in case of overflow. The most common methods are:
    - » Overflow riser
    - » Curb / gutter bypass
- Discharge excess waters to an appropriate location, such as another Green Street LID area, storm drain, or water body.
- The overflow device is required at the 18-inch maximum ponding depth.

i Slope Stability

- Slopes used to create the bowl shaped depression should be gradual to ensure slope stability (max. 33%).

Median infiltration trench with vegetation lined edges.

Limitations and Constraints

a Sizing

- Infiltration trenches should infiltrate well enough to avoid vector breeding and drain the captured flow below the planting soil depth in less than 48 hours and completely drain in less than 96 hours.
- The drainage area should be less than or equal to 5 acres. If the inflow rate is greater than the long-term infiltration rate, the depression should be sized to hold the excess storage (18-inch depth maximum).
- If the gravel voids are not adequate to hold the excess storage, either the surface area of the infiltration trench must be increased or the depth of the trench must be increased. If neither of these things can be performed, the infiltration trench will be designed for the maximum volume or runoff it can hold.
- Side slopes in the trench should not be steeper than 3H : 1V.

b Soil Requirements

- Infiltration trenches have a high rate of failure if the native soil and subsurface conditions are not suitable.
- Infiltration rates 0.5 to 1 in/hr require replacing existing soil with a soil mix.
- Soils with infiltration rates > 1 in/hr are typically adequate, unless the inflow rate greatly exceeds this and there is not enough capacity within the 18-inch ponding depth to store the excess water.
- Hydrologic Soil Types C and D are not suitable for infiltration trenches.
- Long-term in-place infiltration of the planting media placed in the trench should achieve a minimum infiltration rate of 5 in/hr and a maximum infiltration rate of 12 in/hr.

c Water Table

- Infiltration trenches are not applicable where groundwater depth is less than 10 feet below the ground surface.

d Infiltration

- Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mm. Generally, waterproof barriers should not be placed at the bottom of the infiltration trench unit, as this would prevent incidental infiltration, which is important to meeting the required pollutant load reduction.

Infiltration trench with dense vegetation

Pollutant Removal Efficiency

Infiltration Trench Pollutant Removal Efficiency Data	
Pollutant	Removal Rate
Total Suspended Solids	80 - 100%
Total Phosphorous	40 - 60%
Total Nitrogen	40 - 60%
Zinc	80 - 100%
Lead	80 - 100%
Biological Oxygen Demand	60 - 80%
Bacteria	60 - 80%

Source: 1

Cost Estimation

Costs are provided only as a relative reference. Estimates are based on 2020 cost.

a Capital Cost

Materials / Installation Cost		
Item	Unit Cost	Cost / SF
Mobilization	$6,274 LS	$2.35
Clearing & Grubbing	$6 SY	$0.65
Excavation / Grading	$18 CY	$2.35
Dewatering	$1,150 DAY	$0.86
Haul / Dispose of Excavated Material	$9 CY	$1.21
Inflow Structure (s)	$2,100 LS	$0.79
Concrete Vault Structure Walls	$390 CY	$3.92
Concrete Vault Structure Floor	$190 CY	$7.04
Outflow Structure	$2,100 LS	$0.79
Overflow Structure (concrete/rock riprap)	$125 CY	$0.33
Maintenance Access Ramp/Pad	$190 CY	$0.68
Revegetation / Erosion Controls	$1,200 AC	$0.03
Traffic Control	$13 LF	$0.25
Signage, Public Education Materials, etc	$75 EA	$0.03
Gravel	$27 CY	$0.67
Media	$58 CY	$4.26
Slotted PVC Underdrain Pipe	$8 LF	$0.22
	Subtotal/SF =	$26

Design Costs		
Item	Unit Cost	Cost / SF
Project Management	$3,451 LS	$1.29
Preliminary Engineering	$6,901 LS	$2.59
Final Design Engineering	$3,451 LS	$1.29
Topographic Survey	$4,025 LS	$1.51
Geotechnical	$2,350 LS	$0.88
Landscape Design	$1,380 LS	$0.52
Legal Services	$690 LS	$0.26
Permitting & Construction Inspection	$690 LS	$0.26
Sales Tax	$4,313 LS	$1.62
Contingency	$13,803 LS	$5.18
	Subtotal/SF =	$15
	Total Capital Cost/SF=	$42

b Maintenance Cost

Routine Maintenance							
Item	Months Between Events	Hours per Event	Average Labor Team Size	Average Labor Rate/Hr (pro-rated) ($)	Machinery Cost/Hr ($)	Materials & Incidentals Cost/Event ($)	Total Cost Per Visit ($)
Inspection, Reporting & Info Mgmt	12	2	2	$50.00	$30.00	$ –	$260.00
Vegetation Mgmt & Trash / Debris Removal	6	2	2	$50.00	$60.00	$ –	$320.00
Sand Removal	60	8	4	$50.00	$200.00	$500.00	$3,700.00
Infrequent / Corrective Maintenance (>3 yrs between events)							
Corrective Maintenance	30	8	2	$50.00	$60.00	$ –	$1,280.00
Sediment Management	240	8	4	$50.00	$150.00	$25.00	$2,825.00
						Total Maintenance Cost =	$2,293 / yr

Source: 9

Design Procedure

01 Identify Project Location → **02** Determine Design Infiltration Rate → **03** Determine Design Volume → **04** Calculate Bioretention Area → **05** Check Ponding Depth Drains

01 Identify Project Location

02 Determine the Design Infiltration Rate

Use the procedures outlined in the most recent GMED Policy GS 200.1 to determine the corrected in-situ infiltration rate, f_{design} (units of in/hr) of the native soil at the project site.

Acceptable infiltration tests include:

1. **Double-ring Infiltrometer Test**
2. **Well Permeameter Test**
3. Boring Percolation Test Procedure
4. Excavation Percolation Test Procedure
5. High Flowrate Percolation Test Procedures
6. Policy for New Percolation Basin Testing, Design and Maintenance

double ring infiltrometer test

The double-ring Infiltrometer and well permeameter tests are preferred, but whatever test is used must be performed at each location and elevation where the Green Street LID Application is proposed. Multiple tests at each site are recommended.

Procedures and example data forms for Double-Ring Infiltrometer tests are laid out in ASTM D3385. Details for the Well Permeameter Test can be found in the Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89).

In-situ infiltration rates should be between 0.5 in/hr and 12 in/hr. Anything above 12 in/hr or below 0.5 in/hr must have amended soil to achieve an adequate infiltration rate.

03 Determine Design Volume

In new development, infiltration trenches should be sized to capture the 85th percentile runoff volume for their contributing catchment. For redevelopment or retrofit projects, however, the infiltration trench can either be sized to capture the 85th percentile runoff volume or the design volume will be based on the maximum size the infiltration trench can be. For example, in a retrofit project, the available area and depth that can be used for design may not be enough to completely capture the 85th percentile runoff volume. The design volume, in this case, would be the maximum volume of runoff the proposed infiltration trench can hold. This volume would correspond to some "percentile" volume lower than 85th.

If the 85th percentile runoff volume can be designed for, it should. Otherwise, the infiltration trench will not be able to capitalize on a majority of storms. Alternatively, the infiltration trench should not be designed for a volume greater than the 85th percentile, even if there is sufficient room. Storm events producing runoff greater than the 85th percentile are not as common, so a larger infiltration trench will cost more money to infiltrate and treat an insignificant increase in runoff volume.

85th Percentile Design Volume Approach

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil. Catchment areas should be less than 5 acres.
- Determine the runoff coefficient. The runoff coefficient is an indicator of how much pervious / impervious surface makes up the watershed draining to the Green Street LID project location (0.25, 0.5, 0.75, or 1.00). A runoff coefficient of 0.25 is used for watersheds with almost 0% impervious area while a coefficient of 1.00 is used for watersheds with almost 100% impervious areas. Analyzing the watershed area, determine the runoff coefficient to be used for design. A higher, conservative estimate is always better to use.
- Using the Sizing Curves graph below, find the "Unit Basin Storage Volume" (inches), corresponding to the intersection of the 85% runoff capture and the selected runoff coefficient curve.
- Multiply the contributing watershed drainage area, DA (units of ft^2) by the unit basin storage volume (units of feet), to obtain the 85th percentile volume, V_{design} (units of ft^3), the infiltration trench must hold.

$$V_{design}\ (ft^3) = DA\ (ft^2) \times \text{Unit Basin Storage Volume (ft)}$$

Maximum Runoff Volume Design Approach

- Find the total area available for the infiltration trench (ATOT, ft2) with the following equation:

$$A_{TOT} = L \times W_{top}$$

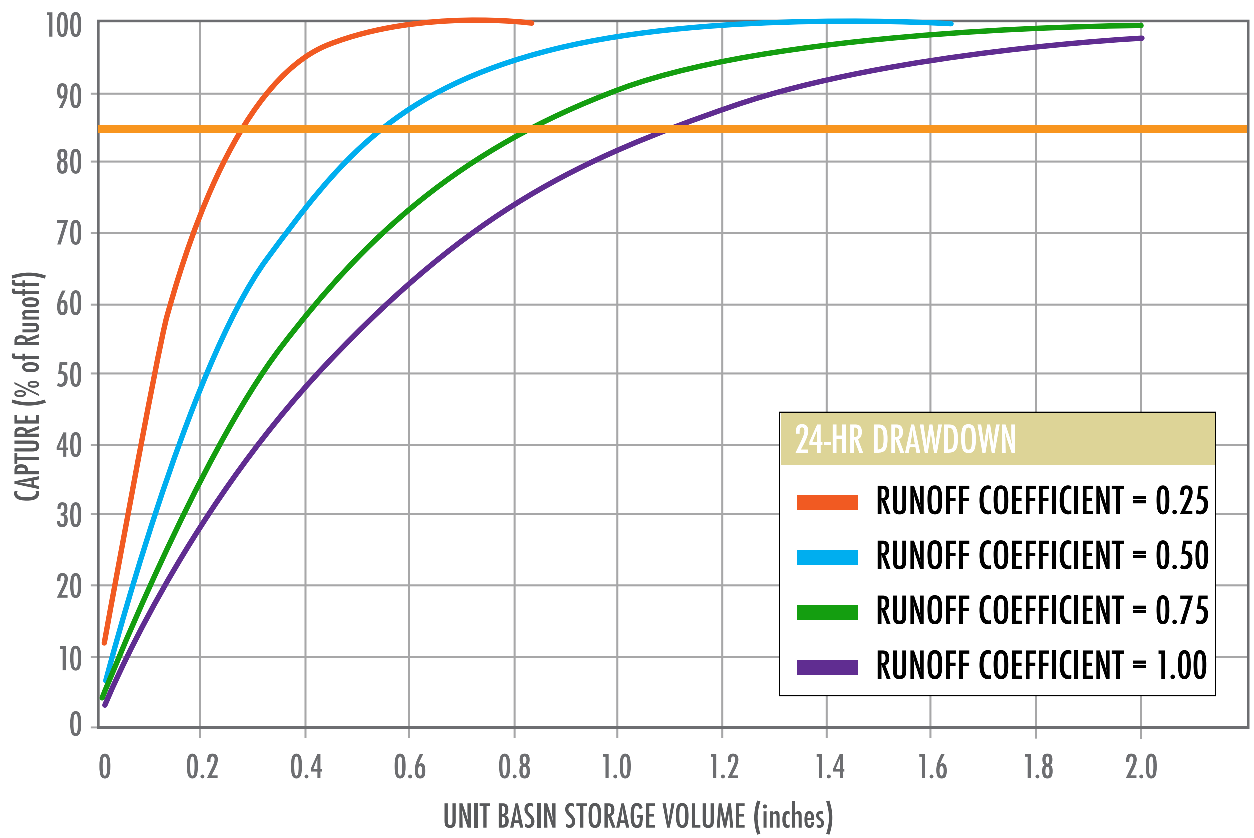
Where: A_{TOT} = Total Trench Area (ft^2)
L = Length (ft)
W_{top} = Top Width (ft)

- Assume a depression depth (d_d, ft) of 3 ft. (1.5 ft. ponding depth (d_p) + 1.5 ft. freeboard (d_{FB})).
- Find the trench width (W_{trench}, ft) with the following equation:

$$W_{trench} = W_{TOT} - 2 \times (d_d \times H)$$

Where: W_{trench} = Width of the trench at bottom of depression (ft)
W_{TOT} = Top width of trench (ft)
d_d = Depression depth (ft)
H = Side slope of the trench perpendicular to flow (H : V)

If $W_{trench} < 2$ ft., decrease the assumed ponding depth (d_p) and re-calculate.



Sizing Curves Source: 4

- Find the design capture volume (V_{design}, ft^3) with the following equation:

$$V_{design} = A_{trench} \times (f_{design} / 12 \text{ in/hr})$$

Where: V_{design} = volume of water trench is designed to capture (ft^3)
A_{trench} = Area the trench itself takes up (ft^2) = L x W_{trench}
f_{design} = design infiltration rate (in/hr)

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil.
- Divide the design volume of the trench (Vtrench, ft^3), by the total catchment drainage area, DA (ft^2) to obtain the equivalent Unit Basin Storage Volume (ft). Convert this to inches.
- Analyzing the watershed area, determine the runoff coefficient to be used for design.
- Using the Sizing Curves graph to the right, find the "Capture (% Runoff)" corresponding to the intersection of the Unit Basin Storage Volume (inches) and the selected runoff coefficient curve. This is the "percentile" stormwater runoff that the Green Street LID Application can capture.

04 Determine the Trench Volume

Assume the design capture volume will fill the void spaces in the infiltration trench based on an assumed porosity of 35%.

$$V_{trench} = V_{design} / 0.35$$

Where: V_{trench} = Volume of trench fill (ft^3)
V_{design} = Design capture volume (ft^3)

05 Calculate the Infiltration Trench Bottom Surface Area *(85th Percentile Design Volume Approach Only)*:

$$A = V_{design} / (f_{design} / 12)$$

Where: A = design surface area (ft2)
V_{design} = design volume (ft^3)
f_{design} = design infiltration rate (in / hr)

06 Calculate Trench Depth

$$d = (V_{design} + V_{trench}) / A$$

Where: d = trench depth (ft)
V_{design} = design volume (ft^3)
V_{trench} = Volume of trench fill (ft^3)
A = design surface area (ft^2)

07 Check that Trench Drains within 96 hrs

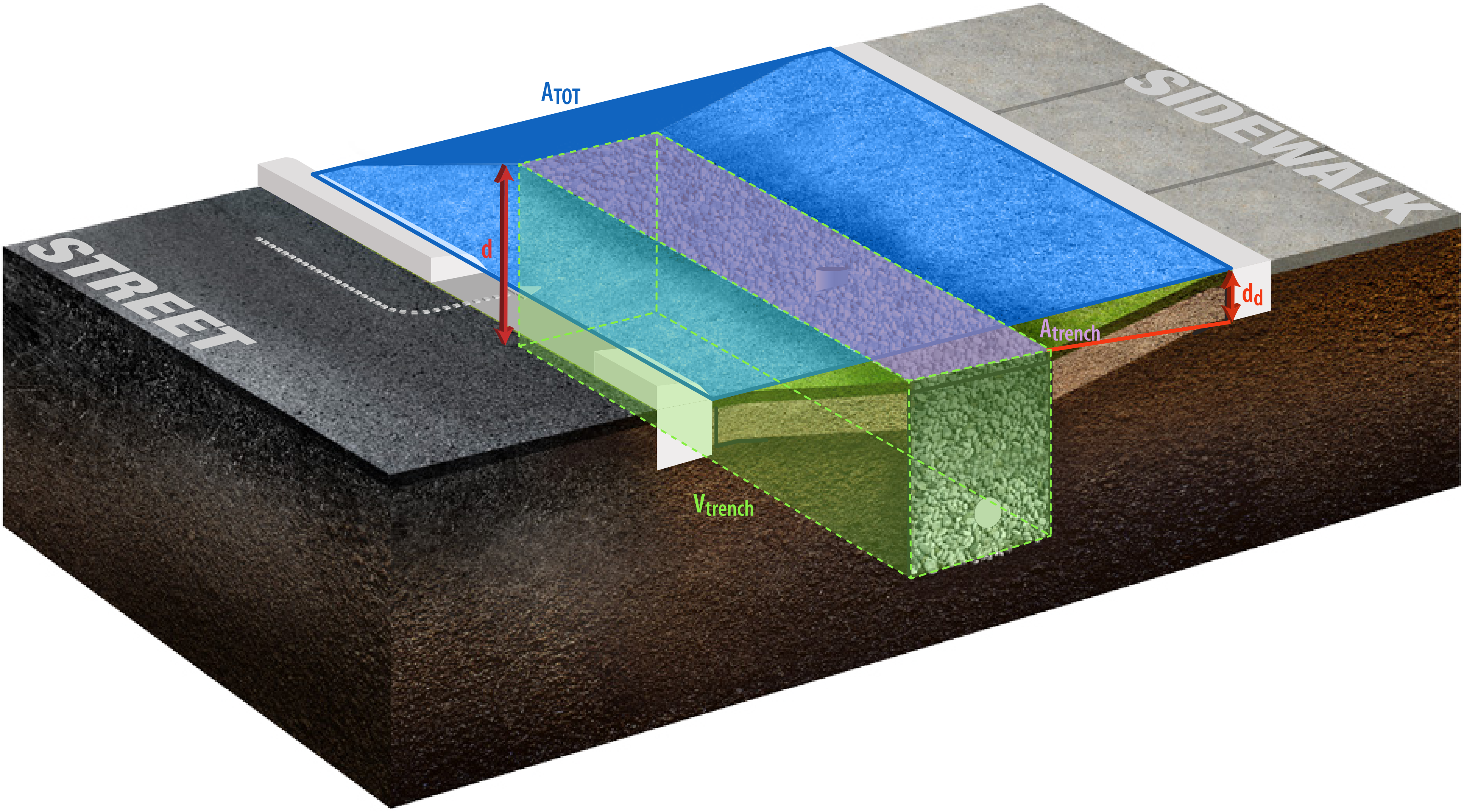
The infiltration trench needs to be able to drain within 96 hours. Check that the design volume can infiltrate with the following equation:

$$t = (V_{design} / A) / (f_{design} / 12)$$

Where: t = time to infiltrate (hrs)
V_{design} = design volume (ft^3)
A = design surface area (ft^2)
f_{design} = design infiltration rate (in/hr)

If $t \leq 96$ hrs then the design area, depth, and infiltration rate are adequate. If $t > 96$ hrs, the area needs to be expanded or the soil can be amended to drain in the required amount of time.

Curb side infiltration trench with meandering centerline.



Isometric illustration of infiltration trench dimension and variables.

Example Scenario

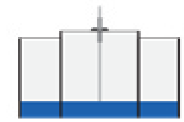
01 Identify Project Location

Looking back at the General Application example that was previously shown, we will size a hypothetical infiltration trench. The drainage area is 2 acres:

02 Determine the Design Infiltration Rate

- Choose a type of infiltration test to perform: Double-ring Infiltrometer
- Follow the procedures laid out in ASTM D-3385

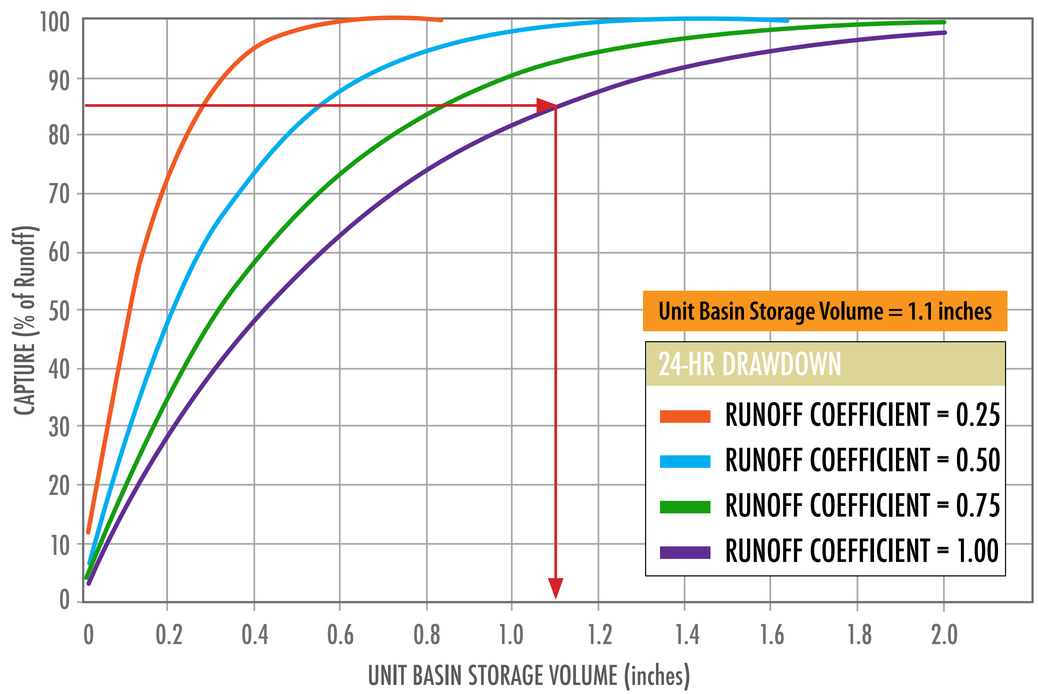
- $f_{design} = 0.8$ in/hr
- 12 in/hr > 11 in/hr > 0.5 in/hr ✓



03 Determine Design Volume

85th Percentile Design Volume Approach:

- Determine Total Catchment area: 2 acres
- Determine the Runoff Coefficient: 1.00 (almost 100% impervious)
- Use the Sizing Curves graph to determine the Unit Basin Storage Volume (inches)



- Calculate the design Volume necessary to capture the 85th percentile runoff:

$$V_{design} = (\text{Unit Basin Storage Volume ft}) \times (\text{Drainage Area ft}^2)$$

$$V_{design} = (1.1 \text{ inches} / 12 \text{ in/ft}) \times (2 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre})$$

$$\mathbf{V = 7{,}986 \text{ ft}^3}$$

04 Determine the Trench Volume

$$V_{trench} = V_{design} / 0.35$$
$$V_{trench} = 7{,}986 / 0.35$$
$$\mathbf{V_{trench} = 22{,}817\ ft^3}$$

05 Calculate the Infiltration Trench Bottom Surface Area

(85th Percentile Design Volume Approach Only)

$$A = V_{design} / (f_{design} / 12)$$
$$A = 7{,}986 / (11 / 12)$$
$$\mathbf{A = 8{,}712\ ft^2}$$

06 Calculate Trench Depth

$$d = (V_{design} + V_{trench}) / A$$
$$d = (7{,}986 + 22{,}817) / 8{,}712$$
$$\mathbf{d = 3.5\ ft}$$

07 Check that the Trench Drains within 96 hours

$$t = (V_{design} / A) / (f_{design} / 12\ in/ft)$$
$$t = (7{,}986\ ft^3 / 8{,}712\ ft2) / (11\ in/hr / 12\ in/ft)$$
$$\mathbf{t = 1\ hours < 96\ hrs}\ ✓$$

SUMMARY OF SIZING

- $V = 7{,}986\ ft^3$
- $A = 8{,}712\ ft^2$
- $d = 3.5\ ft$
- $f_{design} = 11\ in/hr$
- $t = 1\ hrs$

Curb side infiltration trench with varying rock sizes.

Permeable Pavements

- Water Quality Improvement Objectives
- Suitable Applications
- Design Principles
- Limitations and Constraints
- Pollutant Removal Efficiency
- Cost Estimation
- Design Procedure
- Example Scenario

Permeable pavement comes in three forms which all operate similarly: permeable pavers, permeable asphalt, and permeable concrete. Permeable pavement offers a similar features as traditional pavements without the undesirable side effect of preventing storm flows from infiltrating into the ground. The pores within permeable pavement allow water to filter into the underlying soil, providing:

- Groundwater recharge
- Storm runoff volume reduction
- Flow rate reduction
- Pollutant removal
- Reduction of ponding areas

Objectives

Filtration | Infiltration

Suitable Applications

Permeable pavers and concrete are typically used in walking, parking, and gutter areas, while permeable asphalt is typically used on low-vehicle movement roadway surfaces and parking lots. Permeable pavers are the most aesthetically pleasing of the three options, but can pose problems in areas of high traffic volume and heavy loads.

Permeable pavement is ideally suited for areas where sheet flow and ponding occur. While they can help reduce the volume contributing to channelized areas, they should not be used as a substitute to channelization itself. Permeable pavement performs particularly well in gutters, parking stalls, and sidewalks, but is suitable for a wide variety of applications.

Replace traditional street and sidewalk materials with pervious materials, promoting infiltration, groundwater recharge, and pollutant reduction.

Permeable pavers

Permeable concrete

Design Principles

a Layers

- Visible layer: Asphalt, Concrete, or Pavers.
- Top Filter Layer: crushed stone.
- Reservoir Layer:
  - » Drain the captured flow below the planting soil depth in less than 48 hours.
  - » Designed to drain completely in 96 hours.
  - » Must be constructed in lifts and highly compacted
- Bottom Filter Layer: crushed stone.
- Geomembrane Liner:
  - » Covers the underlying soil and the entire area where permeable pavement will be used (including the sides) to prevent soil from migrating into the reservoir layer, which would reduce the storage capacity.

b Vegetated Voids

- Grass may be planted in permeable paver block voids, but must be irrigated and maintained.

c Follow Manufacturer Recommendations

- Dimensions, specifications, and strength requirements are product-specific and must comply with the permeable pavement manufacturer's recommendations.

d Overflow Precautions

- Large stormwater runoff flows will need to be directed to another stormwater control measure (i.e. storm drain, gutter, secondary Green Street LID Application, etc.). This can be achieved by an overflow device.

e Underdrain Design

- Underdrain should be blanketed in gravel.
- Underdrain and gravel blanket should be covered with a geomembrane liner to prevent clogging. Geomembrane liner should have an infiltration rate greater than or equal to the infiltration rate of the soil.
- Minimum underdrain slope is 0.5%.
- Clean-out points (non-perforated) of the same diameter of the underdrain should be installed for easy maintenance.

f Maintenance

In order for permeable pavers/pavement to function optimally, maintenance must be routinely performed. This prevents the pores within the pavers/pavement from becoming clogged. Maintenance typically involves a vacuum truck that removes dirt and other small particles which build up over time and reduce the system's performance.

Permeable pavers in recreational area

Limitations and Constraints

a Flat Surface

- Permeable pavement should be installed on relatively flat surfaces with less than 10% slope.

b Protection of High Traffic Areas

- Non-permeable pavement should be used in vehicle movement lanes leading up to the area of permeable pavement.
- Permeable pavement should not be installed in high turning areas or areas with heavy truck or equipment use.

c Soil Requirements

- May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Permeable pavement applications do not provide significant mitigation of stormwater pollutants if the underlying soils have a high permeability.
- Permeable pavement should not be used for drainage areas with high sediment production potential unless protected by a full treatment control Green Street LID or similar application that is effective for sediment removal.

d Sizing

- Permeable pavement area should be sized to infiltrate the 85th percentile runoff volume in 96 hours or less. The reservoir layer voids should be completely absent of water at the end of the 96-hour period.
- The depth of the reservoir layer is found by multiplying the design infiltration rate by the 96-hour retention time and dividing by the reservoir layer's porosity. The design should ensure sufficient void space exists for the storage of sediments to extend the time between remedial works.
- The surface area required to appropriately size the permeable pavement is the 85th percentile runoff volume divided by the reservoir layer depth multiplied by the reservoir layer porosity.

e Water Table

- The water table must be more than 10 ft below the invert of the permeable pavement system to ensure adequate infiltration.

f Infiltration

- Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mm. Generally, waterproof barriers should not be placed at the bottom of the permeable pavement system, as this would prevent incidental infiltration, which is important to meeting the required pollutant load reduction.

Permeable pavers in recreational picnic are.

Pollutant Removal Efficiency

Permeable Pavement Pollutant Removal Efficiency Data	
Pollutant	Removal Rate
TSS	80%
Total Phosphorous	65%
Total Nitrogen	80 - 85%
Zinc	90%
Lead	90%
Chemical Oxygen	90%

Source: 10 & 11

Cost Estimation

Costs are provided only as a relative reference. Estimates are based on 2020 cost.

a Capital Cost

Materials / Installation Cost		
Item	Unit Cost	Cost / SF
Mobilization	$1,850 LS	$0.08
Paving	$270 SY-IN	$30
Cold Milling Asphalt Paving	$3 CSY	$0.30
Haul / Dispose of Excavated Material	$10 CY	$0.06
Traffic Control	$12 LF	$0.08
Signage, Public Education Materials, etc	$77 EA	$ –
	Subtotal/SF =	$31

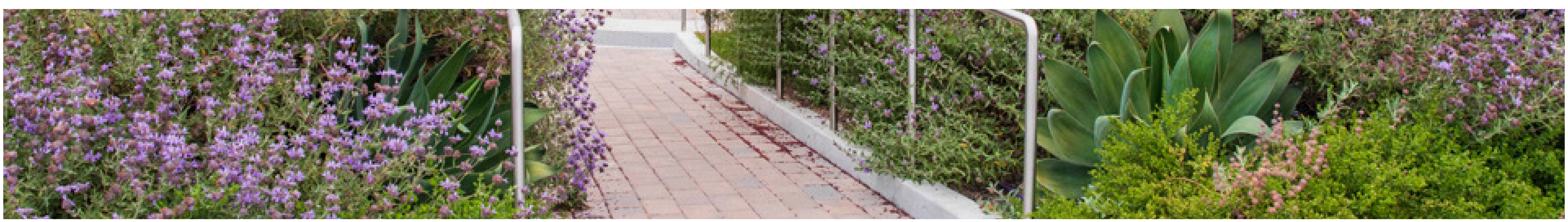
Design Costs		
Item	Unit Cost	Cost / SF
Project Management	$1,018 LS	$0.05
Preliminary Engineering	$2,035 LS	$0.09
Final Design Engineering	$1,018 LS	$0.05
Topographic Survey	$4,025 LS	$ –
Geotechnical	$2,350 LS	$ –
Landscape Design	$407 LS	$ –
Legal Services	$204 LS	$ –
Permitting & Construction Inspection	$204 LS	$ –
Sales Tax	$1,272 LS	$ –
Contingency	$4,070 LS	$ –
	Subtotal/SF =	$0
	Total Capital Cost/SF=	$31

Source: 12

b Maintenance Cost

Materials / Installation Cost							
Item	Months Between Events	Hours per Event	Average Labor Team Size	Average Labor Rate/Hr (pro-rated) ($)	Machinery Cost/Hr ($)	Materials & Incidentals Cost/Event ($)	Total Cost Per Visit ($)
Inspection, Reporting & Info Mgmt	36	2	6	$50.00	$100.00	$ –	$800.00
Infrequent / Corrective Maintenance (>3 yrs between events)							
Replace PFC	144	16	2.5	$50.00	$150.00	$25.00	$4,425.00
						Total Maintenance Cost =	$1,542 / yr

Source: 12



Permeable paver walkway amidst flowering drought tolerant landscape.

Design Procedure

01 Identify Project Location ➔ **02** Determine Design Volume ➔ **03** Determine Design Infiltration Rate ➔ **04** Calculate Bioretention Area ➔ **05** Check Ponding Depth Drains

01 Identify Project Location

02 Determine the Design Infiltration Rate

Use the procedures outlined in the most recent GMED Policy GS 200.1 to determine the corrected in-situ infiltration rate, f_{design} (units of in/hr), of the native soil at the project site.

Acceptable infiltration tests include:

1. **Double-ring Infiltrometer Test**
2. **Well Permeameter Test**
3. Boring Percolation Test Procedure
4. Excavation Percolation Test Procedure
5. High Flowrate Percolation Test Procedures
6. Policy for New Percolation Basin Testing, Design and Maintenance

The double-ring Infiltrometer and well permeameter tests are preferred, but whatever test is used must be performed at each location and elevation where the Green Street LID Application is proposed. Multiple tests at each site are recommended.

Procedures and example data forms for Double-Ring Infiltrometer tests are laid out in ASTM D3385. Details for the Well Permeameter Test can be found in the Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89).

In-situ infiltration rates should be between 0.3 in/hr and 12 in/hr. Anything above 12 in/hr or below 0.3 in/hr must have amended soil to achieve an adequate infiltration rate.

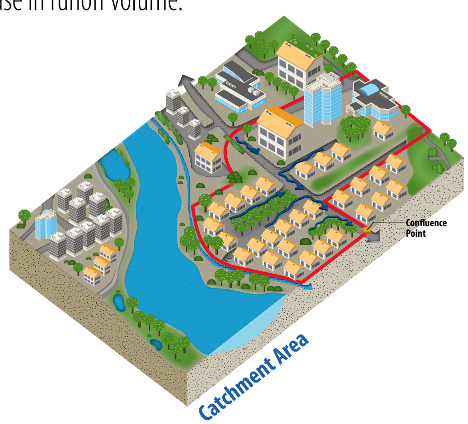

double-ring infiltrometer test

The permeable pavers / pavement selected should have an infiltration rate greater than or equal to fdesign. If that cannot be achieved, revise f_{design} to match the maximum allowable infiltration rate of the pavers / pavement selected.

03 Determine Design Volume

In new development, permeable pavement should be sized to capture the 85th percentile runoff volume for their contributing catchment. For redevelopment or retrofit projects, however, the permeable pavement can either be sized to capture the 85th percentile runoff volume or the design volume will be based on the maximum size the permeable pavement can be. For example, in a retrofit project, the available area and depth that can be used for design may not be enough to completely capture the 85th percentile runoff volume. The design volume, in this case, would be the maximum volume of runoff the proposed permeable pavement can hold. This volume would correspond to some "percentile" volume lower than 85th.

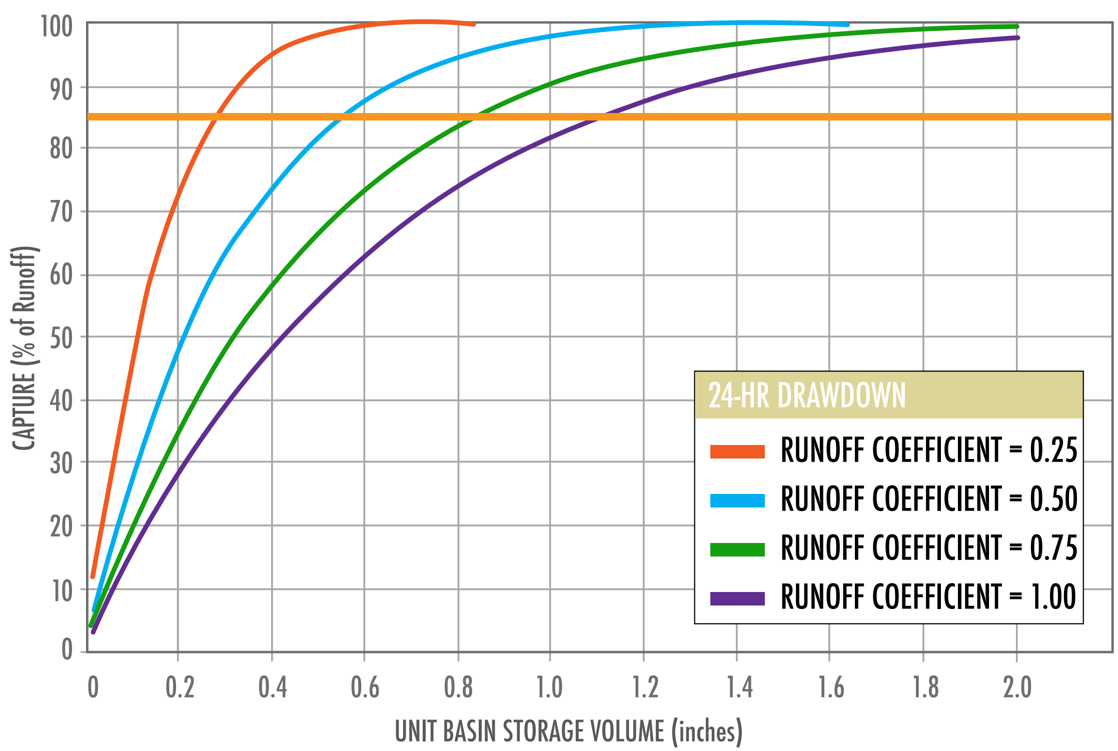
If the 85th percentile runoff volume can be designed for, it should. Otherwise, the permeable pavement will not be able to capitalize on a majority of storms. Alternatively, the permeable pavement should not be designed for a volume greater than the 85th percentile, even if there is sufficient room. Storm events producing runoff greater than the 85th percentile are not as common, so a larger permeable pavement will cost more money to infiltrate and treat an insignificant increase in runoff volume.



85th Percentile Design Volume Approach

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil. Catchment areas should be between 0.25 to 5 acres.
- Determine the runoff coefficient. The runoff coefficient is an indicator of how much pervious / impervious surface makes up the watershed draining to the Green Street LID project location (0.25, 0.5, 0.75, or 1.00). A runoff coefficient of 0.25 is used for watersheds with almost 0% impervious area while a coefficient of 1.00 is used for watersheds with almost 100% impervious areas. Analyzing the watershed area, determine the runoff coefficient to be used for design. A higher, conservative estimate is always better to use.
- Using the Sizing Curves graph below, find the "Unit Basin Storage Volume" (inches), corresponding to the intersection of the 85% runoff capture and the selected runoff coefficient curve.
- Multiply the contributing watershed drainage area, DA (units of ft^2) by the unit basin storage volume (units of feet), to obtain the 85th percentile volume, V_{design} (units of ft^3), the permeable pavement must hold.

$$V_{design}\ (ft^3) = DA\ (ft^2) \times \text{Unit Basin Storage Volume (ft)}$$



Sizing Curves Source: 4

Maximum Runoff Volume Design Approach

- Determine the maximum volume, V_{max} (units of ft³), that can be contained in the permeable pavement at the selected site. This will be the maximum area available, A_{max} (units of ft²), multiplied by the depth of the sub-base reservoir layer.

» *The depth of the sub-base reservoir layer, d_t (units of ft), is equal to:*

$$d_t = (f_{design} / 12) \times t / n_t$$

Where: f_{design} = Design infiltration rate (in/hr)
t = Maximum retention time (max 96 hours) (hr)
n_t = porosity of sub-base reservoir layer

» *The maximum storage volume in the permeable pavement, V_{max} (units of ft³), is:*

$$V_{max} = A_{max} \times d_t \times n_t$$

Where: A_{max} = maximum area available (ft²)
d_t = depth of sub-base reservoir layer (ft)
n_t = porosity of sub-base reservoir layer

- Determine the total catchment area, DA (ft²), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil.
- Divide the maximum permeable pavement volume, Vmax (ft³), by the total catchment drainage area, DA (ft²), to obtain the equivalent Unit Basin Storage Volume (ft). Convert this to inches.
- Analyzing the watershed area, determine the runoff coefficient to be used for design.
- Using the Sizing Curves graph from the previous page, find the "Capture (% Runoff)" corresponding to the intersection of the Unit Basin Storage Volume (inches) and the selected runoff coefficient curve. This is the "percentile" stormwater runoff that the Green Street LID Application can capture.

04 Calculate the Bioretention Area and Sub-Base Reservoir Layer Depth *(85th Percentile Design Volume Approach Only)*

Assume the design volume, V (units of ft³), will fill the available voids in the sub-base reservoir with a depth of d_t (units of ft).

$$d_{max} = (f_{design} / 12) \times t$$

Where: d_{max} = maximum depth of sub-base reservoir layer (ft)
f_{design} = design infiltration rate (in/hr)
t = maximum retention time (max 96 hrs) (hrs)

$$d_t \leq d_{max} / n_t$$

Where: d_t = depth of sub-base reservoir layer (ft)
d_{max} = maximum depth of sub-base reservoir layer (ft)
n_t = porosity of sub-base reservoir layer

NOTE: Use a maximum value of 6ft for d_t. Values greater than this are unrealistic due to costs of excavation and project footprint; however, greater values of d_t may be used if site conditions allow.

The surface area, A (units of ft²), required to accommodate the design volume is:

$$A = V / (d_t \times n_t)$$

Where: A = design surface area (ft²)
V = design volume (ft³)
d_t = sub-base reservoir layer depth (ft)
n_t = porosity of sub-base reservoir layer

05 Check that the Storage Volume Drains within 96 hrs

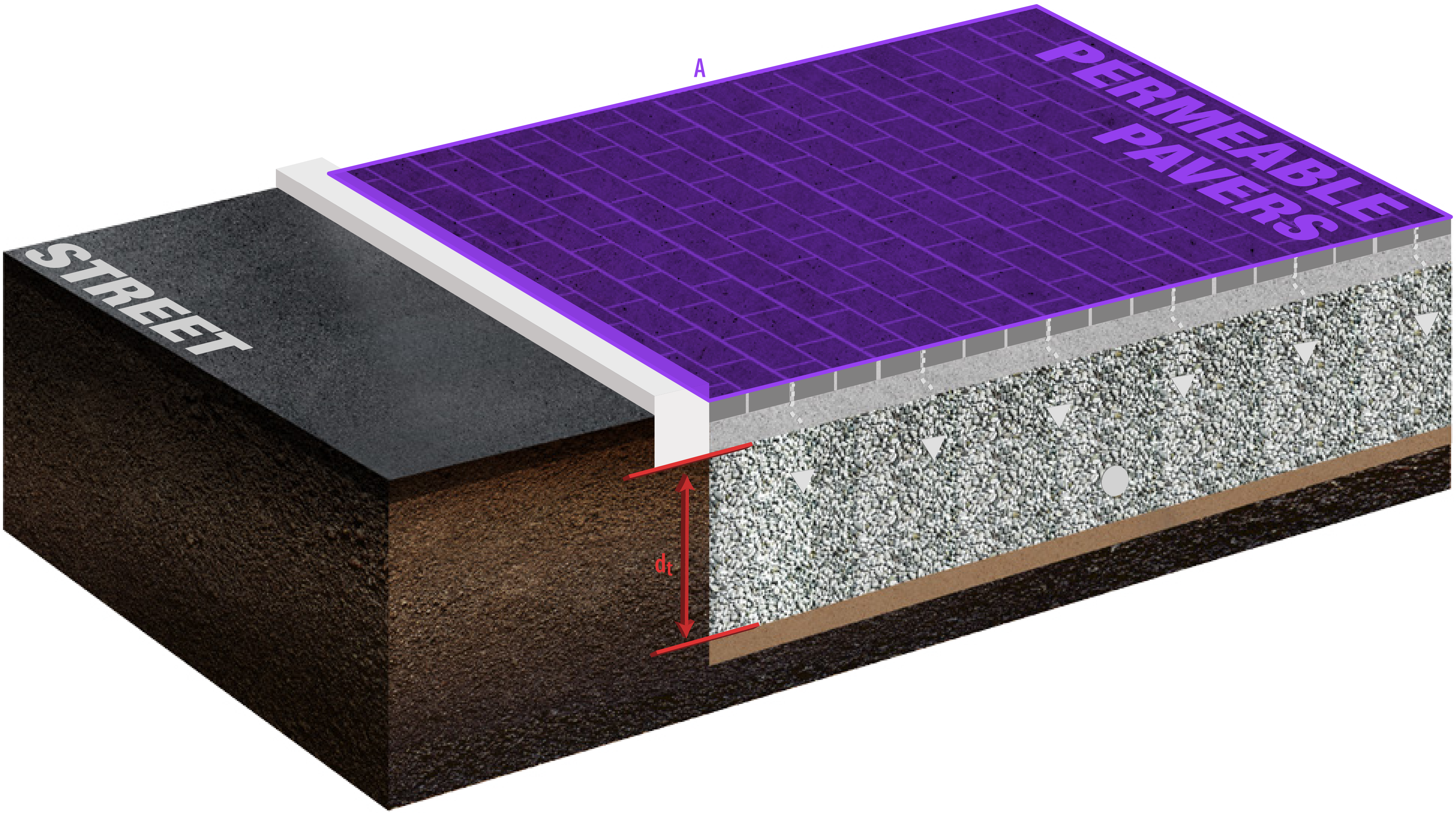
The permeable pavement needs to be able to drain within 96 hours. Check that the design volume can infiltrate with the following equation:

$$t = V / ((f_{design} / 12) \times A)$$

Where: t = time to infiltrate (hrs)
V = design storage volume (ft³)
A = design surface area (ft²)
f_{design} = design infiltration rate (in/hr)

If $t \leq 96$ hrs then the design area, depth, and infiltration rate are adequate. If $t > 96$ hrs, the area needs to be expanded or the soil can be amended to drain in the required amount of time.

Permeable paver walkway adjacent to vegetated swale.

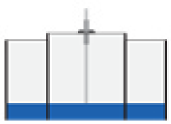


Isometric illustration of permeable pavement dimension and variables.

Example Scenario

01 Identify Project Location

Looking back at the General Application example that was previously shown, suppose permeable pavement turned out to be the most suitable application, instead of an infiltration trench. The drainage area is 2 acres:



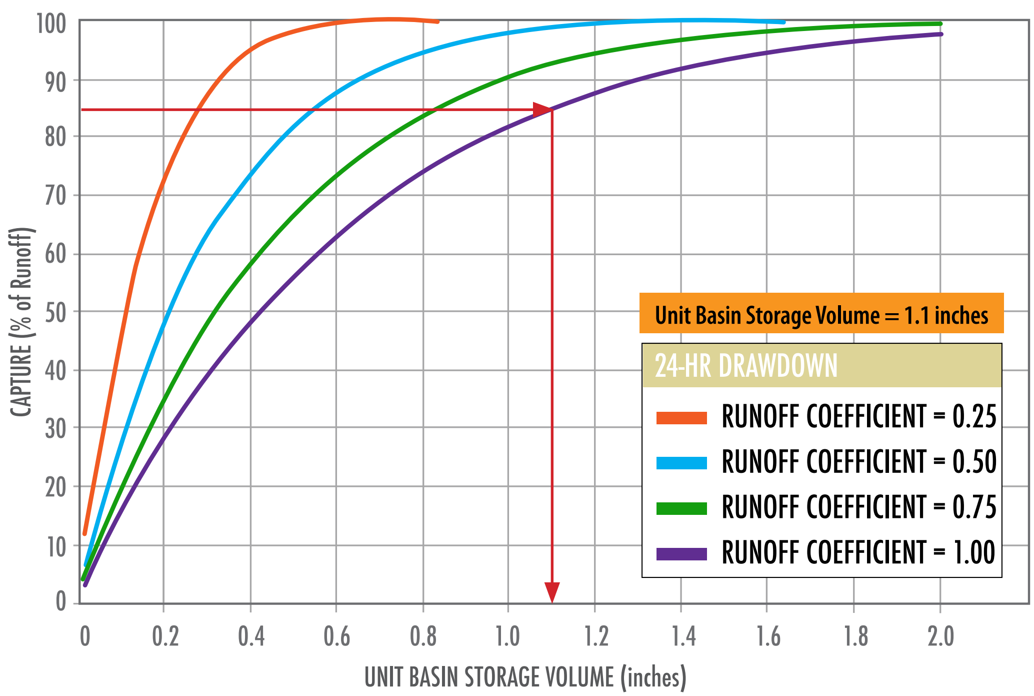
02 Determine the Design Infiltration Rate

- Choose a type of infiltration test to perform: Double-ring Infiltrometer
- Follow the procedures laid out in ASTM D-3385
- $f_{design} = 0.52$ in/hr
- 12 in/hr > 0.52 in/hr > 0.3 in/hr ✓

03 Determine Design Volume

85th Percentile Design Volume Approach:

- Determine Total Catchment area: 2 acres
- Determine the Runoff Coefficient: 1.00 (almost 100% impervious)
- Use the Sizing Curves graph to determine the Unit Basin Storage Volume (inches)



- Calculate the design Volume necessary to capture the 85th percentile runoff:

$$V = (\text{Unit Basin Storage Volume ft}) \times (\text{Drainage Area ft}^2)$$
$$V = (1.1 \text{ inches} / 12 \text{ in/ft}) \times (2 \text{ acres} \times 43{,}560 \text{ ft}^2/\text{acre})$$
$$\mathbf{V = 7{,}986 \text{ ft}^3}$$

04 Calculate the Permeate Area and Sub-Base Reservoir Layer Depth *(85th Percentile Design Volume Approach Only)*

The material selected for the sub-base reservoir has a porosity of 0.4. Use this value in the equations for d_{max} and d_t to find A:

$$\mathbf{d_{max} = (f_{design} / 12) \times t}$$
$$d_{max} = (0.52 / 12) \times 96$$
$$\mathbf{d_{max} = 4.16 \text{ ft}}$$

$$\mathbf{d_t \leq d_{max} / n_t}$$
$$d_t = 4.16 / 0.4$$
$$d_t = 10.4 \text{ ft}$$
$$\mathbf{d_t > 5 \text{ ft} \therefore d_t = 5\text{ft}}$$

$$\mathbf{A = V / (d_t \times n_t)}$$
$$A = 7{,}986 / (5 \times 0.4)$$
$$\mathbf{A = 3{,}993 \text{ ft}^2}$$

05 Check that the Storage Volume Drains within 96 hours

$$\mathbf{t = V / ((f_{design} / 12) \times A)}$$
$$t = 7{,}986 / ((0.52 \text{ in/hr} / 12 \text{ in/ft}) \times 3{,}993)$$
$$\mathbf{t = 46.15 \text{ hours} < 96 \text{ hrs}} \checkmark$$

SUMMARY OF SIZING

- $V = 7{,}986 \text{ ft}^3$
- $A = 3{,}993 \text{ ft}^2$
- $d_t = 5$ ft
- $f_{design} = 0.52$ in/hr
- $t = 46.2$ hrs

Green Space Vegetated Buffers

Curb side vegetated buffer strip between walkway and road

A wide strip of lawn designed to intercept and treat stormwater flows before releasing them into the local storm drain system.

Vegetated buffers are moderately sloped areas vegetated with some type of grass. They are most effectively placed between a pollutant source and a downstream receiving water body or storm water conveyance system inlet. They can also be used as pretreatment devices for other Green Street LID Applications to prevent sediments and other pollutants from inhibiting their performance. As runoff is dispersed evenly across the grassy surface, pollutants are trapped and then treated as they are infiltrated into the ground.

Flows that exceed the vegetated buffer's infiltration rate may either bypass the system or flow through the system to the nearest receiving water body or storm water conveyance system inlet without being treated. Features of vegetated buffers include:

- Sediment and contaminant removal
- Capture of dry-weather flows

Objectives

Filtration | Infiltration

Suitable Applications

Vegetated buffers can be applied in almost any scenario where there is sufficient room to designate as green space, but are most ideally placed along the edges of roads in an area where they can intercept sheet-flow runoff from a watershed.

Installation and maintenance costs for vegetated buffers are relatively low, but they still require irrigation and upkeep to maintain functionality and visual appeal.

Design Principles

a Even Flow Distribution

- Runoff reaching the vegetated strip should go through a level spreading device, such as a short weir or gravel trench, etc. to prevent erosion.
- Runoff on the downstream end of the vegetated strip should also be spread level by a similar device.

b Slow the Flow

- The vegetated buffer area should be sloped approximately 2%-6% with high velocities avoided as much as possible. High velocities have the potential to erode the buffer surface and channelize flow. This lowers the pollutant removal rates of the buffer in addition to adding sediment pollution to the downstream drainage point. Velocities should not exceed 1 ft/s across the vegetated surface.

c Vegetative Cover

- The vegetative cover used on buffer strips is typically close-growing grasses. Studies have shown that grass length has negligible impact on pollutant removal rates. Uniform vegetative cover along the entire buffer is important to prevent erosion and to maximize both pollutant removal and time of concentration.
- Minimal fertilizers should be used to reduce pollutants contribution.
- In order to maximize the pollutant removal rates of the vegetated buffer, vegetation used should be a mix of erosion-resistant plant species that bind the soil and native or adapted grasses that require minimal fertilizer and maintenance.
- Trees and shrubs are discouraged because they shade the turf.
- Irrigation will be necessary.

d Underdrain Design

- Underdrain should be blanketed in gravel.
- Underdrain and gravel blanket should be covered with a geomembrane liner to prevent clogging. Geomembrane liner should have an infiltration rate greater than or equal to the infiltration rate of the soil.
- Minimum underdrain slope is 0.5%.
- Clean-out points (non-perforated) of the same diameter of the underdrain should be installed for easy maintenance.

Curb side vegetated buffer strip with scattered trees.

Limitations and Constraints

a Water Table

- The water table must be more than 10 ft below the vegetated buffer surface.
- Sites with contaminated soils or sites susceptible to spills are not suitable for vegetated buffers due to the potential threat of groundwater contamination.

b Existing Slopes

- Vegetated buffers are not suitable for sites with steep slopes, since the maximum design slope is between 2 and 6%.

c Sizing

- Length: Length of strip (in direction of flow) should be between 15 and 150 feet with a minimum of 25 feet preferred. If the buffer is intended for pretreatment, it should be at least 4 feet long (in direction of flow). The length should be designed to ensure a hydraulic residence time of at least 10 minutes (600 seconds).
- Slope: The design slope of the vegetated buffer should be between 2% and 6%.
- Top / Toe: Both the top and toe of the slope should be as flat as possible to promote even flow distribution.
- Flow Depth and Velocity: The vegetated buffer should be designed to capture and infiltrate the 85th percentile runoff volume. The design width perpendicular to flow and slope parallel to flow should be based on a flow depth not to exceed 1-inch. The flow velocities across the buffer should also not exceed 1 ft/s.

d Flow Spreader

- The gravel filled trench acting as a flow spreader is placed between the contributing watershed and the vegetated buffer areas.
- The size of the trench should be a minimum of 6-inches deep and 12-inches wide.
- The gravel surface should be a minimum of one inch below the pavement surface to trap incoming sediment.
- Curb slots (i.e. curb inlets, curb ports, interrupted curbs, etc.) must be used in tandem with a gravel spreader. Openings or gaps in the curb should be at regular intervals. As a general rule, no opening should discharge more than 10% of the overall flow entering the vegetated buffer.

e Soils

- Unless the organic content of the existing soil is already greater than 10%, vegetated buffers should be amended with 2-inches of well-rotted compost. The compost should be mixed in with the existing soil to a minimum depth of 6-inches.

f Infiltration

- Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mm. Generally, waterproof barriers should not be placed at the bottom of the vegetated buffer unit, as this would prevent incidental infiltration, which is important to meeting the required pollutant load reduction.
- Infiltration rates 0.3 to 1 inch per hour require replacing existing soil with a soil mix. The in-situ or amended soil mut have an infiltration rate under saturated conditions of no less than 0.3 inches per hour.

Curb side vegetated buffer strip adjacent to a park.

Pollutant Removal Efficiency

Vegetated Filter Strip Pollutant Removal Efficiency Data	
Pollutant	Removal Rate
TSS	74%
Total Phosphorous	-52%
Total Nitrogen	15%
Zinc	78%
Lead	88%
BOD	Data Unavailable
Bacteria	Data Unavailable

Source: 4

Cost Estimation

Costs are provided only as a relative reference. Estimates are based on 2020 cost.

a Capital Cost

Materials / Installation Cost		
Item	Unit Cost	Cost / SF
Mobilization	$2,423 LS	$0.08
Clearing & Grubbing	$6 SY	$0.65
Excavation / Grading	$0.08 CY	$ –
Irrigation	$9 SF	$ 9.00
Signage, Public Education, Materials, etc.	$77 CY	$0.08
	Subtotal/SF =	$10

Design Costs		
Item	Unit Cost	Cost / SF
Preliminary Engineering	$2,665 LS	$0.09
Final Design Engineering	$1,333 LS	$0.04
Topographic Survey	$4,025 LS	$0.13
Geotechnical	$2,350 LS	$0.88
Landscape Design	$533 LS	$0.02
Legal Services	$267 LS	$0.01
Permitting & Construction Inspection	$267 LS	$0.01
Sales Tax	$1,666 LS	$0.06
Contingency	$5,330 LS	$0.18
	Subtotal/SF =	$0.61
	Total Capital Cost/SF=	$11

Source: 13

b Maintenance Cost

Materials / Installation Cost							
Item	Months Between Events	Hours per Event	Average Labor Team Size	Average Labor Rate/Hr (pro-rated) ($)	Machinery Ccost/Hr ($)	Materials & Incidentals Cost/Eevent ($)	Total Cost Per Visit ($)
Inspection, Reporting & Info Mgmt	12	1	2	$50.00	$30.00	$ –	$130.00
Vegetation Mgmt & Trash / Debris Removal	6	4	2	$50.00	$60.00	$ –	$640.00
Infrequent / Corrective Maintenance (>2 yrs between events)							
Corrective Maintenance	60	8	2	$50.00	$60.00	$ –	$1,280.00
						Total Maintenance Cost =	$1,666 / yr

Source: 13

Design Procedure

01 Identify Project Location	→	02 Determine Design Volume	→	03 Determine Design Infiltration Rate	→	04 Calculate Bioretention Area	→	05 Check Ponding Depth Drains

01 Identify Project Location

02 Determine the Design Infiltration Rate

Use the procedures outlined in the most recent GMED Policy GS 200.1 to determine the corrected in-situ infiltration rate, f_{design} (units of in/hr), of the native soil at the project site.

Acceptable infiltration tests include:

1. **Double-ring Infiltrometer Test**
2. **Well Permeameter Test**
3. Boring Percolation Test Procedure
4. Excavation Percolation Test Procedure
5. High Flowrate Percolation Test Procedures
6. Policy for New Percolation Basin Testing, Design and Maintenance

The double-ring Infiltrometer and well permeameter tests are preferred, but whatever test is used must be performed at each location and elevation where the Green Street LID Application is proposed. Multiple tests at each site are recommended.

Procedures and example data forms for Double-Ring Infiltrometer tests are laid out in ASTM D3385. Details for the Well Permeameter Test can be found in the Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89).

In-situ infiltration rates should be between 0.3 in/hr and 12 in/hr. Anything above 12 in/hr or below 0.3 in/hr must have amended soil to achieve an adequate infiltration rate.

double-ring infiltrometer test

03 Determine Design Volume

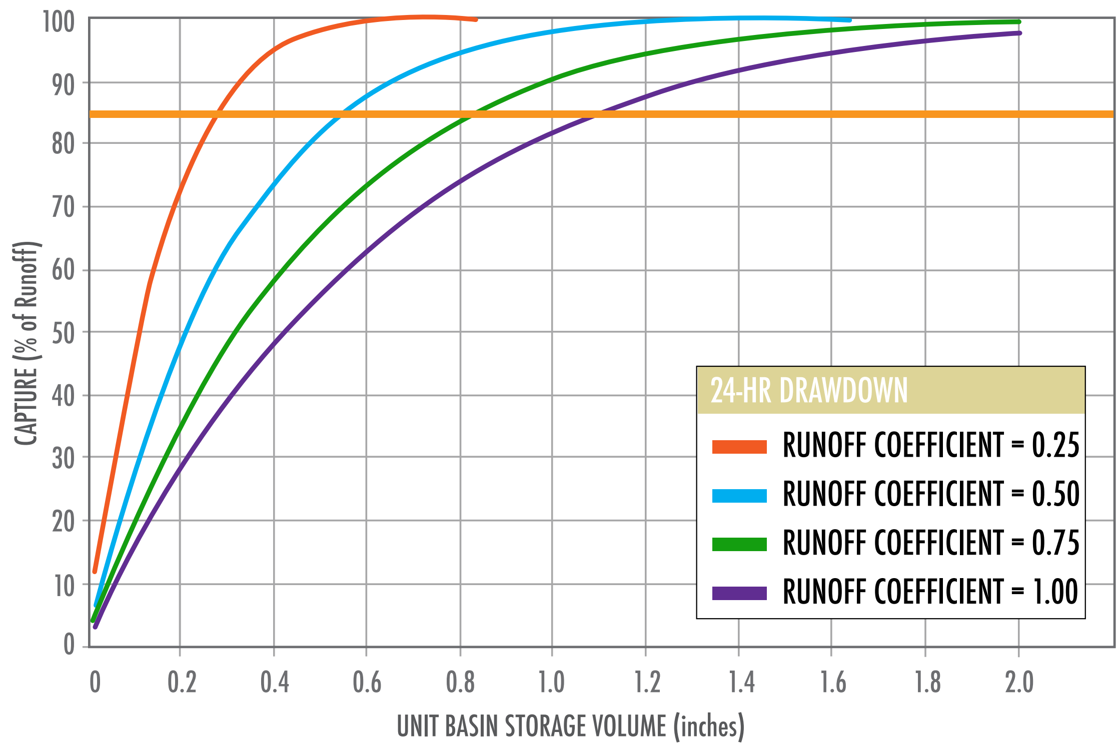
In new development, vegetated buffers should be sized to capture the 85th percentile runoff volume for their contributing catchment. For redevelopment or retrofit projects, however, the vegetated buffer can either be sized to capture the 85th percentile runoff volume or the design volume will be based on the maximum size the vegetated buffer can be. For example, in a retrofit project, the available area and depth that can be used for design may not be enough to completely capture the 85th percentile runoff volume. The design volume, in this case, would be the maximum volume of runoff the proposed vegetated buffer can hold. This volume would correspond to some "percentile" volume lower than 85th.

If the 85th percentile runoff volume can be designed for, it should. Otherwise, the vegetated buffer will not be able to capitalize on a majority of storms. Alternatively, the vegetated buffer should not be designed for a volume greater than the 85th percentile, even if there is sufficient room. Storm events producing runoff greater than the 85th percentile are not as common, so a larger vegetated buffer will cost more money to infiltrate and treat an insignificant increase in runoff volume.

85th Percentile Design Volume Approach

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil. Catchment areas should be between 0.25 and 5 acres.
- Determine the runoff coefficient. The runoff coefficient is an indicator of how much pervious / impervious surface makes up the watershed draining to the Green Street LID project location (0.25, 0.5, 0.75, or 1.00). A runoff coefficient of 0.25 is used for watersheds with almost 0% impervious area while a coefficient of 1.00 is used for watersheds with almost 100% impervious areas. Analyzing the watershed area, determine the runoff coefficient to be used for design. A higher, conservative estimate is always better to use.
- Using the Sizing Curves graph below, find the "Unit Basin Storage Volume" (inches), corresponding to the intersection of the 85% runoff capture and the selected runoff coefficient curve.
- Multiply the contributing watershed drainage area, DA (units of ft^2) by the unit basin storage volume (units of feet), to obtain the 85th percentile volume, V_{design} (units of ft^3), the permeable pavement must hold.

$$V_{design}\ (ft^3) = DA\ (ft^2) \times \text{Unit Basin Storage Volume (ft)}$$



Sizing Curves Source: 4

Maximum Runoff Volume Design Approach

- Determine the maximum volume, V_{max} (units of ft^3), that can be captured by the vegetated buffer at the selected site. This will be:

$$V_{max} = A_{max} \times f_{design} \times t$$

Where: A_{max} = maximum area available (ft^2)
f_{design} = design infiltration rate (in/hr)
t = maximum retention time (max 96 hrs) (hrs)

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil.
- Divide the maximum infiltration trench volume, V_{max} (ft^3), by the total catchment drainage area, DA (ft^2), to obtain the equivalent Unit Basin Storage Volume (ft). Convert this to inches.
- Analyzing the watershed area, determine the runoff coefficient to be used for design.
- Using the Sizing Curves graph on the previous page, find the "Capture (% Runoff)", corresponding to the intersection of the Unit Basin Storage Volume (inches) and the selected runoff coefficient curve. This is the "percentile" stormwater runoff that the Green Street LID Application can capture.

04 Calculate Peak Flow Rate

Since the contributing watershed should be small (<20 acres), the rational method is sufficient to calculate the peak runoff. Using precipitation-intensity tables from the NOAA database to determine storm intensity, the flow rate will be:

$$Q = CiA$$

Where: Q = flow rate of captured runoff (cfs)
i = intensity (in/hr)
A = drainage area (acres)

05 Calculate the Design Width

The vegetated buffer width (perpendicular to direction of flow) is dependent on the slope:

The slope (s, ft/ft) will be either an assumption or known value.

$$W = (Q \times n) / (1.49 \times s0.5 \times d1.67)$$

Where: W = Width of buffer perpendicular to direction of flow (ft) (max. 200 ft.)
n = 0.025 - 0.050
s = Slope in direction of flow (ft/ft) (between 2% and 6%)
d = Flow depth (ft) (1 inch max)

If W > 200 ft., increase the slope or decrease the flow depth.

06 Calculate the Design Velocity

The design velocity (1 ft/s maximum) is found with the following equation:

$$v = Q / (d \times W)$$

Where: v = Design velocity (ft/s) (1 ft/s max)
Q = Peak flow rate (cfs)
d = Flow depth (ft) (1 inch max)
W = Width of buffer perpendicular to direction of flow (ft) (max 200 ft.)

If v > 1, increase W (max = 200 ft.)
If v >1 when W = 200 ft., increase slope, recalculate W, and re-calculate v. Repeat as necessary.

07 Calculate the Design Length

Use a minimum hydraulic residence time (h, seconds) of 10 minutes (600 seconds) to calculate the buffer length:

$$L = h \times v$$

Where: L = buffer length in direction of flow (ft)
h = hydraulic residence time (sec) (10 minutes minimum)
v = design velocity (ft/s)

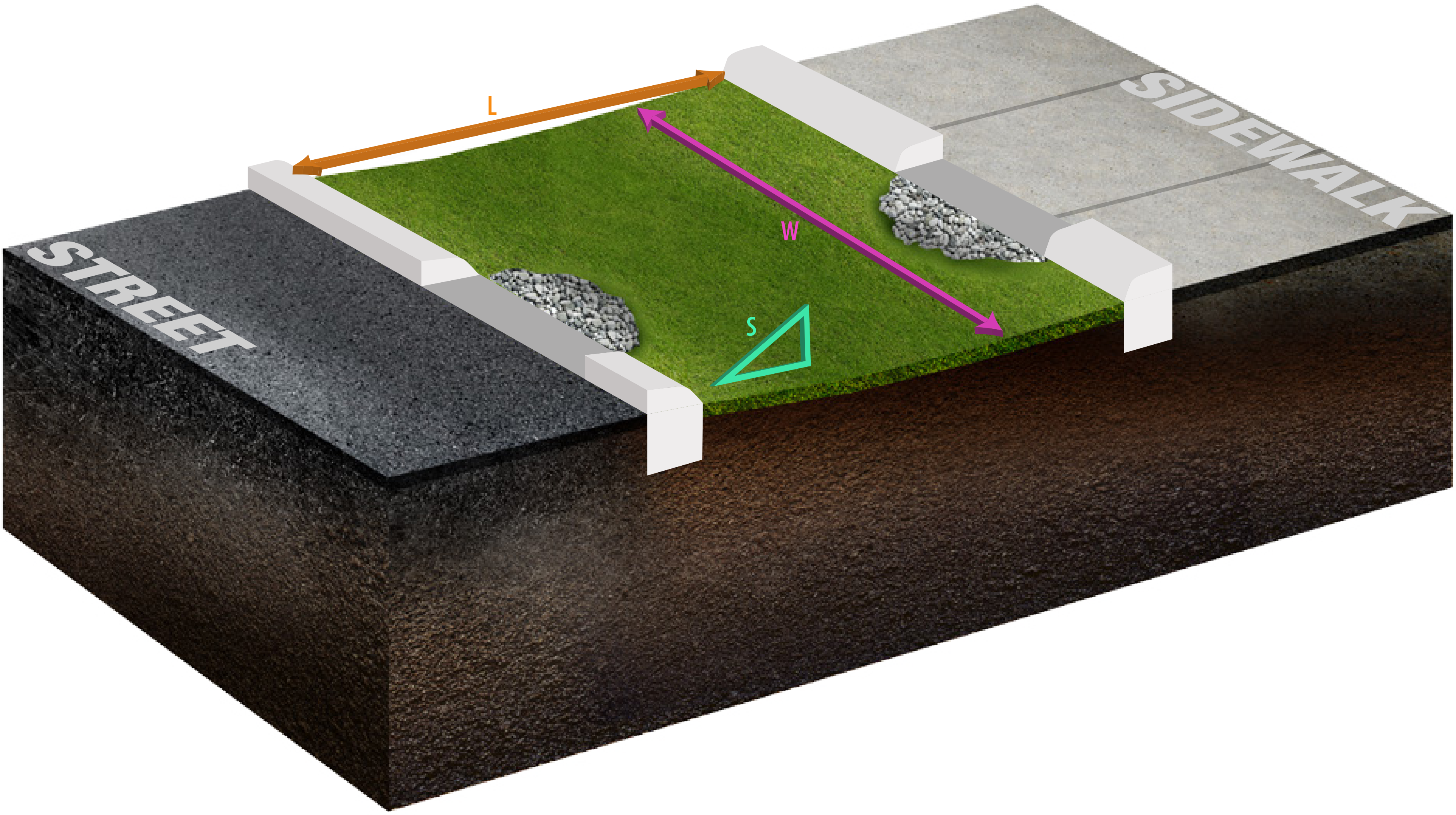
08 Check that Captured Volume Drains within 96 hrs

The vegetated buffer needs to be able to drain within 96 hours. Check that the design volume can infiltrate with the following equation:

$$t = V / ((f_{design} / 12) \times L \times W)$$

Where: t = time to infiltrate (hrs)
V = design volume (ft^3)
f_{design} = design infiltration rate (in/hr)
L = length of vegetated buffer in direction of flow (ft)
W = width of vegetated buffer perpendicular to direction of flow (ft)

If t ≤ 96 hrs then the design area, depth, and infiltration rate are adequate. If t > 96 hrs, the area needs to be expanded or the soil can be amended to drain in the required amount of time.



Isometric illustration of green space vegetated buffer dimension and variables.

Example Scenario

01 Identify Project Location

Looking back at the General Application example that was previously shown, suppose vegetated buffer turned out to be the most suitable application, instead of an infiltration trench. The drainage area is 5 acres:

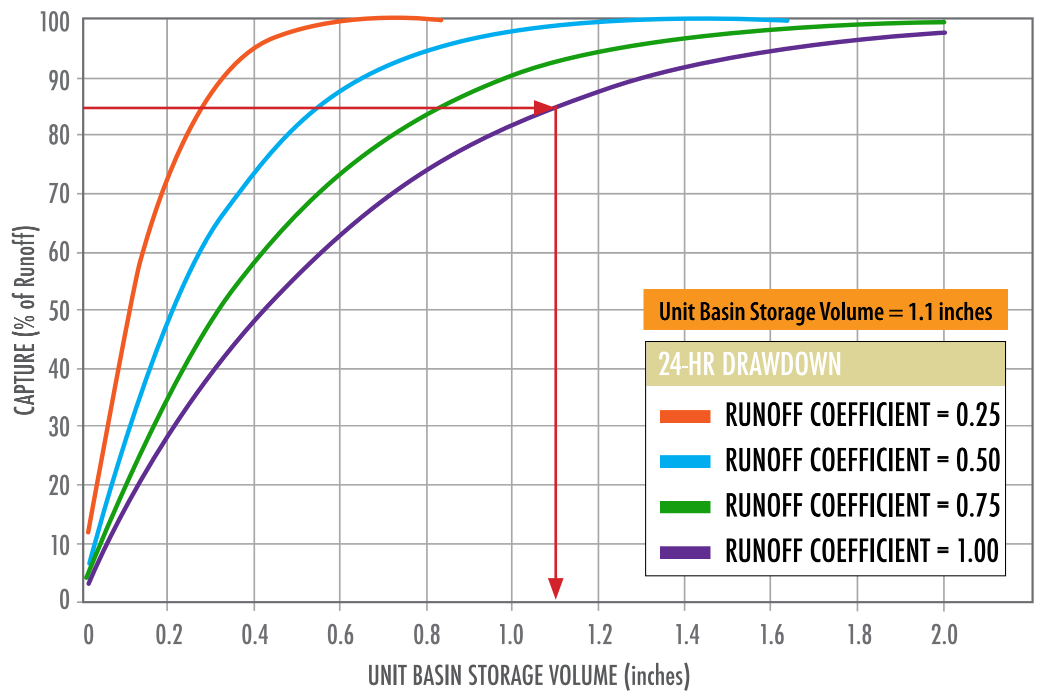
02 Determine the Design Infiltration Rate

- Choose a type of infiltration test to perform: Double-ring Infiltrometer
- Follow the procedures laid out in ASTM D-3385
- f_{design} = 11.8 in/h
- 12 in/hr > 11.8 in/hr > 0.3 in/hr

03 Determine Design Volume

85th Percentile Design Volume Approach:

- Determine Total Catchment area: 2 acres
- Determine the Runoff Coefficient: 1.00 (almost 100% impervious)
- Use the Sizing Curves graph to determine the Unit Basin Storage Volume (inches)



- Calculate the design Volume necessary to capture the 85th percentile runoff:

V = (Unit Basin Storage Volume ft) x (Drainage Area ft²)

V = (1.1 inches / 12 in/ft) x (5 acres x 43,560 ft²/acre)

V = 19,965 ft³

04 Calculate Peak Flow Rate

From NOAA, the precipitation intensity for a 24-hr storm of 1-yr frequency is ~0.1 in/hr. The 85th percentile precipitation is a precipitation value that encompasses up to 85% of storms that occur in a year. Since an 85th percentile storm is guaranteed to happen every year, the 1-yr storm was selected.

C = 1.00 since the drainage area is heavily urbanized

The drainage area is the area shown at the beginning of this design example: 5 acres

Q = CiA
Q = 1.00 x 0.1 x 5 acres
Q = 0.5 cfs

05 Calculate the Design Width

Use a design flow depth of 0.15 inch and a Manning's coefficient of 0.050 to solve for W. The flow depth of 0.15 inch was chosen as an initial estimate and not based on any constraints other than meeting a minimum / maximum range of 0 and 1 inch respectively.

Based on site constraints, a slope of 0.020 is selected.

W = (Q x n) / (1.49 x s0.5 x d1.67)
W = (0.5 cfs x 0.050) / (1.49 x 0.0200.5 x (0.15/12)1.67)
W = 178.81 ft
W < 200 ft. ✓

06 Calculate the Design Velocity

Calculate the design velocity (1 ft/s maximum) using a design flow depth of 1 inch:

v = Q / (d x W)
v = 0.5 cfs / ((0.25 in. /12) x 178.81 ft.)
L = 30 ftv = 0.13 ft/s
v < 1 ft/s ✓

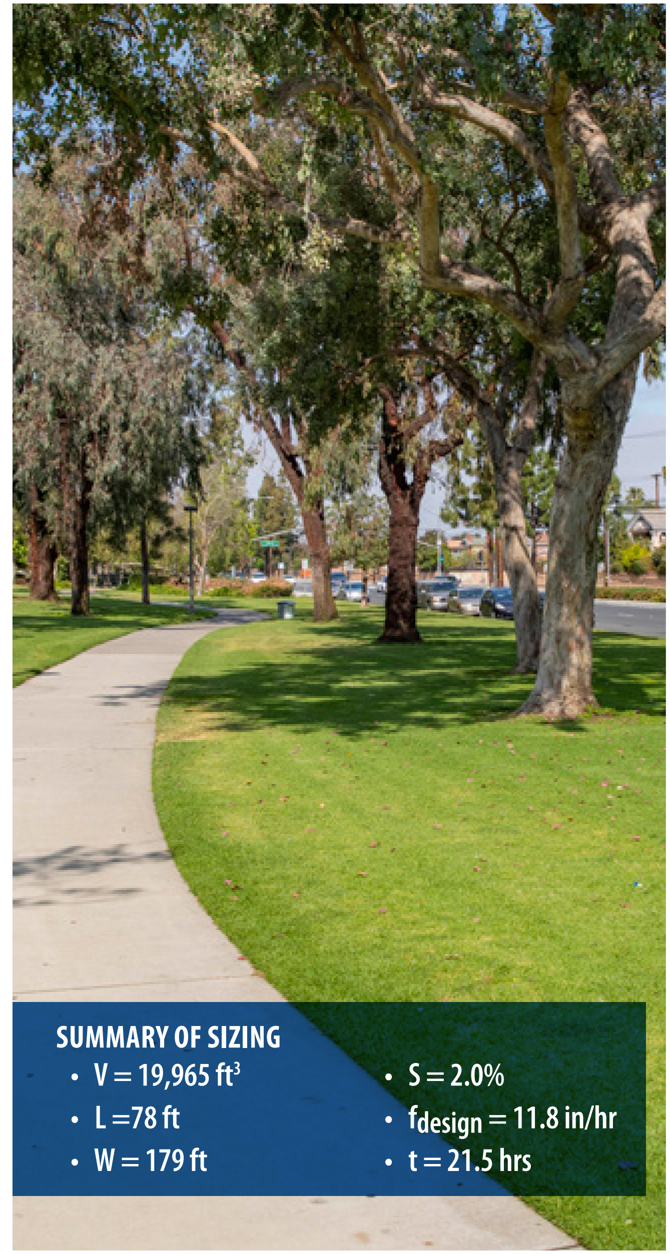
07 Calculate the Design Length

Use a hydraulic residence time (h, seconds) of 10 minutes (600 seconds) to calculate the buffer length:

L = h x v
L = (600 sec) x 0.13 ft/s
L = 78 ft

08 Check that the Captured Volume Drains within 96 hours

$t = V / (f_{design} / 12) \times L \times W)$
t = 19,965 / ((0.8 / 12) x 78 x 178.8)
t = 21.47 hrs < 96 hrs ✓



Curb side vegetated buffer strip with meandering walkway.

Enhanced Open Swales

- Water Quality Improvement Objectives
- Suitable Applications
- Design Principles
- Limitations and Constraints
- Pollutant Removal Efficiency
- Cost Estimation
- Design Procedure
- Example Scenario

Vegetated channels in the urban environment, designed to transport, filter, and infiltrate stormwater runoff while beautifying the street landscape.

Vegetated swale with pedestrian bridge

Enhanced open swales (i.e. vegetated swales) are shallow channels cut into the ground with a roughly trapezoidal cross-section. They are planted with vegetation such as grasses and shrubs. These plants slow down the flow, providing:

- Sediment and contaminant removal
- Reduction of stormwater runoff volume and peak flow rates
- Groundwater recharge
- Capture of dry-weather flows
- Aesthetic appeal

Objectives

Detention | Filtration | Infiltration

Suitable Applications

Vegetated swales are best suited between a roadway and sidewalk, where they can create a barrier between pedestrians and vehicle traffic as well as intercept flows from the curb and gutter flow path. Placing them close to an existing storm drain facility will also be beneficial to release filtered flows back into the drainage system.

Vegetated swales can also serve as treatment prior to bioretention or infiltration devices.

Design Principles

a Gentle Slopes

- Slopes both parallel and perpendicular to the flow should be mild. Parallel slopes should be between 2 and 6%, while the steepest side slopes (perpendicular to flow) should be a maximum of 2H : 1V. Gradual slopes increase times of concentration, increase the removal rate of sediment and pollutants, and promote infiltration into the groundwater. Gentle slopes also decrease flow velocities, reducing erosion and damage to the established vegetation.

b Vegetation

- Vegetated swales rely on vegetation to filter out sediment and pollutants from storm water runoff as well as slow down the velocities of the flow. Plants used in the swale design should be drought tolerant as well as capable of surviving short periods of inundation / submergence.
- Vegetation selected in the swale design should be low-growing plants that are a mixture of dry-area and wet-area grass species that can continue to grow through silt deposits. Native and drought-tolerant species are preferred because they require less fertilizer and maintenance than others.
- Trees and shrubs may be used in the swale, but are discouraged because they shade the turf and stunt vegetation growth. If they are used, however, they should be spaced far apart. For moderately shaded areas, shade-tolerant plants should be used. Any trees planted in the swale should not drop leaves or needles. Dropped leaves and needles can smother the grass, impede the flow through the swale, and / or lower infiltration rates. This usually has a negative impact on aesthetics as well.
- Vegetation will still need to be irrigated.

Vegetated swale between walkway and recreational area.

c Inlet / Outlet

- Water enters a vegetated swale at its upstream end through some diversion structure, such as a pipe diverging from a storm drain, a curb slot in the gutter flow line, concentration of surface flows, etc. Once flows enter the vegetated swale, they will need to be slowed down through an energy dissipating device (i.e. large cobbles, concrete blocks, gravel pad, etc.).
- Vegetated swales must be connected to an outlet at their downstream end. This outlet can carry the stormwater to any drainage infrastructure, such as a secondary Green Street LID application, curb and gutter, storm drain, channel, river, stream, etc.
- Access to the vegetated swale's inlet / outlet structures should be unimpeded for operation and maintenance crews.
- If check dams are installed (see below), energy dissipaters or flow spreaders must also be used at the base of the vertical drops.
- If curb cuts are used at the inlet, openings should be a minimum of 12-inches wide to prevent clogging.

d Low Flow Drain

- A low flow drain must be installed for dry weather flows for the entire swale length. The drain should have a 6-inch minimum depth and maximum width of 5% the design swale base width.

e Soil Amendment

- Unless the organic content of the existing soil is already greater than 10%, the soil at the swale surface must be amended with 2-inches of compost. The compost should be mixed in with the existing soil to a minimum depth of 6-inches. Compost used should not contain sawdust, unsterilized manure, green or under-composted material, or any other toxic or harmful substance.

Vegetated swale with tall grasses and flowering landscape.

f Check Dams (Optional)

- Check dams are useful in increasing the detention time of storm flows. They can be installed at 50-foot increments along the flow length, creating "cells" where water is temporarily detained for infiltration, filtration, and increasing the time of concentration.
- Check dams may not be appropriate for sites with low infiltration rates that would have issues with ponding (<0.3 in/hr).
- A secondary outlet should be incorporated into the check dam design in case ponding occurs in one of the "cells". This can be as simple as a pipe installed at the base of the check dam that can be manually plugged / unplugged to drain the cell as needed.
- Treated wood should not be used as a check dam material.
- If an earthen check dam is used, maximum slope is 2H : 1V.
- Any non-earthen material must be embedded deep enough into the soil to be stable.

g Underdrain

- Underdrain should be blanketed in gravel .
- Underdrain and gravel blanket should be covered with a geomembrane liner to prevent clogging. Geomembrane liner should have an infiltration rate greater than or equal to the infiltration rate of the soil.
- Minimum underdrain slope is 0.5%.
- Clean-out points (non-perforated) of the same diameter of the underdrain should be installed for easy maintenance.

h Overflow Device

- The vegetated swale should be designed with adequate precautions in case of overflow. The most common methods are:
  - » Overflow riser
  - » Curb / gutter bypass
- Discharge excess waters to an appropriate location, such as another Green Street LID area, storm drain, or water body.
- The overflow device is required at the 18-inch maximum ponding depth.

Limitations and Constraints

a Water Table

- The water table must be more than 10 ft below the vegetated swale.
- Sites with contaminated soils or sites susceptible to spills are not suitable for vegetated swales due to the potential threat of groundwater contamination.

b Existing Slopes

- Vegetated swales are not suitable for sites with existing slopes greater than 10%, since the maximum design slope is between 2% and 6%.

c Vegetation

- Vegetated swales are not suitable in areas where existing trees will drop leaves or needles into the swale. This has the potential to smother the grass, impede flow rate through the swale, and / or lower infiltration rates. This usually has a negative impact on aesthetics as well.
- Irrigation will be necessary.

d Sizing

- Swale Depth: Overall depth from invert to top of slope should be a minimum of 1-foot.
- Base Width: The minimum base width of the roughly trapezoidal section is 2-feet to provide easy mowing equipment access. Maximum base width to be used is 10-feet unless a check dam is incorporated, in which case the maximum base width is 16-feet.
- Length: The longer the swale can be (in direction of flow), the better. Length can be increased by incorporating a meandering flow path into the design. Minimum swale length should either be 100-feet or the design velocity (not to exceed 1 ft/s) multiplied by a minimum hydraulic residence time of 10 minutes (600 seconds), whichever is greater. Although, maximum hydraulic residence times and lengths as allowed by the available area are preferred.
- Slope: The design slope of the vegetated swale (in direction of flow) should be between 2 and 6%. Steepest side slope used should be 2H : 1V.
- Flow Depth and Velocity: The vegetated swale should be designed to capture and infiltrate the 85th percentile runoff volume. The depth of flow in the swale should be designed such that it does not exceed 2/3 the height of the vegetation in the swale (approximately 4-inches). Flow velocity should not exceed 1 ft/s.
- Drain Time: Vegetated swales should infiltrate well enough to avoid vector breeding and drain the captured flow below the planting soil depth in less than 48 hours and completely drain in less than 96 hours.

e Infiltration

- Infiltration pathways may need to be restricted due to the close proximity of roads, foundations, or other infrastructure. A geomembrane liner, or other equivalent water proofing, may be placed along the vertical walls to reduce lateral flows. This liner should have a minimum thickness of 30 mm. Generally, waterproof barriers should not be placed at the bottom of the vegetated swale unit, as this would prevent incidental infiltration, which is important to meeting the required pollutant load reduction.
- Long term in-place infiltration of the planting media placed in the cell should achieve a minimum infiltration rate of 0.3 in/hr and a maximum infiltration rate of 12 in/hr.

Typical tall grasses used in vegetated swales

Pollutant Removal Efficiency

Vegetated Swale Pollutant Removal Efficiency Data	
Pollutant	Removal Rate
TSS	65%
Total Phosphorous	30%
Total Nitrogen	30%
Zinc	30%
Lead	30%
BOD	Data Unavailable
Bacteria	Negligible

TSS = Total Suspended Solids
TP = Total Phosphorous
TN = Total Nitrogen
NO_3 = Nitrate

Source: 4

Curb slot flow entrance with energy dissipator.

Cost Estimation
Costs are provided only as a relative reference. Estimates are based on 2020 cost.

a Capital Cost

Materials / Installation Cost		
Item	Unit Cost	Cost / SF
Mobilization	$55,956 LS	$2.04
Clearing & Grubbing	$2 SY	$0.65
Excavation / Grading	$69 CY	$13.78
Haul / Dispose of Excavated Material	$10 CY	$2.06
Inflow Structure(s)	$2,200 LS	$0.08
Overflow Structure (concrete / rock riprap)	$125 CY	$0.03
Hydroseed / Erosion Control	$0.08 SF	$0.02
Irrigation	$9 SF	$9.00
Landscape	$4 SF	$4.00
Metal Beam Guard Rail	$58 LF	$4.20
Signage, Public Education Materials, etc	$77 EA	$ –
	Subtotal/SF =	$36

Design Costs		
Item	Unit Cost	Cost / SF
Project Management	$30,776 LS	$1.12
Preliminary Engineering	$61,552 LS	$2.25
Final Design Engineering	$30,776 LS	$1.12
Topographic Survey	$4,025 LS	$0.15
Geotechnical	$2,350 LS	$0.09
Landscape Design	$12,310 LS	$0.45
Legal Services	$6,155 LS	$0.22
Permitting & Construction Inspection	$6,155 LS	$0.22
Sales Tax	$38,470 LS	$1.41
Contingency	$123,104 LS	$4.50
	Subtotal/SF =	$12

Total Capital Cost/SF= $48

b Maintenance Cost

Item	Months Between Events	Hours per Event	Average Labor Team Size	Average Labor Rate/Hr (pro-rated) ($)	Machinery Cost/Hhr ($)	Materials & Incidentals (Cost/Eevent ($)	Total Cost Per Visit ($)
Routine Maintenance							
Inspection, Reporting & Info Mgmt	12	1	2	$50.00	$30.00	$ –	$130.00
Vegetation Mgmt & Trash / Debris Removal	6	4	2	$50.00	$60.00	$ –	$640.00
Infrequent / Corrective Maintenance (>3 yrs between events)							
Corrective Maintenance	96	24	4	$50.00	$60.00	$500.00	$1,280.00
					Total Maintenance Cost =		$1,666 / yr

Source: 14

Curb side vegetated swale with a diverse drought tolerant landscape.

Design Procedure

01 Identify Project Location	→	02 Determine Design Volume	→	03 Determine Design Infiltration Rate	→	04 Calculate Bioretention Area	→	05 Check Ponding Depth Drains

01 Identify Project Location

02 Determine the Design Infiltration Rate

Use the procedures outlined in the most recent GMED Policy GS 200.1 to determine the corrected in-situ infiltration rate, f_{design} (units of in/hr), of the native soil at the project site.

Acceptable infiltration tests include:

1. Double-ring Infiltrometer Test
2. Well Permeameter Test
3. Boring Percolation Test Procedure
4. Excavation Percolation Test Procedure
5. High Flowrate Percolation Test Procedures
6. Policy for New Percolation Basin Testing, Design and Maintenance

The double-ring Infiltrometer and well permeameter tests are preferred, but whatever test is used must be performed at each location and elevation where the Green Street LID Application is proposed. Multiple tests at each site are recommended.

Procedures and example data forms for Double-Ring Infiltrometer tests are laid out in ASTM D3385. Details for the Well Permeameter Test can be found in the Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89).

In-situ infiltration rates should be between 0.3 in/hr and 12 in/hr. Anything above 12 in/hr or below 0.3 in/hr must have amended soil to achieve an adequate infiltration rate.

double-ring infiltrometer test

03 Determine Design Volume

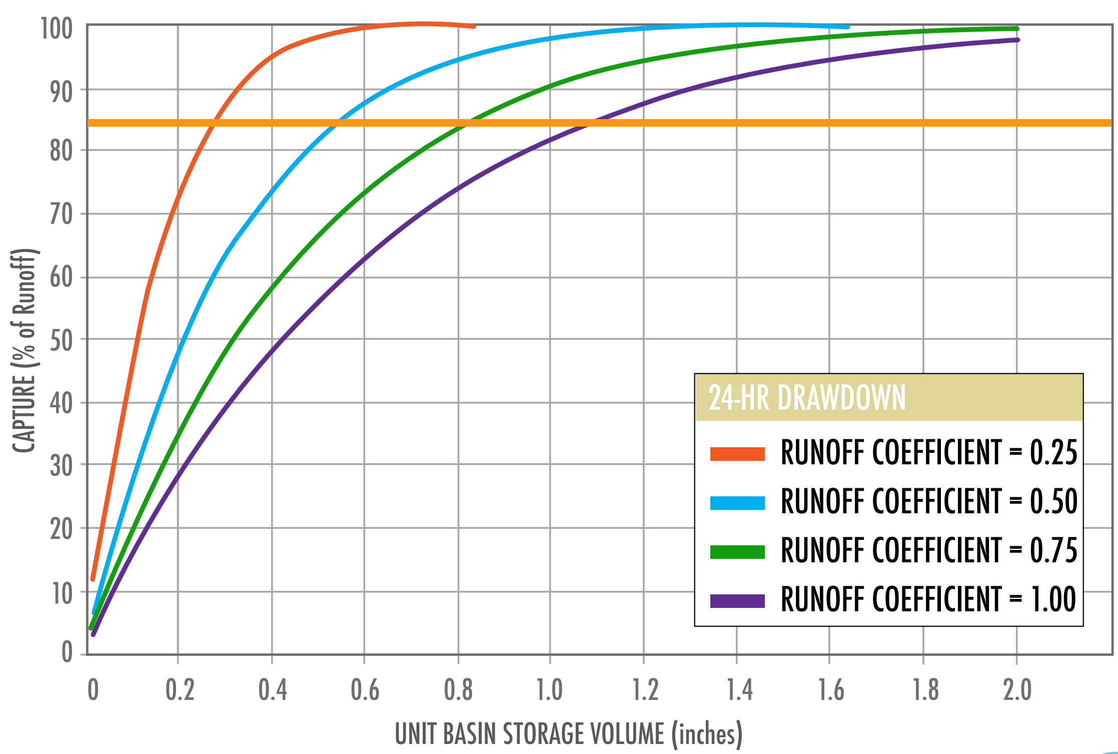
In new development, vegetated swales should be sized to capture the 85th percentile runoff volume for their contributing catchment. For redevelopment or retrofit projects, however, the vegetated swale can either be sized to capture the 85th percentile runoff volume or the design volume will be based on the maximum size the vegetated swale can be. For example, in a retrofit project, the available area and depth that can be used for design may not be enough to completely capture the 85th percentile runoff volume. The design volume, in this case, would be the maximum volume of runoff the proposed vegetated swale can hold. This volume would correspond to some "percentile" volume lower than 85th.

If the 85th percentile runoff volume can be designed for, it should. Otherwise, the vegetated swale will not be able to capitalize on a majority of storms. Alternatively, the vegetated swale should not be designed for a volume greater than the 85th percentile, even if there is sufficient room. Storm events producing runoff greater than the 85th percentile are not as common, so a larger vegetated swale will cost more money to infiltrate and treat an insignificant increase in runoff volume.

85th Percentile Design Volume Approach

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil. Catchment areas should be less than 5 acres.
- Determine the runoff coefficient. The runoff coefficient is an indicator of how much pervious / impervious surface makes up the watershed draining to the Green Street LID project location (0.25, 0.5, 0.75, or 1.00). A runoff coefficient of 0.25 is used for watersheds with almost 0% impervious area while a coefficient of 1.00 is used for watersheds with almost 100% impervious areas. Analyzing the watershed area, determine the runoff coefficient to be used for design. A higher, conservative estimate is always better to use.
- Using the Sizing Curves graph below, find the "Unit Basin Storage Volume" (inches), corresponding to the intersection of the 85% runoff capture and the selected runoff coefficient curve.
- Multiply the contributing watershed drainage area, DA (units of ft^2) by the unit basin storage volume (units of feet), to obtain the 85th percentile volume, V_{design} (units of ft^3), the vegetated swale must hold.

$$V_{design}\ (ft^3) = DA\ (ft^2) \times \text{Unit Basin Storage Volume (ft)}$$



Sizing Curves Source: 4

Maximum Runoff Volume Design Approach

- Determine the maximum volume, V_{max} (units of ft^3), that can be captured by the vegetated swale at the selected site. This will be:

$$V_{max} = A_{max} \times f_{design} \times t$$

Where: A_{max} = maximum area of the vegetated swale (ft^2)
f_{design} = design infiltration rate (in/hr)
t = maximum retention time (max 96 hrs) (hrs)

- Determine the total catchment area, DA (ft^2), that drains to the upstream-most point of the project. This area will most likely be made up of various land use and soil types that have an effect on how much precipitation is absorbed by the soil.
- Divide the maximum infiltration trench volume, V_{max} (ft^3), by the total catchment drainage area, DA (ft^2) to obtain the equivalent Unit Basin Storage Volume (ft). Convert this to inches.
- Analyzing the watershed area, determine the runoff coefficient to be used for design.
- Using the Sizing Curves graph below, find the "Capture (% Runoff)", corresponding to the intersection of the Unit Basin Storage Volume (inches) and the selected runoff coefficient curve. This is the "percentile" stormwater runoff that the Green Street LID Application can capture.

04 Calculate Peak Flow Rate

Since the contributing watershed should be small (<20 acres), the rational method is sufficient to calculate the peak runoff. Using precipitation-intensity tables from the NOAA database to determine storm intensity, the flow rate will be:

$$Q = CiA$$

Where: Q = flow rate of captured runoff (cfs)
i = intensity (in/hr)
A = drainage area (acres)

05 Calculate the Swale Bottom Width

For shallow flow depths in vegetated swales, channel side slopes can be ignored to create the following modified Manning's equation:

$$b = (Q \times n) / (1.49 \times d^{1.67} \times s^{0.5})$$

Where: b = swale base width (2-ft min to 10-ft max) (ft)
Q = flow rate (cfs)
n = Manning's coefficient (0.25-0.3)
d = design flow depth (4-inch max) (ft)
s = design slope (2% min to 6% max) (ft/ft)

If the available width is less than the required width (Maximum Runoff Volume Design Approach), use the maximum available width and adjust the capture / treatment volume accordingly.

If the calculated base width is less than 2 ft, use a design base width of 2 ft and proceed to Step 6. If the calculated base width is greater than 10 ft, either increase "s", increase "d", or use a divider. If a divider is implemented, the maximum base width can be increased to 16 ft. The divider is placed in the center of the swale in the direction of flow at least ¾ of the swale length, beginning at the inlet.

06 Calculate the Design Velocity

$$v = Q / A_{cs}$$

Where: v = velocity (max 1 ft/s) (ft/s)
Q = flow rate (cfs)
A_{cs} = swale cross-sectional area (ft^2)

If the calculated velocity is greater than 1 ft/s, modify the longitudinal slope, bottom width, or flow depth accordingly.

07 Calculate Design Length

The length of the swale in the direction of flow can be found using the following equation:

$$L = t \times v$$

Where: L = length of swale in direction of flow (100 ft minimum) (ft)
t = hydraulic residence time (10min minimum) (seconds)
v = design velocity (ft/s)

If the calculated length is less than 100 ft, increase the length to a minimum of 100 ft and proceed to Step 8.

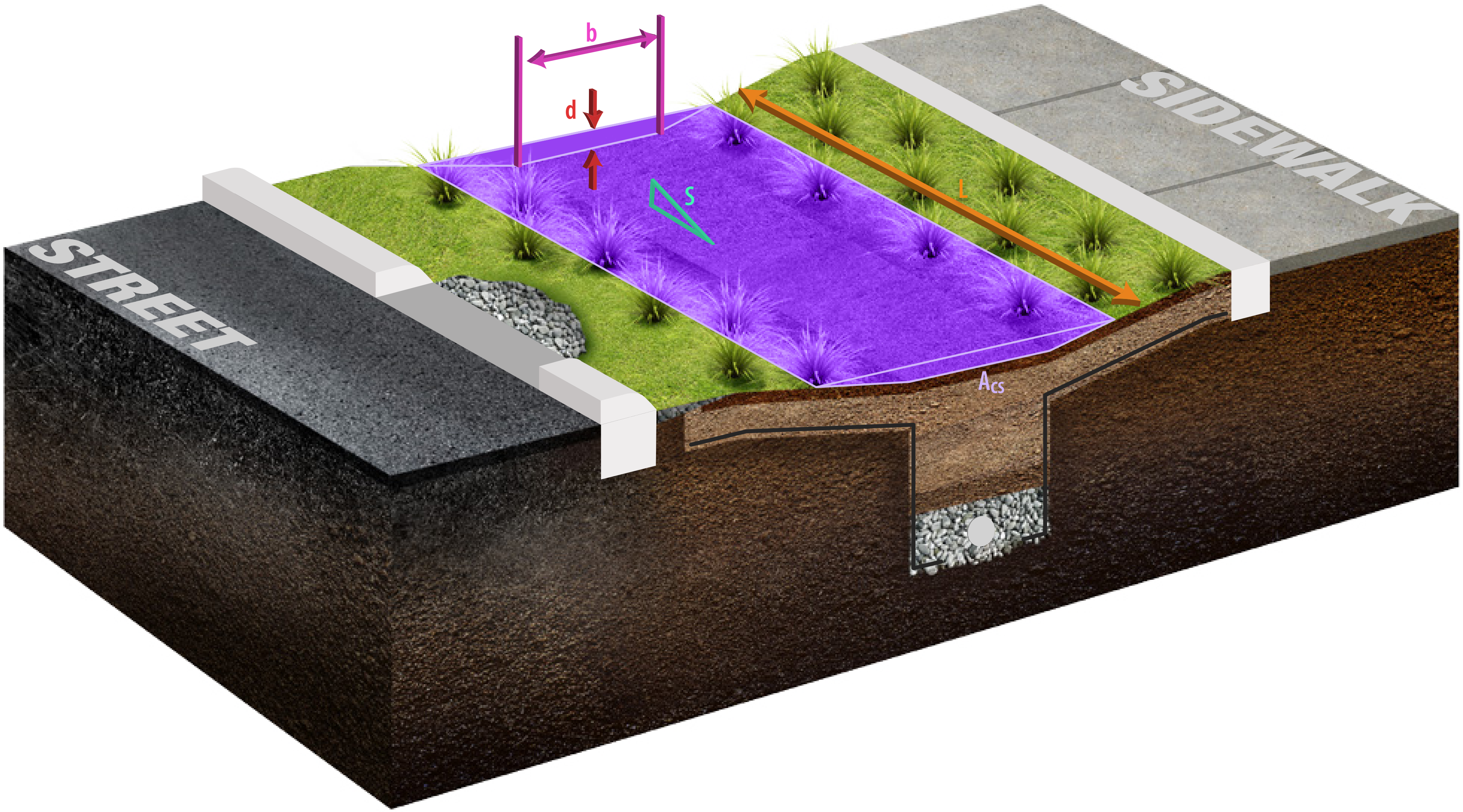
08 Check that Captured Volume Drains within 96 hrs

The vegetated swale needs to be able to drain within 96 hours. Check that the design volume can infiltrate with the following equation:

$$t = V / ((f_{design} / 12) \times L \times b)$$

Where: t = time to infiltrate (hrs)
V = design volume (ft^3)
f_{design} = design infiltration rate (in/hr)
L = length of vegetated swale in direction of flow (ft)

If $t \leq 96$ hrs then the design area, depth, and infiltration rate are adequate. If $t > 96$ hrs, the area needs to be expanded or the soil can be amended to drain in the required amount of time.

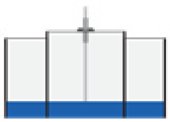


Isometric illustration of enhanced open swales dimension and variables.

Example Scenario

01 Identify Project Location

Looking back at the General Application example that was previously shown, suppose the vegetated swale turned out to be the most suitable application, instead of an infiltration trench. The drainage area is 2 acres:



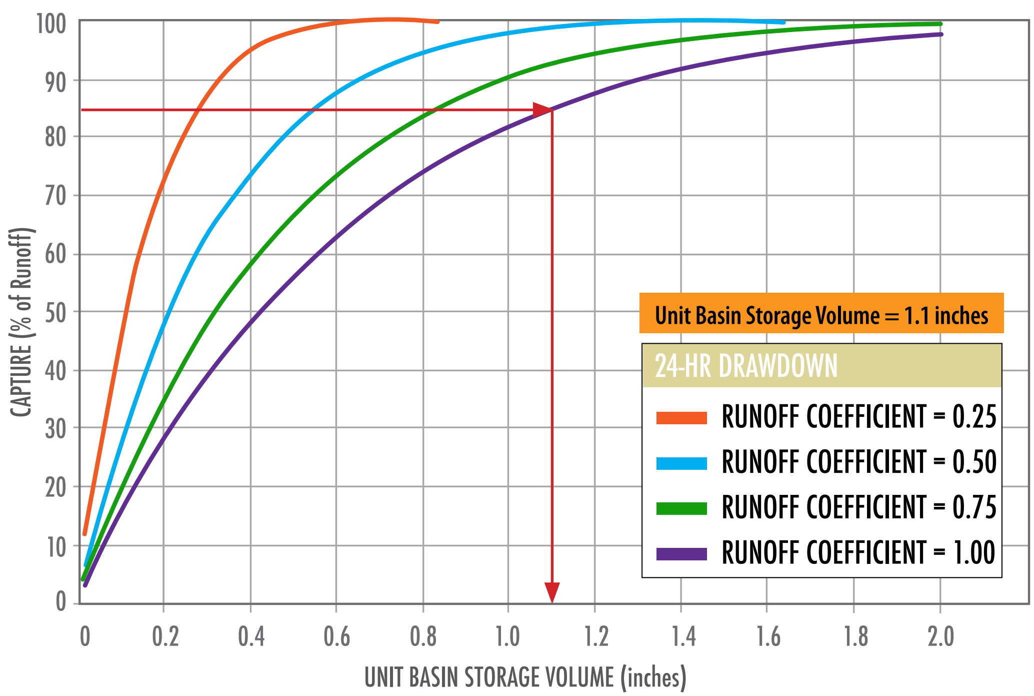
02 Determine the Design Infiltration Rate

- Choose a type of infiltration test to perform: Double-ring Infiltrometer
- Follow the procedures laid out in ASTM D-3385
- $f_{design} = 11.8$ in/hr
- 12 in/hr > 6 in/hr > 0.5 in/hr ✓

03 Determine Design Volume

85th Percentile Design Volume Approach:

- Determine Total Catchment area: 2 acres
- Determine the Runoff Coefficient: 1.00 (almost 100% impervious)
- Use the Sizing Curves graph to determine the Unit Basin Storage Volume (inches)



- Calculate the design Volume necessary to capture the 85th percentile runoff:

$$\mathbf{V = (Unit\ Basin\ Storage\ Volume\ ft) \times (Drainage\ Area\ ft^2)}$$

$$V = (1.1\ \text{inches} / 12\ \text{in/ft}) \times (2\ \text{acres} \times 43{,}560\ \text{ft}^2/\text{acre})$$

$$\mathbf{V = 7{,}986\ ft^3}$$

04 Calculate Peak Flow Rate

From NOAA, the precipitation intensity for a 24-hr storm of 1-yr frequency is ~0.1 in/hr. The 85th percentile precipitation is a precipitation value that encompasses up to 85% of storms that occur in a year. Since an 85th percentile storm is guaranteed to happen every year, the 1-yr storm was selected.

C = 1.00 since the drainage area is heavily urbanized

The drainage area is the area shown at the beginning of this design example: 2 acres

$$\mathbf{Q = CiA}$$

$$Q = 1.00 \times 0.1 \times 2\ \text{acres}$$

$$\mathbf{Q = 0.2\ cfs}$$

05 Calculate the Swale Bottom Width

Use a Manning's coefficient of 0.25, a design depth of 4-inches, and a slope of 2%:

$$\mathbf{b = (Q \times n) / (1.49 \times d^{1.67} \times s^{0.5})}$$

$$b = (0.2 \times 0.25) / (1.49 \times (4/12)^{1.67} \times 0.02^{0.5})$$

$$b = 1.49\ \text{ft}$$

$$\mathbf{Since\ b < 2ft,\ b = 2ft}$$

06 Calculate the Design Velocity

Use a design swale depth of 2 ft and side slopes at 2:1 to calculate velocity:

$$v = Q / A$$
$$v = 0.2 / (2 \times 2 + 2 \times (0.5 \times (2 \times 1) \times 2))$$
$$\mathbf{v = 0.025\ ft/s}$$

07 Calculate the Design Length

Use a hydraulic residence time of 60 mins (3600 seconds) and a design velocity of 0.025 ft/s:

$$L = t \times v$$
$$L = 3{,}600 \times 0.025$$
$$\mathbf{L = 100\ ft}$$

$L < 100$ ft therefore use $L = 100$ ft

08 Check that the Captured Volume Drains within 96 hours

$$t = V / (f_{design} / 12) \times L \times W)$$
$$t = 7{,}986 / ((6 / 12) \times 100 \times 2)$$
$$\mathbf{t = 88.73\ hrs < 96\ hrs} \ \checkmark$$

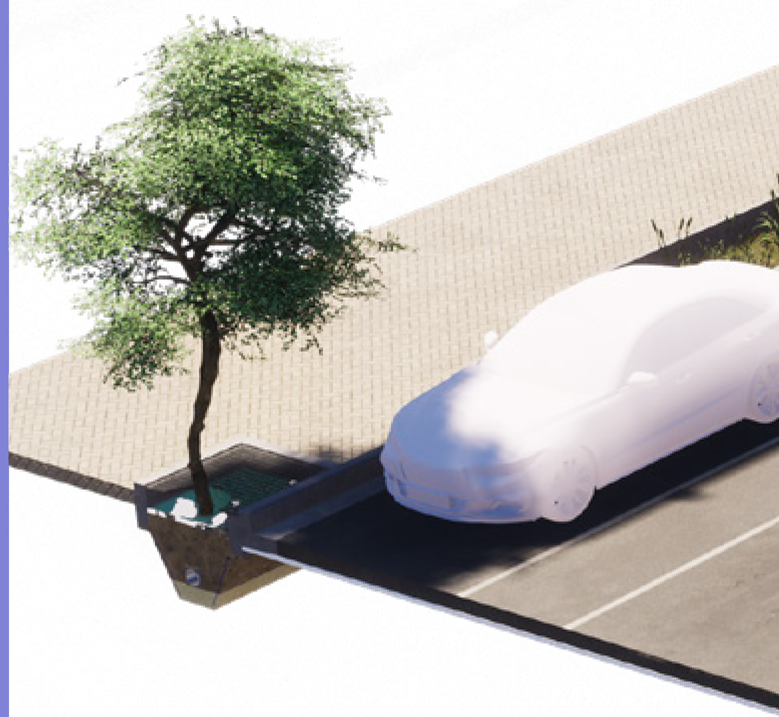
Curb side vegetated swale with outlet structure

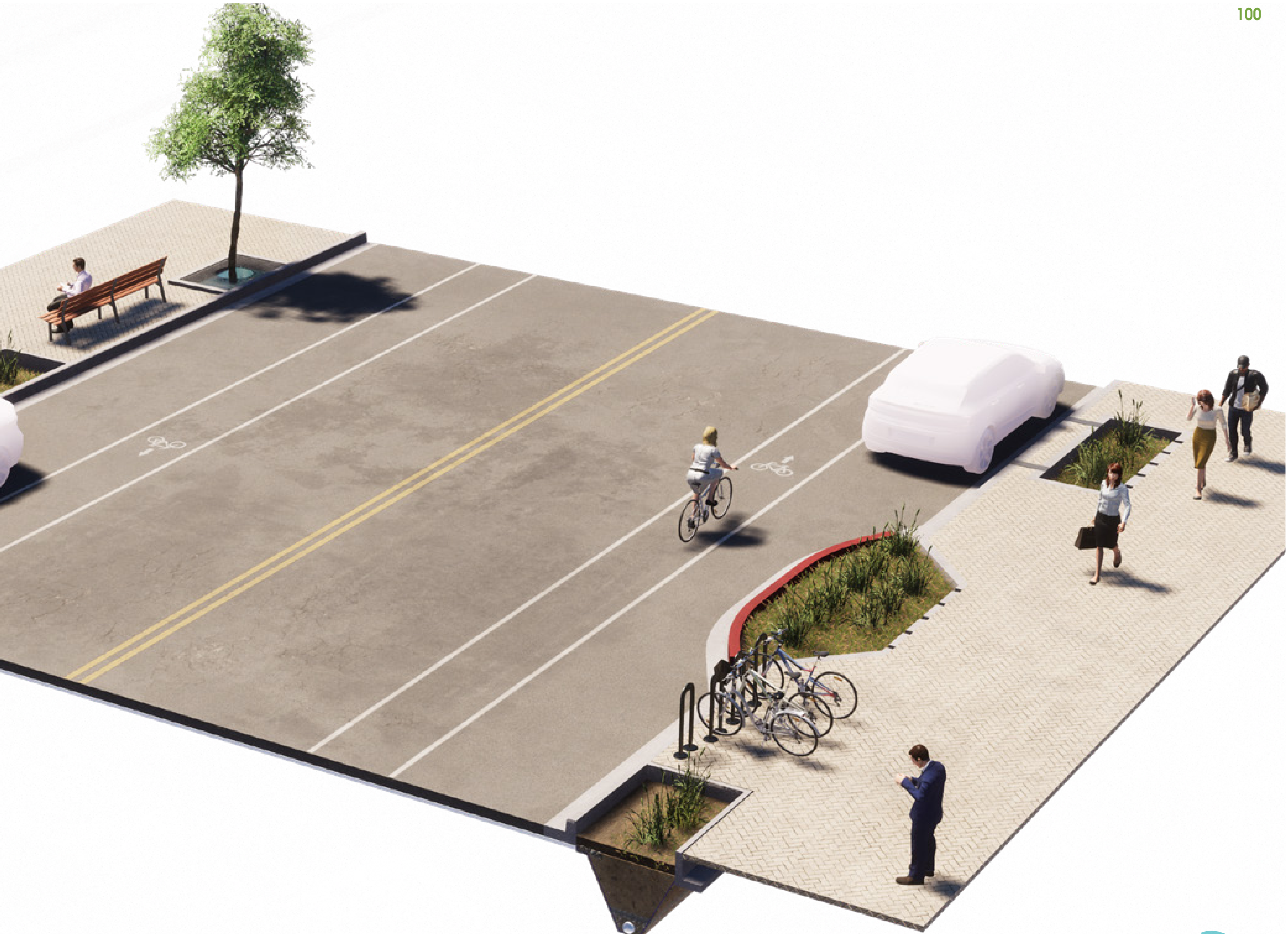
SUMMARY OF SIZING

- $V = 7{,}986\ ft^3$
- $L = 100$ ft
- $b = 2$ ft
- $S = 2\%$
- $f_{design} = 6$ in/hr
- $t = 89$ hrs

04 STANDARD DETAIL DRAWINGS

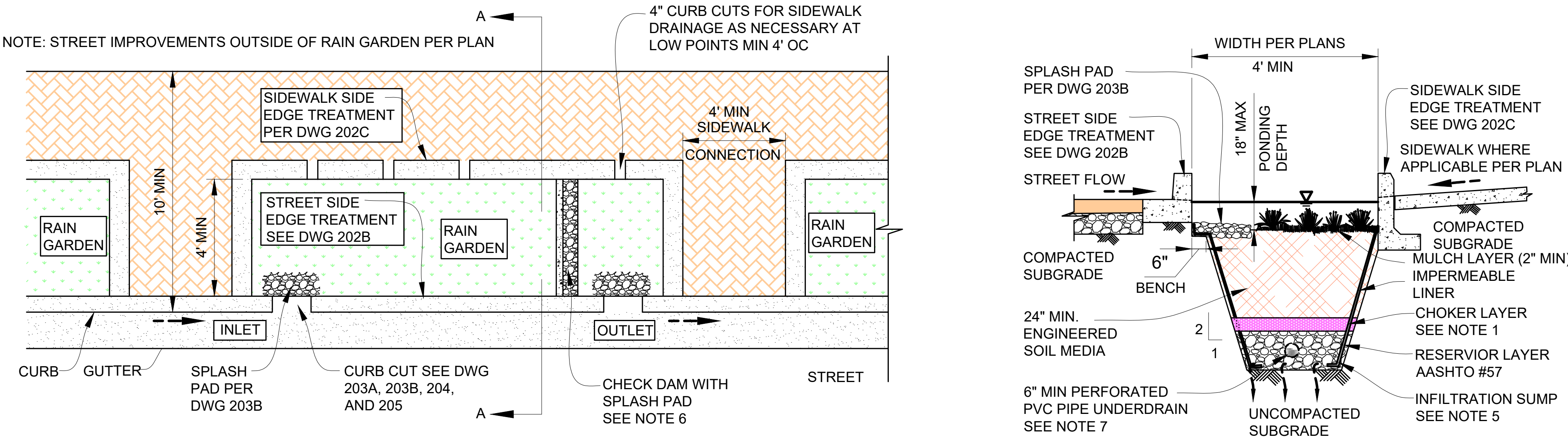
- Rain Garden
- Tree Box Filter
- Infiltration Trench
- Permeable Pavements
- Vegetated Buffers
- Enhanced Open Swales
- Miscellaneous LID Details





Rain Garden

NOTE: STREET IMPROVEMENTS OUTSIDE OF RAIN GARDEN PER PLAN



PLAN VIEW

SECTION A-A

NOTES:

1. CHOKER LAYER IS OPTIONAL PER GEOTECHNICAL ENGINEER RECOMMENDATION.
2. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
3. PLANTINGS SHALL BE INSTALLED IN ACCORDANCE WITH DESIGN PLAN.
4. BOTTOM OF RAIN GARDEN SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE, AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
5. DEPTH OF INFILTRATION SUMP AS SHOWN ON DESIGN PLANS SHALL BE SIZED TO ADDRESS STORMWATER MANAGEMENT REQUIREMENTS.
6. CHECK DAM SHALL BE SPECIFIED AS NECESSARY PER DWG 209A THROUGH 210B.
7. SEE DWG 208 FOR MINIMUM BEDDING REQUIREMENT AND CONNECTION TO CATCH BASIN.

CITY OF SANTA CLARITA

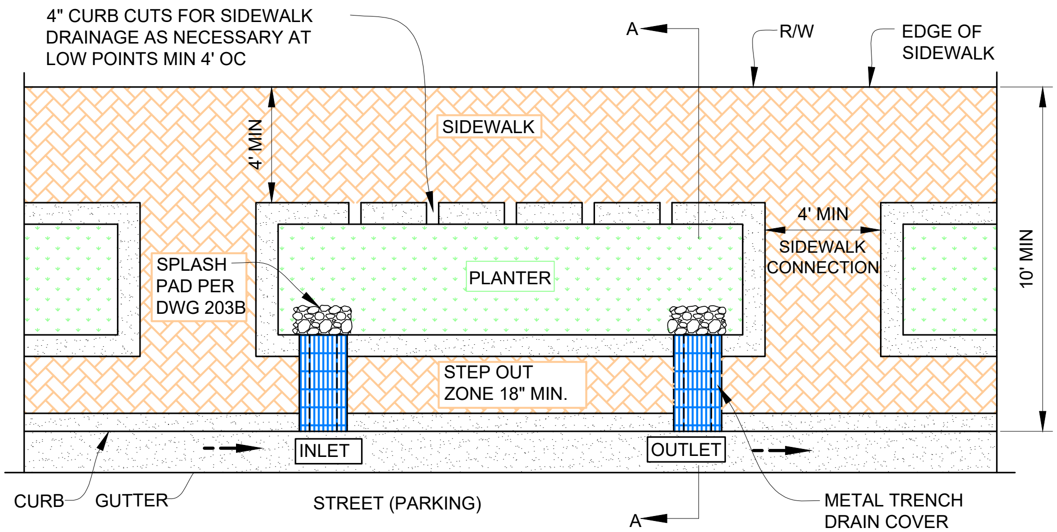
RAIN GARDEN PLANTER - 1 (NO STEP OUT ZONE)

CURB SIDE

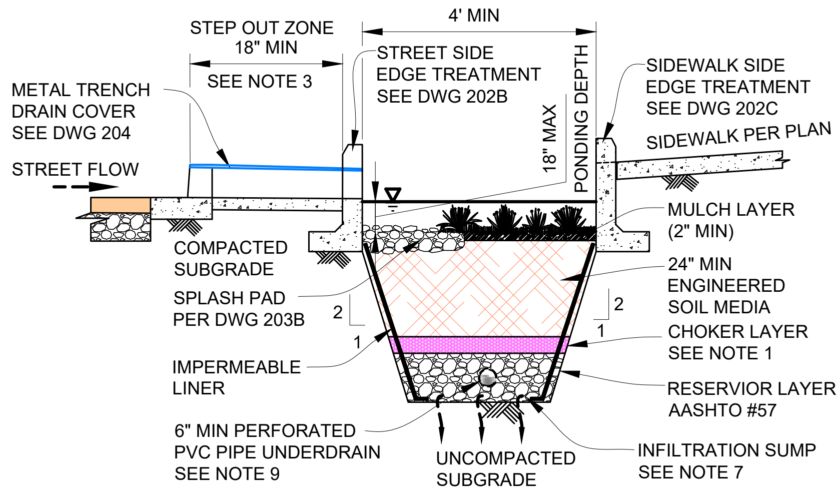
NOT TO SCALE

DRAWING NUMBER

100



PLAN VIEW



SECTION A-A

NOTES:

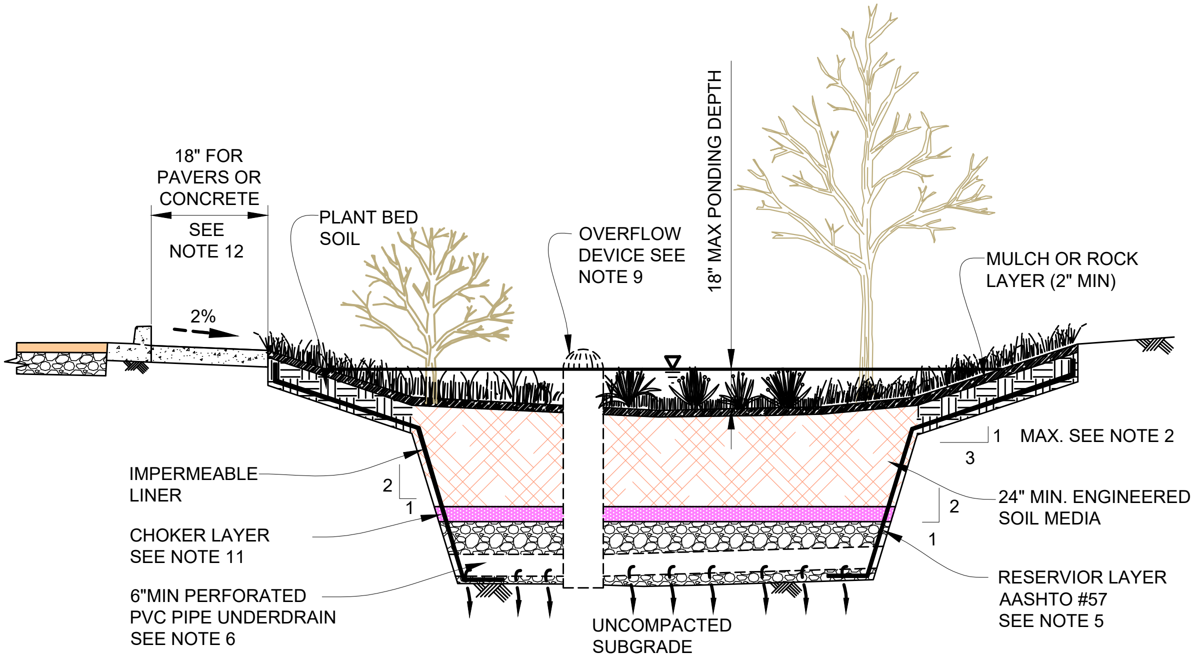
1. CHOKER LAYER IS OPTIONAL PER GEOTECHNICAL ENGINEER RECOMMENDATION.
2. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
3. STEP OUT ZONE REQUIRED WHEN PARALLEL PARKING IS PROVIDED. INSTALLATION MAY BE STANDARD CONCRETE SIDEWALK OR PAVEMENT BASED ON SURROUNDING CONDITIONS.
4. FOR EDGE TREATMENT OPTIONS SEE DWG 202A/B/C.
5. PLANTINGS SHALL BE INSTALLED IN ACCORDANCE WITH DESIGN PLAN.
6. BOTTOM OF RAIN GARDEN SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE, AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
7. DEPTH OF INFILTRATION SUMP AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER MANAGEMENT REQUIREMENTS.
8. OUTLET REQUIRED AS SPECIFIED BY PLANS.
9. SEE 208 FOR MINIMUM BEDDING REQUIREMENT AND CONNECTION TO CATCH BASIN.

CITY OF SANTA CLARITA

RAIN GARDEN PLANTER - 2 (WITH STEP OUT ZONE) CURB SIDE

NOT TO SCALE

DRAWING NUMBER **101**



ELEVATION

NOTES:

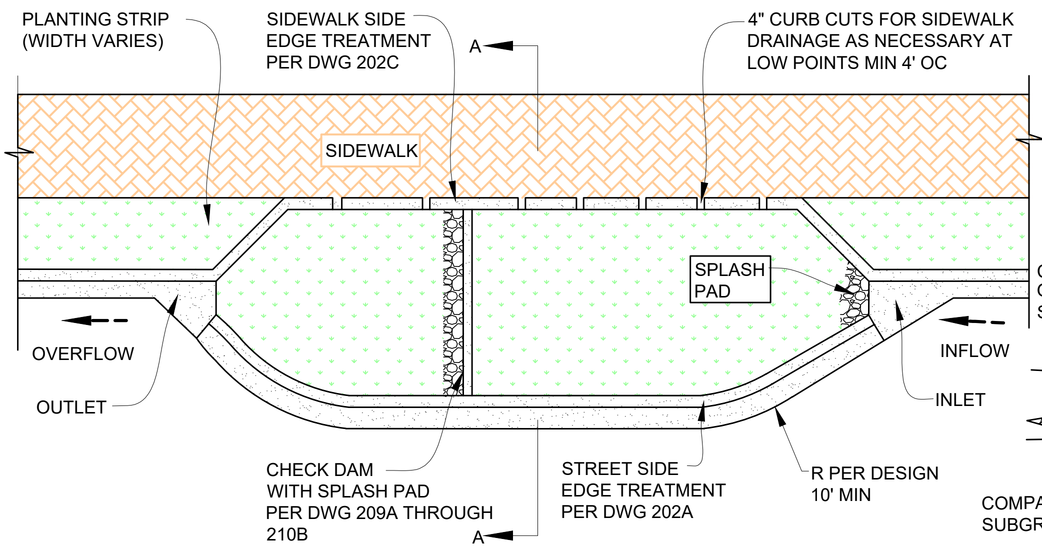
1. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
2. SIDE SLOPES STEEPER THAN 3:1 MAY BE ALLOWED WITH CITY APPROVAL.
3. FOR ALTERNATIVE EDGE TREATMENT CONDITIONS, SEE DWG 202A.
4. BOTTOM OF RAIN GARDEN SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE, AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
5. RESERVOIR LAYER DEPTH SHALL VARY PER DESIGN PLANS, TO ACHIEVE A WATER STORAGE LAYER/ INFILTRATION SUMP WHEN APPLICABLE.
6. SEE DWG 208 FOR MINIMUM BEDDING REQUIREMENT AND CONNECTION TO CATCH BASIN.
7. DISTANCE TO ROADWAY MAY BE REDUCED WHEN THE SIDE IS LINED WITH IMPERMEABLE LINER, PER DESIGN PLANS.
8. SEE DWG 207 FOR CLEAN OUT AND OBSERVATION WELL DETAIL.
9. RAIN GARDEN FACILITY DEPICTED IS ONE WITH AN OVERFLOW STRUCTURE. "OFF-LINE" FACILITIES DESIGNED TO LIMIT INFLOW SO THAT OVERFLOW STRUCTURES ARE NOT REQUIRED ARE ALSO PERMISSIBLE, AS SHOWN ON DESIGN PLANS; OUTFALL/ OVERFLOW ELEVATION 2" MIN BELOW SIDEWALK.
10. IF DEPTH FROM SURROUNDING GRADE TO LOW POINT OF FACILITY EXCEEDS 5 FEET, A FENCE IS REQUIRED AROUND ENTIRE FACILITY.
11. CHOKER LAYER IS OPTIONAL PER GEOTECHNICAL ENGINEER RECOMMENDATION.
12. THE MAINTENANCE STRIP SHALL BE 18" FOR PAVERS OR CONCRETE, AND 6" FOR THE CURB, FOR A TOTAL WIDTH OF 24" WIDE WALKABLE SURFACE. SEE MAINTENANCE STRIP DETAIL, DRAWING NUMBER 212.

CITY OF SANTA CLARITA

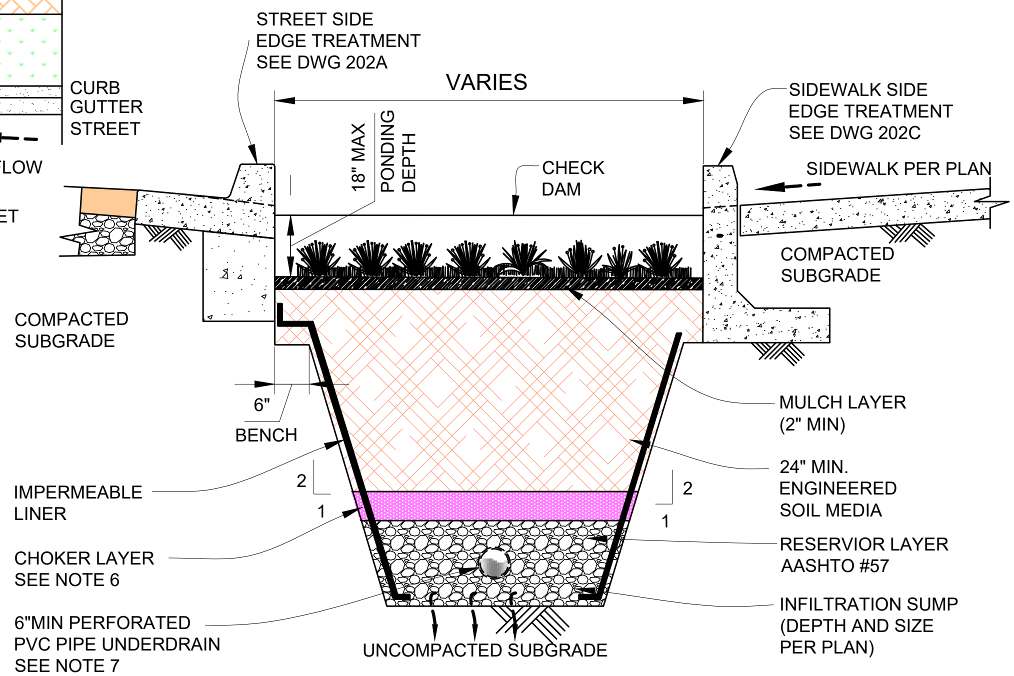
RAIN GARDEN PLANTER IN OPEN AREA STREET MEDIAN

NOT TO SCALE

DRAWING NUMBER **102**



IN-PLANTING STRIP PLAN VIEW



SECTION A-A
(WALL OPTION)

NOTES:

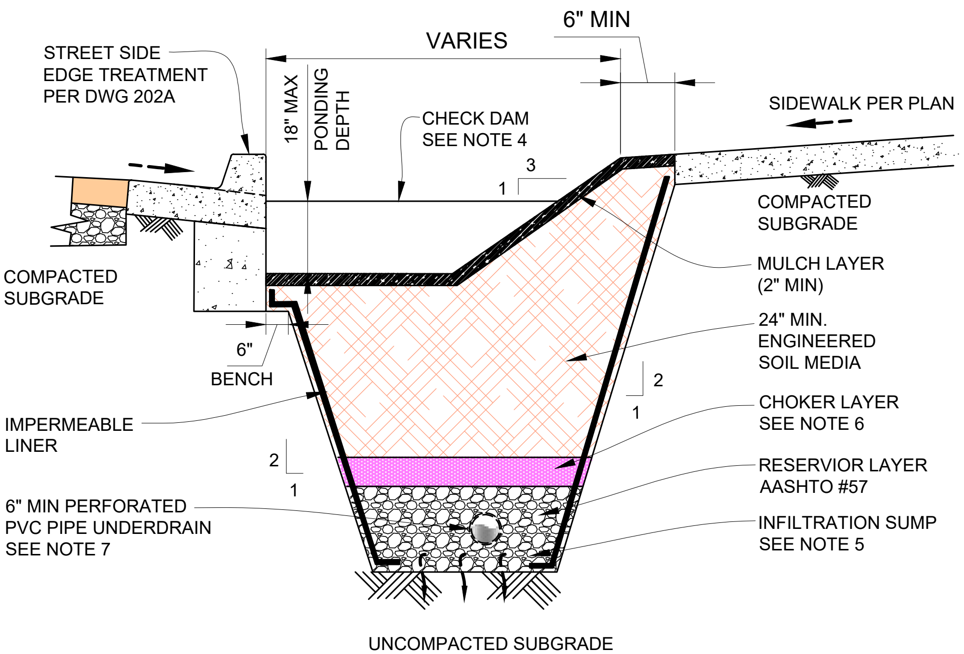
SEE DWG 103B FOR NOTES.

CITY OF SANTA CLARITA

RAIN GARDEN PLANTER - 1 (NON-SLOPED OPTION)
STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER **103A**



SECTION A-A
(SLOPE OPTION)

NOTES:

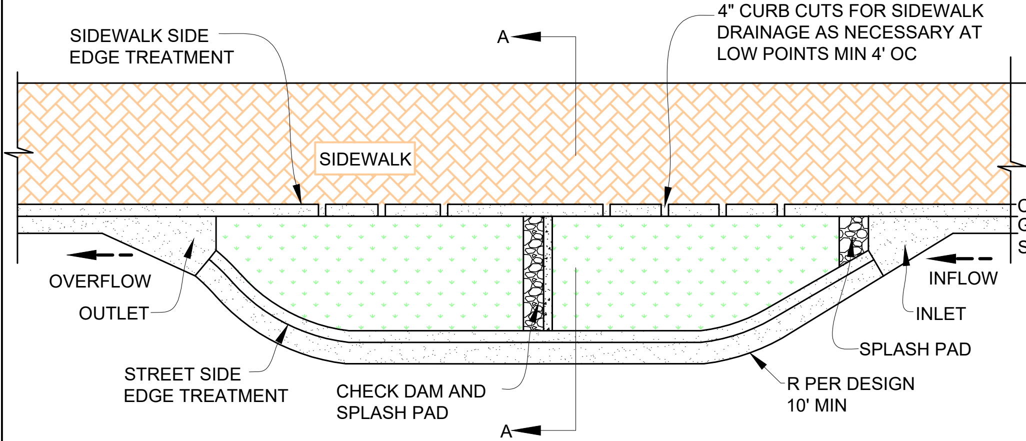
1. LONGITUDINAL SLOPE OF PLANTER MATCHES ROAD OR FLATTER AS REQUIRED PER DESIGN PLANS.
2. SIDEWALK ELEVATION MUST BE SET ABOVE INLET AND OUTLET ELEVATIONS TO ALLOW OVERFLOW TO DRAIN TO STREET BEFORE PONDING LEVEL REACHES SIDEWALK.
3. SEE DWG 206 FOR INLET AND OUTLET DETAILS.
4. CHECK DAMS REQUIRED AS PER DESIGN PLANS. SEE DWG 209A THROUGH 210B.
5. DEPTH OF INFILTRATION SUMP AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER MANAGEMENT REQUIREMENTS.
6. CHOKER LAYER IS OPTIONAL PER GEOTECHNICAL ENGINEER RECOMMENDATION.
7. SEE 208 FOR MINIMUM BEDDING REQUIREMENT AND CONNECTION TO CATCH BASIN.

CITY OF SANTA CLARITA

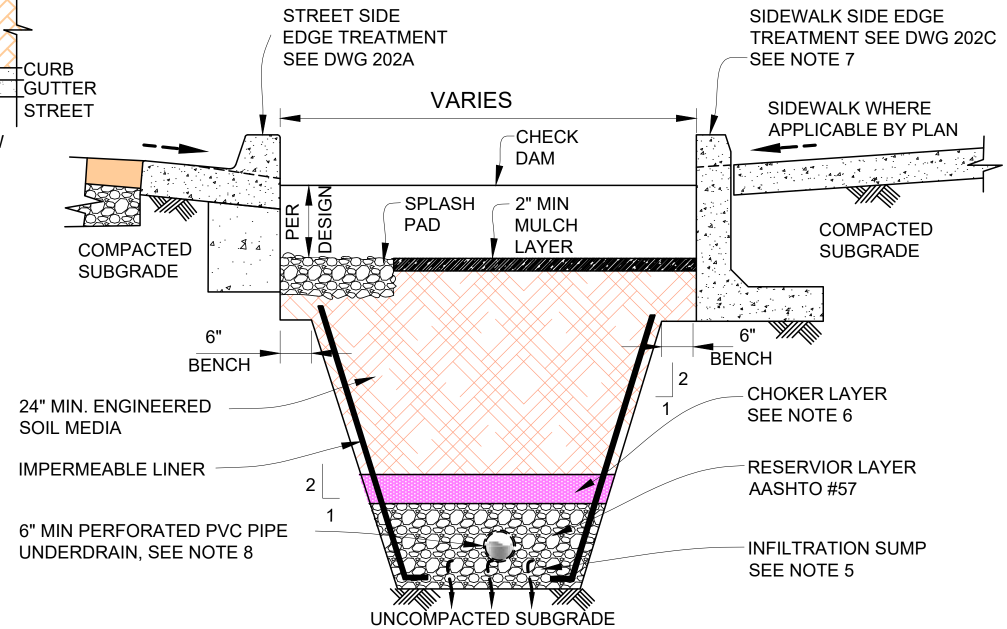
RAIN GARDEN PLANTER - 2 (SLOPED OPTION)
STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
103B



IN-STREET PLAN VIEW



SECTION A-A

NOTES:

1. LONGITUDINAL SLOPE OF PLANTER MATCHES ROAD OR FLATTER AS REQUIRED PER DESIGN PLANS.
2. SIDEWALK ELEVATION MUST BE SET ABOVE INLET AND OUTLET ELEVATIONS TO ALLOW OVERFLOW TO DRAIN TO STREET BEFORE PONDING LEVEL REACHES SIDEWALK.
3. SEE DWG 206 FOR INLET AND OUTLET DETAILS.
4. DEPTH OF INFILTRATION SUMP AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER MANAGEMENT REQUIREMENTS.
5. CHOKER LAYER IS OPTIONAL PER GEOTECHNICAL ENGINEER RECOMMENDATION.
6. A 3 TO 1 SLOPE MAY BE USED IN LIEU OF THE L-WALL WHERE ADEQUATE SPACE IS AVAILABLE SEE DWG 103B.
7. CHECK DAMS REQUIRED AS PER DESIGN PLANS SEE DWG 209A THROUGH 210.
8. SEE DWG 208 FOR MINIMUM BEDDING REQUIREMENT AND CONNECTION TO CATCH BASIN.

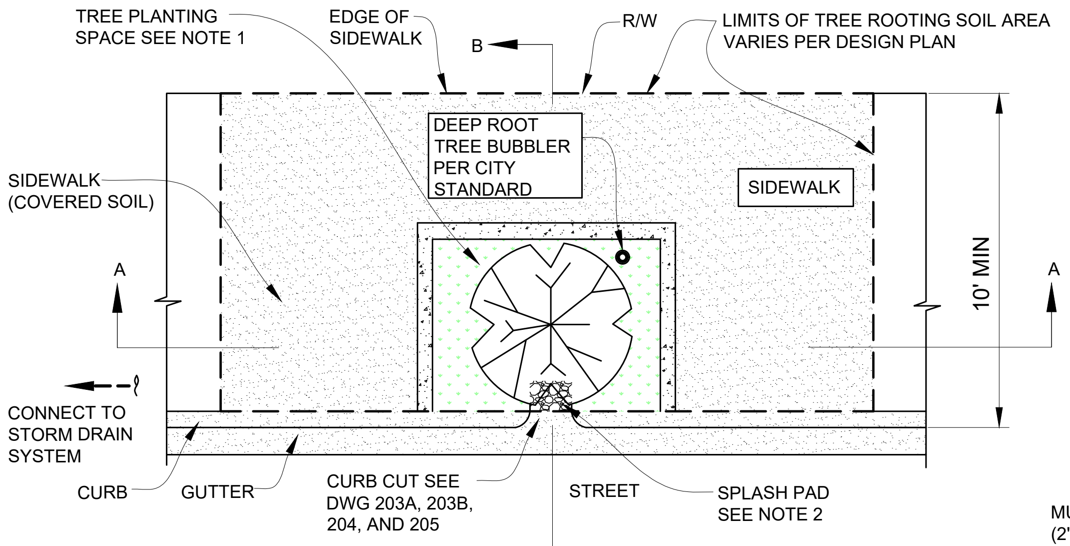
CITY OF SANTA CLARITA

RAIN GARDEN PLANTER (WITHOUT PLANTING STRIP) STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
103C

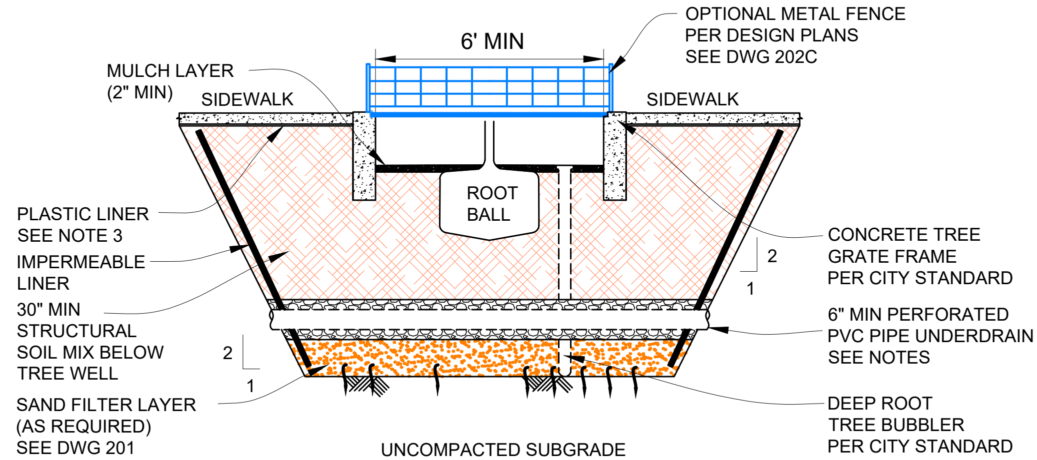
Tree Box Filter



PLAN VIEW

NOTES:

1. MINIMUM OPEN TREE PLANTING SPACE SHALL BE PROVIDED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
2. PROVIDE SPLASH PAD FOR TREE PLANTING SPACE PER DWG 203B.
3. PROVIDE PLASTIC LINER WHERE CONCRETE WILL BE POURED ON TOP OF STRUCTURAL SOIL PER GREEN BOOK STANDARD SPECIFICATIONS SECTION 210-2.
4. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
5. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
6. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.



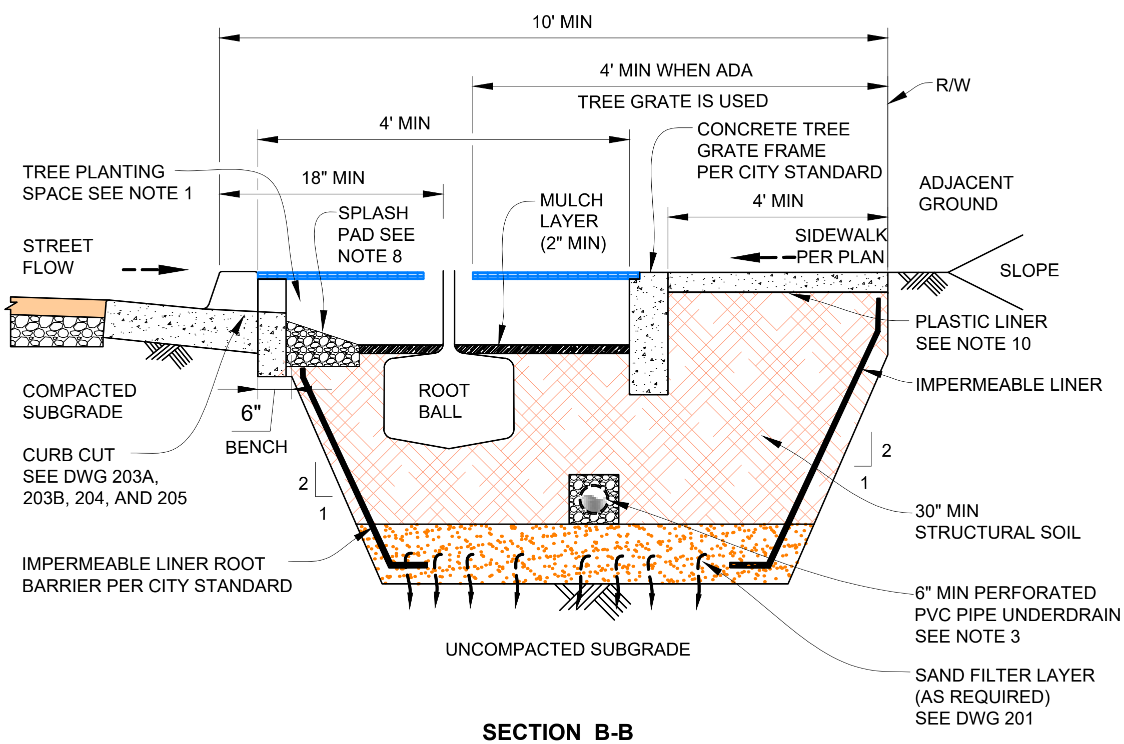
SECTION A-A

CITY OF SANTA CLARITA

TREE BOX FILTER
STREET MEDIAN/CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
104A



SECTION B-B

NOTES:

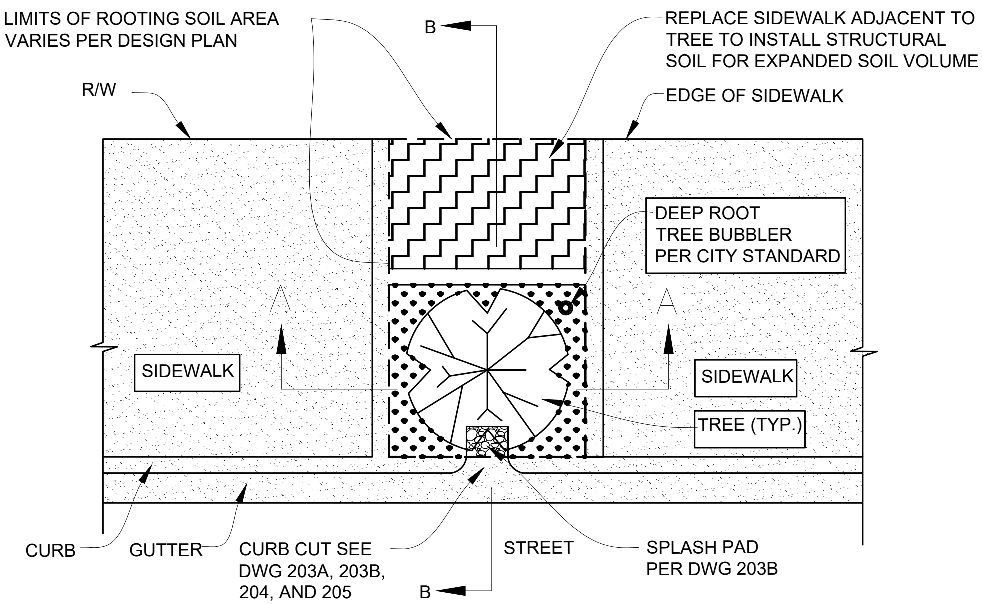
1. MINIMUM OPEN TREE PLANTING SPACE SHALL BE PROVIDED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
2. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
3. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
4. FOR SIDEWALK OVER STRUCTURAL SOIL DETAIL OPTIONS, SEE DWG 201.
5. SEE 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.
6. PROVIDE 18" DEEP ROOT BARRIER ON STREET SIDE OF TREE WELL AS NECESSARY.
7. REMOVE WIRE AND BURLAP FROM ROOT BALL PRIOR TO BACKFILLING.
8. PROVIDE SPLASH PAD FOR TREE PLANTING SPACE PER DWG 203B.
9. IN SOME INSTANCES A MODIFIED SECTION BELOW CURB MAY BE REQUIRED BASED ON SOIL CONDITIONS.
10. PROVIDE PLASTIC LINER WHERE CONCRETE WILL BE POURED ON TOP OF STRUCTURAL SOIL PER GREEN BOOK STANDARD SPECIFICATIONS SECTION 210-2.
11. CURRENT AMERICANS WITH DISABILITIES ACT (ADA) REQUIRES A MINIMUM WIDTH OF 4' FROM THE EDGE OF THE SIDEWALK TO THE BASE OF THE TREE TRUNK.

CITY OF SANTA CLARITA

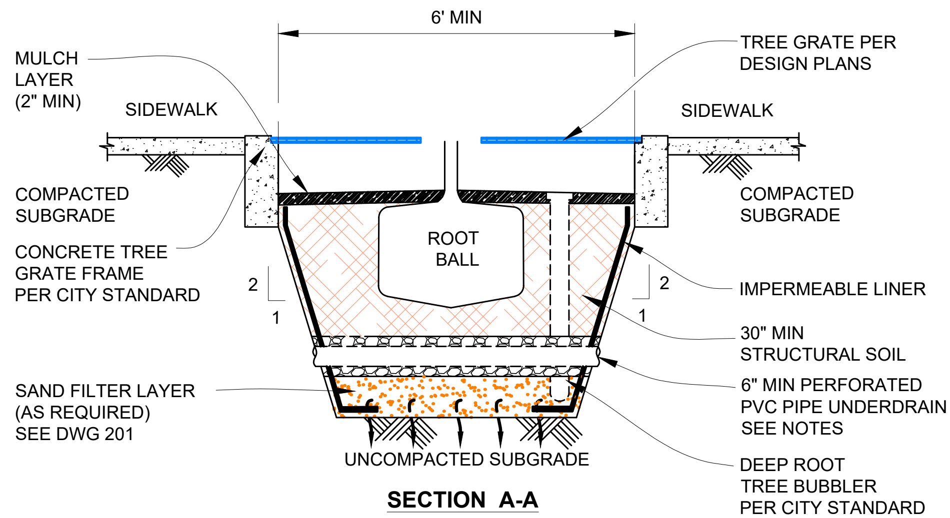
TREE BOX FILTER
CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
104B



PLAN VIEW



SECTION A-A

NOTES:

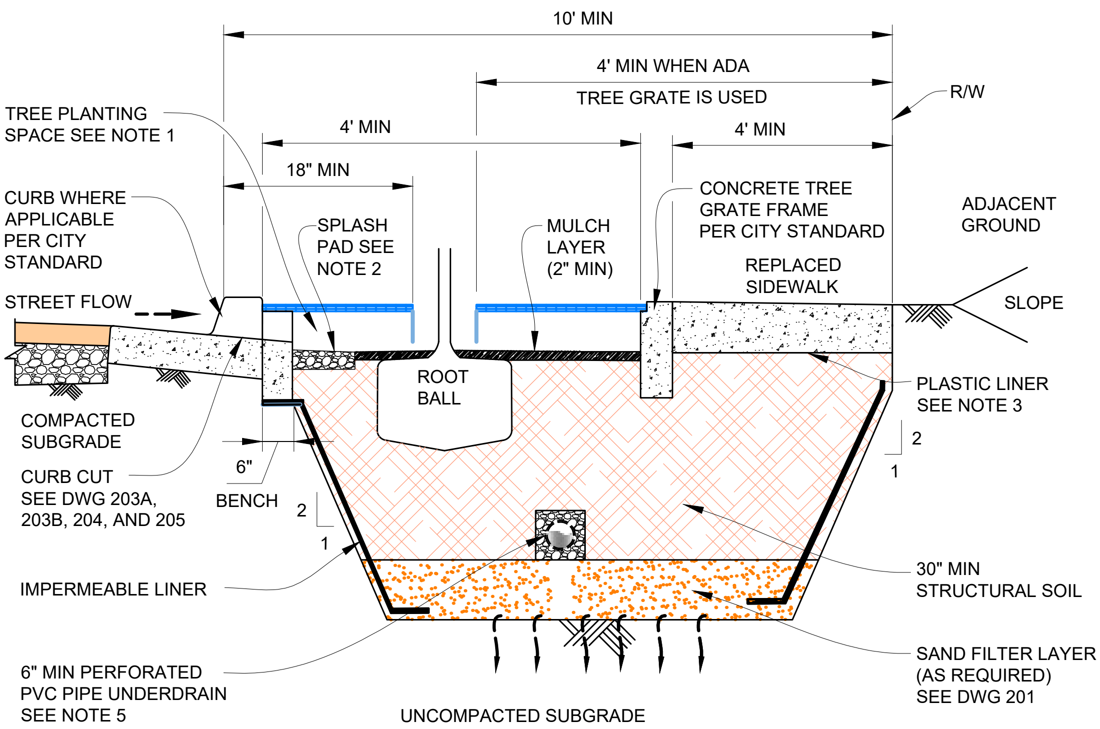
SEE DWG 105B FOR NOTES.

CITY OF SANTA CLARITA

TREE BOX FILTER
CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
105A



SECTION B-B

NOTES:

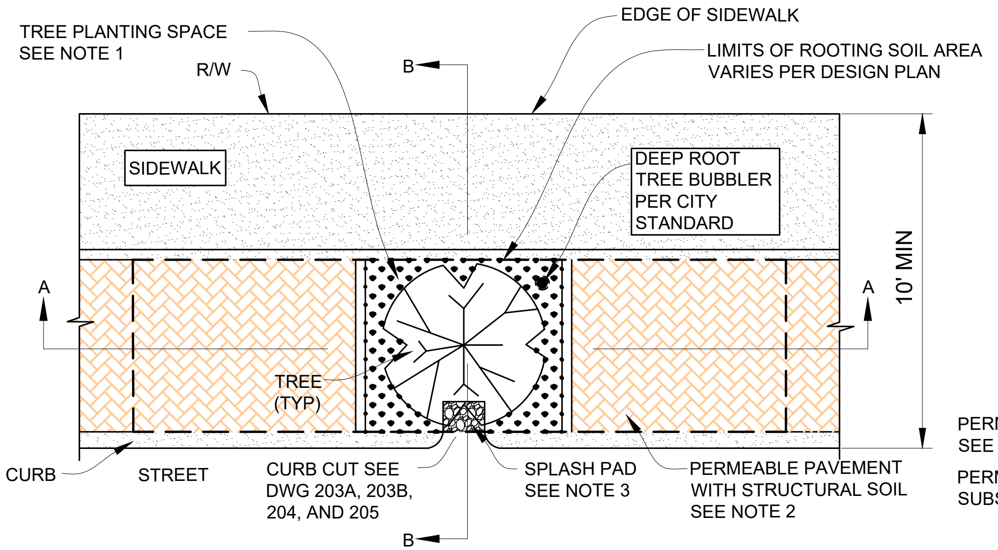
1. MINIMUM OPEN TREE PLANTING SPACE SHALL BE PROVIDED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
2. PROVIDE SPLASH PAD FOR TREE PLANTING SPACE PER DWG 203B.
3. PROVIDE PLASTIC LINER WHERE CONCRETE WILL BE POURED ON TOP OF STRUCTURAL SOIL PER GREEN BOOK STANDARD SPECIFICATIONS SECTION 210-2.
4. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
5. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
6. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.
7. PROVIDE 18" DEEP ROOT BARRIER ON STREET SIDE OF TREE WELL AS NECESSARY.

CITY OF SANTA CLARITA

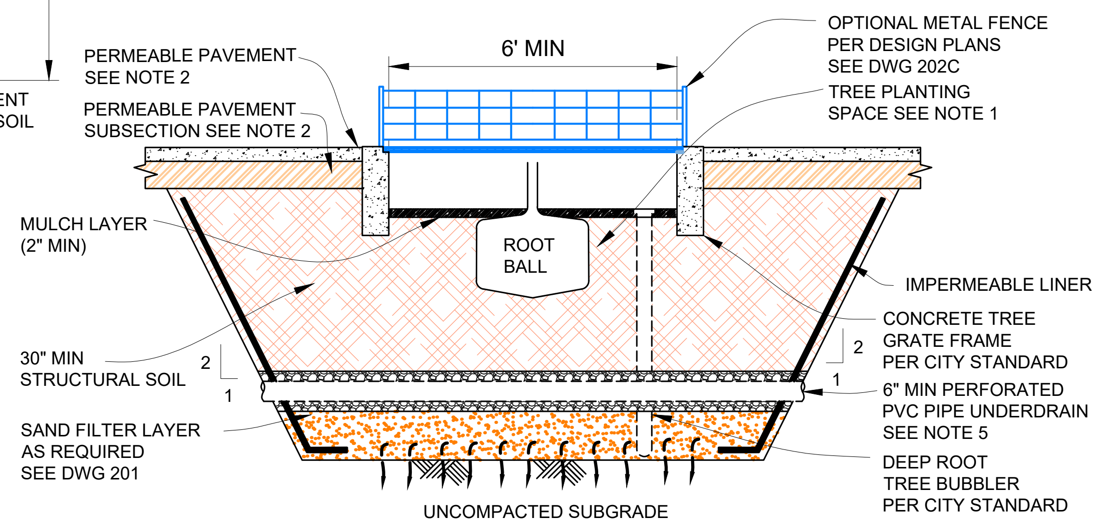
TREE BOX FILTER
CURB SIDE

NOT TO SCALE

DRAWING NUMBER
105B



PLAN VIEW



SECTION A-A

NOTES:

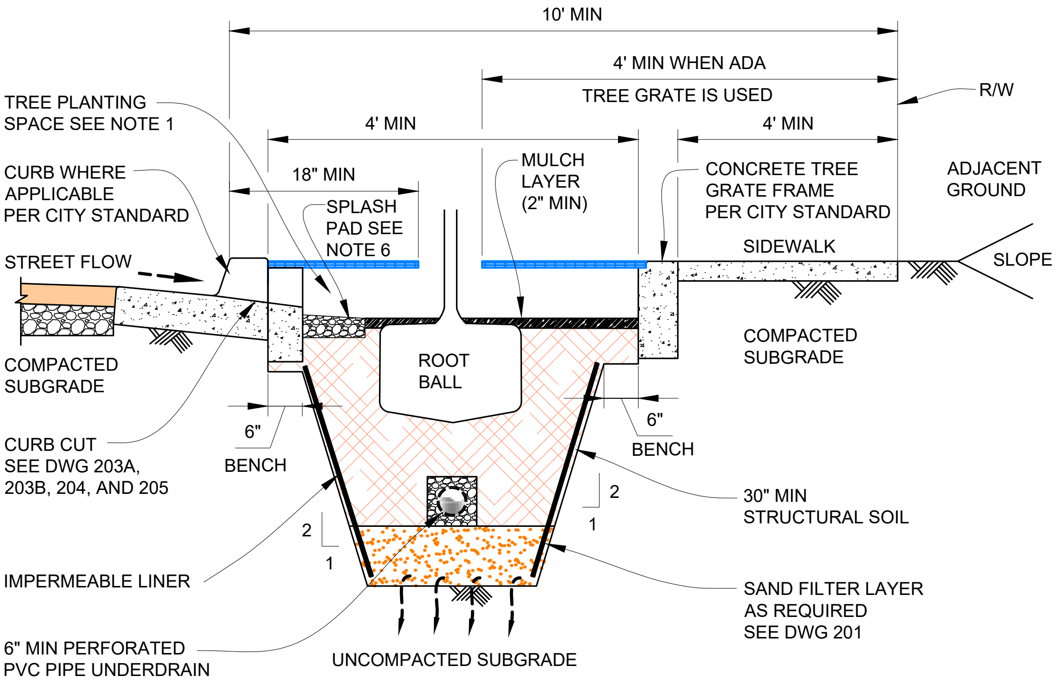
1. MINIMUM OPEN TREE PLANTING SPACE SHALL BE PROVIDED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
2. SEE DWG 120, 121, AND 122 FOR PERMEABLE PAVEMENT DETAIL OPTIONS.
3. PROVIDE SPLASH PAD FOR TREE PLANTING SPACE PER DWG 203B.
4. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
5. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
6. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.

CITY OF SANTA CLARITA

TREE BOX FILTER WITH PERMEABLE PAVEMENT CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
106A



SECTION B-B

NOTES:

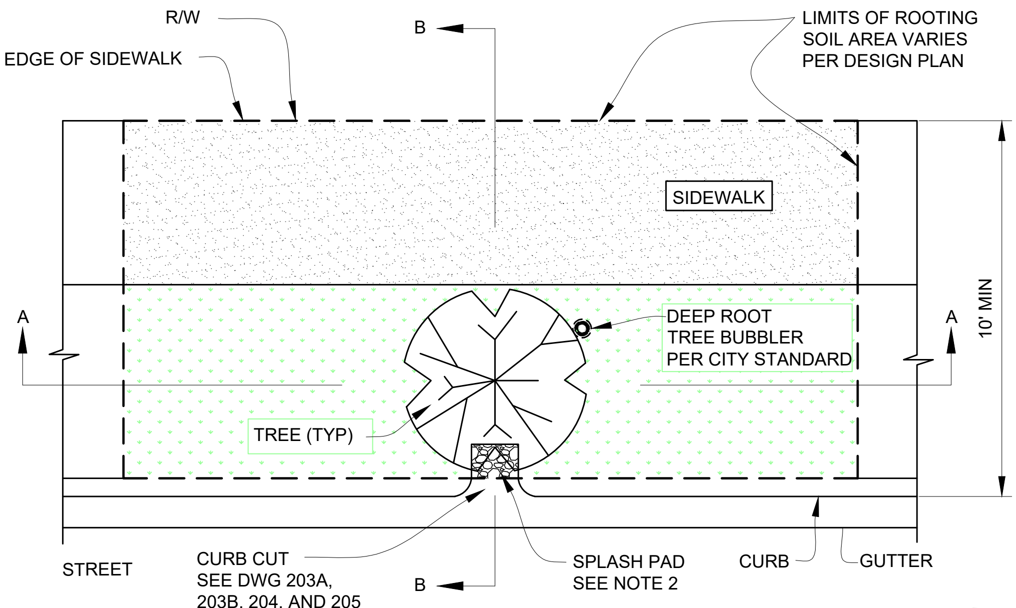
1. MINIMUM OPEN TREE PLANTING SPACE SHALL BE PROVIDED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
2. PROVIDE SPLASH PAD FOR TREE PLANTING SPACE PER DWG 203B.
3. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
4. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
5. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.

CITY OF SANTA CLARITA

TREE BOX FILTER WITH PERMEABLE PAVEMENT CURB SIDE/STREET BUMP OUT

NOT TO SCALE

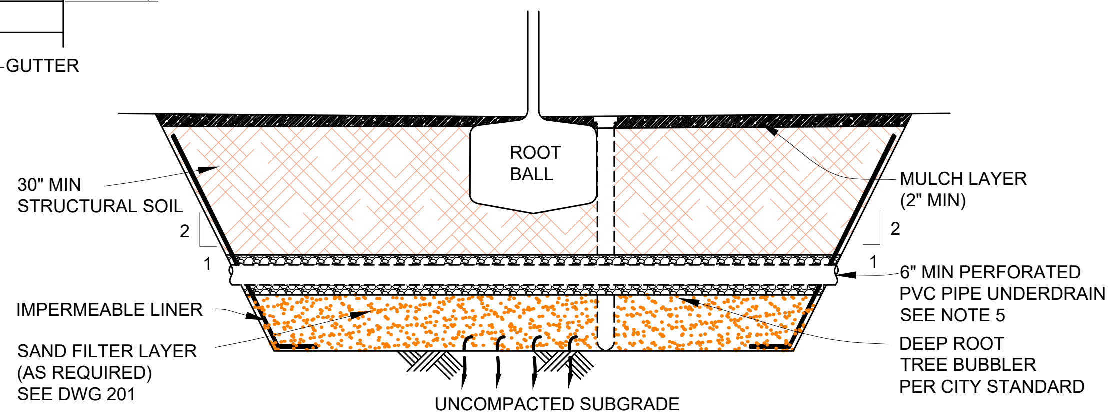
DRAWING NUMBER
106B



PLAN VIEW

NOTES:

1. MINIMUM OPEN TREE PLANTING SPACE SHALL BE PROVIDED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
2. PROVIDE SPLASH PAD FOR TREE PLANTING SPACE PER DWG 203B.
3. PROVIDE PLASTIC LINER WHERE CONCRETE WILL BE POURED ON TOP OF STRUCTURAL SOIL PER GREEN BOOK STANDARD SPECIFICATIONS SECTION 210-2.
4. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
5. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
6. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.
7. DEEP ROOT TREE BUBBLERS SHALL BE PLACED DIRECTLY OUTSIDE THE ROOT BALL PER CITY STANDARD



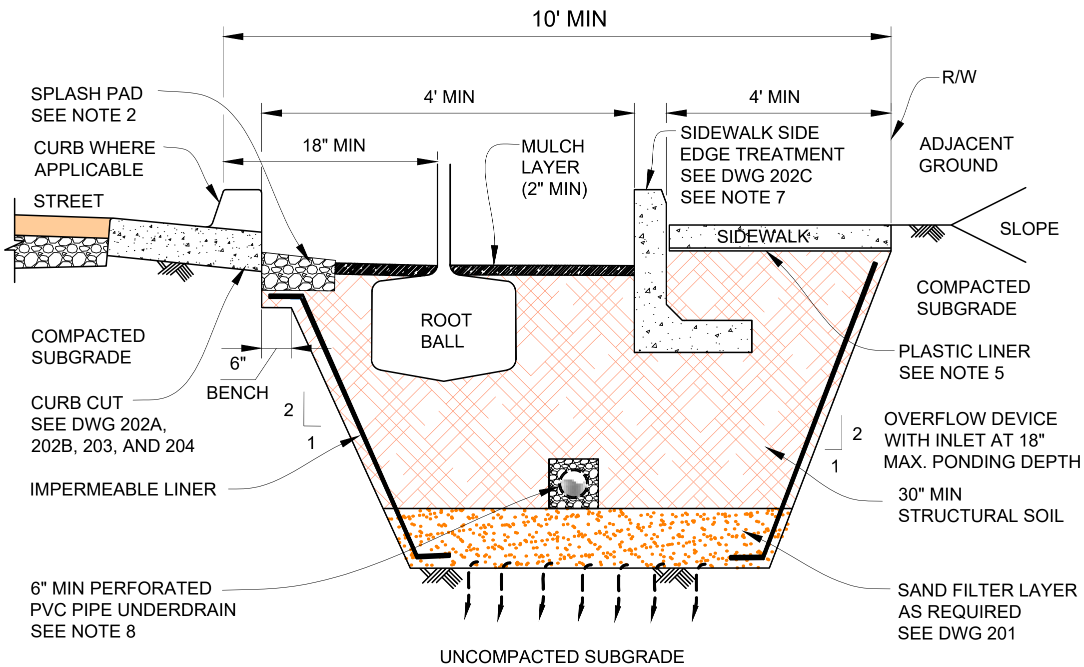
SECTION A-A

CITY OF SANTA CLARITA

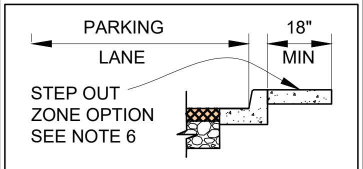
TREE BOX FILTER WITH OPEN SPACE CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
107A



SECTION B-B



NOTES:

1. MINIMUM OPEN TREE PLANTING SPACE SHALL BE PROVIDED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
2. PROVIDE SPLASH PAD FOR TREE PLANTING SPACE PER DWG 203B.
3. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
4. PROVIDE 18" DEEP ROOT BARRIER ON STREET SIDE AS NECESSARY.
5. PROVIDE PLASTIC LINER WHERE CONCRETE WILL BE POURED ON TOP OF STRUCTURAL SOIL PER GREEN BOOK STANDARD SPECIFICATIONS SECTION 210-2.
6. 18" MINIMUM STEP OUT ZONE IS REQUIRED WHEN PARALLEL PARKING IS PROVIDED.
7. A 3 TO 1 SLOPE MAY BE USED IN LIEU OF THE L-WALL WHERE ADEQUATE SPACE IS AVAILABLE SEE DWG 104B.
8. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
9. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.

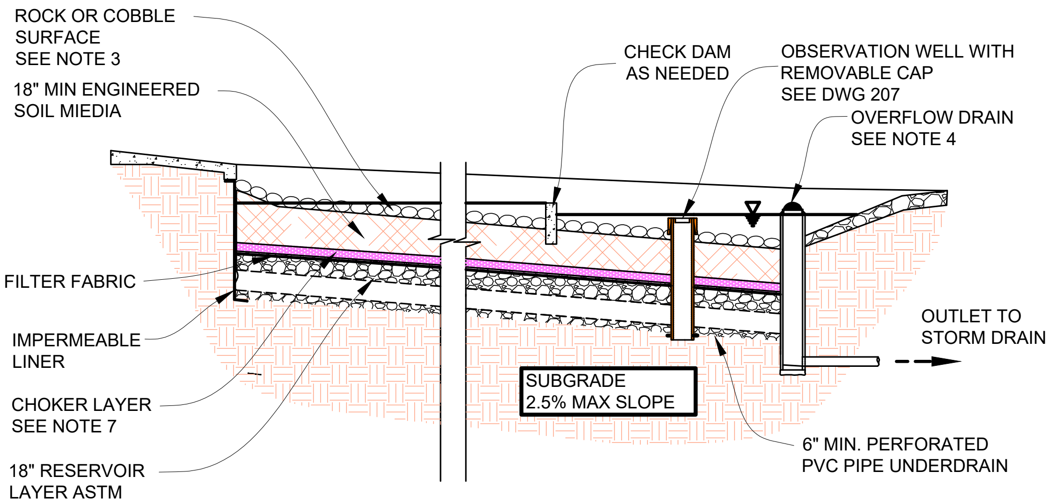
CITY OF SANTA CLARITA

TREE BOX FILTER WITH OPEN TREE SPACE CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER **107B**

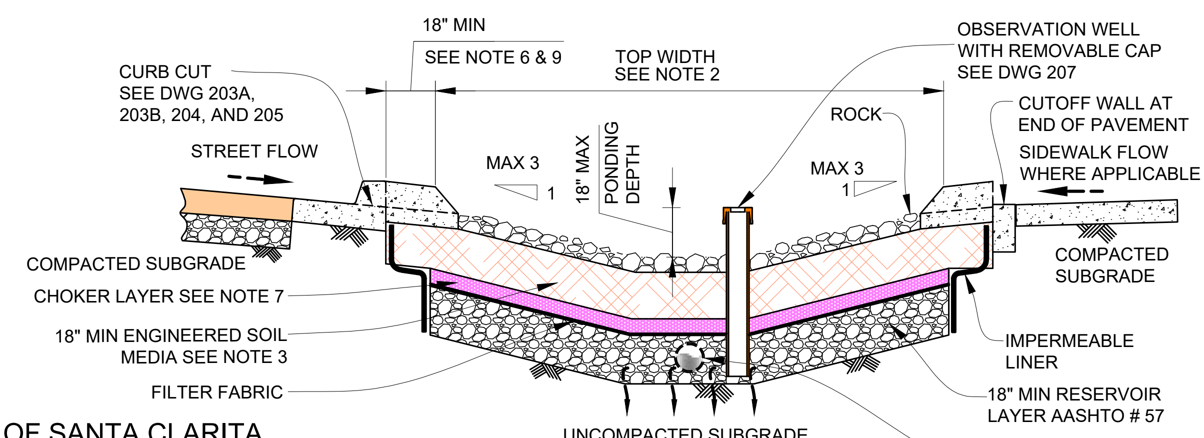
Infiltration Trench



INFILTRATION TRENCH PROFILE (TYP)

NOTES:

1. PROVIDE PROTECTION FROM ALL VEHICLE TRAFFIC, EQUIPMENT STAGING, AND FOOT TRAFFIC IN PROPOSED SWALE AREAS PRIOR TO, DURING, AND AFTER CONSTRUCTION.
2. DIMENSIONS:
   a. INFILTRATION TRENCH SHALL BE SIZED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
   b. WIDTH 4' MINIMUM.
   c. DEPTH FROM TOP OF GROWING MEDIUM TO OVERFLOW ELEVATION; SIMPLIFIED:6"-18".
   d. LONGITUDINAL SLOPE OF SWALE: 2.5% MAX.
3. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA
4. OVERFLOW:
   a. OVERFLOW INLET AT 18" MAXIMUM PONDING DEPTH
   b. PROTECT FROM DEBRIS AND SEDIMENT WITH STRAINER OR GRATE.
5. BOTTOM OF TRENCH SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
6. 18" MINIMUM CONCRETE STEP OUT ZONE REQUIRED WHEN PARKING IS ADJACENT TO CURB.
7. CHOKER LAYER IS OPTIONAL PER GEOTECHNICAL ENGINEER RECOMMENDATION.
8. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.
9. THE MAINTENANCE STRIP SHALL BE 18" FOR PAVERS OR CONCRETE, AND 6" FOR THE CURB, FOR A TOTAL WIDTH OF 24" WIDE WALKABLE SURFACE. SEE MAINTENANCE STRIP DETAIL, DRAWING NUMBER 212.
10. MEDIAN DESIGN SHALL MATCH THE CURRENT CITY AESTHETIC. REFER TO THE CITY LANDSCAPE MAINTENANCE DISTRICT MEDIAN GUIDE FOR MORE INFORMATION.



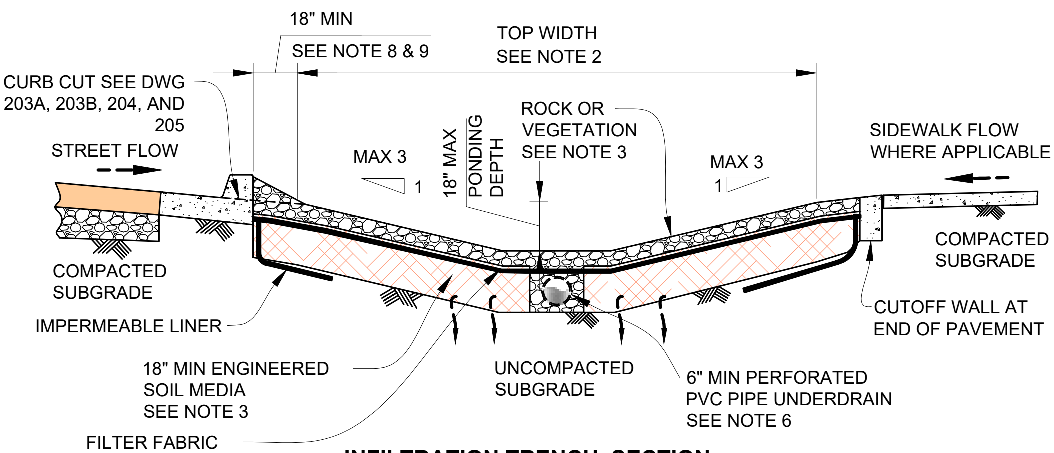
INFILTRATION TRENCH SECTION (TYP)

CITY OF SANTA CLARITA

INFILTRATION TRENCH
STREET MEDIAN/CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
110



INFILTRATION TRENCH SECTION

NOTES:

1. PROVIDE PROTECTION FROM ALL VEHICLE TRAFFIC, EQUIPMENT STAGING, AND FOOT TRAFFIC IN PROPOSED BASIN AREAS PRIOR TO, DURING, AND AFTER CONSTRUCTION.
2. DIMENSIONS:
   a. INFILTRATION TRENCH SHALL BE SIZED TO COLLECT 85TH PERCENTILE RUNOFF VOLUME WITH AN 18" MAXIMUM PONDING DEPTH.
   b. WIDTH 4' MINIMUM.
   c. DEPTH FROM TOP OF GROWING MEDIUM TO OVERFLOW ELEVATION; SIMPLIFIED:6"-18".
   d. LONGITUDINAL SLOPE OF SWALE: 2.5% MAX.
   e. LONGITUDINAL SLOPE OF BASIN: FLAT
3. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
4. OVERFLOW:
   a. OVERFLOW INLET AT 18" MAXIMUM PONDING DEPTH.
   b. PROTECT FROM DEBRIS AND SEDIMENT WITH STRAINER OR GRATE.
5. BOTTOM OF BASIN SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
6. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL. SEE DWG 208 FOR CONNECTION TO CATCH BASIN.
7. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.
8. 18" MINIMUM CONCRETE STEP OUT ZONE REQUIRED WHEN PARKING IS ADJACENT TO CURB.
9. THE MAINTENANCE STRIP SHALL BE 18" FOR PAVERS OR CONCRETE, AND 6" FOR THE CURB, FOR A TOTAL WIDTH OF 24" WIDE WALKABLE SURFACE. SEE MAINTENANCE STRIP DETAIL, DRAWING NUMBER 212.
10. MEDIAN DESIGN SHALL MATCH THE CURRENT CITY AESTHETIC. REFER TO THE CITY LANDSCAPE MAINTENANCE DISTRICT MEDIAN GUIDE FOR MORE INFORMATION.

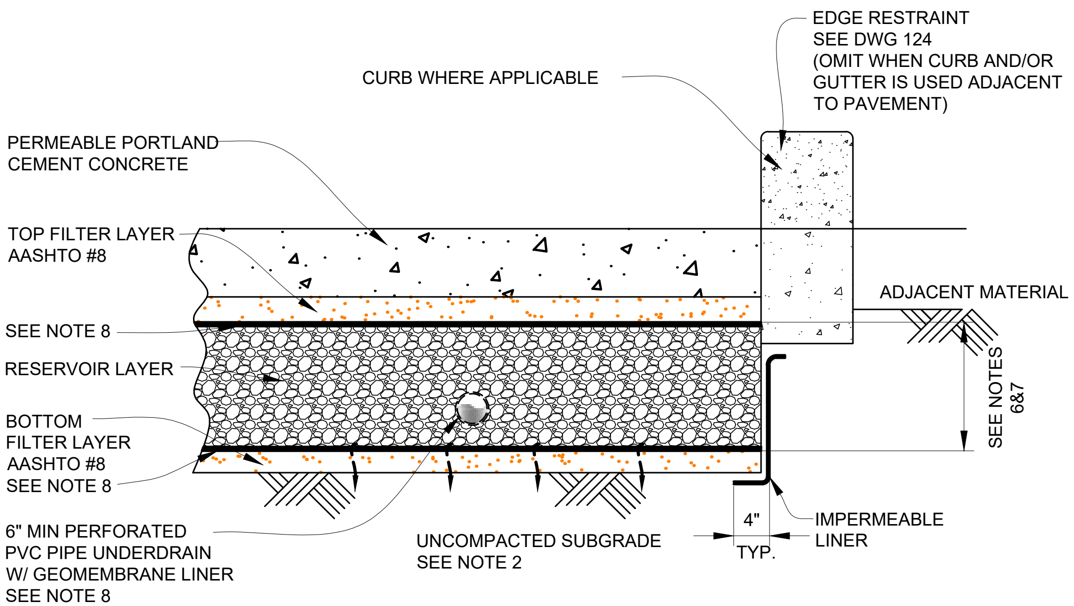
CITY OF SANTA CLARITA

INFILTRATION TRENCH
STREET MEDIAN/CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
111

Permeable Pavements



NOTES:

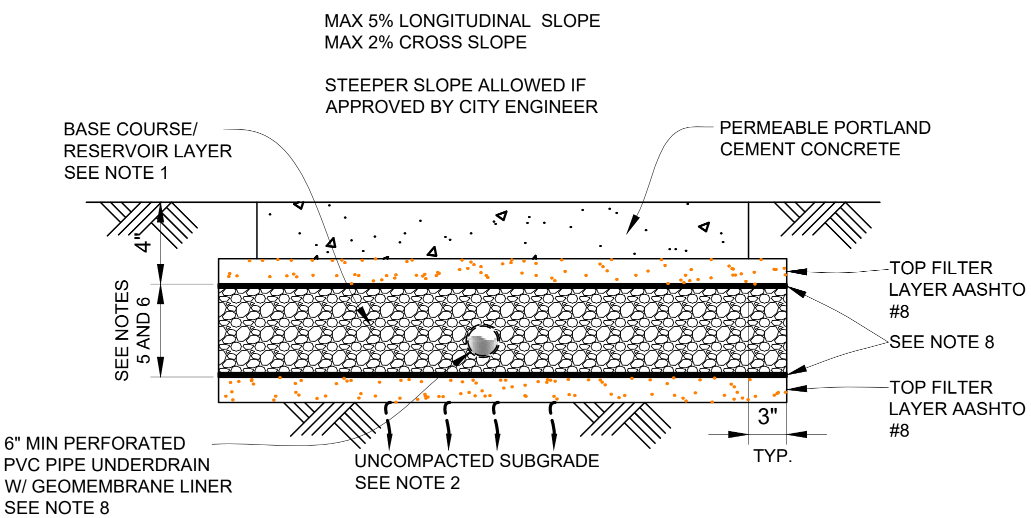
1. DETAIL TO BE USED ONLY WHEN APPROVED BY CITY AND SHALL MEET CURRENT APPROVED CITY SPECIFICATION FOR "IMPERMEABLE PORTLAND CEMENT CONCRETE PAVEMENT".
2. UNCOMPACTED SUBGRADE FOR AREAS DESIGNED FOR INFILTRATION PRACTICES. FOR OTHER AREAS, COMPACT AS SPECIFIED. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.
3. AGGREGATE LAYERS SHALL HAVE INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
4. SEE DWG 123 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.
5. IMPERMEABLE LINER TO BE USED TO PROMOTE WATER RE-USE, PROTECT NEARBY BUILDING FOUNDATIONS, AND AVOID INFILTRATION AROUND UTILITIES.
6. DEPTH OF RESERVOIR LAYER AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER STORAGE AND POROSITY REQUIREMENTS, AND PAVEMENTS STRUCTURAL DESIGN.
7. ENHANCED DESIGN CONTAINS A WATER STORAGE LAYER AND AN INFILTRATION SUMP BENEATH THE UNDERDRAIN SIZED TO DRAIN THE DESIGN STORM WITHIN 96 HOURS.
8. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
9. BOTTOM OF RESERVOIR LAYER SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
10. TOP OF PAVEMENT SHOULD BE DESIGNED TO ACHIEVE 1% MINIMUM SLOPE IN ANY DIRECTION.

CITY OF SANTA CLARITA

PERMEABLE CONCRETE PAVEMENT SIDEWALKS

NOT TO SCALE

DRAWING NUMBER **120A**



NOTES:

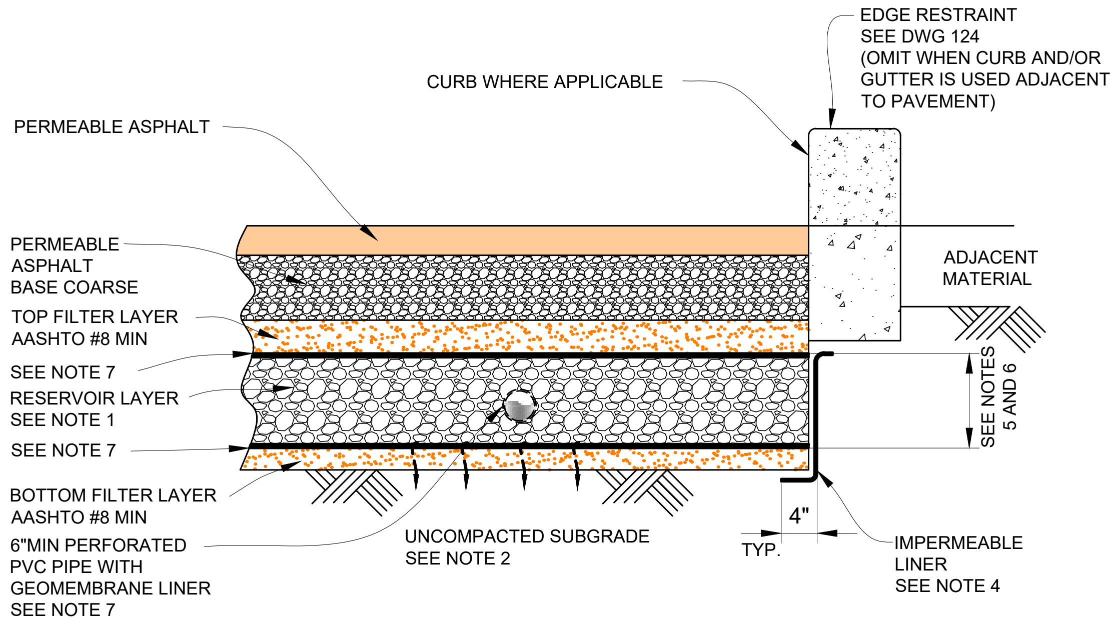
1. DETAIL TO BE USED ONLY WHEN APPROVED BY CITY AND SHALL MEET CURRENT APPROVED CITY SPECIFICATION FOR "PERVIOUS PORTLAND CEMENT CONCRETE PAVEMENT".
2. UNCOMPACTED SUBGRADE FOR AREAS DESIGNED FOR INFILTRATION PRACTICES. FOR OTHER AREAS, COMPACT AS SPECIFIED. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.
3. AGGREGATE LAYERS SHALL HAVE INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
4. IMPERMEABLE LINER TO BE USED TO PROMOTE WATER RE-USE, PROTECT NEARBY BUILDING FOUNDATIONS, AND AVOID INFILTRATION AROUND UTILITIES.
5. DEPTH OF RESERVOIR LAYER AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER STORAGE AND POROSITY REQUIREMENTS, AND PAVEMENTS STRUCTURAL DESIGN.
6. ENHANCED DESIGN CONTAINS A WATER STORAGE LAYER AND AN INFILTRATION SUMP BENEATH THE UNDERDRAIN SIZED TO DRAIN THE DESIGN STORM WITHIN 96 HOURS.
7. BOTTOM OF RESERVOIR LAYER SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
8. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
9. IN CASE OF TREE PLANTINGS, STRUCTURAL SOIL MAY EXTEND UNDER RESERVOIR LAYER.
10. TOP OF PAVEMENT SHOULD BE DESIGNED TO ACHIEVE 1% MINIMUM SLOPE IN ANY DIRECTION.

CITY OF SANTA CLARITA

PERMEABLE CONCRETE PAVEMENT SIDEWALKS

NOT TO SCALE

DRAWING NUMBER
120B



NOTES:

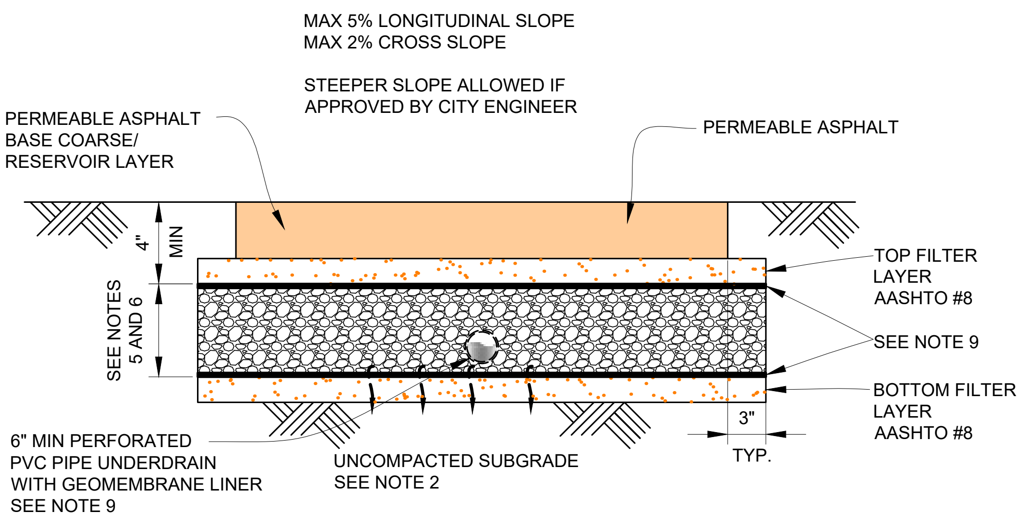
1. DETAIL TO BE USED ONLY WHEN APPROVED BY CITY AND SHALL MEET CURRENT APPROVED CITY SPECIFICATION FOR "PERMEABLE ASPHALT PAVEMENT".
2. UNCOMPACTED SUBGRADE FOR AREAS DESIGNED FOR INFILTRATION PRACTICES. FOR OTHER AREAS, COMPACT AS SPECIFIED. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.
3. AGGREGATE LAYERS SHALL HAVE INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL. SEE DWG 123 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.
4. IMPERMEABLE LINER TO BE USED TO PROMOTE WATER RE-USE, PROTECT NEARBY BUILDING FOUNDATIONS, AND AVOID INFILTRATION AROUND UTILITIES.
5. DEPTH OF RESERVOIR LAYER AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER STORAGE AND POROSITY REQUIREMENTS, AND PAVEMENTS STRUCTURAL DESIGN.
6. ENHANCED DESIGN CONTAINS A WATER STORAGE LAYER AND AN INFILTRATION SUMP BENEATH THE UNDERDRAIN SIZED TO DRAIN THE DESIGN STORM WITHIN 96 HOURS.
7. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
8. BOTTOM OF RESERVOIR LAYER SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
9. TOP OF PAVEMENT SHOULD BE DESIGNED TO ACHIEVE 1% MINIMUM SLOPE IN ANY DIRECTION.
10. DIMENSIONS, SPECIFICATIONS, AND STRENGTH REQUIREMENTS ARE PRODUCT SPECIFIC AND MUST COMPLY WITH PERMEABLE PAVEMENT MANUFACTURER'S RECOMMENDATIONS.

CITY OF SANTA CLARITA

PERMEABLE ASPHALT PAVEMENT SIDEWALKS

NOT TO SCALE

DRAWING NUMBER
121A



NOTES:

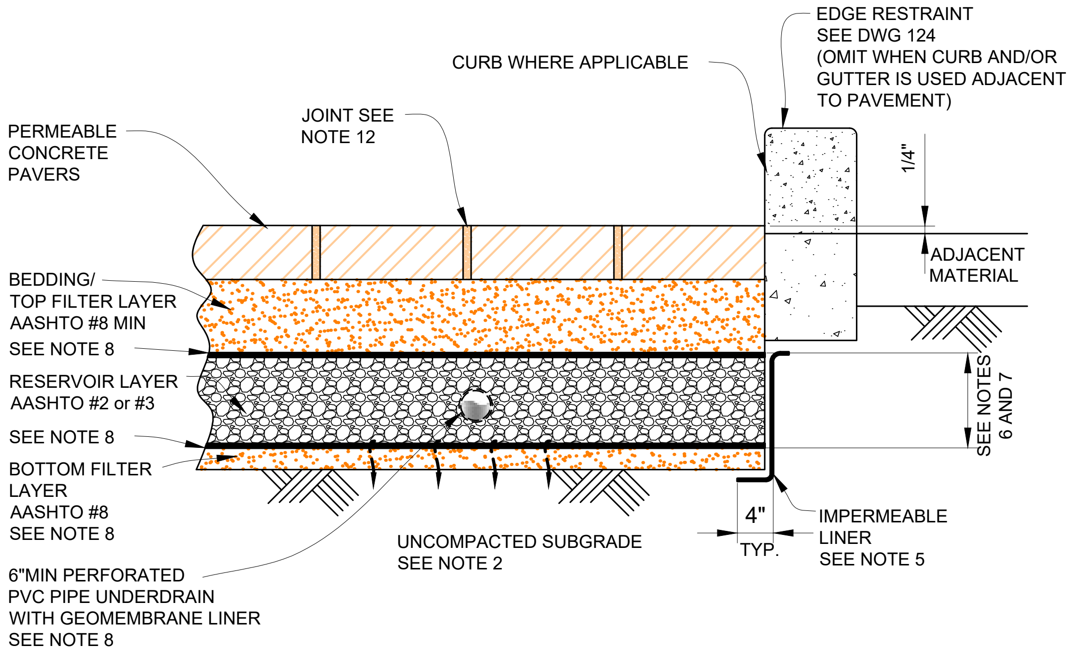
1. DETAIL TO BE USED ONLY WHEN APPROVED BY CITY AND SHALL MEET CURRENT APPROVED CITY SPECIFICATION FOR "PERMEABLE ASPHALT PAVEMENT".
2. UNCOMPACTED SUBGRADE FOR AREAS DESIGNED FOR INFILTRATION PRACTICES. FOR OTHER AREAS, COMPACT AS SPECIFIED. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.
3. AGGREGATE LAYERS SHALL HAVE INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
4. IMPERMEABLE LINER TO BE USED TO PROMOTE WATER RE-USE, PROTECT NEARBY BUILDING FOUNDATIONS, AND AVOID INFILTRATION AROUND UTILITIES.
5. DEPTH OF RESERVOIR LAYER AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER STORAGE AND POROSITY REQUIREMENTS, AND PAVEMENTS STRUCTURAL DESIGN.
6. ENHANCED DESIGN CONTAINS A WATER STORAGE LAYER AND AN INFILTRATION SUMP BENEATH THE UNDERDRAIN SIZED TO DRAIN THE DESIGN STORM WITHIN 96 HOURS.
7. BOTTOM OF RESERVOIR LAYER SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
8. TOP OF PAVEMENT SHOULD BE DESIGNED TO ACHIEVE 1% MINIMUM SLOPE IN ANY DIRECTION.
9. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL

CITY OF SANTA CLARITA

PERMEABLE ASPHALT PAVEMENT SIDEWALKS

NOT TO SCALE

DRAWING NUMBER
121B



NOTES:

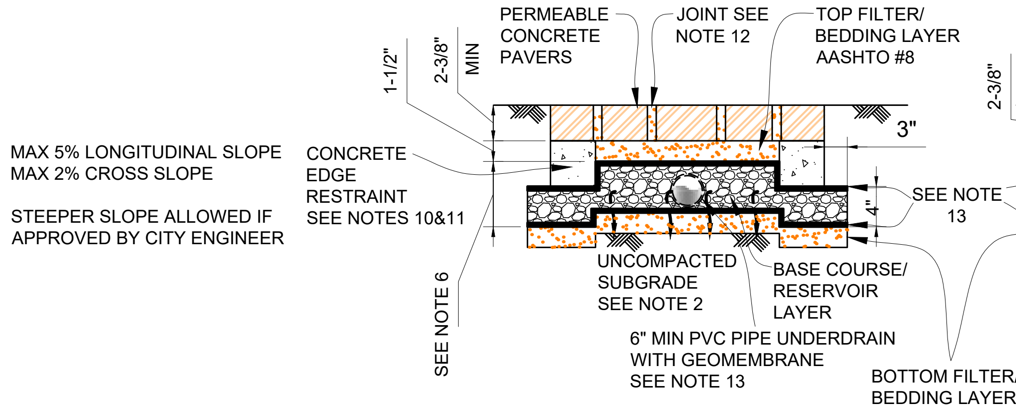
1. DETAIL TO BE USED ONLY WHEN APPROVED BY CITY AND SHALL MEET CURRENT APPROVED CITY SPECIFICATION FOR "PERMEABLE CONCRETE PAVERS".
2. UNCOMPACTED SUBGRADE FOR AREAS DESIGNED FOR INFILTRATION PRACTICES. FOR OTHER AREAS, COMPACT AS SPECIFIED SPECIFICATION. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.
3. AGGREGATE LAYERS SHALL HAVE INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
4. SEE DWG 123 FOR LONGITUDINAL AND CROSS SLOPE REQUIREMENTS.
5. IMPERMEABLE LINER TO BE USED TO PROMOTE WATER RE-USE, PROTECT NEARBY BUILDING FOUNDATIONS AND AVOID INFILTRATION AROUND UTILITIES.
6. DEPTH OF RESERVOIR LAYER AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER CONVEYANCE REQUIREMENTS AND PAVEMENT STRUCTURAL DESIGN.
7. ENHANCED DESIGN CONTAINS A WATER STORAGE LAYER AND AN INFILTRATION SUMP BENEATH THE UNDERDRAIN SIZED TO DRAIN THE DESIGN STORM WITHIN 96 HOURS.
8. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
9. BOTTOM OF RESERVOIR LAYER SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
10. TOP OF PAVEMENT SHOULD BE DESIGNED TO ACHIEVE 1% MINIMUM SLOPE IN ANY DIRECTION.
11. OTHER TYPES OF EDGE RESTRAINTS SUCH AS STEEL OR PLASTIC SHALL BE ALLOWED AS APPROVED BY THE CITY ENGINEER AND BASED ON MANUFACTURER'S RECOMMENDATIONS.
12. JOINT TO HAVE 1/2" MAXIMUM GAP IN ACCORDANCE WITH THE LATEST ADA REQUIREMENTS AND TO BE FILLED WITH AASHTO #8 OR APPROVED EQUIVALENT. MINIMUM GAP SHALL BE 1/4" OR PER MANUFACTURER'S RECOMMENDATIONS FOR PERMEABLE CONCRETE PAVERS.
13. DIMENSIONS, SPECIFICATIONS, AND STRENGTH REQUIREMENTS ARE PRODUCT SPECIFIC AND MUST COMPLY WITH PERMEABLE PAVEMENT MANUFACTURER'S RECOMMENDATIONS.

CITY OF SANTA CLARITA

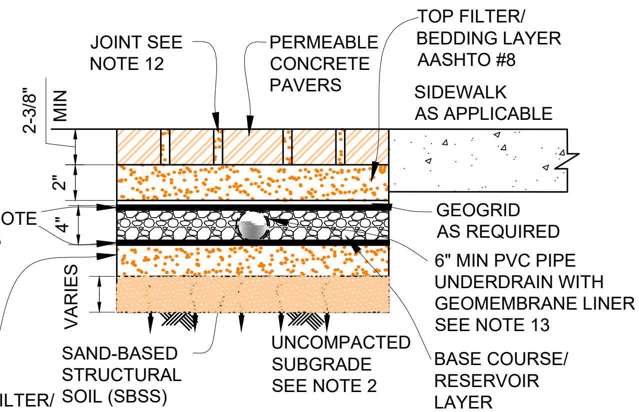
PERMEABLE PAVERS SIDEWALKS

NOT TO SCALE

DRAWING NUMBER **122A**



SIDEWALK SECTION



PERMEABLE PAVERS OVER SAND-BASED STRUCTURAL SOIL

NOTES:

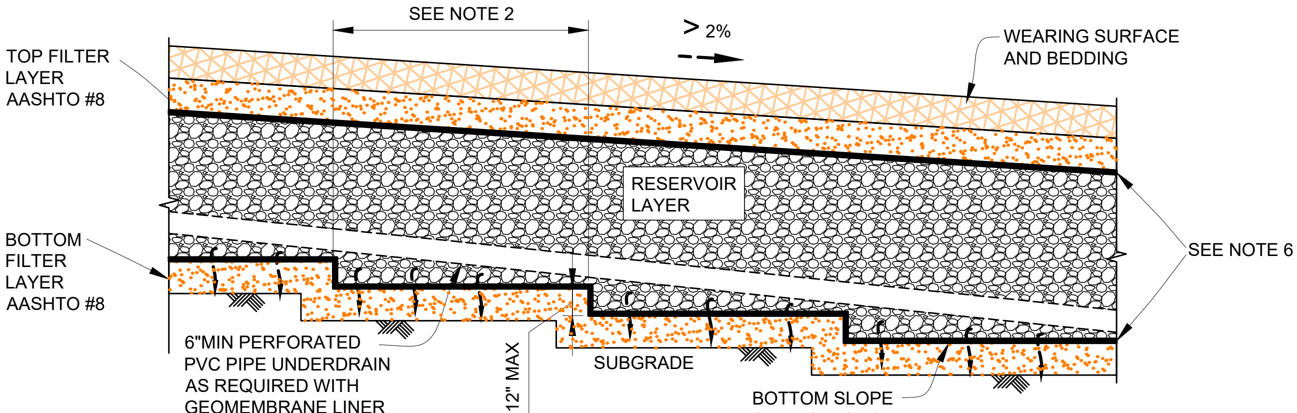
1. DETAIL TO BE USED ONLY WHEN APPROVED BY CITY AND SHALL MEET CURRENT APPROVED CITY SPECIFICATION FOR PERMEABLE CONCRETE PAVERS
2. UNCOMPACTED SUBGRADE FOR AREAS DESIGNED FOR INFILTRATION PRACTICES. FOR OTHER AREAS, COMPACT AS SPECIFIED. FOR SOFT SOILS, INSTALL GEOGRID PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.
3. AGGREGATE LAYERS SHALL HAVE INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.
4. IMPERMEABLE LINER TO BE USED TO PROMOTE WATER RE-USE, PROTECT NEARBY BUILDING FOUNDATIONS, AND AVOID INFILTRATION AROUND UTILITIES.
5. DEPTH OF RESERVOIR LAYER AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER CONVEYANCE REQUIREMENTS, AND PAVEMENTS STRUCTURAL DESIGN.
6. ENHANCED DESIGN CONTAINS A WATER STORAGE LAYER AND AN INFILTRATION SUMP BENEATH THE UNDERDRAIN SIZED TO DRAIN THE DESIGN STORM WITHIN 96 HOURS.
7. BOTTOM OF PERMEABLE PAVEMENT STRUCTURE SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
8. TOP OF PAVEMENT SHOULD BE DESIGNED TO ACHIEVE 1% MINIMUM SLOPE IN ANY DIRECTION.
9. IN AREAS OF TREE PLANTINGS WHICH CALL FOR SAND BASED STRUCTURAL SOIL (SSBS). THE SSBS MAY EXTEND UNDER THE AGGREGATE BASE LAYER OF THE SIDEWALK.
10. CONCRETE EDGE RESTRAINT MIN 4" WIDE AND 7 1/2" DEEP; MORTAR OR POLYMER ADHERED PAVERS TO TOP; ALTERNATIVELY EXTEND EDGE RESTRAINT TO SURFACE.
11. OTHER TYPE OF EDGE RESTRAINTS SUCH AS STEEL OR PLASTIC SHALL BE ALLOWED AS APPROVED BY CITY ENGINEER AND BASED ON MANUFACTURER'S RECOMMENDATIONS.
12. JOINT TO HAVE 1/2" MAXIMUM GAP IN ACCORDANCE WITH THE LATEST ADA REQUIREMENTS AND TO BE FILLED WITH AASHTO #8 OR APPROVED EQUIVALENT. MINIMUM GAP SHALL BE 1/4"OR PER MANUFACTURER'S RECOMMENDATIONS FOR PERMEABLE CONCRETE PAVERS.
13. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.

CITY OF SANTA CLARITA

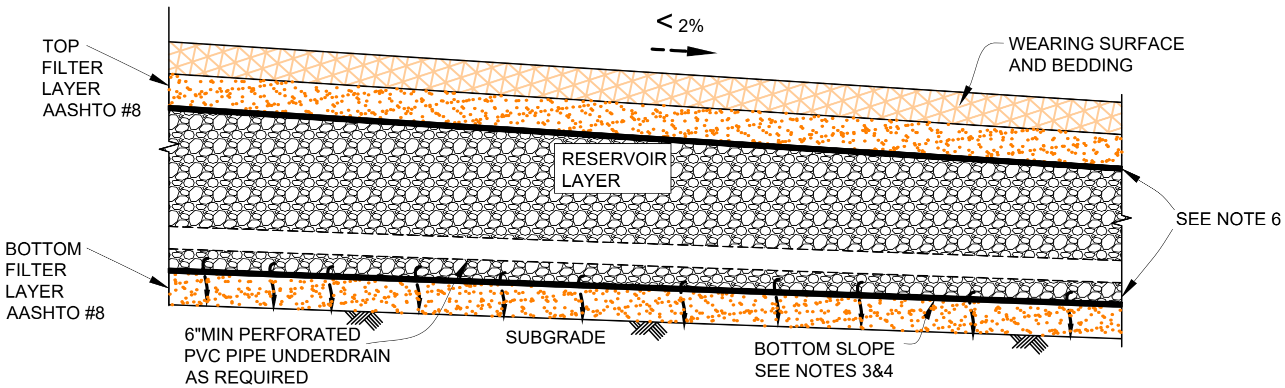
PERMEABLE PAVERS SIDEWALKS

NOT TO SCALE

DRAWING NUMBER **122B**



TERRACED SLOPE
LONGITUDINAL SLOPE > 2%



TERRACED SLOPE
LONGITUDINAL SLOPE < 2%

NOTES:

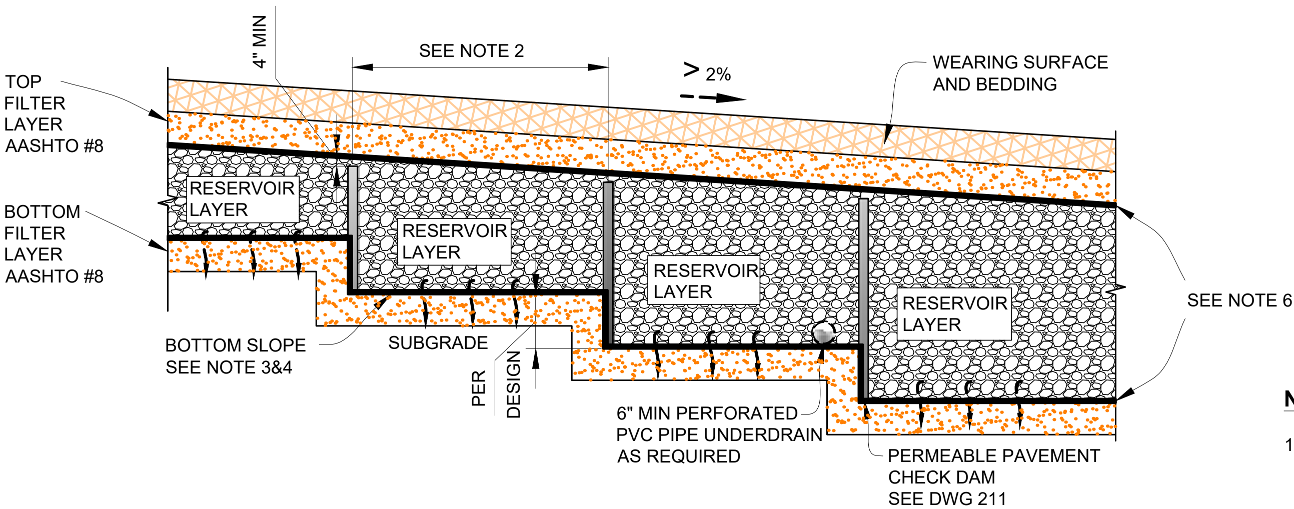
1. CHECK DAMS TO BE USED FOR INSTALLATION WITH BOTTOM SLOPES GREATER THAN 2% LONGITUDINAL. OR AS DIRECTED BY THE CONTRACT DOCUMENTS.
2. DISTANCE BETWEEN STEPS IS DETERMINED BY THE SLOPE OF THE PAVEMENT TO ACHIEVE A STEP NO MORE THAN 12" TALL.
3. BOTTOM SLOPE=0% TO 5% BUT NOT STEEPER THAN TOP SLOPE, PER DESIGN PLANS. ENGINEER TO DESIGN SYSTEM TO ACHIEVE STORAGE, DRAW-DOWN, AND STRUCTURAL REQUIREMENTS. BOTTOM SLOPE DOES NOT HAVE TO BE PARALLEL TO TOP SLOPE.
4. FOR FACILITIES WITH IMPERMEABLE LINER, MINIMUM BOTTOM SLOPE SHALL BE 2% TO DRAIN DRY.
5. TRANSVERSE BOTTOM SLOPES AND CROSS SLOPES SHALL BE LESS THAN 3%.
6. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.

CITY OF SANTA CLARITA

PERMEABLE PAVEMENTS ELEVATION - 1

NOT TO SCALE

DRAWING NUMBER
123A



LONGITUDINAL SLOPE > 2%

NOTES:

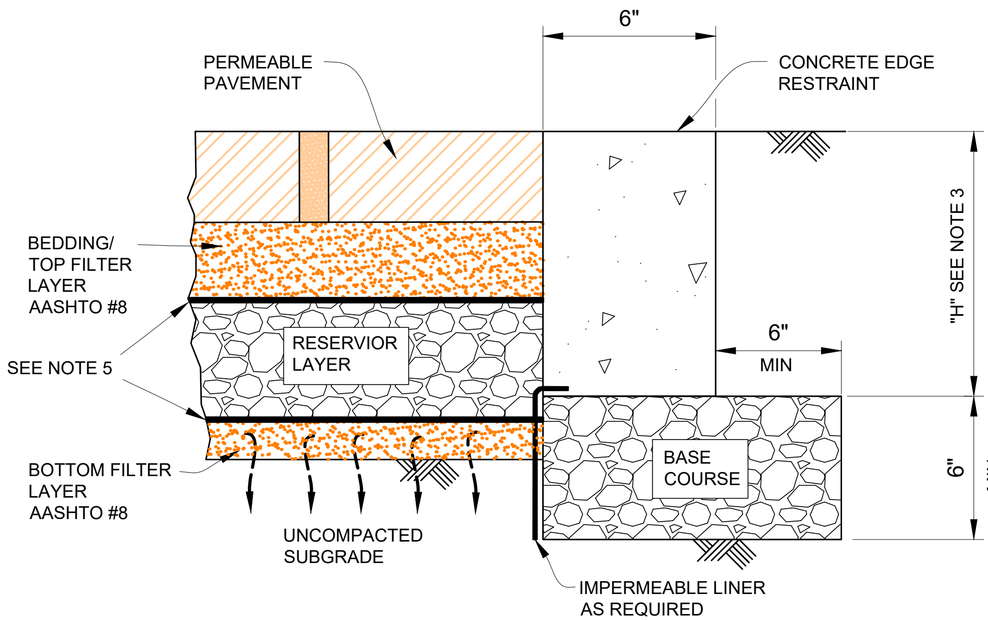
1. CHECK DAMS TO BE USED FOR INSTALLATION WITH BOTTOM SLOPES GREATER THAN 2% LONGITUDINAL, OR AS DIRECTED BY THE CONTRACT DOCUMENTS.
2. DISTANCE BETWEEN STEPS IS DETERMINED BY THE SLOPE OF THE PAVEMENT TO ACHIEVE A STEP NO MORE THAN 12" TALL.
3. BOTTOM SLOPE = 0% TO 5% BUT NOT STEEPER THAN TOP SLOPE, PER DESIGN PLANS. ENGINEER TO DESIGN SYSTEM TO ACHIEVE STORAGE, DRAW-DOWN, AND STRUCTURAL REQUIREMENTS. BOTTOM SLOPE DOES NOT HAVE TO BE PARALLEL TO TOP SLOPE.
4. FOR FACILITIES WITH WATERPROOF MEMBRANE, MINIMUM BOTTOM SLOPE SHALL BE 2% TO DRAIN DRY.
5. TRANSVERSE BOTTOM SLOPES AND CROSS SLOPES SHALL BE LESS THAN 3%.
6. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.

CITY OF SANTA CLARITA

PERMEABLE PAVEMENTS ELEVATION - 2

NOT TO SCALE

DRAWING NUMBER
123B



NOTES:

1. PERIMETER RESTRAINTS ARE REQUIRED FOR PERMEABLE INTERLOCKING CONCRETE PAVER SYSTEM. ENGINEER TO DETERMINE IF EDGE RESTRAINTS ARE NECESSARY FOR PERMEABLE ASPHALT AND PERMEABLE CONCRETE INSTALLATION.
2. MATERIALS, TYPE F, 3,500 PSI CONCRETE; OTHER TYPES OF EDGE RESTRAINT, SUCH AS STEEL OR PLASTIC SHALL BE ALLOWED AS APPROVED BY THE CITY ENGINEER, AND BASED ON MANUFACTURER'S RECOMMENDATIONS.
3. H = 10" FOR PERMEABLE ASPHALT CLASS B; 6" FOR PERMEABLE CONCRETE PAVERS AND PERMEABLE ASPHALT CLASS A.
4. FOR REGULAR PAVEMENT, USE CUTOFF WALL AT END OF PAVEMENT.
5. PROVIDE A GEOTEXTILE FABRIC WITH AN INFILTRATION RATE GREATER THAN OR EQUAL TO THE RATE OF THE SOIL.

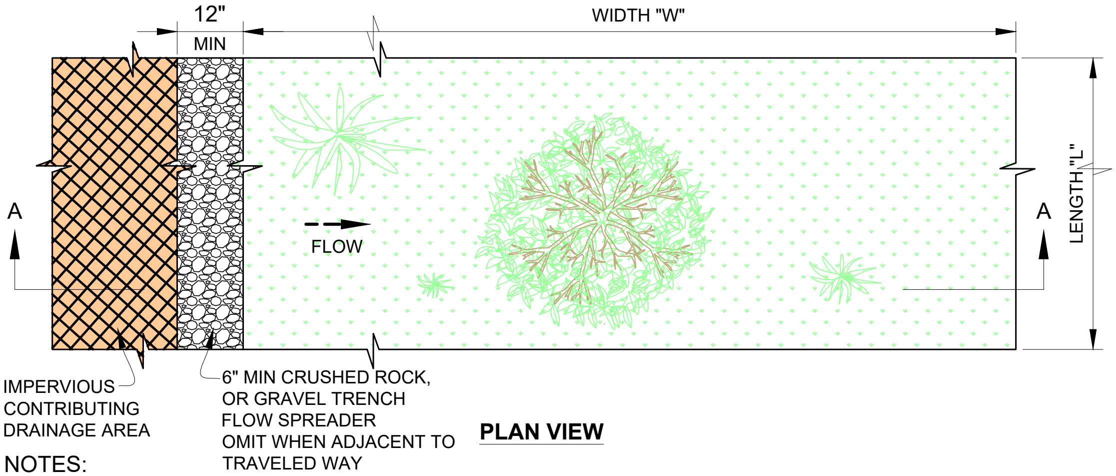
CITY OF SANTA CLARITA

PERMEABLE PAVEMENT EDGE RESTRAINT

NOT TO SCALE

DRAWING NUMBER
124

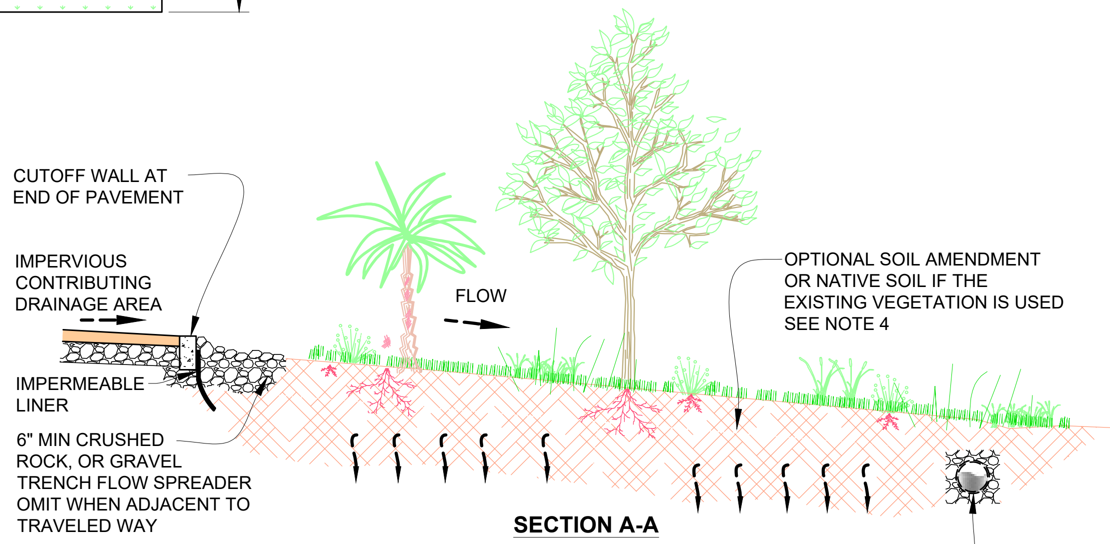
Vegetated Buffers



PLAN VIEW

NOTES:

1. PROVIDE PROTECTION FROM ALL VEHICLE TRAFFIC, EQUIPMENT STAGING, AND FOOT TRAFFIC IN PROPOSED INFILTRATION AREAS PRIOR TO, DURING, AND AFTER CONSTRUCTION.
2. DIMENSIONS:
   a. WIDTH: 15' MIN (SHOULD ALLOW FOR 10 MINUTES HYDRAULIC RESIDENCE TIME).
   b. SLOPES: 2% MIN - 6% MAXIMUM.
   c. FLOW DEPTH: 1" MAXIMUM.
3. VEGETATION COVER MAINTAINED AT HEIGHT OF 4" MINIMUM.
4. OPTIONAL 2" SOIL AMENDMENT PER PROJECT SOIL SPECIFICATIONS. MIX THE AMENDMENT INTO NATIVE SOIL TO A DEPTH OF 6" TO PREVENT SOIL LAYERING.
5. VEGETATED BUFFER SURFACE SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE, AS DETERMINED BY GEOTECHNICAL ENGINEER.
6. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL.
7. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.



SECTION A-A

6" MIN PVC PIPE UNDERDRAIN, SEE NOTE 6. SEE DWG 208 FOR MIN BEDDING REQUIREMENT AND CONNECTION TO CATCH BASIN

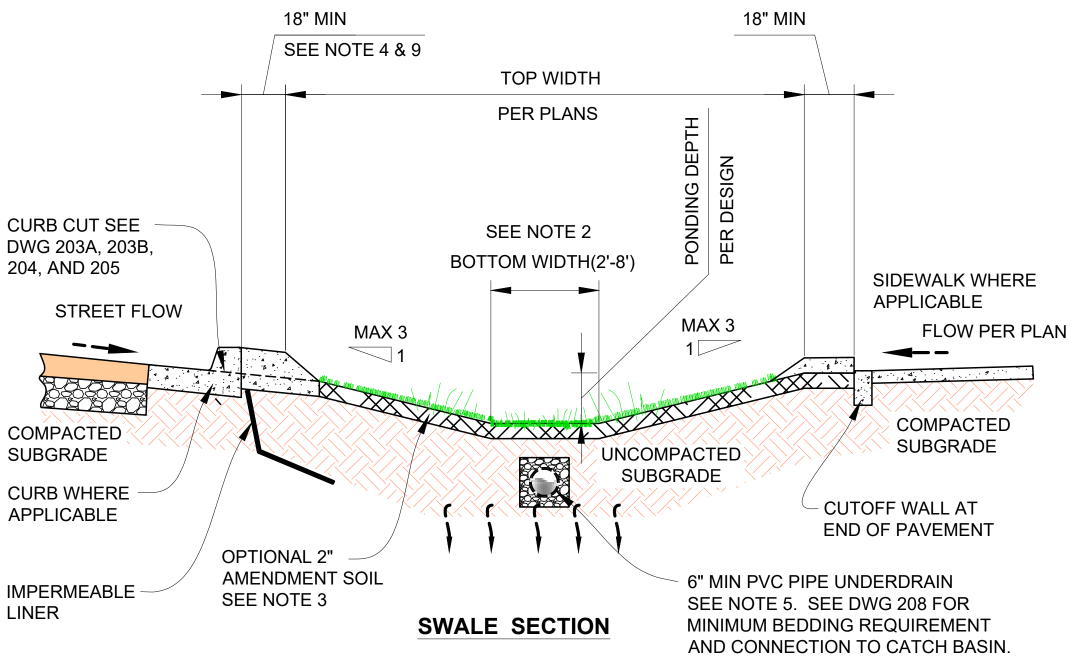
CITY OF SANTA CLARITA

VEGETATED BUFFER
CURB SIDE

NOT TO SCALE

DRAWING NUMBER
130

Enhanced Open Swales



SWALE SECTION

NOTES:

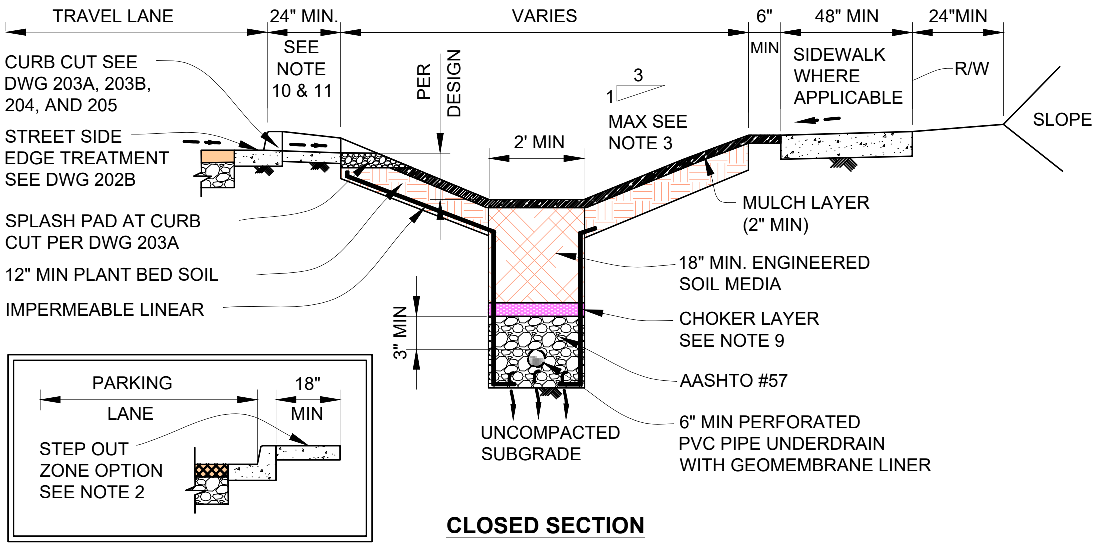
1. PROVIDE PROTECTION FROM ALL VEHICLE TRAFFIC, EQUIPMENT STAGING, AND FOOT TRAFFIC IN PROPOSED INFILTRATION AREAS PRIOR TO, DURING, AND AFTER CONSTRUCTION.
2. DIMENSIONS:
   a. BOTTOM WIDTH: IF WIDER THAN 8', CHANNEL DIVIDERS MAY BE NECESSARY TO PREVENT MEANDERING AND LOW FLOW CHANNEL FORMATION. 10' MAXIMUM WIDTH, UNLESS CHECK DAM IS INCORPORATED, IN WHICH CASE MAXIMUM WIDTH IS 16'.
   b. FLOW DEPTH: WATER QUALITY DESIGN FLOW DEPTH NOT TO EXCEED TWO THIRDS THE HEIGHT OF THE VEGETATION FOR OPTIMUM WATER QUALITY TREATMENT.
   c. LONGITUDINAL SLOPE: 2% TO 6% OVERALL SLOPE. SLOPES GREATER THAN 2.5% SHOULD INCORPORATE 6"-18" CHECK DAM TO MAINTAIN 2.5% MAX LONGITUDINAL INVERT SLOPE. MAXIMUM FLOW VELOCITY SHALL MEET REQUIREMENTS OF COUNTY HYDRAULIC DESIGN MANUAL.
3. OPTIONAL 2" SOIL AMENDMENT PER SWALE SOIL SPECIFICATION; MIX THE AMENDMENT INTO NATIVE SOILS TO A DEPTH OF 6" TO PREVENT SOIL LAYERING.
4. 18" MINIMUM CONCRETE STEP OUT REQUIRED WHEN PARKING IS ADJACENT TO CURB.
5. UNDERDRAIN SHALL BE BLANKETED IN GRAVEL AND A PERMEABLE GEOMEMBRANE LINER WITH PERMEABILITY EQUAL OR GREATER THAN THE INFILTRATION RATE OF THE SOIL.
6. SEE DWG 207 FOR UNDERDRAIN CLEANOUT REQUIREMENTS.
7. BOTTOM OF SWALES SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
8. ALL PLANT SELECTION AND INSTALLATION SHALL BE IN ACCORDANCE WITH CITY APPROVED LANDSCAPE PLANS.
9. THE MAINTENANCE STRIP SHALL BE 18" FOR PAVERS OR CONCRETE, AND 6" FOR THE CURB, FOR A TOTAL WIDTH OF 24" WIDE WALKABLE SURFACE. SEE MAINTENANCE STRIP DETAIL, DRAWING NUMBER 212.

CITY OF SANTA CLARITA

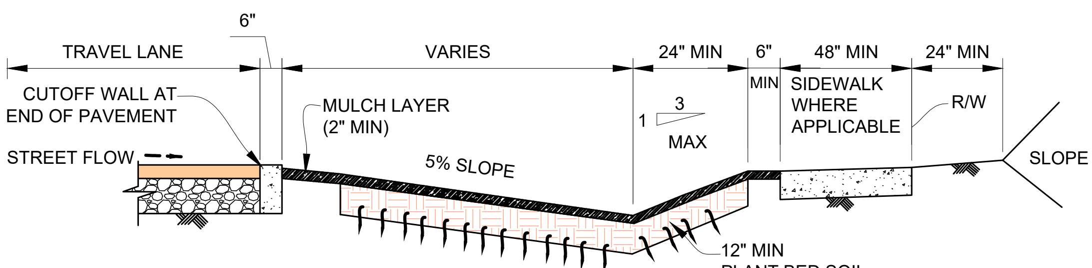
ENHANCED OPEN SWALE
STREET MEDIAN/CURB SIDE/STREET BUMP OUT

NOT TO SCALE

DRAWING NUMBER
131



CLOSED SECTION



OPEN SECTION

NOTES:

1. MATERIALS AND CONSTRUCTION SHALL MEET CURRENT APPROVED SPECIFICATION FOR PLANTING AND ENGINEERED SOIL MEDIA.
2. STEP OUT ZONE REQUIRED WHEN PARALLEL PARKING IS PROVIDED. INSTALLATION MAY BE STANDARD CONCRETE SIDEWALK OR PAVEMENT BASED ON SURROUNDING CONDITIONS.
3. SIDE SLOPES STEEPER THAN 3:1 MAY BE ALLOWED WITH CITY APPROVAL.
4. ALL PLANT SELECTION AND INSTALLATION SHALL BE IN ACCORDANCE WITH CITY APPROVED LANDSCAPE PLANS.
5. BOTTOM OF SWALES SHALL BE AT LEAST 10' ABOVE THE SEASONAL HIGH WATER TABLE AS DETERMINED BY GEOTECHNICAL INVESTIGATION.
6. OFFSET TO SWALES MAY BE REDUCED IF ALTERNATIVE EDGE TREATMENT IS USED, SEE DWG 202A.
7. DEPTH OF INFILTRATION SUMP AS SHOWN ON DESIGN PLANS SHOULD BE SIZED TO ADDRESS STORMWATER REQUIREMENTS.
8. INSTALL TRAFFIC BARRIER AS NECESSARY BASED ON ROADWAY DESIGN.
9. CHOKER LAYER IS OPTIONAL PER GEOTECHNICAL ENGINEER RECOMMENDATION.
10. THE MAINTENANCE STRIP SHALL BE 18" FOR PAVERS OR CONCRETE, AND 6" FOR THE CURB, FOR A TOTAL WIDTH OF 24" WIDE WALKABLE SURFACE. SEE MAINTENANCE STRIP DETAIL, DRAWING NUMBER 212.
11. 18" MINIMUM CONCRETE STEP OUT REQUIRED WHEN PARKING IS ADJACENT TO CURB.

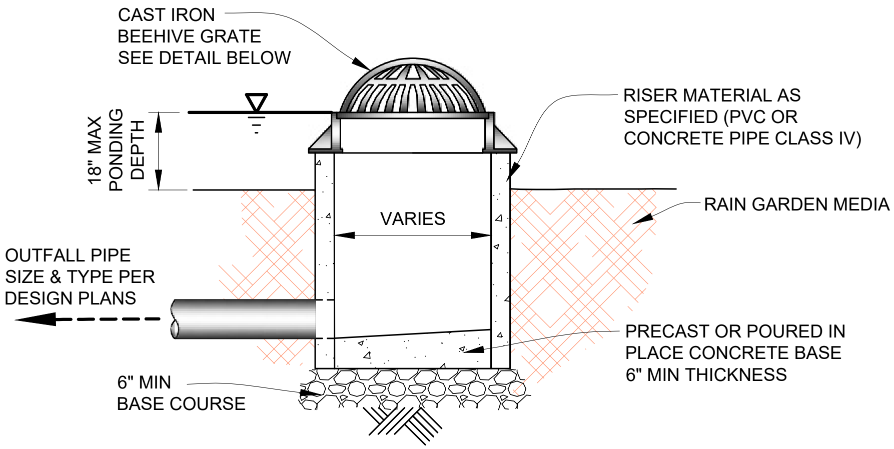
CITY OF SANTA CLARITA

ENHANCED OPEN SWALE
STREET MEDIAN/CURB SIDE/STREET BUMP OUT

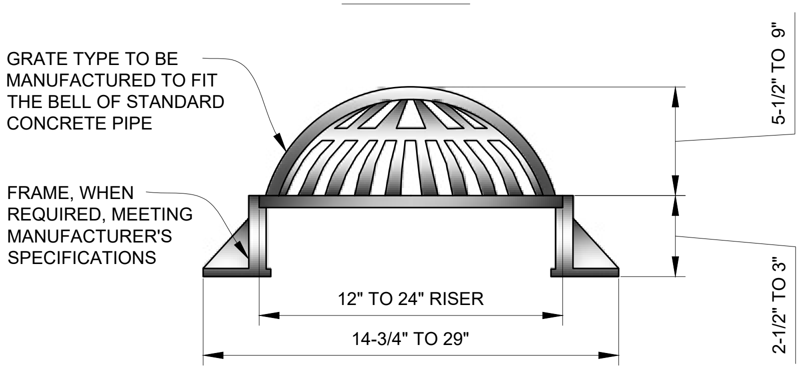
NOT TO SCALE

DRAWING NUMBER
132

Miscellaneous LID Details



ELEVATION



CAST IRON BEEHIVE GRATE DETAIL

NOTES:

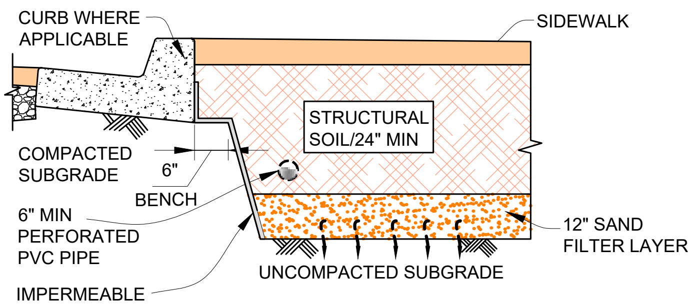
1. SIZE OF GRATE SHALL MATCH SIZE OF THE RISER, PER PLANS, SHALL FIT SNUG, AND SHALL BE REMOVABLE FOR MAINTENANCE PURPOSES.
2. ALTERNATIVE MATERIAL TO CAST IRON SHALL BE ALLOWED AS APPROVED BY CITY ENGINEER.

CITY OF SANTA CLARITA

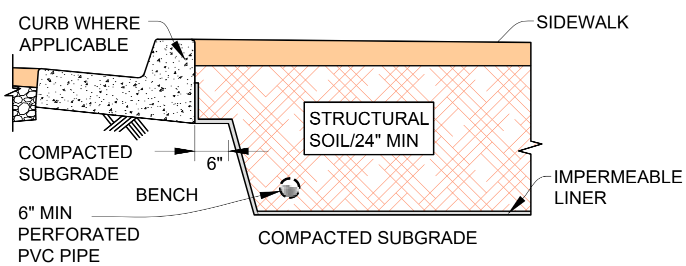
OVERFLOW RISER WITH BEEHIVE GRATE

NOT TO SCALE

DRAWING NUMBER
200



STRUCTURAL SOIL OVER SAND WITH UNDERDRAIN (SEE NOTE 1)



STRUCTURAL SOIL WITH UNDERDRAIN AND IMPERMEABLE LINER (SEE NOTE 2)

NOTES:

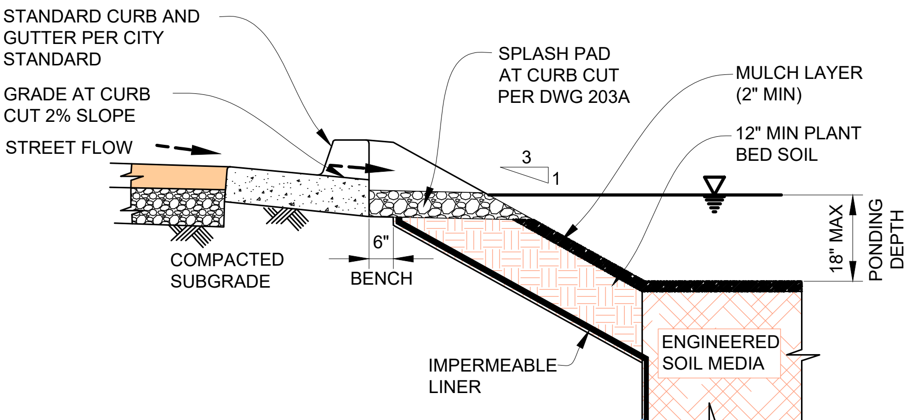
1. FOR NRCS HYDROLOGIC SOIL GROUPS A THOUGH D, PERFORATED 6" MINIMUM PVC UNDERDRAIN PIPE SHALL BE EMBEDDED IN SAND FILTER OR STRUCTURAL SOIL LAYER AND CONNECTED TO THE STORM DRAINAGE SYSTEM.
2. IF NRCS HYDROLOGIC SOIL GROUP HAS NO SIGNIFICANT INFILTRATION CHARACTERISTICS OR THE SUBGRADE IS CONTAMINATED, PERFORATED 6" MINIMUM PVC UNDERDRAIN PIPE SHALL BE EMBEDDED ON IMPERMEABLE LINEAR OVER COMPACTED SUBGRADE AND CONNECTED TO THE STORM DRAINAGE SYSTEM.

CITY OF SANTA CLARITA

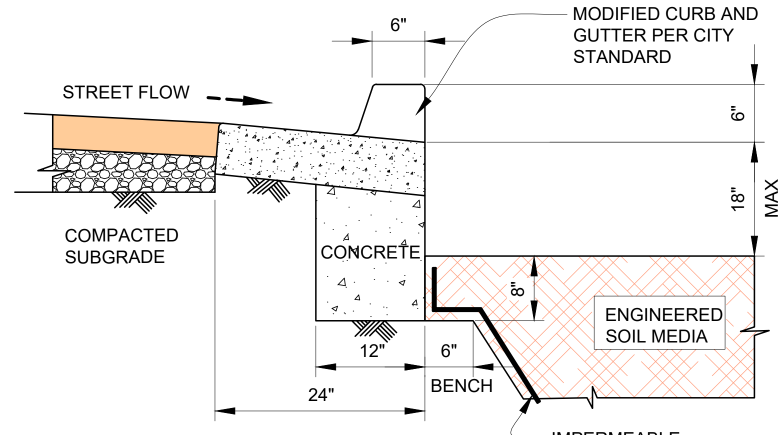
TREE WELL WITH STRUCTURAL SOIL SUBSURFACE DRAINAGE OPTIONS

NOT TO SCALE

DRAWING NUMBER
201



CURB WITH SLOPE



THICKENED CONCRETE CURB AND GUTTER

NOTES:

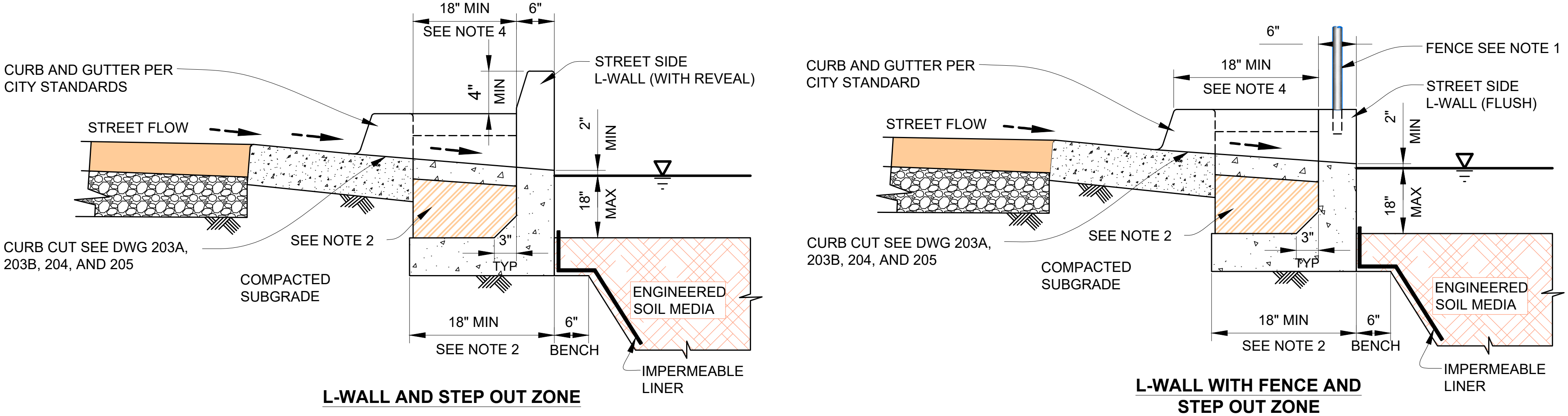
1. FINISH ALL EXPOSED CONCRETE SURFACES.
2. CURB TYPE AND MATERIAL TO MATCH PLANS.
3. SLOPE OF GUTTER AND CURB REVEAL TO MATCH STANDARD CURB AND GUTTER PER CITY STANDARD
4. EXPANSION AND CONTRACTION JOINTS SHALL BE PLACED IN ACCORDANCE WITH STANDARD CONCRETE CURB REQUIREMENTS.
5. PROVIDE AND MAINTAIN A SAFE PEDESTRIAN WALKWAY ACCESS THAT COMPLIES WITH APPLICABLE ADA STANDARDS AND CITY SUPPLEMENT TO GREEN BOOK SEC 7-10 "PUBLIC CONVENIENCE AND SAFETY".

CITY OF SANTA CLARITA

STREET SIDE EDGE TREATMENT (NO STEP OUT ZONE)

NOT TO SCALE

DRAWING NUMBER **202A**



NOTES:

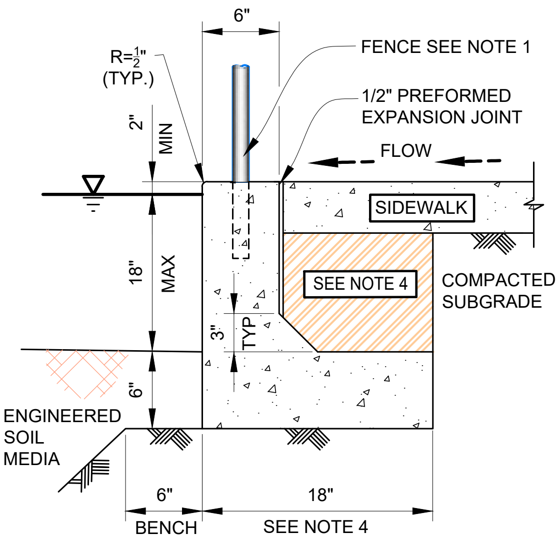
1. WHEN FLUSH WALLS ARE SELECTED, TYPICALLY IN HIGH-VOLUME PEDESTRIAN AREAS, PROVIDE RAILING OR FENCE PER PLAN.
2. 18" BASE WIDTH MAY BE REDUCED TO 15" IF CONCRETE IS USED IN THE HATCHED AREA.
3. FINISH ALL EXPOSED CONCRETE SURFACES.
4. STEP OUT ZONE INSTALLATION MAY BE STANDARD CONCRETE SIDEWALK OR OTHER PAVEMENT AS SHOWN ON PLANS.
5. EXPANSION JOINTS SHALL BE PLACED AT MAXIMUM 90 FOOT INTERVAL. CONTRACTION JOINTS SHALL BE FORMED OR SAWED AT 30 FOOT MAXIMUM INTERVALS BETWEEN EXPANSION JOINTS. WHERE ADJACENT TO CURB, SIDEWALK OR CONCRETE PAVEMENT, JOINTS SHALL LINE UP.

CITY OF SANTA CLARITA

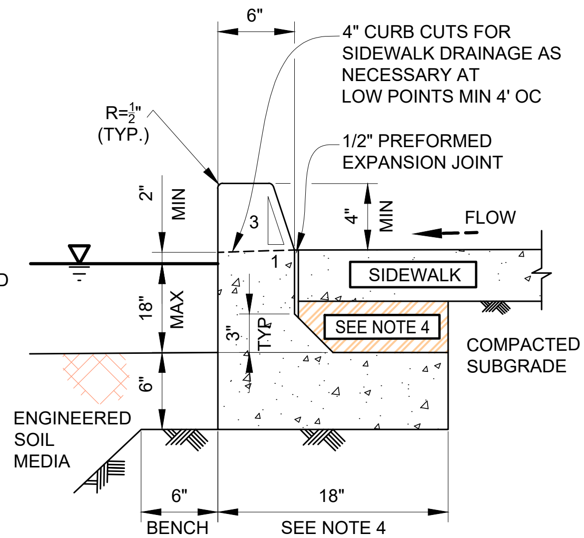
STREET SIDE EDGE TREATMENT (WITH STEP OUT ZONE)

NOT TO SCALE

DRAWING NUMBER **202B**



WITH PEDESTRIAN FENCE



WITH CURB

NOTES:

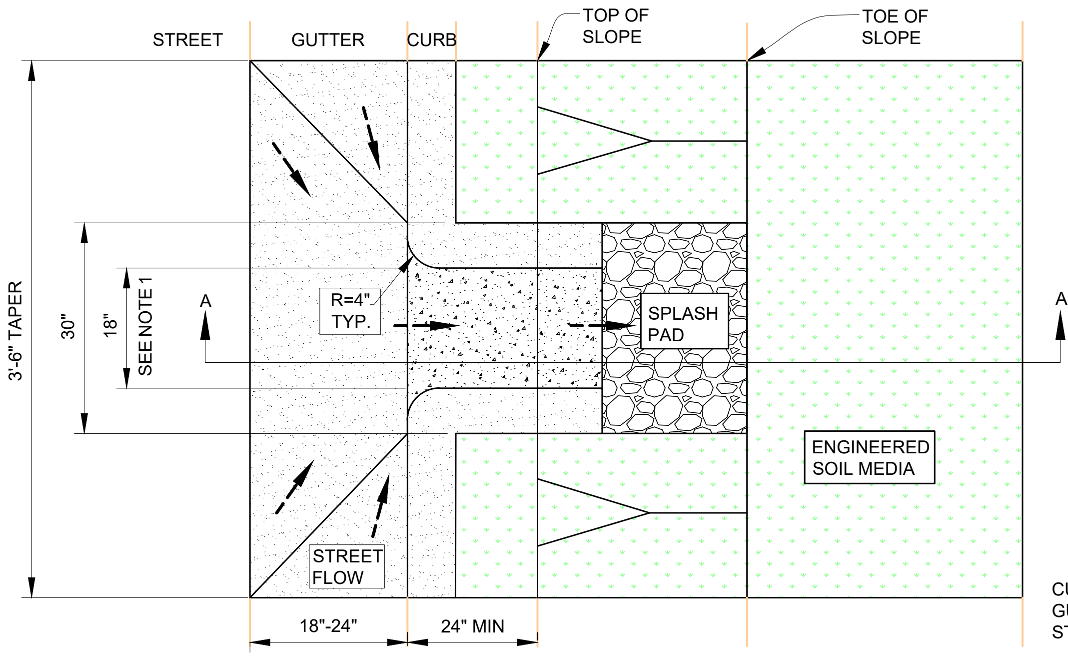
1. WHEN FLUSH WALLS ARE SELECTED, TYPICALLY IN HIGH-VOLUME PEDESTRIAN AREAS, PROVIDE RAILING OR FENCE PER PLAN. FENCE TYPE, STYLE, AND FINISH TO BE APPROVED BY CITY.
2. WHEN WALLS WITH REVEALS ARE USED, TYPICALLY IN LOW-VOLUME PEDESTRIAN AREA, PROVIDE BREAKS IN REVEAL AS SHOWN ON PLANS TO ALLOW FOR SIDEWALK RUNOFF INTO STORMWATER MANAGEMENT FACILITY.
3. FINISH ALL EXPOSED CONCRETE SURFACES.
4. BASE WIDTH MAY BE REDUCED TO 15" IF CONCRETE IS USED IN THE HATCHED AREA.
5. EXPANSION JOINTS SHALL BE PLACED AT MAXIMUM 90 FOOT INTERVAL. CONTRACTION JOINTS SHALL BE FORMED OR SAWED AT 30 FOOT MAXIMUM INTERVALS BETWEEN EXPANSION JOINTS. WHERE ADJACENT TO CURB, SIDEWALK OR CONCRETE PAVEMENT, JOINTS SHALL LINE UP.

CITY OF SANTA CLARITA

SIDEWALK SIDE EDGE TREATMENT

NOT TO SCALE

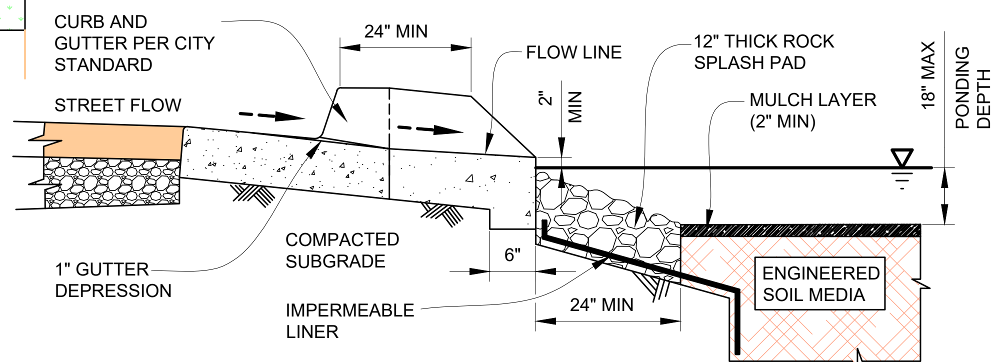
DRAWING NUMBER **202C**



CONCRETE FLUME WITH WINGWALLS AND ROCK SPLASH PAD

NOTES:

1. CURB OPENING DIMENSION SHOWN IS A MINIMUM. CURB CUT SHALL BE SIZED TO CONVEY 85TH PERCENTILE RAINFALL.
2. SEE DWG 205 FOR METAL TRENCH DRAIN COVER CURB CUT.
3. SIDE SLOPES STEEPER THAN 3:1 MAY BE ALLOWED WITH CITY APPROVAL.



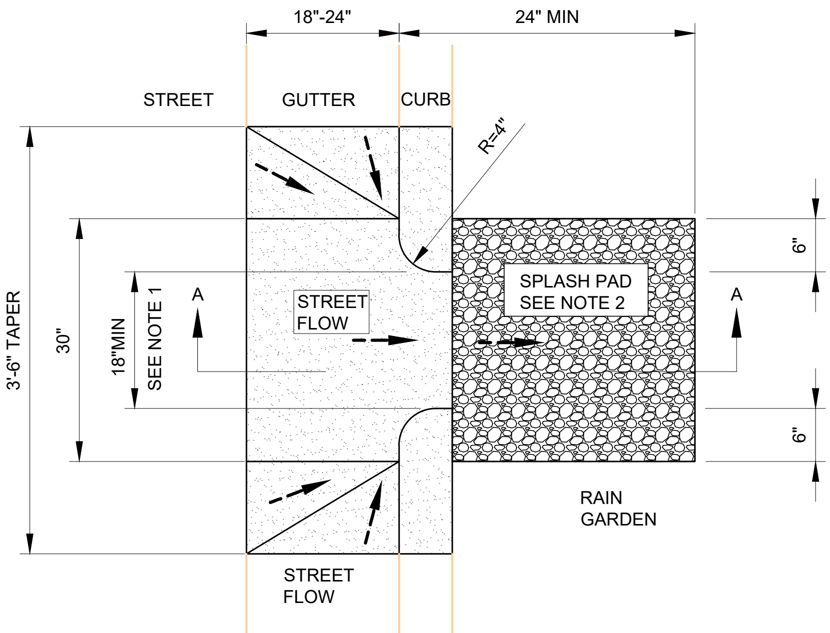
SECTION A-A

CITY OF SANTA CLARITA

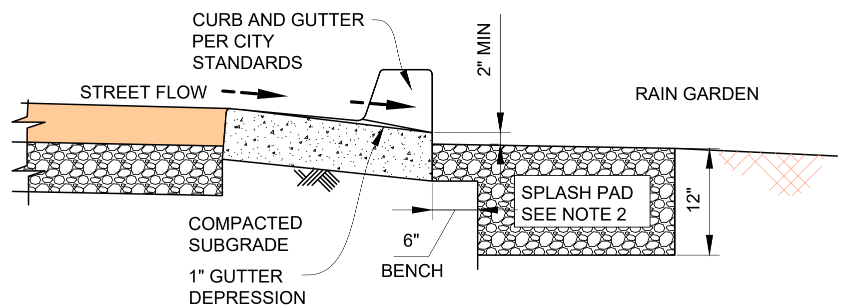
CURB CUT WITH SPLASH PAD - 1

NOT TO SCALE

DRAWING NUMBER **203A**



CONCRETE FLUME WITH ROCK SPLASH PAD



SECTION A-A

NOTES:

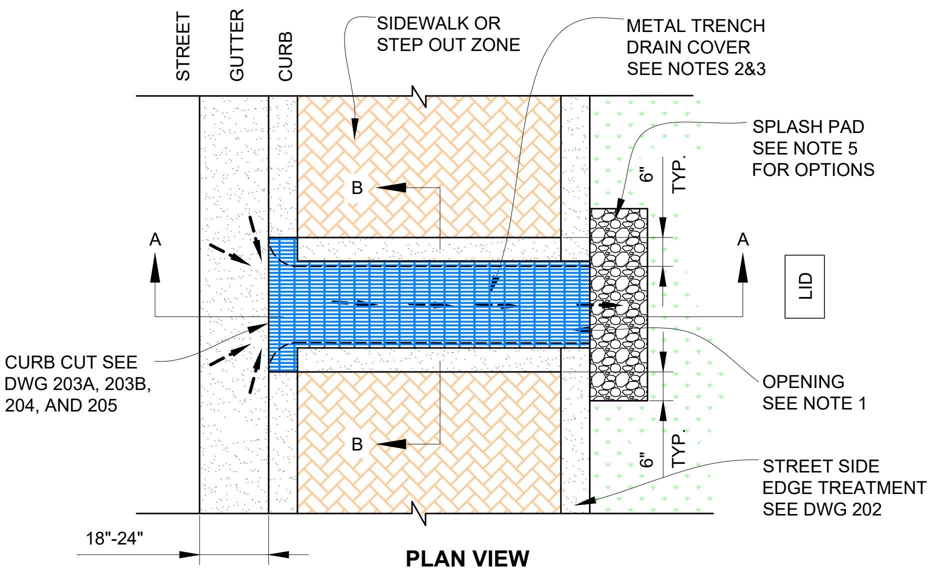
1. CURB OPENING DIMENSION SHOWN IS A MINIMUM. CURB CUT SHALL BE SIZED TO CONVEY 85TH PERCENTILE RAINFALL.
2. SPLASH PAD THICKNESS OPTIONS: 12" STONE #2, 4" CONCRETE SLAB, OR PAVER BLOCKS ON 6" AGGREGATE AASHTO #57.

CITY OF SANTA CLARITA

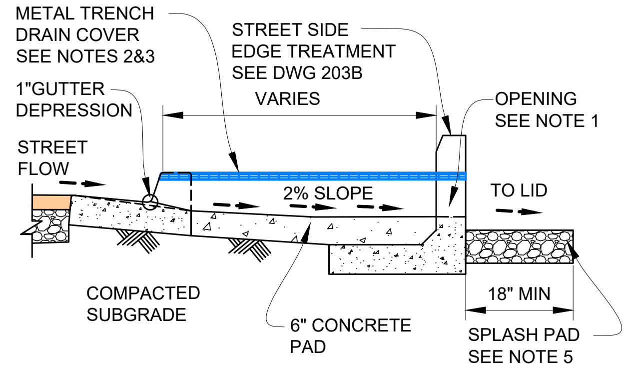
CURB CUT WITH SPLASH PAD - 2

NOT TO SCALE

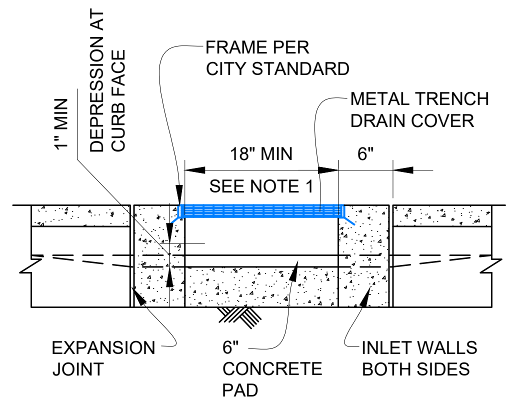
DRAWING NUMBER
203B



PLAN VIEW



SECTION A-A



SECTION B-B

NOTES:

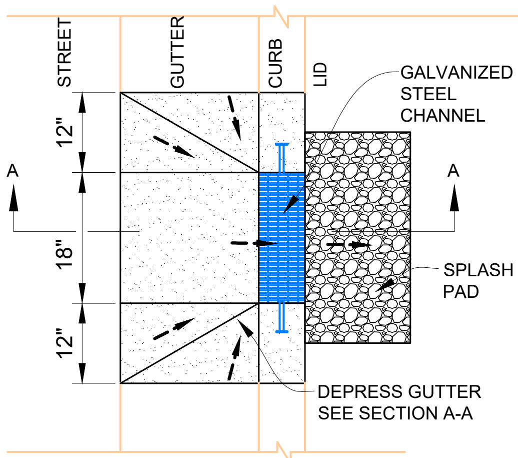
1. CURB OPENING DIMENSION SHOWN IS 18" MINIMUM. CURB CUT SHALL BE SIZED TO CONVEY 85TH PERCENTILE RAINFALL.
2. PROVIDE AND MAINTAIN A SAFE PEDESTRIAN WALKWAY ACCESS THAT COMPLIES WITH APPLICABLE ADA STANDARDS AND GREEN BOOK SEC 7-10 "PUBLIC CONVENIENCE AND SAFETY".
3. REFER TO DESIGN PLANS FOR SIZE AND TYPE OF COVER.
4. METAL TRENCH DRAIN COVER TO BE BOLTED DOWN (THEFT PROTECTED) BUT REMOVABLE.
5. SPLASH PAD DEPTH OPTIONS: 12" STONE #2, 4" CONCRETE SLAB, OR PAVER BLOCKS ON 6" AGGREGATE AASHTO #57.

CITY OF SANTA CLARITA

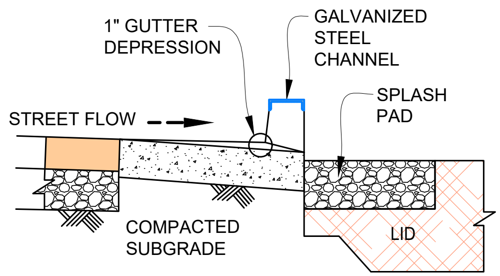
CURB CUT METAL TRENCH COVER

NOT TO SCALE

DRAWING NUMBER **204**



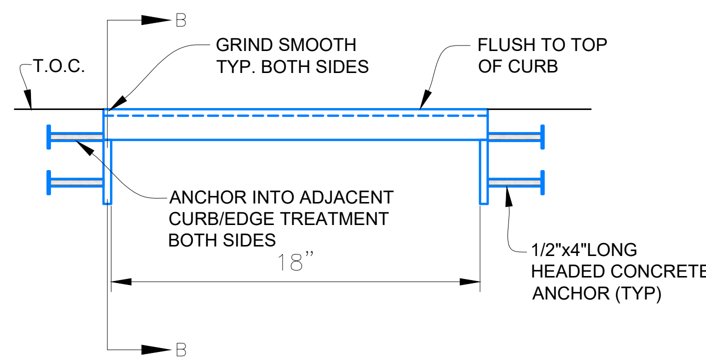
PLAN VIEW



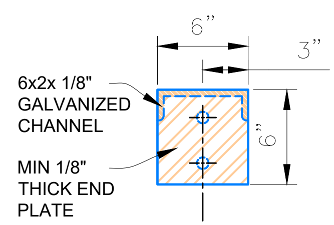
SECTION A-A

NOTES:

1. METAL COVER OVER CURB CUT MAY BE OMITTED WITH CITY APPROVAL.
2. ENTIRE ASSEMBLY SHALL BE HOT DIP GALVANIZED STEEL IN ACCORDANCE WITH ASTM A-123.
3. SHARP POINTS, CORNERS AND EDGES OF METAL COVER SHALL BE POLISHED SMOOTH.
4. SINGLE BEVEL GROOVE WELD.
5. DESIGN VERTICAL WHEEL LOAD IS 8.5 KIPS ONE HALF OF TANDEM AXLE WEIGHT SPECIFIED IN FHWA HOP-06-105).
6. ALTERNATE MATERIAL FOR ASSEMBLY MAY BE USED PER CITY APPROVAL.



ELEVATION



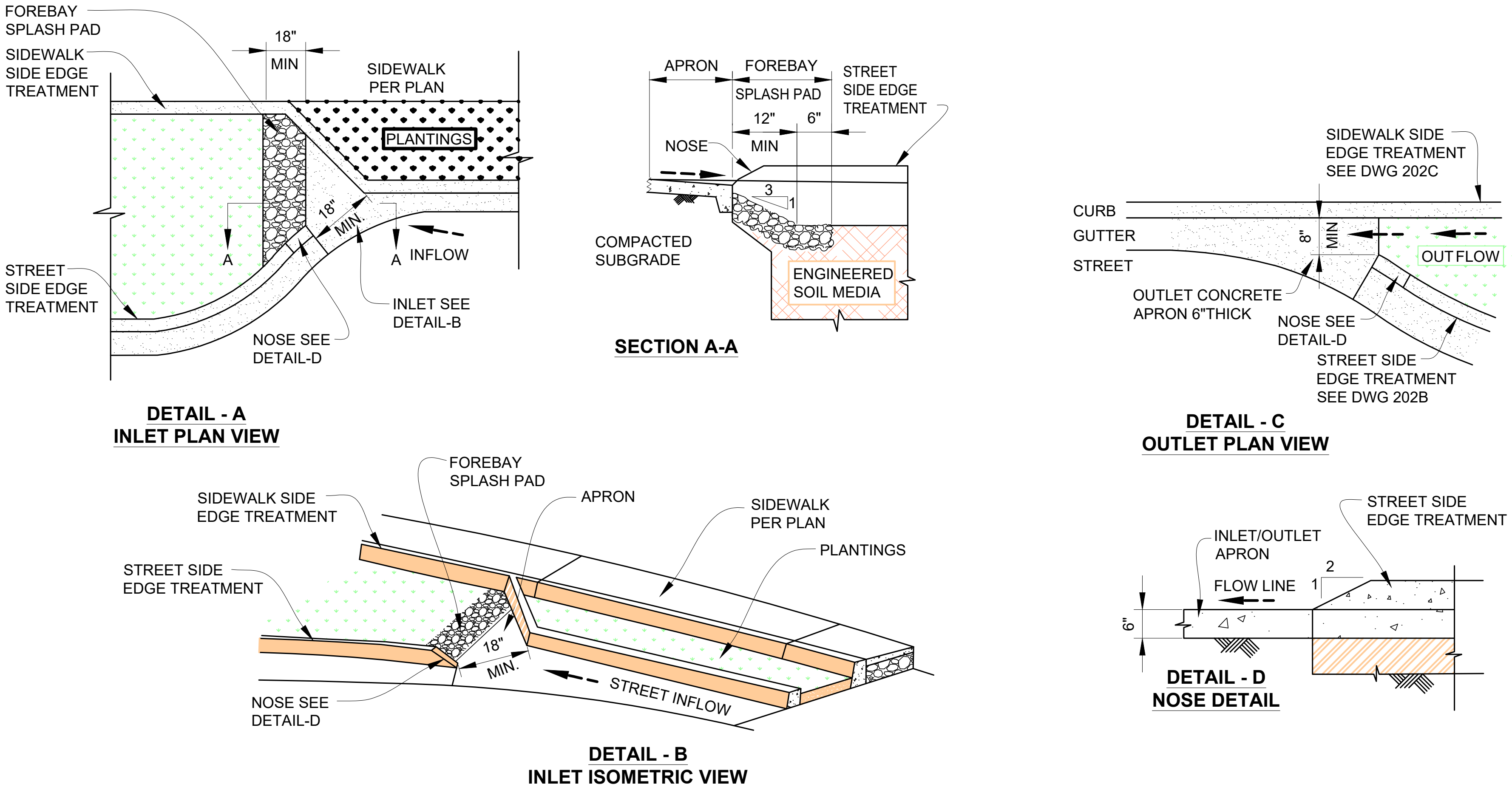
SECTION B-B

CITY OF SANTA CLARITA

GALVANIZED STEEL CHANNEL OVER CURB CUT

NOT TO SCALE

DRAWING NUMBER
205

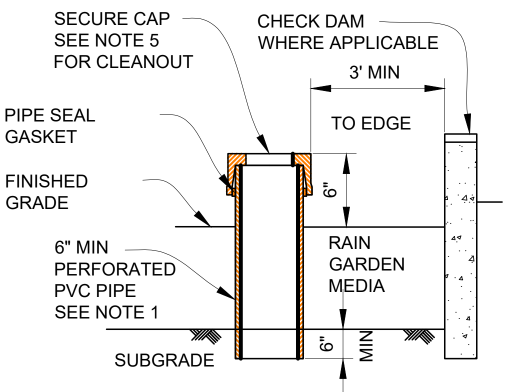


CITY OF SANTA CLARITA

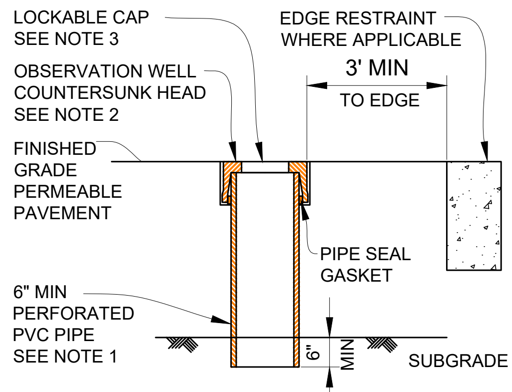
INLET AND OUTLET DETAILS FOR CURB EXTENSION

NOT TO SCALE

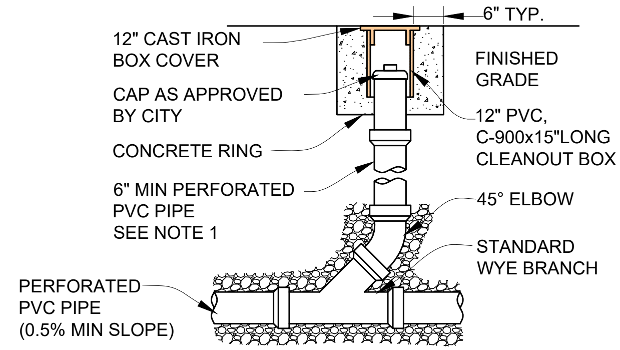
DRAWING NUMBER
206



IN RAIN GARDEN



IN PERMEABLE PAVEMENT



CLEANOUT IN PERMEABLE PAVEMENT

NOTES:

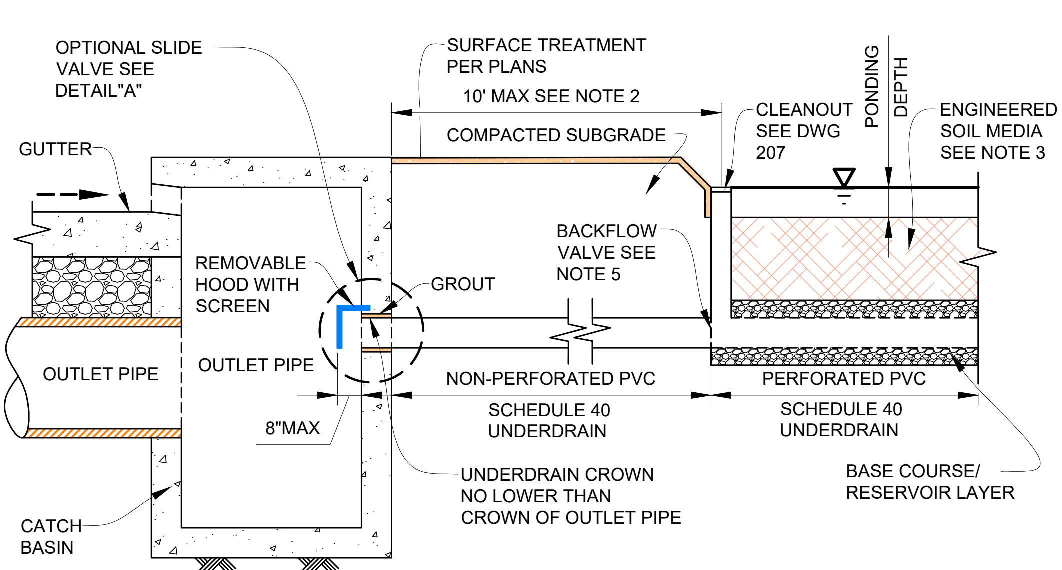
1. PROVIDE A TUBE MADE OF NON-CORROSIVE MATERIAL, SCHEDULE 40 PVC OR EQUAL, AT LEAST 3 FEET LONG WITH AN INSIDE DIAMETER OF 6" MINIMUM. PERFORATED PIPE IS REQUIRED FOR ALL OBSERVATION WELLS, OR CLEANOUTS USED AS OBSERVATION WELLS.
2. FACTORY ATTACHED BRASS OR HIGH IMPACT PLASTIC HEAD WITH RIBS TO PREVENT ROTATION WHEN REMOVING LOCKABLE CAP.
3. LOCKABLE CAP SHALL BE BRASS AND RATED FOR HS-20 LOADING IN VEHICULAR AREAS, MOUNTED FLUSH TO GRADE. LOCKABLE CAP MAY BE HIGH IMPACT PLASTIC THAT IS UV STABLE IN NON-VEHICULAR LOADING AREA, AT LEAST 6 INCHES ABOVE GRADE.
4. IN FACILITIES SUBJECT TO VEHICULAR TRAFFIC, CONCRETE APRONS AROUND CLEANOUTS ARE AN OPTION, AS SHOWN IN DESIGN PLANS.
5. CAP ON RISERS IN RAIN GARDEN FACILITY SHALL BE PVC SCREW IN PLUG.

CITY OF SANTA CLARITA

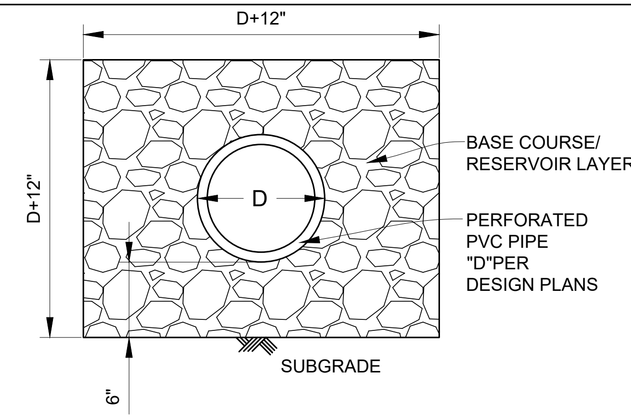
STORMWATER FACILITY CLEANOUT / OBSERVATION WELL

NOT TO SCALE

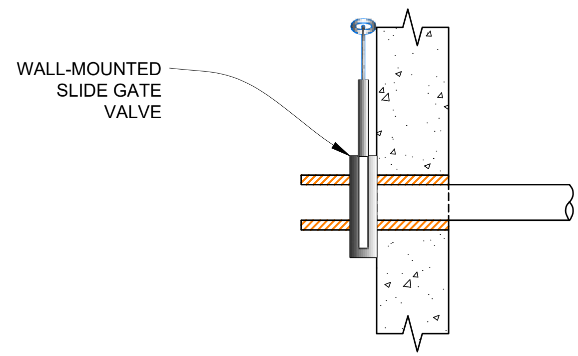
DRAWING NUMBER **207**



UNDERDRAIN CONNECTION TO CATCH BASINS



UNDERDRAIN AND BEDDING SECTION



DETAIL - A
WALL-MOUNTED SLIDE GATE VALVE

NOTES:

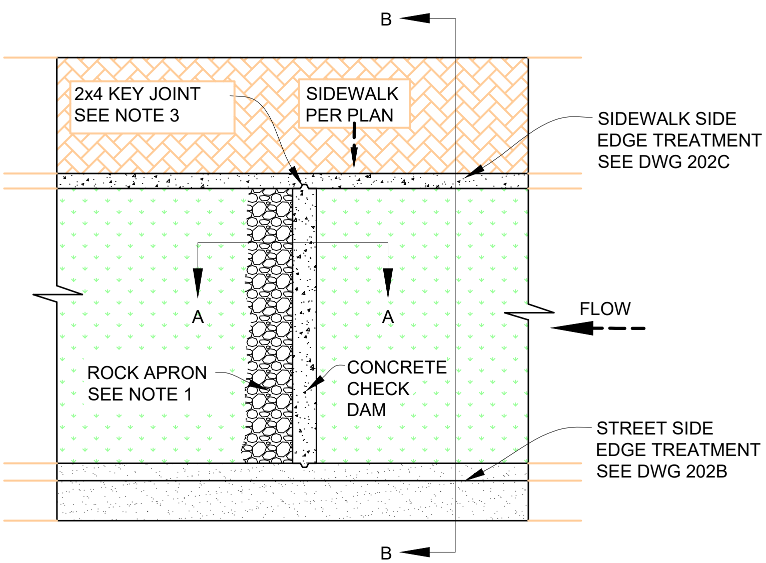
1. CATCH BASIN CONNECTIONS FROM UNDERDRAINS SERVICING PRIVATE PROPERTY ARE PROHIBITED.
2. WHEN STORMWATER FACILITY IS LOCATED > 10' FROM CATCH BASIN, PROVIDE ADDITIONAL CLEANOUT OUTSIDE OF STORMWATER FACILITY WITHIN 10' OF CATCH BASIN.
3. STORMWATER FACILITY DEPICTED IS RAIN GARDEN PRACTICE. CONNECTIONS TO CATCH BASIN WILL ALSO APPLY TO PERMEABLE PAVEMENTS AND SWALES WITH UNDERDRAINS.
4. WALL-MOUNTED SLIDE GATE VALVE TO BE USED TO REGULATE FLOW IN UNDERDRAIN PIPE AS INDICATED IN PLANS. VALVE MAY ALSO BE USED IN OVERFLOW RISER AS DIRECTED.
5. PVC PIPE SLOPE SHALL BE PER PLAN.

CITY OF SANTA CLARITA

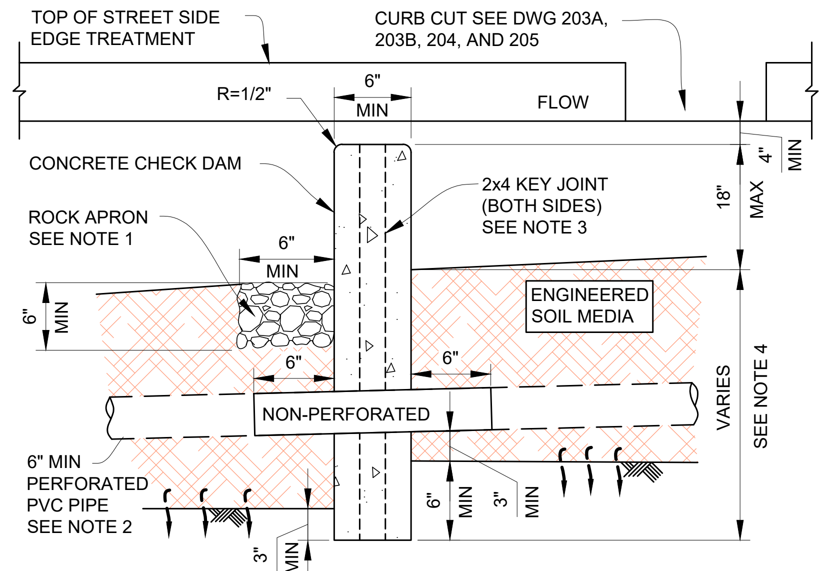
STORMWATER FACILITY UNDERDRAIN BEDDING AND CATCH BASIN CONNECTION

NOT TO SCALE

DRAWING NUMBER **208**



PLAN VIEW



SECTION A-A

NOTES:

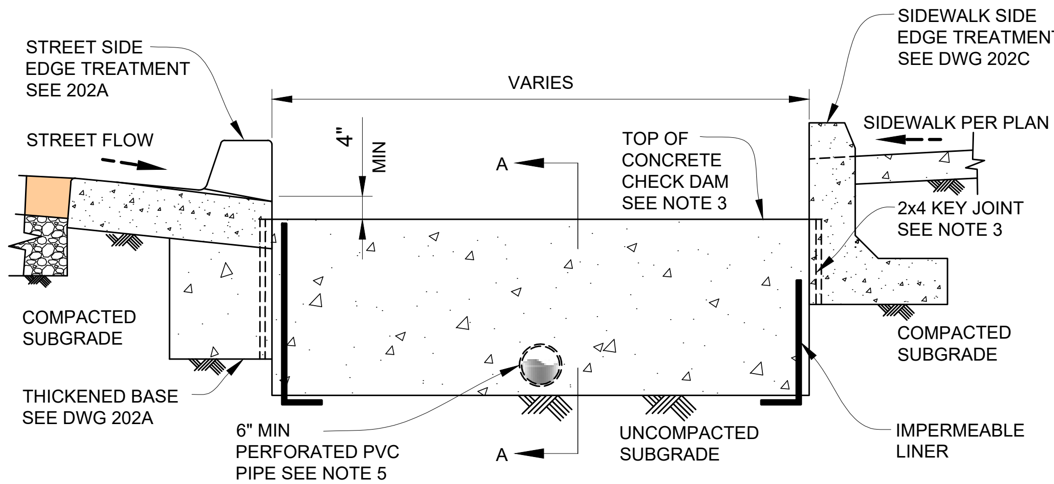
1. SIZE OF ROCK OR AGGREGATE TO BE SPECIFIED IN THE DESIGN PLANS.
2. UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE (6" MIN).
3. TO INSURE PROPER BONDING BETWEEN THE CONCRETE CHECK DAM AND THE EDGE TREATMENT, A 2x4 KEY JOINT SHALL BE FORMED ON BOTH SIDES.
4. DEPTH OF CHECK DAM VARIES DEPENDING ON THE DEPTH OF THE FACILITY.

CITY OF SANTA CLARITA

CONCRETE CHECK DAM

NOT TO SCALE

DRAWING NUMBER
209A



SECTION B-B

NOTES:

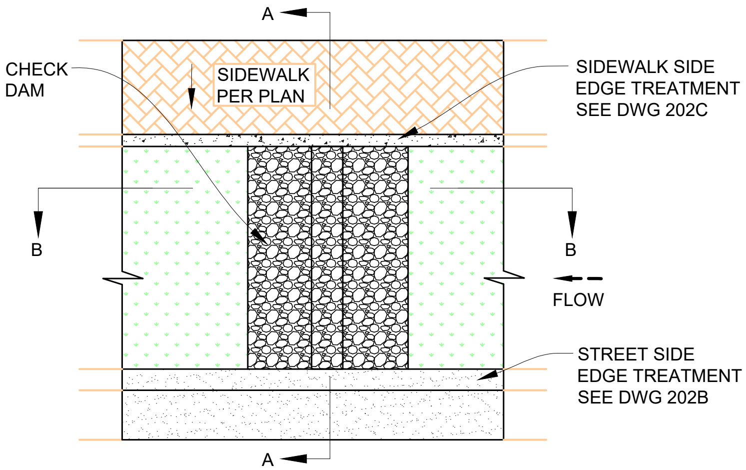
1. LOCATION, HEIGHT, AND WIDTH OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
2. CONCRETE CHECK DAM SHALL BE CONTINUOUS (NO JOINTS).
3. TO INSURE PROPER BONDING BETWEEN THE CHECK DAM AND THE EDGE TREATMENT, A 2x4 KEY JOINT SHALL BE FORMED ON BOTH SIDES.
4. DEPTH OF CHECK DAM VARIES DEPENDING ON THE DEPTH OF THE FACILITY.
5. IF PRESENT, UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE.
6. FOR EDGE TREATMENT OPTIONS SEE DWG 202A, 202B, AND 202C.
7. EXCLUDE EDGE TREATMENT OPENING WHEN THE TOP OF SIDEWALK ELEVATION IS FLUSH WITH THE TOP OF EDGE TREATMENT WALL SEE DRAWING DWG 202C.

CITY OF SANTA CLARITA

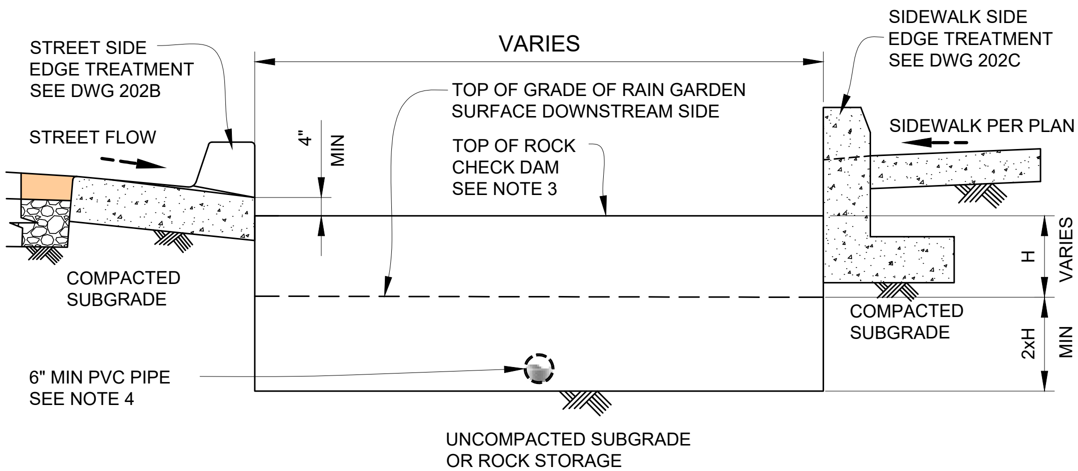
CONCRETE CHECK DAM

NOT TO SCALE

DRAWING NUMBER
209B



PLAN VIEW



SECTION A-A

NOTES:

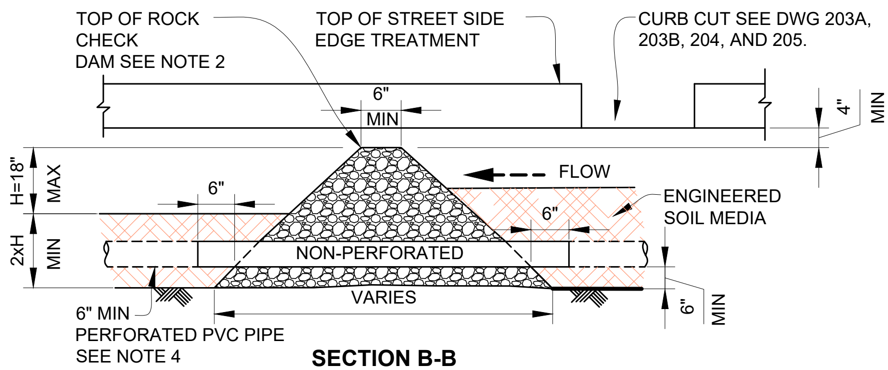
1. LOCATION, HEIGHTS, AND WIDTH OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
2. SIZE OF STONE OR AGGREGATE TO BE SPECIFIED IN THE DESIGN PLANS.
3. DEPTH OF CHECK DAM VARIES DEPENDING ON THE DEPTH OF THE FACILITY.
4. UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE
5. FOR EDGE TREATMENT OPTIONS SEE DWG 202A, 202B, AND 202C.
6. PROVIDE GABION BASKET, WELDED MESH TYPE WHEN UNDERDRAIN IS USED, TIE ALL WIRE BASKETS TOGETHER TO CREATE A CONTINUOUS STRUCTURE ALONG ITS LENGTH.

CITY OF SANTA CLARITA

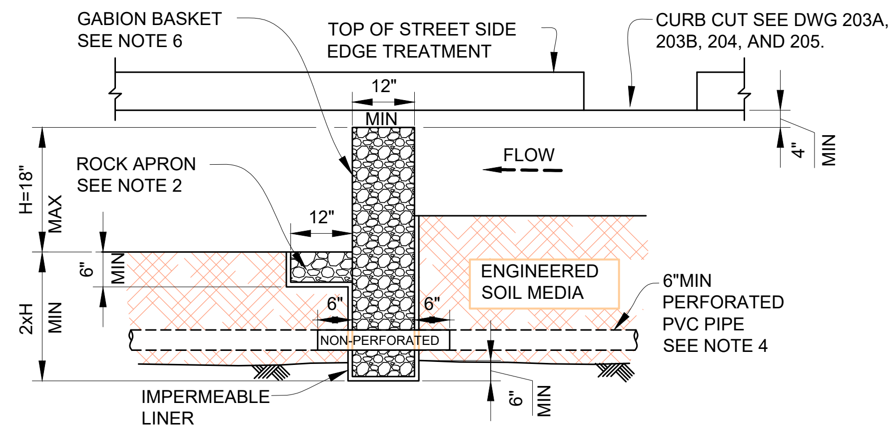
ROCK CHECK DAM

NOT TO SCALE

DRAWING NUMBER **210A**



SECTION B-B
SLOPED STONE



SECTION B-B
GABION BASKET

NOTES:

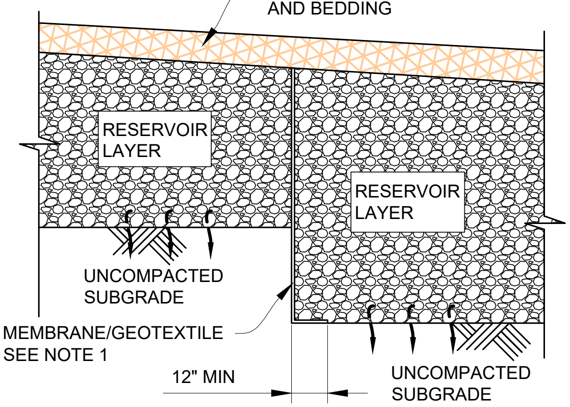
1. LOCATION, HEIGHTS, AND WIDTH OF CHECK DAMS TO BE SPECIFIED IN THE DESIGN PLANS.
2. SIZE OF ROCK OR AGGREGATE TO BE SPECIFIED IN THE DESIGN PLANS.
3. DEPTH OF CHECK DAM VARIES DEPENDING ON THE DEPTH OF THE FACILITY.
4. UNDERDRAIN TO PASS THROUGH CHECK DAM IN A NON-PERFORATED PVC PIPE
5. FOR EDGE TREATMENT OPTIONS SEE DWG 202A, 202B, AND 202C.
6. FOR GABION BASKET CHECK DAM USE WELDED MESH TYPE WHEN UNDERDRAIN IS USED, TIE ALL WIRE BASKETS TOGETHER TO CREATE A CONTINUOUS STRUCTURE ALONG ITS LENGTH PER CALTRANS 2006 STANDARD PLAN D-100B.

CITY OF SANTA CLARITA

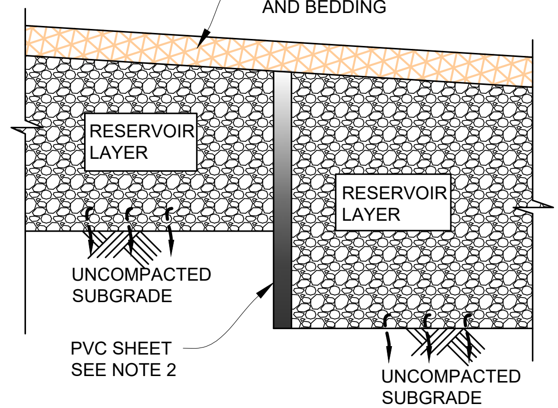
ROCK CHECK DAM

NOT TO SCALE

DRAWING NUMBER
210B



MEMBRANE/GEOTEXTILE CHECK DAM



PVC SHEET CHECK DAM

NOTES:

1. IMPERMEABLE LINER OR LOW PERMEABILITY GEOTEXTILE (PERMITTIVITY OF 0.05 SEC OR LESS).
2. SHEET TO BE 3/8" PVC SHEET TYPE I, GRAY.

CITY OF SANTA CLARITA

PERMEABLE PAVEMENT CHECK DAMS

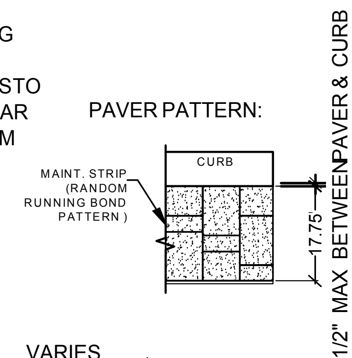
NOT TO SCALE

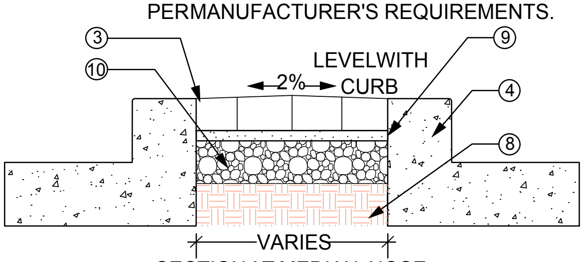
DRAWING NUMBER **211**

1. BARK MULCH PER SPECIFICATIONS. TOP OF MULCH 1" BELOW FINISHED SURFACE OF ADJACENT PAVING
2. FINISHED GRADE 3" BELOW FINISHED SURFACE OF ADJACENT PAVING
3. INTERLOCKING CONCRETE UNIT PAVERS TO BE 60MM MIN. THICKNESS, SHAPE AND COLOR PER MATERIAL LEGEND
4. CONCRETE CURB. SEE C-1.01 FOR CURB AND ROADWAY IMPROVEMENTS, (TYP.)
5. 36" DEEP 6MM. DUAL PURPOSE ROOT/ MOISTURE BARRIER CONTINUOUS ALONG PAVING EDGE, CITY-APPROVED; INSTALL PER MANUFACTURER'S REQUIREMENTS.
6. 2500 P.S.I., 4" THICK CONCRETE SUBBASE
7. SET PAVER IN +/- 1" MORTAR SETTING BED AT EDGE OF PLANTING AREA, TYP.
8. COMPACTED SUBGRADE
9. +/- 1" SAND SETTING BED. ALIGN TOP OF PAVERS WITH TOP OF ADJACENT CURB
10. 4" THICK COMPACTED AGGREGATE SUB BASE.
11. 6"x12" POURED-IN-PLACE COLORED CONCRETE HEADER. COLOR: DAVIS COLORS ADOBE 61078.

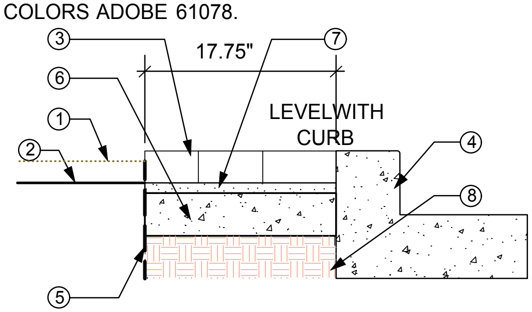
NOTES:
1) PROVIDE 1.5 LB. SUPERNET FIBER BY FORTA CORP. PER CU. YD. CONCRETE FOR ALL FLATWORK.
2) PAVER PATTERN: RANDOM RUNNING BOND (SEE RIGHT).
3) STANDARD CONCRETE UNIT PAVERS TO BE 60MM MIN. THICKNESS, VEHICULAR CONCRETE UNIT PAVERS TO BE 80MM MIN. THICKNESS.

PAVER PATTERN:

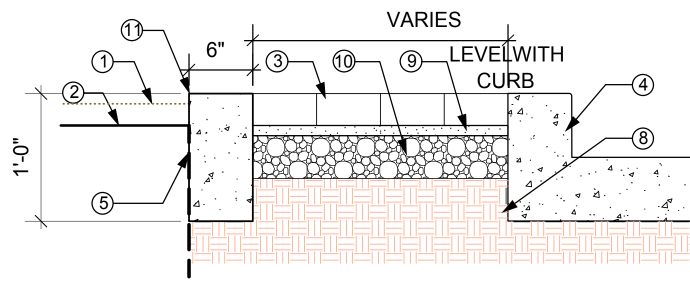




SECTION AT MEDIAN NOSE



STANDARD PAVER MAINTENANCE STRIP ON CONCRETE



STANDARD MEDIAN SECTION WITH PAVERS ON SAND

CITY OF SANTA CLARITA

MEDIAN MAINTENANCE STRIP

NOT TO SCALE

DRAWING NUMBER
212

05 MAINTENANCE

REQUIREMENTS

- Rain Garden
- Treebox Filter
- Infiltration Trench
- Permable Pavements
- Green Space Vegetated Buffers
- Enhanced Open Swales

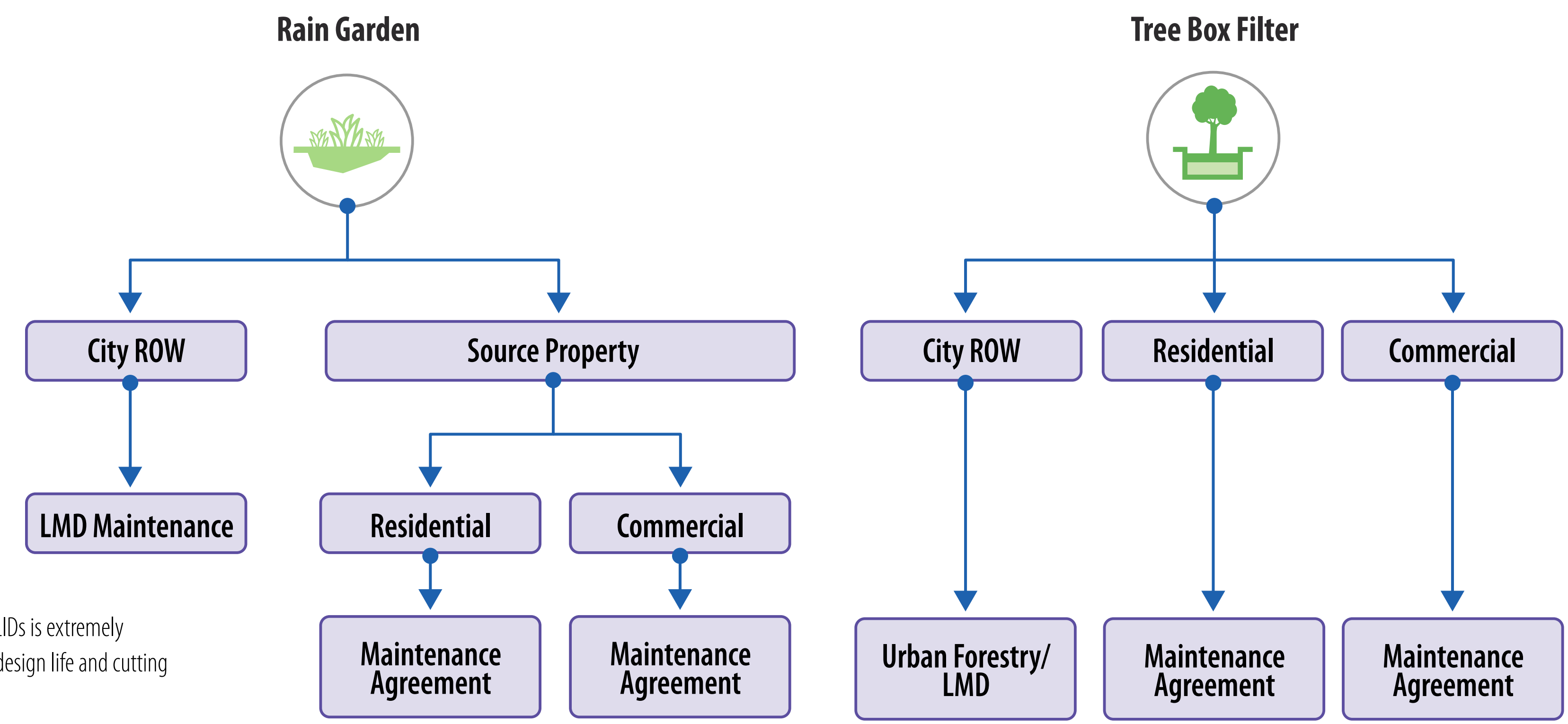
Top: Flowering landscape.
Bottom: Curb side rain garden with inlet beneath walkway.

LID and Landscape MAINTENANCE REQUIREMENTS

Inspection / Maintenance/ Reporting

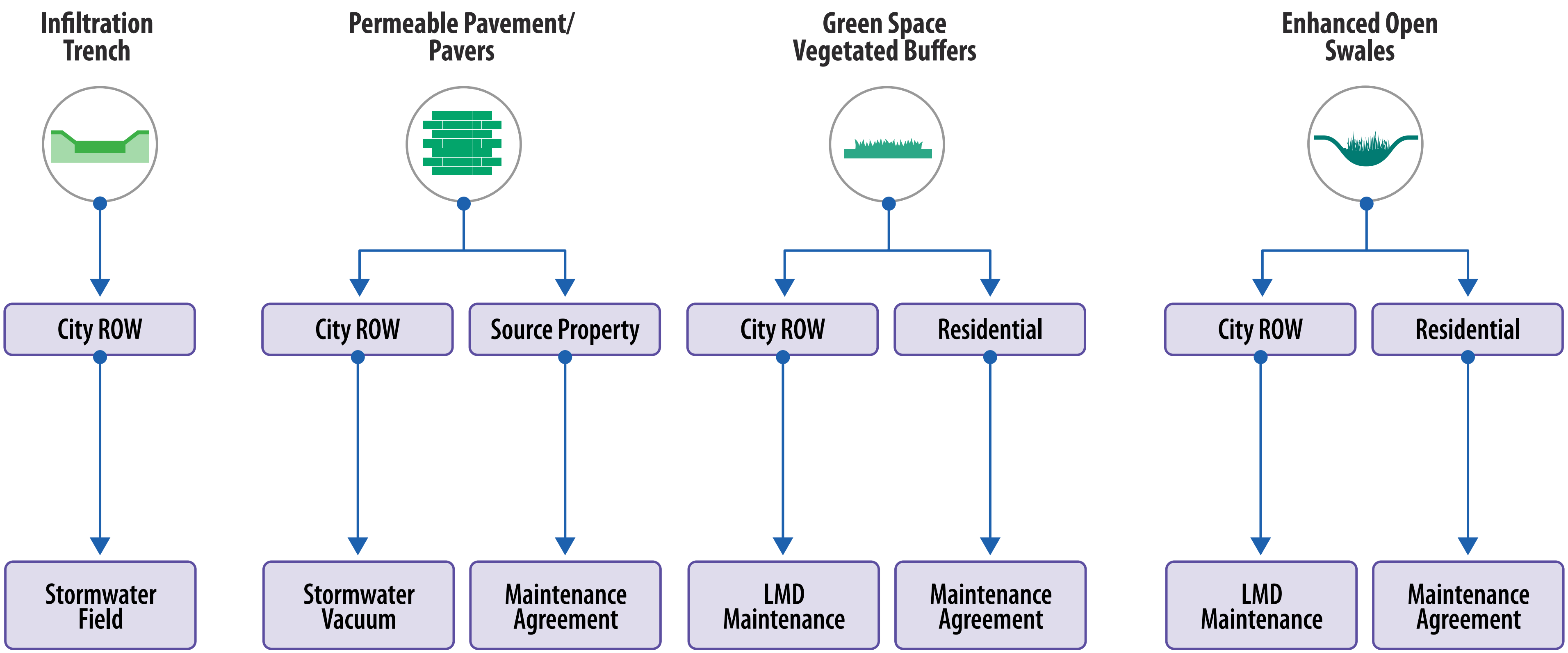
Depending on the type of Green Street LID constructed, as well as the location of construction, responsibility for maintenance could fall into any of the following categories:

- Landscape Maintenance District (LMD) Maintenance
- Maintenance Agreement
- Urban Forestry
- Stormwater Field



Maintenance of Green Street LIDs is extremely important in extending their design life and cutting down on lifetime costs.

In order to determine where responsibility of maintenance lies for the Green Street LID selected, utilize the flow chart to the right.


Infiltration Trench
City ROW
Stormwater Field
Permeable Pavement/ Pavers
City ROW
Source Property
Stormwater Vacuum
Maintenance Agreement
Green Space Vegetated Buffers
City ROW
Residential
LMD Maintenance
Maintenance Agreement
Enhanced Open Swales
City ROW
Residential
LMD Maintenance
Maintenance Agreement

Rain Garden

Typical maintenance activities:

- Bi-annual inspection of vegetation and removal of any dead or diseased plants. Any treatment applied to diseased plants should be preventative and low-toxic. Aggressive plant species with the potential to invade the rain garden should be removed, since they can increase the likelihood of standing water and vector production.
- Mulch replacement in erosion spots will be necessary and total mulch replacement will be necessary every 2 years. This should be performed before the start of the wet season following weeding, preferably in June.
- Depending on site performance, soils may need to be replaced within 5 to 10 years of construction.
- Standing water should be removed promptly to avoid vector breeding and corrective measures should be taken to restore proper infiltration rates.
- Aesthetics are an important aspect of rain gardens, so pruning and weeding will be needed.
- Accumulated sediment and debris removal, especially at inflow points.
- Soil pH regulation as needed.
- Unclogging the underdrain as needed.
- Repair overflow structures as needed.

Curb side rain garden with curb slot inlet and high grasses

Rain Garden Maintenance Checklist

Problem	Conditions When Maintenance is Needed	Maintenance Required
Vegetation	Overgrown.	Mow and prune vegetation as needed.
	Invasive, poisonous, nuisance, or noxious vegetation or weeds.	Remove vegetation and replace with design plant species as needed.
Trash / Debris	Trash, dead plant material present.	Remove and properly dispose of trash and debris.
Irrigation	Not functioning correctly.	Check irrigation system for clogs or breaks and repair as needed.
Flow Entrance / Overflow Device	Flow entrance / overflow areas clogged with sediment and / or debris.	Remove material.
	Overflow device blocked or broken.	Clean and / or repair as needed.
Erosion / Sediment Accumulation	Presence of erosion or sediment accumulation.	Check flow entrance to ensure proper function. Repair or replace the flow entrance as necessary. Repair eroded areas with gravel as needed. Re-grade rain garden as needed.
Contaminants and Pollution	Evidence of oil, gasoline, contaminants, or other pollutants.	Remove any visual contamination from floatables such as oil and grease.
Standing water	Standing water observed more than 96 hours after a storm event.	Remove / replace plant media (sand, gravel, topsoil, mulch) and vegetation.

Source: 15

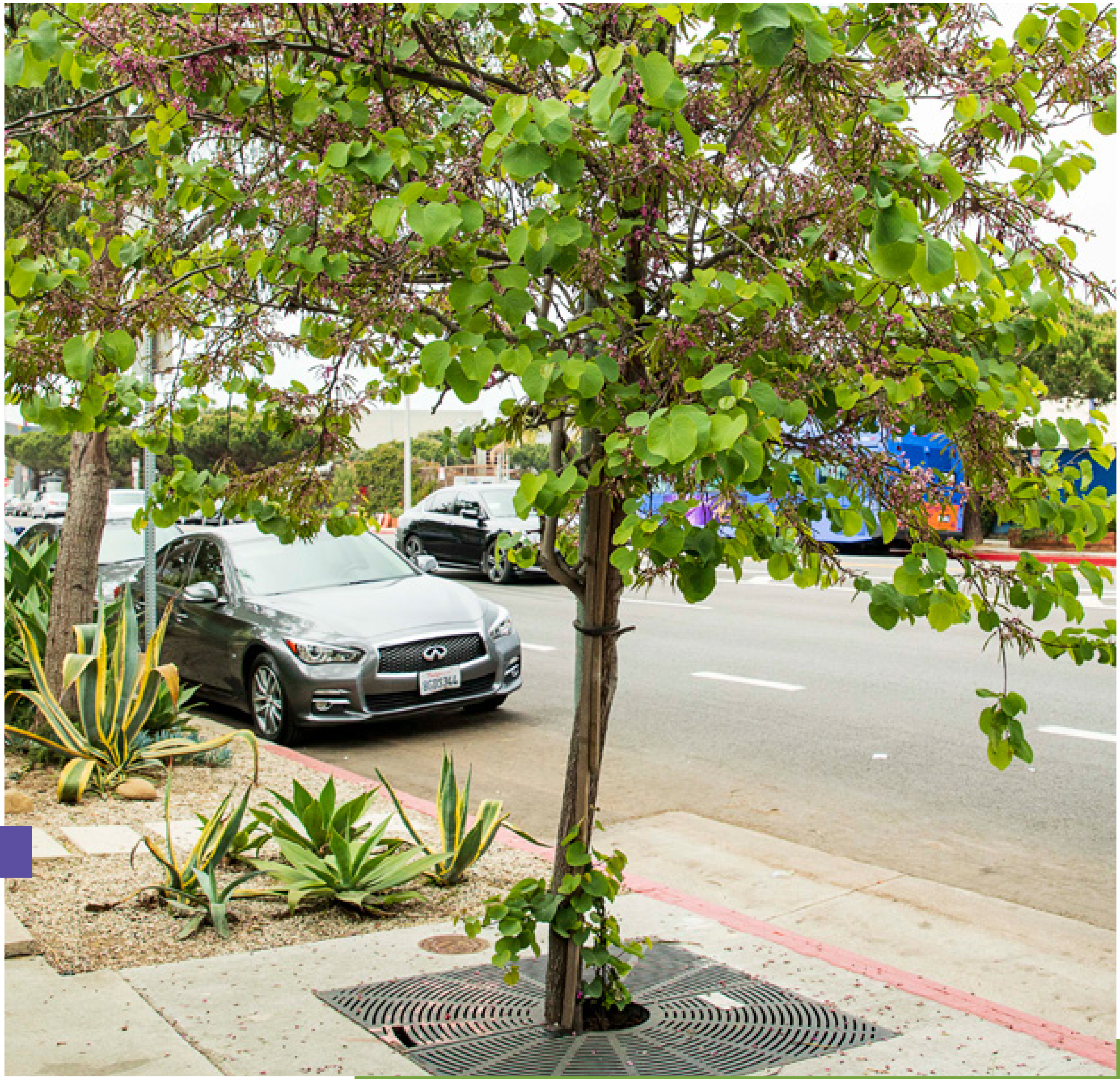
Curb side rain garden with curb slot inlets

Tree Box Filter

Typical maintenance activities:

- Periodic removal of trash and debris is required, ideally right before the wet and dry seasons and after large storm events.
- Replacement of mulch is recommended before the wet season following weeding, preferably in June.
- The tree box should be inspected regularly for clogging. Any clogging which occurs can be remedied by flushing via the cleanout.
- Evaluate the grate opening to ensure proper clearance for growth of the tree trunk. If standard staking is not feasible for trees within grates, more frequent inspections will be required to ensure no damage to the tree trunk.
- Periodic inspection and removal of sucker growth is required. Note that access to the tree's base may be restricted by the grate

Note: Urban Forestry will be reviewing all plans proposing street trees for type, size, and maintenance requirements.



Curb side tree box filter adjacent to street parking

Tree Box Filter Maintenenace Checklist

Problem	Conditions When Maintenance is Needed	Maintenance Required
Vegetation	Overgrown.	Prune vegetation and remove suckers as needed.
	Invasive, poisonous, nuisance, or noxious vegetation or weeds.	Remove weeds and offending vegetation.
Trash / Debris	Trash, dead plant material present.	Remove and properly dispose of trash and debris.
Irrigation	Not functioning correctly.	Check irrigation system for clogs or breaks and repair as needed.
Flow Entrance / Overflow Device	Inlet / overflow areas clogged with sediment and / or debris.	Remove material and ensure downspout is clear of debris.
	Overflow device blocked or broken.	Clean and / or repair as needed.
Erosion / Sediment Accumulation	Inlet structure incorrectly placed or presence of erosion or sediment accumulation.	Check inlet structure to ensure proper function. Repair or replace the flow entrance as necessary. Repair eroded areas with gravel as needed. Re-grade tree well as needed.
Contaminants and Pollution	Evidence of oil, gasoline, contaminants, or other pollutants.	Remove any visual contamination from floatables such as oil and grease.
Standing water	Standing water observed more than 96 hours after a storm event.	Inspect and clean the underdrain as needed. Clear clogs, remove / replace tree-well filter media (sand, gravel, topsoil, mulch) and vegetation as needed.

Source: 15

Infiltration Trench

Infiltration trenches require the least amount of maintenance attention out of all the other LID types presented here. According to a Caltrans study, approximately 8hrs/yr. are spent inspecting the infiltration trench*. If the trench takes more than 96 hours to drain, the rock filler material should be removed and the trench dimensions should be expanded 2 inches in each direction before replacing the rock filler material.

Infiltration Trench Maintenance Checklist

Problem	Conditions When Maintenance is Needed	Maintenance Required
Vegetation	Overgrown.	Mow and prune vegetation as needed.
	Invasive, poisonous, nuisance, or noxious vegetation or weeds.	Remove vegetation and replace with design plant species as needed.
Trash / Debris	Trash and debris > 5 ft^3 / 1,000 ft^2.	Remove and dispose of trash and debris.
Irrigation	Not functioning correctly.	Check irrigation system for clogs or breaks and repair as needed.
Contaminants and Pollution	Any evidence of oil, gasoline, contaminants, or other pollutants.	Remove any evidence of visual contamination.
Erosion / Sediment Accumulation	Undercut or eroded areas at inlet structures.	Repair eroded areas and re-grade if necessary.
	Accumulation of sediment, debris, and oil / grease in pretreatment devices.	Remove sediment, debris, and / or oil / grease.
	Accumulation of sediment, debris, and oil / grease on surface, inlet or overflow structures.	Remove sediment, debris, and / or oil / grease.
Water Drainage Rate	Standing water, or by inspection of observation wells.	Remove the top layer of the infiltration trench bottom and replace if necessary.

Source: 15 & 16

Permeable Pavements

Permeable pavement requires regular inspections and maintenance for long term functionality. Typical maintenance activities include:

- Inspect for proper infiltration at least twice during the wet season after significant storms. If infiltration is poor, remove particles causing blockage by vacuuming.
- Sweep to clear off leaves, debris, and sediment.
- Prune nearby vegetation that interfere with the permeable pavement. Any nearby mowing activities should also bag and remove grass clippings to prevent them from getting lodged in the permeable pavement pores.
- Provide irrigation to grass in paver voids (optional) as needed.
- Eliminate standing water to prevent vector breeding.
- Inspect overflow devices for obstruction or debris. Repair or replace broken pipes upon discovery.
- Limit application of pesticides and fertilizers to reduce pollutants.
- Fill and compact holes that may develop in the permeable pavement.

Permeable Pavements / Pavers Maintenance Checklist

Problem	Conditions When Maintenance is Needed	Maintenance Required
Vegetation	Overgrown vegetation.	Mow and trim vegetation.
	Presence of invasive, poisonous, nuisance, or noxious vegetation or weeds.	Remove this vegetation.
	Excessive loss of turf or ground cover.	Replant and / or reseed as needed.
Trash / Debris	Trash and debris present.	Remove and dispose of trash and debris.
Contaminants and Pollution	Any evidence of oil, gasoline, contaminants, or other pollutants.	Remove any evidence of visual contamination.
Erosion / Sediment Accumulation	Eroded areas at overflow structures.	Fill eroded areas and re-grade if necessary.
	Accumulation of sediment, debris, and oil / grease on surface, inlet or overflow structures.	Remove sediment, debris, and / or oil / grease.
Water Drainage Rate	Standing water.	Vacuum sweep and / or high pressure wash to remove sediment. Replace aggregate if necessary, but never with impervious materials.

Source: 15

Green Space
Vegetated Buffers

Typical maintenance activities:

- Inspect filter strips bi-annually for evidence of erosion, damaged vegetation, and sediment / debris accumulation. It is best to perform these inspections at the end of the dry and wet seasons, but additional inspections should ideally occur after large storms as well.
- Mowing is only necessary once or twice a year; more if safety, aesthetics, or prevention of woody vegetative growth is desired.
- Frequency of trash removal depends on the location of the filter strip, but should always be performed before any mowing.
- Standing water should be removed promptly to avoid vector breeding and the cause of ponding should be identified and remedied.

Curb side vegetated buffer strip intercepting runoff from park

Green Space Vegetated Buffers Maintenance Checklist

Problem	Conditions When Maintenance is Needed	Maintenance Required
Sediment Accumulation	Sediment depth exceeds 2-inches or covers vegetation.	Remove sediment without disturbing vegetation. Ensure the vegetated filter strip is level from side to side and drains freely to the outlet when sediment is removed.
Irrigation	Not functioning correctly.	Check irrigation system for clogs or breaks and repair as needed.
Trash / Debris	Trash / debris > 5 ft^3 / 1,000 ft^2.	Remove and dispose of trash and debris.
Standing Water	Standing water observed more than 48-hours after storm event.	Inspect and clean underdrain as needed. Clear clogs as needed and till / re-vegetate the surface if necessary.
Flow Spreader	Flow spreader is uneven or flow is not evenly distributed to the vegetated swale.	Remove obstructions and clean / re-level flow spreader as needed.
Excessive Shading	Poor vegetation growth.	Prune overhanging limbs and bushy vegetation.
Erosion	Presence of erosion or channelization.	Repair ruts or bare areas less than 12-inches wide with crushed gravel. Re-grade channel if necessary. Inspect flow spreader to ensure the flow is evenly distributed. Re-vegetate if necessary.
Contaminants and pollution	Any evidence of oil, gasoline, contaminants, or other pollutants.	Remove visual contamination from floatables such as oil and grease.
Vegetation	Overgrown.	Mow / prune vegetation as needed.
	Presence of invasive, poisonous, nuisance, or noxious vegetation or weeds.	Remove vegetation and replace with design plant species as needed.
Flow Entrance / Overflow Device	Inlet / overflow areas clogged with sediment and / or debris.	Remove material.
	Overflow pipe blocked or broken.	Repair as needed.

Source: 15

Enhanced Open Swales

Typical maintenance activities:

- Bi-annual inspection of swales for evidence of erosion, damaged vegetation, and sediment / debris accumulation. It is best to perform these inspections at the end of the dry and wet seasons.
- Mowing is only necessary once or twice a year; more if safety, aesthetics, or prevention of woody vegetative growth is desired.
- Frequency of trash removal depends on the location of the swale, but should always be performed before any mowing.
- Sediment should be removed when it accumulates to a depth of 3 inches in any spot or buries vegetation.
- Standing water should be removed promptly to avoid vector breeding and the cause of ponding should be identified and remedied.

Vegetated swale with overflow device

Enhanced Open Swales Maintenance Checklist

Problem	Conditions When Maintenance is Needed	Maintenance Required
Sediment Accumulation	Sediment depth exceeds 2-inches or covers vegetation.	Remove sediment without disturbing vegetation. Ensure that the vegetated swale is level from side to side and drains freely to the outlet when sediment is removed.
Irrigation	Not functioning correctly.	Check irrigation system for clogs or breaks and repair as needed.
Trash / Debris	Trash and debris > 5 ft^3 / 1,000 ft^2.	Remove and dispose of trash and debris.
Standing Water	Standing water observed more than 96 hours after storm event.	Inspect, and clean as needed, the underdrain to ensure proper function. Clear clogs as needed. Till surface and re-vegetate if necessary.
Flow Spreader	Flow spreader is uneven or flow is not evenly distributed into the vegetated swale.	Remove obstructions. Clean and re-level flow spreader as needed.
Excessive Shading	Poor vegetation growth.	Prune overhanging limbs and bushy vegetation.
Erosion	Presence of erosion or channelization.	Repair ruts or bare areas less than 12-inches wide with crushed gravel. Re-grade channel if necessary. Inspect flow spreader to ensure that flow is evenly distributed. Re-vegetate if necessary.
Contaminants and pollution	Any evidence of oil, gasoline, contaminants, or other pollutants.	Remove any evidence of visual contamination from floatables such as oil and grease.
Vegetation	Overgrown vegetation.	Mow and prune vegetation as needed.
	Presence of invasive, poisonous, nuisance, or noxious vegetation or weeds.	Remove this vegetation and plant native species as needed.
Flow Entrance / Overflow Device	Inlet / overflow areas clogged with sediment and / or debris.	Remove material.
	Overflow pipe blocked or broken.	Repair as needed.

Source: 15

Plant Selection

Plant selection for Green Street LID's should be in compliance with the most current Landscape Maintenance District Guidelines for the community. All plant selection and installation shall be in accordance with City approved landscape plans.

REFERENCES

There were many different documents and manual reference for the information that is presented in this manual. A complete list of the sources are listed below.

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