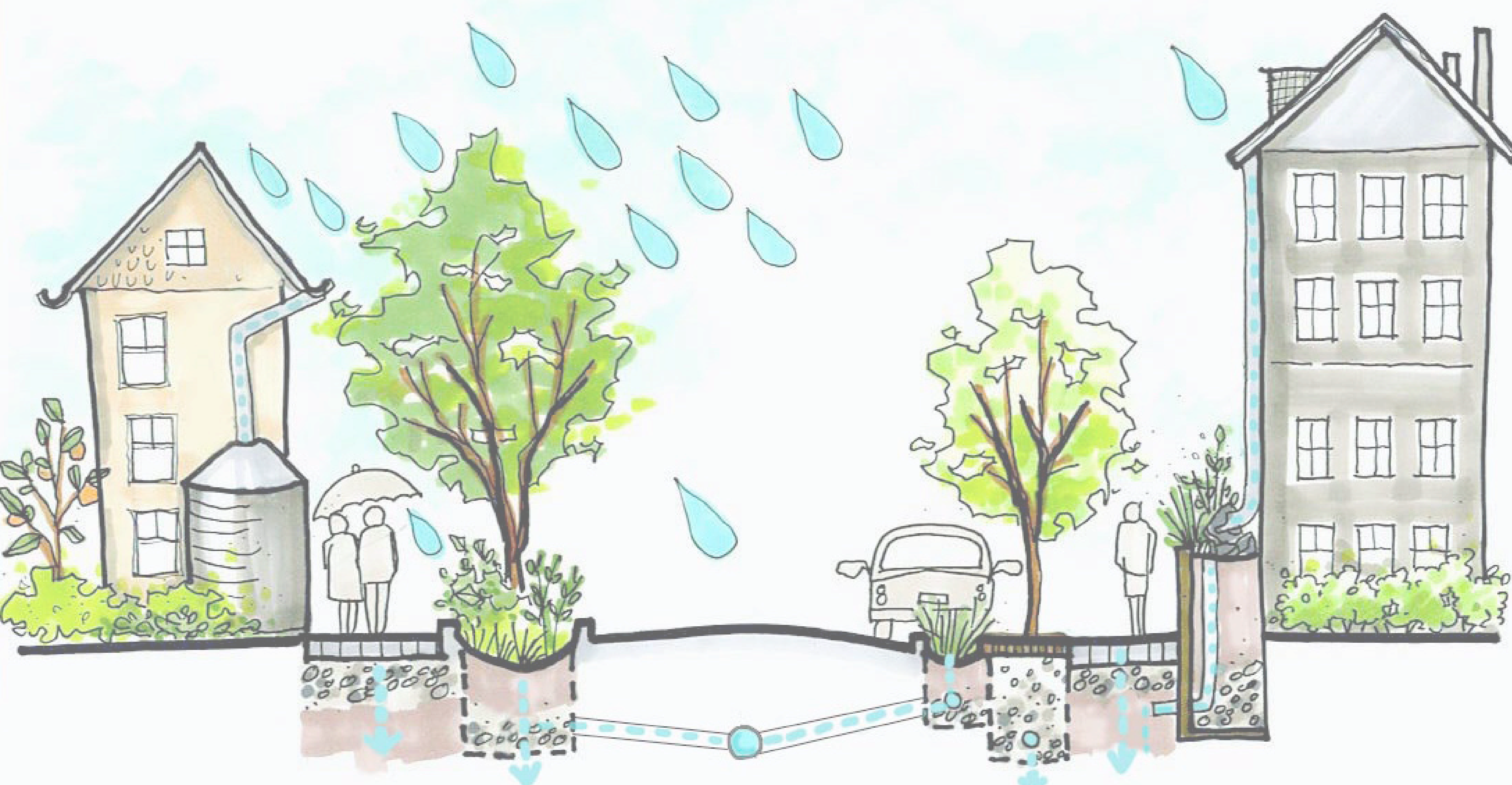
SOLANO PERMITTEES'

GREEN STORMWATER INFRASTRUCTURE



DESIGN GUIDEBOOK

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INTRODUCTION

CHAPTER OBJECTIVES

- Describe the multi-benefits of green stormwater infrastructure and why it should be included in new or retrofit projects.
- Illustrate how to use the Design Guidebook, including its purpose, scope, and organization.

1. Introduction

WELCOME TO THE SOLANO PERMITTEES' GREEN STORMWATER INFRASTRUCTURE DESIGN GUIDEBOOK

This Green Stormwater Infrastructure Design Guidebook (Design Guidebook) reflects the best practices on green stormwater infrastructure (GSI) planning and design locally and nationwide. The Guidebook also reflects the unique challenges and specific needs for constructing GSI within the cities of Fairfield, Suisun City, and Vallejo (FSV), collectively referred to as the Solano Permittees (Permittees).

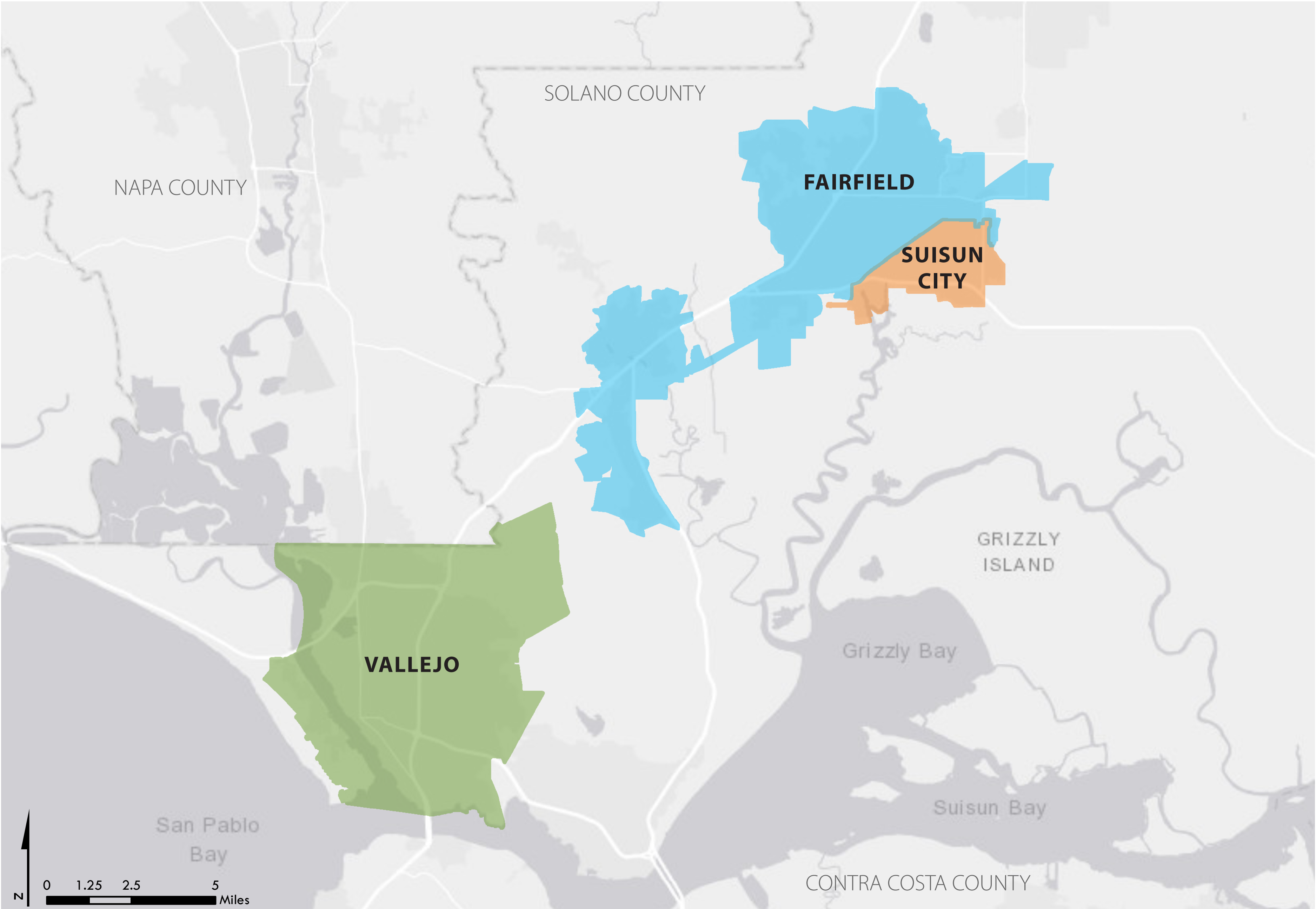
Though implementation is often driven by regulations, GSI planning and design is best when linked to other community priorities to realize multiple benefits and efficiently invest public dollars. For example, green stormwater infrastructure can be integrated into right-of-way improvements to promote active transportation or Complete Street approaches as illustrated in Chapter 3. Landscaped GSI can improve property aesthetics which translates into increased property values. In downtown corridors these improved aesthetics create a sense of community identity and can drive economic development.

Linking GSI implementation with other community priorities creates an opportunity to cost effectively balance GSI construction and operation and maintenance costs. One means to achieve this balance is GSI integration into the Permittee's standard practices, starting with the design details and specifications included in Chapter 4. Every capital project, every street improvement, every private development is an opportunity to integrate GSI into planned investments and capitalize on GSI's multiple benefits.

The goal of this Design Guidebook is to be a Green Stormwater Infrastructure design, planning, and implementation tool that will support the Permittees to achieve water quality targets linked to other community priorities to realize multiple benefits and efficiently invest public dollars.

Regulated Projects must comply with each Cities' separate C3 Guidance for specific LID and GSI requirements, and private developers are encouraged to use this Design Guidebook as a resource. Due to the predominance of soils with low infiltration capacity within the Solano Permittees area, most GSI features won't infiltrate to a significant degree and in most cases will require an underdrain and overflow connected to the existing storm drain system.

1. Introduction



Solano Permittees

1. Introduction

GUIDEBOOK ORGANIZATION

This Design Guidebook is intended as a tool for the Permittees to use to identify and incorporate green stormwater infrastructure into the built environment, including into existing and proposed streets, parking lots, and landscape areas. The four primary chapters are organized to identify these green stormwater infrastructure integration opportunities.

Chapter 2. Green Stormwater Infrastructure Types. This chapter defines a common and consistent terminology for use throughout the Solano Permittees' GSI planning initiatives.

Chapter 3. Streetscape and Project Design Guidelines for Green Stormwater Infrastructure Projects. This chapter illustrates types of GSI opportunities in the Permittees' jurisdictions, specifically in right-of-ways, parking lots, and public spaces; provides GSI landscape design criteria; and identifies considerations for GSI maintenance and post-construction performance.

Chapter 4. Green Stormwater Infrastructure Standard Specification and Design Details. Provides a suite of GSI details and specifications for integration into Permittee standards.

Chapter 5. Green Stormwater Infrastructure Sizing Requirements. This chapter simply explains GSI sizing requirements and provides "real-world" examples of how the sizing requirements apply to specific concept projects identified within the Solano Permittees' jurisdictions. Regulated Projects should consult and comply with each Cities' separate C3 Guidance documents.

What are Design Guidelines?

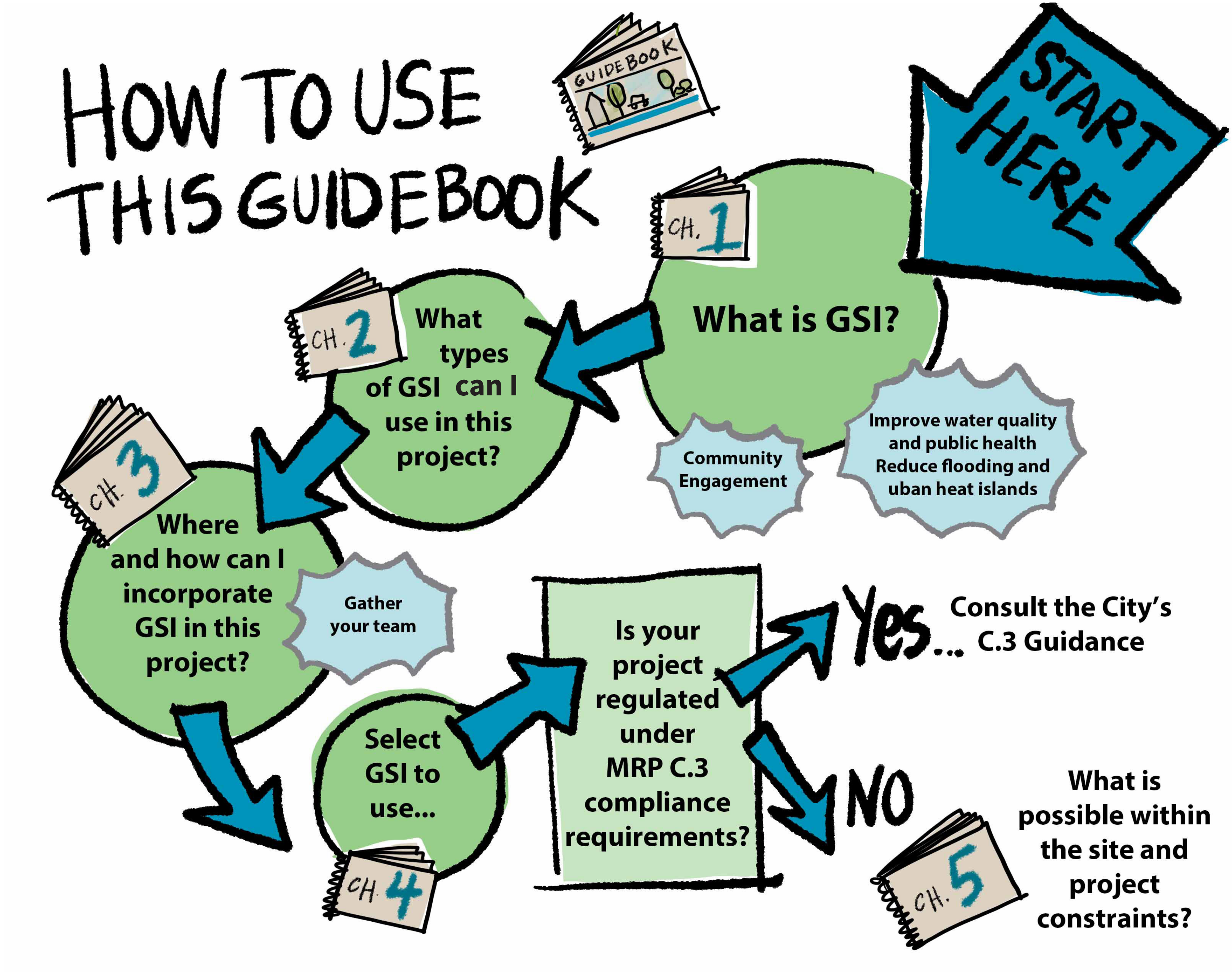
Design guidelines are sets of recommendations towards good practice in design. They are intended to provide clear instructions to designers and developers on how to adopt specific principles, such as intuitiveness, learnability, efficiency, and consistency. Design guidelines convey general policies and best practices in the design of stormwater features in new and retrofit environments. They do not dictate solutions and instead, they define a range of appropriate responses to a variety of specific design issues.

Why have Design Guidelines?

Design Guidelines support the development of a common understanding of GSI design principles and standards. Maintaining a high quality of stormwater infrastructure ensures that the community not only meet its important regulatory requirements but also directs investments in ensuring aesthetic standards and helps to achieve the community's goals on a wide range of issues. Therefore, these guidelines and the associated design review process through which they are administered promotes the functionality and performance for stormwater as well as the contribution of the project to larger community goals. Recognizing this, the Solano Permitees have established these design guidelines.

What is a Design Specification?

A design specification is a detailed document providing information about a designed project. Design specifications include all necessary drawings, dimensions, environmental factors, aesthetic factors, and maintenance that will be needed for construction. It may also give specific examples of how the design should be executed, helping others work properly (a guideline for what the person should do).


HOW TO USE THIS GUIDEBOOK
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1. Introduction

WHAT IS GREEN STORMWATER INFRASTRUCTURE AND HOW DOES IT WORK?

The US Environmental Protection Agency describes green stormwater infrastructure as a range of natural and built approaches to stormwater management that mimic natural systems by cleaning stormwater and letting it absorb back into the ground. An important objective of green stormwater infrastructure is to reduce stormwater volume, which improves water quality by reducing pollutant loads, stream bank erosion, and sedimentation.[1]

Rather than collecting runoff in piped or channelized networks and controlling the flow downstream in a large stormwater management facility, green stormwater infrastructure distributes treatment of non-point source pollution, disperses flows, and manages runoff closer to where it originates. Because green stormwater infrastructure embraces a variety of useful techniques for controlling runoff, designs can be customized according to local resource protection requirements, as well as, site constraints. New projects, redevelopment projects, and capital improvement projects can all be viewed as candidates for implementing green stormwater infrastructure and Low Impact Development design principles, as defined in Chapter 3.

1 https://www.epa.gov/sites/production/files/2015-09/documents/green_infrastructure_roadshow.pdf

> Green stormwater infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. Green stormwater infrastructure can range in scale from site design approaches such as rain gardens and green roofs to regional planning approaches such as conservation of large tracts of open land. In conjunction with gray infrastructure, interconnected networks of green stormwater infrastructure can enhance community resiliency by increasing water supplies, reducing flooding, combating urban heat island effect, and improving water quality.[2]
>
> 2 EPA, Green Infrastructure and Climate Change Collaborating to Improve Community Resiliency, August 2018.

GUIDEBOOK PURPOSE AND SCOPE

This Design Guidebook has been specifically prepared to fulfill the requirements of provisions of the Municipal Regional Stormwater NPDES Permit (MRP) issued by the San Francisco Bay Regional Water Quality Control Board (Order No. R2-2015-0049), by providing:

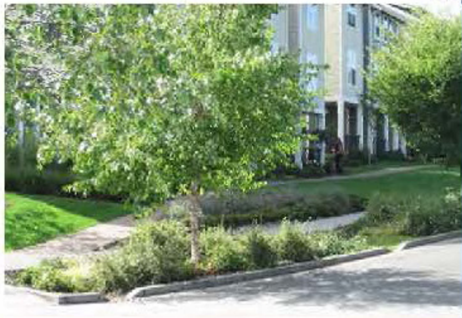
- Guidelines for overall streetscape and project design and construction, so that projects have a unified, complete design that implements the range of functions associated with the projects {MRP Section C.3.j.i.(2)(e)};
- Standard specifications and design details to incorporate green stormwater infrastructure into projects {MRP Section C.3.j.i.(2)(f)}; and
- Sizing requirements for treatment and hydromodification to satisfy Provision C.3.c and C.3.d in the Permit {MRP Section C.3.j.i.(2)(g)}.

These materials can also support public outreach to:

- Educate appropriate elected officials (mayor and city council) on green stormwater infrastructure {MRP Section C.3.j.i.(4)(c)};
- Conduct green stormwater infrastructure public outreach and education {MRP Section C.3.j.i.(4)(a)}; and
- Train appropriate staff on green stormwater infrastructure provisions {MRP Section C.3.j.i.(4)(b)}.

While the design guidelines are written for use by the city family, all readers are strongly encouraged to enlist the assistance of qualified design and planning professionals, including landscape architects, engineers, soil and plants consultants.

Improved Air Quality/Climate Change



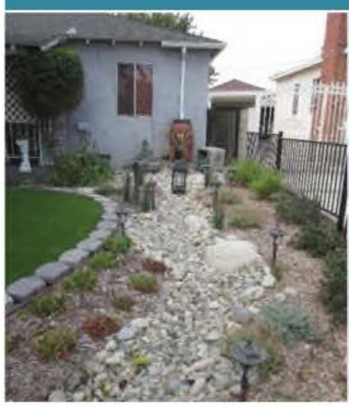
Urban Heat Island
Green infrastructure practices that include trees and other vegetation can reduce the urban heat island effect, which reduces energy use and the incidence and severity of heat-related illnesses.

Air Quality
Green infrastructure improves air quality by increasing vegetation, specifically trees, that absorb air pollutants, including CO_2, NO_2, O_3, SO_2, and PM_{10}.

Greenhouse Gases
Green infrastructure's ability to sequester carbon in vegetation can help to meet greenhouse gas emission goals by contributing to a carbon sink.

Water Quality and Quantity

Water Conservation
Green infrastructure that incorporates locally adapted or native plants reduce the need for irrigation, which reduces demand for potable and recycled water. Rain barrels and cisterns that capture rainwater also reduce water use.



Water Quality and Flood Mitigation
Green infrastructure can decrease the frequency and severity of local flooding by reducing stormwater discharge volumes and rates.

Habitat
Vegetated green infrastructure can provide habitat for wildlife, particularly birds and insects, even at small scales of implementation.

Quality of Life

Public Health
Residents have more recreational opportunities in the presence of large-scale green space in their community, which can improve public health and well-being.

Public Safety
Green streets that include curb bump-outs at pedestrian crossings improve pedestrian safety by slowing traffic and decreasing the distance that pedestrians must travel in the roadway.

Recreational Opportunities
Larger-scale green infrastructure facilities that include public access, such as constructed wetlands, offer recreational opportunities.

Property Aesthetics
Green infrastructure that includes attractive vegetation can improve property aesthetics, which can translate into increased property values.

Educational Opportunities

Public Education
The visible nature of green infrastructure offers enhanced public education opportunities to teach the community about mitigating the adverse environmental impacts of our built environment. Signage is used to inform viewers of the features and functions of the various types of facilities.

The multi-benefits green infrastructure provides (source: [EPA)](EPA)

WATER QUALITY BENEFITS OF GREEN STORMWATER INFRASTRUCTURE

Fish tissue monitoring has identified the bioaccumulation of Polychlorinated Biphenyls (PCBs), mercury, and other pollutants in San Francisco Bay (Bay) in quantities with the potential to affect people consuming fish from the Bay. In response to these findings, the Bay has an interim advisory regarding the consumption of fish, has been designated an impaired water body on the Clean Water Act (CWA) Section 303(d) list for PCBs, mercury, and other pollutants, and has Total Maximum Daily Load (TMDL) water quality restoration programs targeting PCBs and mercury.

The reissued MRP (MRP 2.0, Order R2 2015 0049) requires municipal agencies to move from pilot scale work to focused implementation and defined load reduction goals (e.g., 3 kg/year region wide for PCBs and 10 kg/year for mercury). The Solano Permittees, along with other municipalities in the San Francisco Bay Area, are preparing a suite of watershed-based planning efforts to identify control measure implementation strategies to achieve the pollutant load reduction goals.

One of the strategies, that is part of a long-term approach to meeting the Mercury and PCB TMDLs, is the disconnection of impervious surfaces using green stormwater infrastructure.

Green stormwater infrastructure provides water quality benefits by reducing the concentrations of PCBs and mercury in stormwater, while also reducing concentrations or amounts of other regulated pollutants, such as trash and pesticides. GSI has the potential to reduce concentrations of future pollutants of concern such as nutrients, pathogens, and others.

Green Stormwater Infrastructure can reduce the amount of pollution entering the San Francisco Bay, specifically for some of the pollutants of greatest concern like Mercury, PCBs, and Trash.

Mercury

Mercury in the San Francisco Bay is a concern because it bioaccumulates, or collects in higher concentrations the larger and older a fish is. People eating fish from the Bay are at risk of consuming mercury in concentrations that can lead to health effects. Elevated mercury, in the form of methylmercury is linked to neurological, developmental, immunological, reproductive and cardiovascular problems in wildlife and people.

How does Mercury enter the Bay?

Mercury binds to sediment particles and is found in and near the Bay from a variety of sources. One historic source is from legacy sediments originating from gold miners during the California Gold Rush. Because gold dissolves in mercury, miners used mercury to separate gold from unwanted materials, making it possible for them to collect small pieces of gold. The practice of using mercury, coupled with using powerful jets of water to dislodge soil from hillsides, caused sediments with high concentrations of mercury to flow into the Bay. These sediments remain in the Bay and are a continued source of mercury contamination as they still flow into the Bay from the California foothills and Central Valley.

Mercury also enters the Bay from stormwater runoff, industrial wastewater, air pollution, and from sewage treatment plants.

The primary means for reducing mercury contamination is through reducing sediments from entering the Bay.

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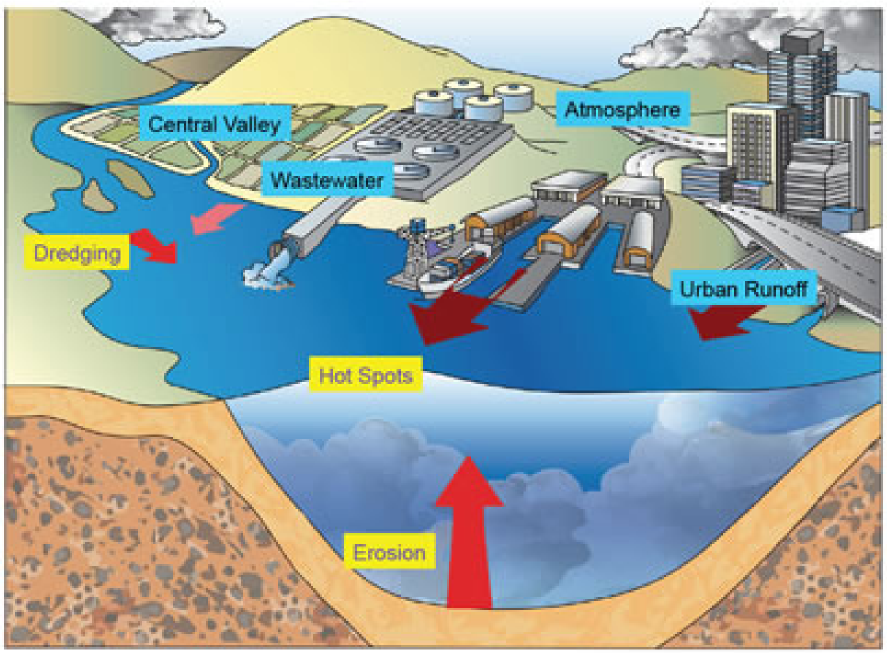
PCBs

Polychlorinated biphenyls (PCBs), like mercury, bind to sediment particles which deposit in the Bay and are a risk to human and ecosystem health.

How do PCBs enter the Bay?

Though PCB production was banned by the United States Congress in 1979, they can still be found due to historic uses and their continued use by electric utilities in transformers. PCBs were widely used as dielectric and coolant fluids in transformers, cutting fluids for machining operations, carbonless copy paper, heat transfer fluids, and other industrial uses.

The primary means for reducing PCB contamination is through reducing sediments from entering the Bay, specifically in the vicinity of sites with historic PCB use.



Trash

Trash in stormwater is defined as manufactured objects made from paper, plastic, cardboard, glass, metal, etc. This definition excludes sediments, oil and grease, and vegetation. Trash in surface waters can inhibit the growth of aquatic vegetation, harm aquatic organisms by ingestion or entanglement, convey other pollutants, such as toxic substances, and cause aesthetic problems on shorelines.

Trash within stormwater is considered to be a significant problem in highly urbanized areas, such as the San Francisco Bay Area. Trash can be addressed using a full capture system such as Gross Solids Removal Devices (GSRDs), institutional controls such as street sweeping, and anti-litter education and outreach programs may also be implemented.

From Caltrans Stormwater Quality Handbooks Project Planning and Design Guide, July 2017

PCBs enter the San Francisco Bay from:

- ***Atmospheric deposition: Some PCBs can evaporate into the air. When it rains, airborne PCBs are deposited on the ground and directly onto the Bay.***
- ***Drainage from the Central Valley***
- ***Municipal and industrial wastewater***
- ***Storm drains and stormwater runoff***
- ***Disturbance of buried Bay sediments by dredging or erosion***

From California Water Quality Control Board, San Francisco Region 2, https://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/TMDLs/sfbaypcbstmdl.html

ACKNOWLEDGMENTS, INFORMATION SOURCES AND REFERENCES

The information in this Design Guidebook draws upon numerous sources from across the country and the San Francisco Bay Area. The following are specific jurisdictions we would like to acknowledge as providing information that was referenced and incorporated and/or adopted into this Design Guidebook. We anticipate these jurisdictions will continue to lead in the innovation, development, and implementation of green stormwater infrastructure and can be referenced as a source of inspiration and guidance.

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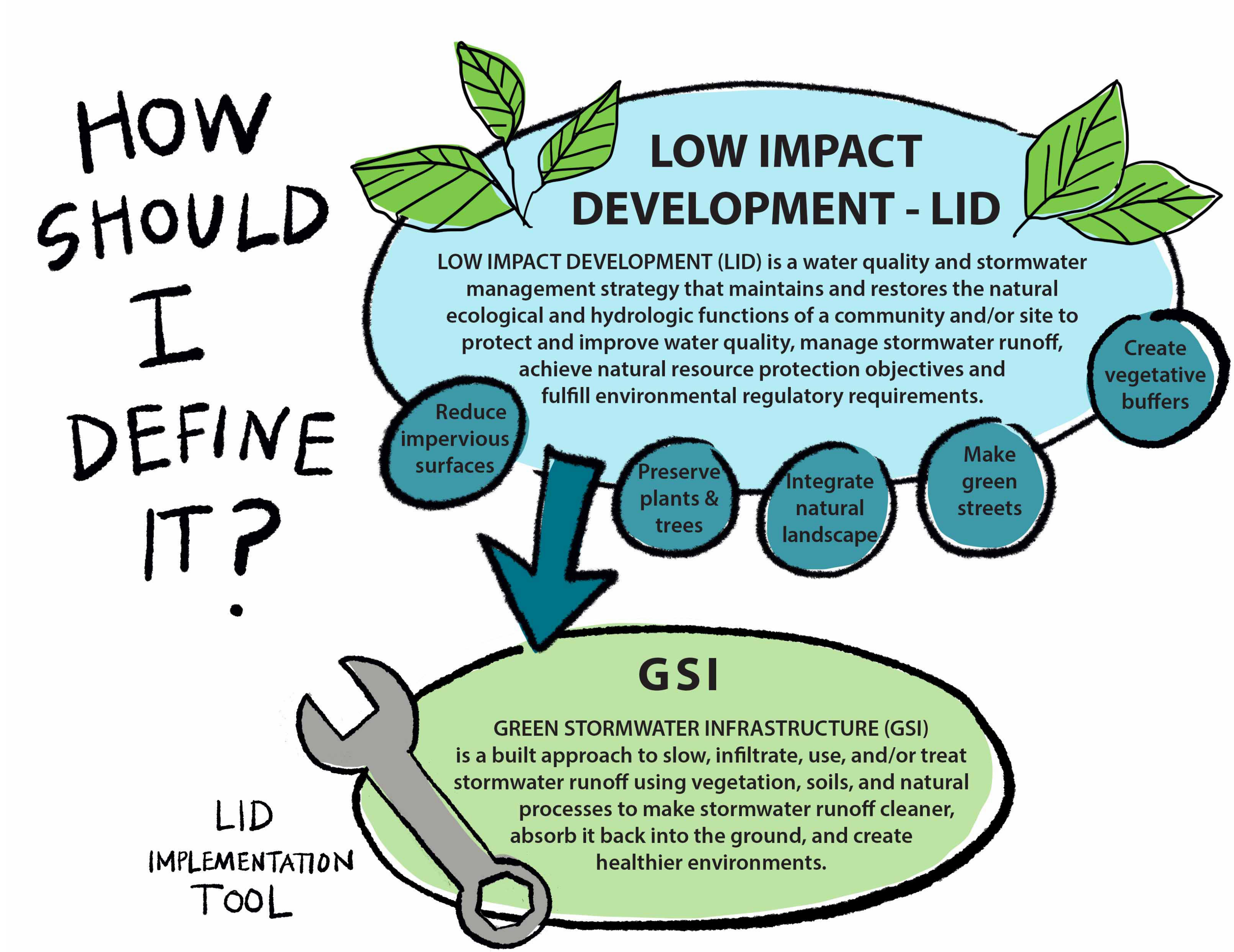
1. Introduction

ACRONYMS & ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ABAG	Association of Bay Area Governments
ASTM	ASTM International, formerly "American Society for Testing and Materials"
BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practice, can refer to both structural and non-structural practices, including GSI and LID.
BP	Bioretention Planter Construction Category
C3	Refers to Provision C3 in the MRP to address stormwater runoff pollutant discharges and increased flows from New Development and Redevelopment using source control, site design, and stormwater treatment measures.
CASQA	California Stormwater Quality Association
CEQA	California Environmental Quality Act
CWA	Clean Water Act
DMA	Drainage Management Area
ESC	Erosion and Sediment Control
FSV	Fairfield, Suisun, Vallejo
GI	Green Infrastructure; Although the MRP uses the term green infrastructure (GI), the Solano Permittees prefer to use the term green stormwater infrastructure (GSI). Henceforward, the term GSI will be used.
GIS	Geographic Information System
GSI	green stormwater infrastructure
IRWMP	Integrated Regional Water Management Plan
LEED®	Leadership in Energy & Environmental Design
LID	Low Impact Design or Low Impact Development
MAP	Mean Annual Precipitation
Max	Maximum
MEP	Maximum Extent Practicable
Min	Minimum
MRP	Municipal Regional Stormwater NPDES Permit
MS4	Municipal Separate Storm Sewer System
Non-structural Stormwater BMPs	Practices or programs designed to manage, treat, and/or improve stormwater quality and/or quantity. Examples include street sweeping practices or educational programs about responsible pesticide or fertilizer use.
NLCD	National Land Cover Data Set
NPDES	National Pollutant Discharge Elimination System
PCBs	Polychlorinated Biphenyls
PP	Pervious Pavement Construction Category
RAA	Reasonable Assurance Analysis
ROW	Right-of-Way
RWQCB	Regional Water Quality Control Board
RWSM	Regional Watershed Spreadsheet Model developed by SFEI
SCP	Stormwater Control Plan
SFEI	San Francisco Estuary Institute
SFPUC	San Francisco Public Utilities Commission
SMARTS	Stormwater Multiple Application & Report Tracking System
SM GSI	Site Management Category
Spec	Standard Specifications
Stormwater BMP	Best Management Practice to manage, treat, and/or improve stormwater quality and/or quantity.
Structural Stormwater BMPs	"In the ground" systems to manage, treat, and/or improve stormwater quality and/or quantity.
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load ; Fish tissue monitoring has identified the bioaccumulation of PCBs, mercury, and other pollutants in San Francisco Bay in quantities with the potential to effect people consuming fish from the Bay. In response to these findings, the Bay has an interim advisory regarding the consumption of fish, has been designated an impaired water body on the CWA Section 303(d) list for PCBs, mercury, and other pollutants, and has TMDL water quality restoration programs targeting PCBs and mercury.
Typ	Typical
USEPA	United States Environmental Protection Agency
WLA	Waste Load Allocation


HOW SHOULD I DEFINE IT?
LOW IMPACT DEVELOPMENT - LID
LOW IMPACT DEVELOPMENT (LID) is a water quality and stormwater management strategy that maintains and restores the natural ecological and hydrologic functions of a community and/or site to protect and improve water quality, manage stormwater runoff, achieve natural resource protection objectives and fulfill environmental regulatory requirements.
Reduce impervious surfaces
Preserve plants & trees
Integrate natural landscape
Make green streets
Create vegetative buffers
GSI
GREEN STORMWATER INFRASTRUCTURE (GSI) is a built approach to slow, infiltrate, use, and/or treat stormwater runoff using vegetation, soils, and natural processes to make stormwater runoff cleaner, absorb it back into the ground, and create healthier environments.
LID IMPLEMENTATION TOOL

CHAPTER 2
GREEN STORMWATER INFRASTRUCTURE TYPES

CHAPTER OBJECTIVES

- Establish consistent terminology for use throughout the Solano Permittees' GSI planning initiatives.

2. Green Stormwater Infrastructure Types

GREEN STORMWATER INFRASTRUCTURE CLASSIFICATIONS

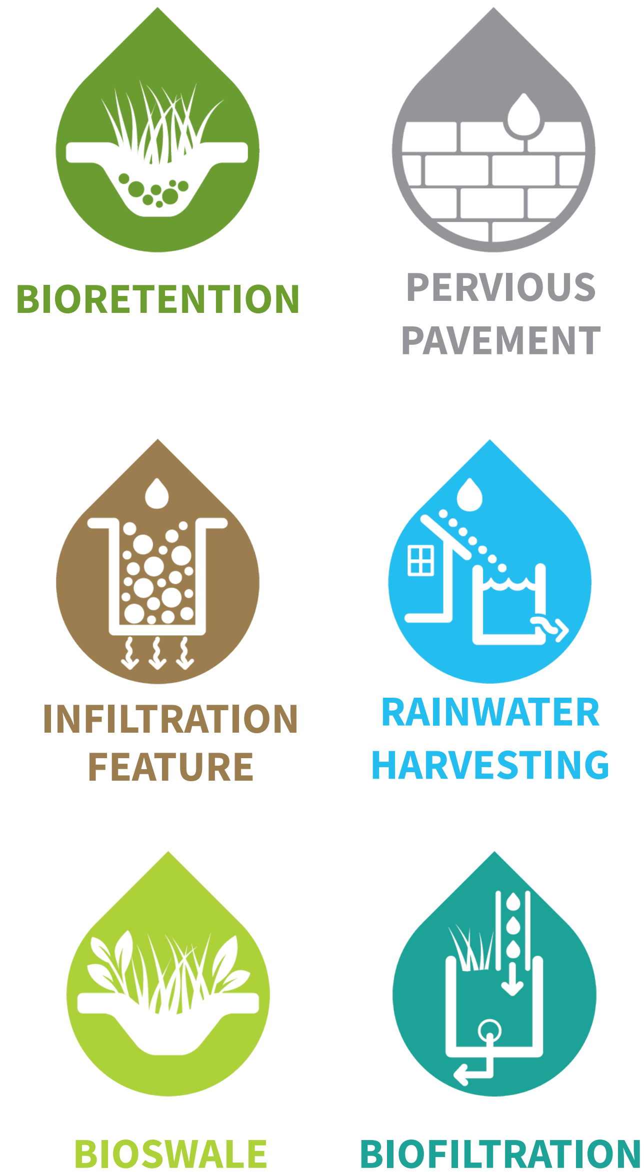
For the purposes of organizing and presenting information, this Design Guidebook classifies green stormwater infrastructure structures into six categories. Any existing or proposed green stormwater infrastructure feature can be identified as one of these six types: a bioretention feature, an infiltration feature, pervious pavement, rainwater harvesting, a bioswale or a biofiltration feature.

There are other common terms associated with green stormwater infrastructure, like "curb cuts", that are specific design elements that can be associated with many different green stormwater infrastructure types. Another example is the term "rain garden", which is a type of bioretention where stormwater can infiltrate into the subsurface soils. Biofiltration is another type of bioretention with an impermeable or concrete liner with an underdrain (pervious) pipe.

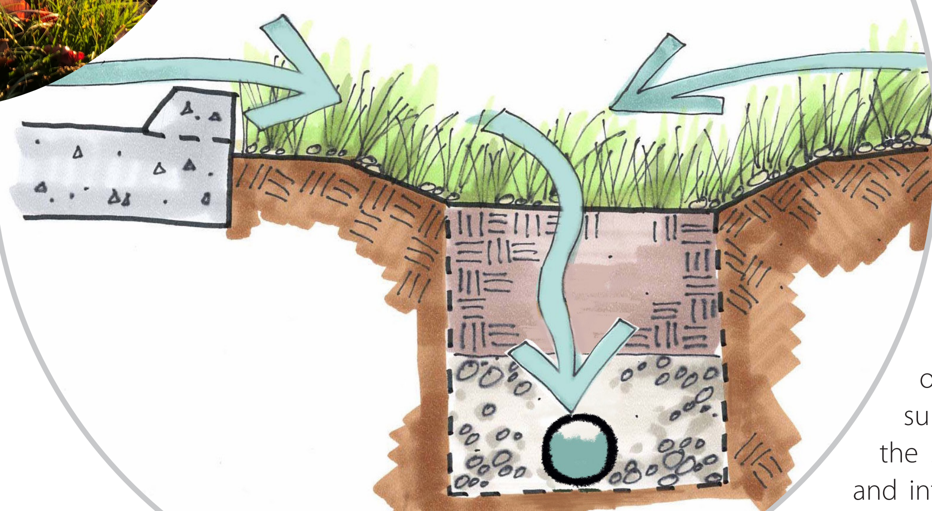
These definitions are consistent throughout the Solano Permittees' green stormwater infrastructure programs, including within the Green Infrastructure Plans and pollutant load models.

Several of these Green Stormwater Infrastructure strategies can be combined into a treatment train to meet stormwater requirements and project goals, depending on what is best suited for a particular project and site. In this context, treatment train refers to GSI in series so overflow, for example, from a biofiltration may flow into a bioretention which may flow into a bioswale. Throughout this Design Guidebook the icons to the right are used to identify different types of Green Stormwater Infrastructure as they are represented within right-of-way improvements or parking lots (Chapter 3) or specific design details (Chapter 4).

> Bioswales and pervious pavements will have limited applicability towards meeting a Regulated Project's stormwater requirements, and are recommended to "treat" impervious area at a 2:1 ratio of pervious to impervious surface..

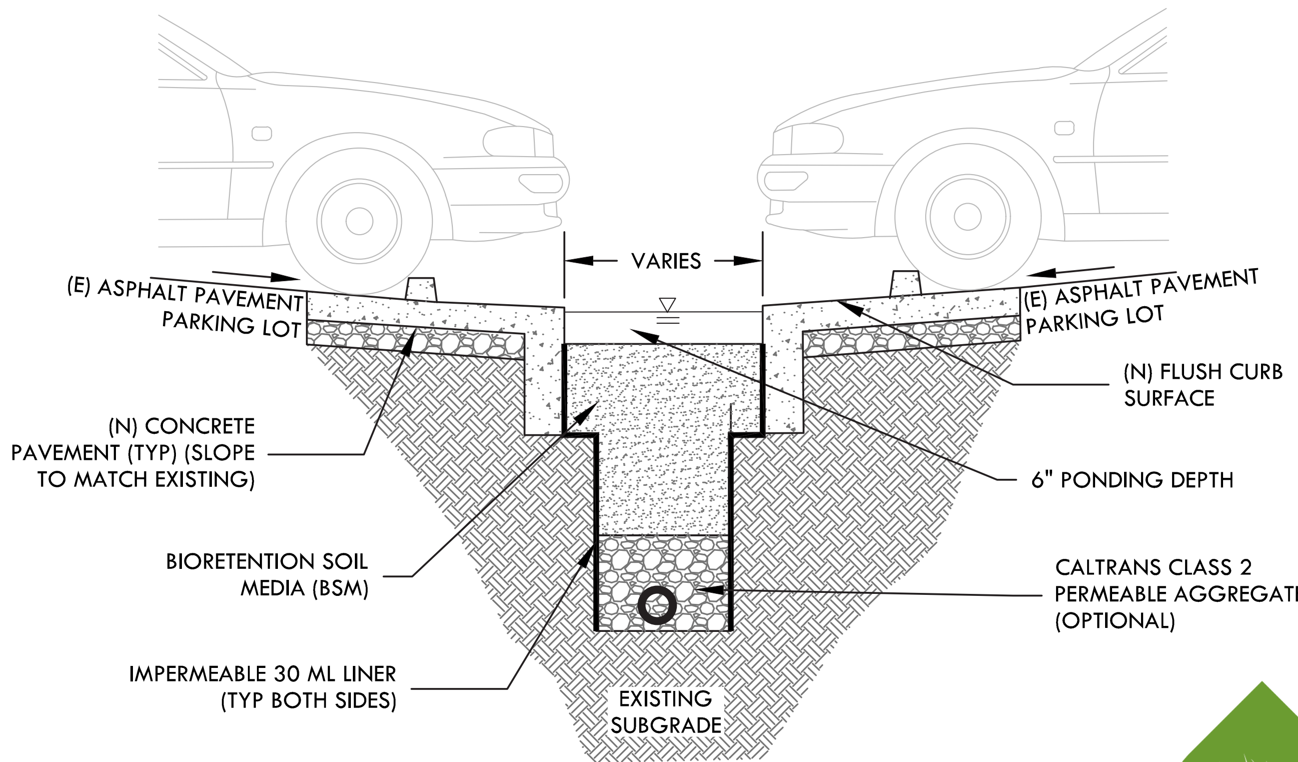


BIORETENTION



A landscaped feature that allows for infiltration into subsurface soils and can be constructed with or without side walls. Other common terms used to refer to bioretention features include rain gardens, self-retaining areas, or biofilters.

Stormwater typically is designed to pond up to 6 inches prior to outflow via a surface outlet (e.g., curb cut) or a piped overflow (e.g., overflow inlet and/or underdrain). Bioretention features may or may not include a perforated underdrain. Bioretention structures are constructed with a specialized soil media ideally 18-24 inches in depth to enhance biogeochemical processes to retain and transform pollutants, and infiltrate at a rate of 5 inches per hour. A rock or aggregate subsurface reservoir can be included under the soil media to enhance stormwater storage and infiltration. A settling forebay can be located at inlet(s) to remove sediment. Bioretention features trap toxic hydrocarbons and asbestos before reaching subsurface and groundwater supplies.

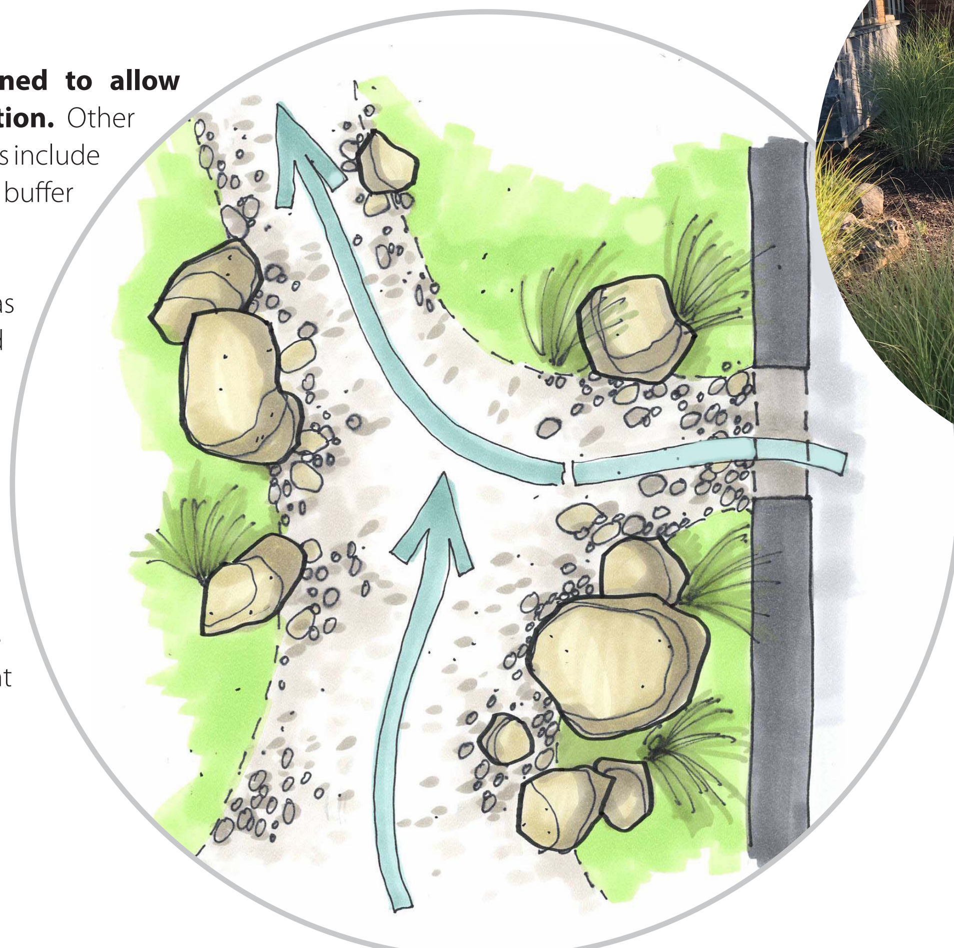


Bioretention features are ideal for median strips, parking lot islands, and swales. Existing medians and parking strips can be evaluated for conversion into bioretention features to manage stormwater, landscaping, and shade.

An inlet pipe, curb cuts, or sheet flow over an impervious area conveys water into the bioretention feature, where it is filtered prior to infiltration or outflowing via the storm drain system. Bioretention features often provide complete on-site infiltration for small storm events. They can be sized to infiltrate larger storms in areas where soils drain well or infiltration basins can overflow to another GSI feature or a discharge point.

Using native plant species reduces fertilizer, pesticide, water, and overall maintenance requirements. Vegetation types include species that can tolerate stormwater ponding and drought conditions. Regulated Projects should reference C3 Guidance for design requirements.

BIOSWALE



A linear landscape feature designed to allow stormwater to flow through vegetation. Other common terms used to refer to bioswales include grass swales, grass filter strips, vegetated buffer strips, or bioslopes.

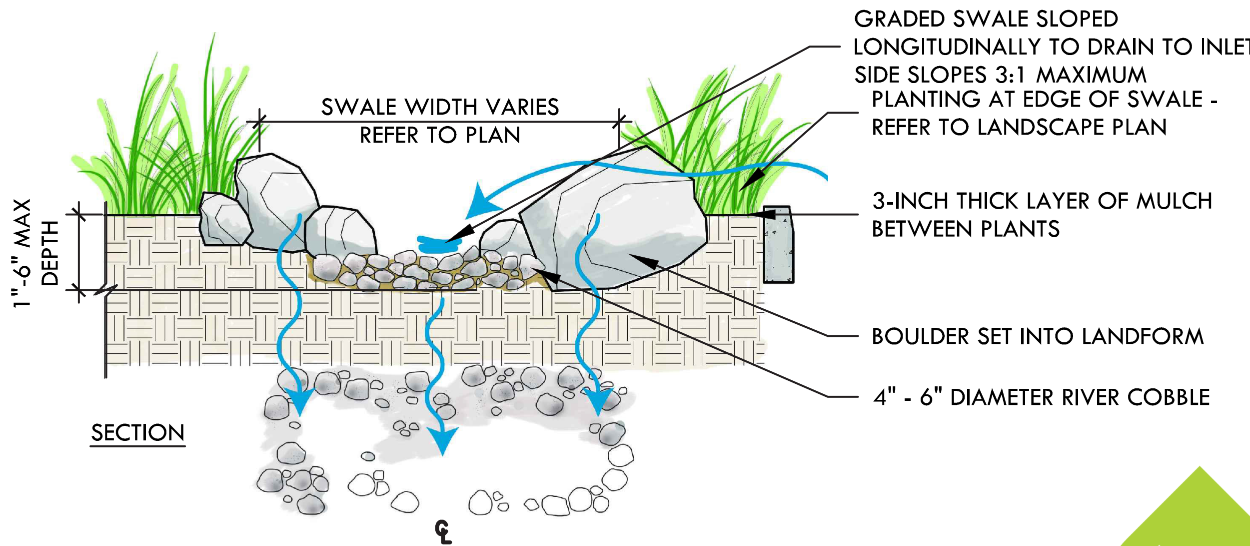
The flow-through area in a bioswale has dense vegetation coverage (>80%) and the topography allows for inundation and conveyance of stormwater through the vegetated areas. The gentle sloped flow paths and dense vegetation promote the filtration of pollutants in stormwater, adsorption of pollutants to vegetation, and settling. Biological processes include geochemical transformation and plant uptake.

Bioswales are depressions that are rock lined or planted with grass, and can be used to collect and convey stormwater runoff. They allow pollutants to settle and filter out as the water infiltrates into the ground or flows through the facility. In addition to providing pollution reduction, they can also decrease flow rates and volumes, if installed on soils where infiltration may occur. Bioswales should be integrated into the overall site design and have the potential to decrease the need for "gray infrastructure" elements.

The location and type of rock used within a bioswale channel should be carefully considered due to potential safety and nuisance concerns.

Employing green infrastructure techniques to meet stormwater regulations versus a combination of detention pipes and cartridge filters ("gray infrastructure") allows stormwater managers to meet multiple objectives in a way that mimics a site's natural function and maximizes overall water quality and quantity improvements.

Bioswales can provide critical linkages between cistern overflows and existing drain inlets within retrofit situations. Bioswales also provide potential solutions to nuisance flooding issues, by providing positive drainage away from buildings or walkways, and can re-establish a hydrologic conveyance element interrupted or buried as a result of site development.

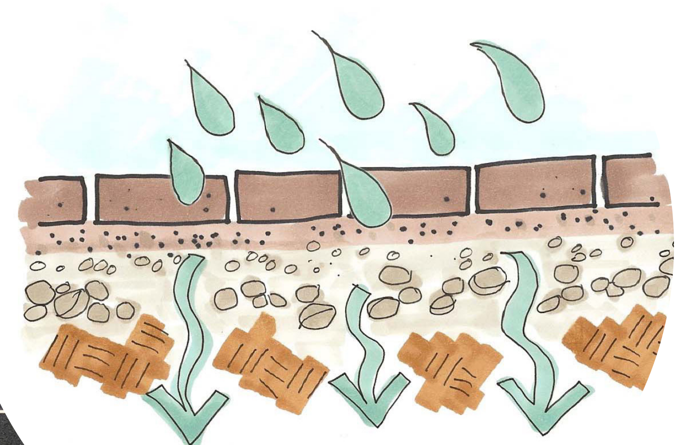


Bioswales cannot be used to meet the LID or stormwater treatment requirements for Regulated Project's.

PERVIOUS PAVEMENT

Use of sustainable materials to create a durable, pervious surface overlaying a crushed stone base that allow stormwater to percolate and infiltrate into the underlying soil.

Pervious pavement refers to Porous Asphalt, Pervious Concrete, Porous Aggregate, Pervious Pavers, or Permeable Pavers, all of which can be used for parking lots, sidewalks, driveways or other hardscaped surfaces in place of traditional concrete and asphalt mixes. Pervious pavement can include an underlying reservoir with aggregate to increase infiltration rates. Typically, if pervious pavement is designed to meet minimum needs for structural stability, there is sufficient reservoir in the base course. Regulated projects should reference C3 Guidance for design requirements.



Pervious pavement allows for stormwater to infiltrate while providing a stable load-bearing surface that does not contribute to a project's impervious area. There are two main categories of pervious pavements: pervious concrete and pervious asphalt, which are poured in place, and permeable pavers, which are discrete units set in place. Pervious asphalt, pervious concrete, and permeable pavers can be used in practically all pedestrian areas and parking lots, especially in parking aisles. Pervious pavements are not recommended where the slope exceeds 2%.

The use of pervious pavement reduces site impervious area which decreases a project's stormwater management obligation. Parking areas and walkways are well suited for conversion to permeable pavement alternatives. Landscaped areas should not drain on to pervious pavement because of the potential to intoduce sediment and debris that can clog the void space in the pervious pavement.

Initial expenses for alternative paving materials may be greater than conventional materials, though in general, the multi-functional nature of pervious pavements can reduce overall new construction costs. Pervious pavement can often eliminate the requirement for underground storm drain pipes and conventional stormwater systems, so a more accurate price comparison would involve the costs of the full stormwater management system. Design costs typically represent 10-15% of the construction cost. Pervious pavement can be more expensive when a deep base course is required, as it is in the clay soils commonly found in the Bay Area.

RAINWATER HARVESTING

Rainwater harvesting is the practice of collecting and using rainwater from roof surfaces or other man-made above-ground surfaces.

Rainwater harvesting has been employed by communities for centuries, such as in ancient Italy where central plazas were designed to filter and collect rainwater in a central well for the community to access. Today, in part due to prolonged drought conditions in California, rainwater harvesting is growing in popularity as people look for ways to increase local resilience and use all water resources more efficiently. Preventing rainwater from discharging to hard surfaces or directly into the storm drain system reduces demand on the storm drain system and protects the quality of nearby surface waters. Typical elements in a rainwater harvesting systems include (1) debris separation to remove, for example, leaf litter, (2) conveyance such as roof gutters and downspouts, (3) storage such as an above ground tank, and (4) distribution to the intended use, for example, plumbed to a toilet for toilet flushing.

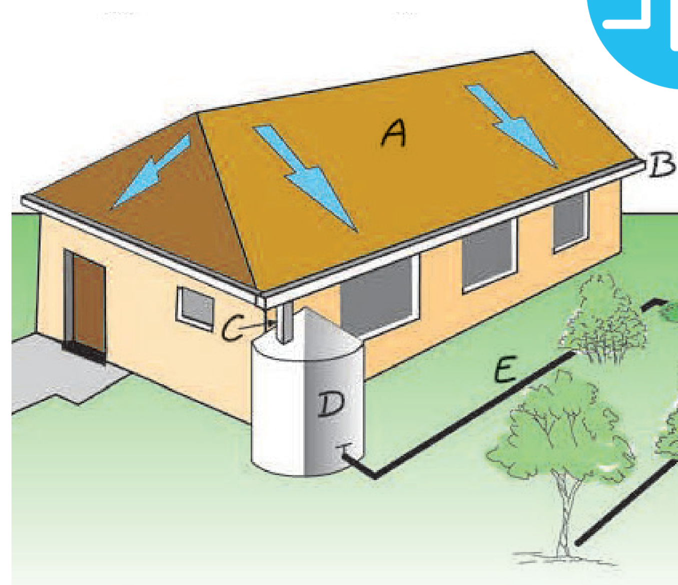
All new construction and building retrofits can be evaluated for opportunities to incorporate a rainwater harvesting system. For regulated projects it is almost always necssary to include a downstreram bioretention facility to manage overflows that cannot be directed to reuse.

2. Green Stormwater Infrastructure Types

Rainwater includes precipitation collected from roof surfaces or other man-made above-ground collection surfaces. Cisterns are containers of various sizes that store runoff from building downspouts. Rain barrels are generally smaller structures, located above ground. Cisterns are larger, can be buried underground, and may be connected to the building's plumbing or irrigation system. Cisterns may be used to store and release water for landscape irrigation or for domestic purposes. Disinfection of rainwater may be required for all uses with potential for human contact.

Preventing rainwater from discharging to hard surfaces or directly into the storm drain system reduces demand on the storm drain system, reduces water demand, and protects the quality of nearby surface waters.

A general rule of thumb is $1 per gallon for the cost of cisterns, which does not include additional costs for shipping, installation, plumbing, and pumping if needed, which can vary based on design, material, brand and supplier. Design costs typically represent 10-15% of the construction cost.



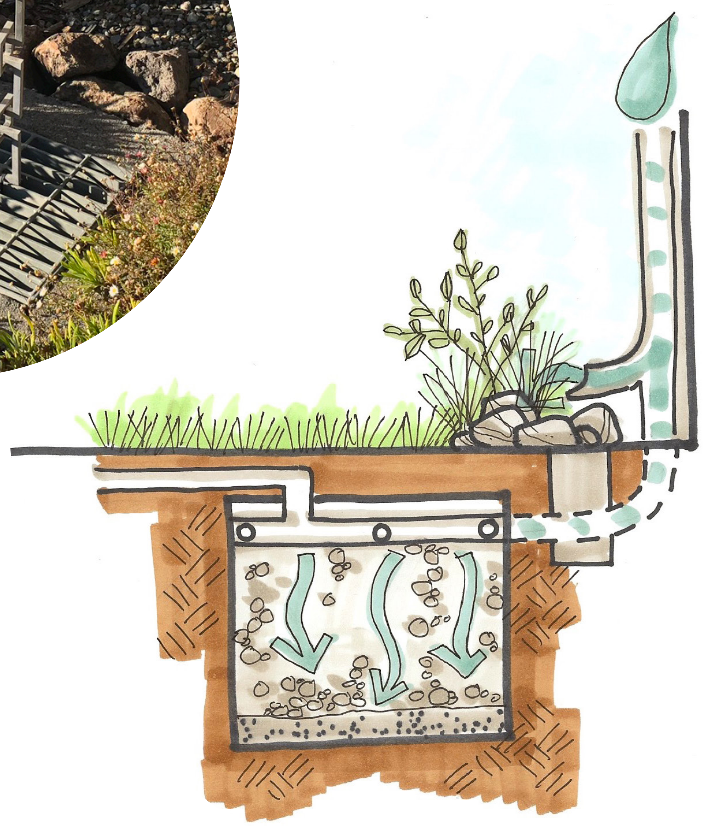
A

B

Photos:

A. Cisterns for rainwater harvesting (source: LID Urban Design Tools)
B. Rainwater harvesting with collection (A), conveyance (B and C), storage (D) and distribution (E). (source: New Mexico Office of the State Engineer)

INFILTRATION FEATURE



A structure designed to retain stormwater from small impervious drainage areas and infiltrate that stormwater into an unsaturated zone.

Infiltration features typically include the vertical excavation of native soils and filling with coarse drain rock or other highly permeable material to maximize infiltration rates. Vegetation and landscaping is typically not present in infiltration features which can be applied where space is a constraint. Other terminology or examples of infiltration features are infiltration, exfiltration, or percolation trenches, dry wells, or french drains. Regulated projects should reference C3 Guidance for design requirements.

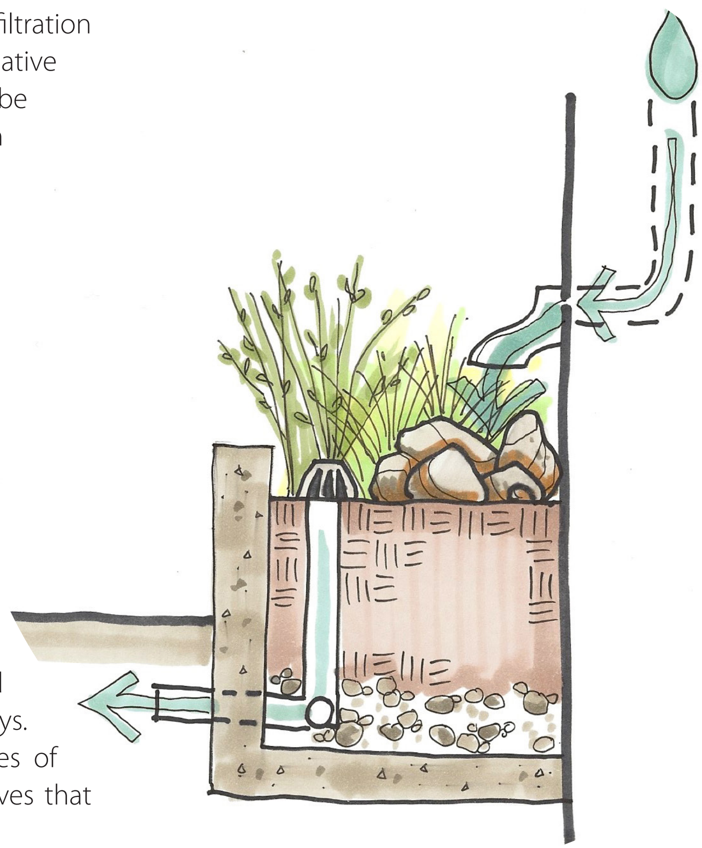
Infiltration features are appropriate where the soil is well drained, for example in hydrologic soil groups A or B, that allow runoff to infiltrate at a rate of 5 inches per hour or greater.

BIOFILTRATION

A landscape feature that allows stormwater to filter through a specialized soil media before it is discharged via an underdrain (perforated) pipe.

Biofiltration features are suitable where infiltration cannot be accomplished due to site context, native soils, or other site constraints, and they can be built with or without walls and lined with an impermeable membrane or concrete. Outlet designs typically require surface ponding prior to surface outflow typically with a max ponding depth of 6". Site designed biofiltration systems use specialized soil media ideally 18-24 inches in depth to enhance biogeochemical processes to retain and transform pollutants. Proprietary designs vary and may or may be confined space and difficult to access for inspection. Regulated projects should reference C3 Guidance for design requirements.

Biofiltration planters provide water quality treatment and reduce runoff volumes, and may be applied in more limited right-of-ways. Urban Biofilters or Tree Box Biofilters are types of biofiltration features, with proprietary alternatives that can be considered on a case-by-case basis.



CHAPTER 3

STREETSCAPE AND PROJECT DESIGN GUIDELINES FOR GREEN STORMWATER INFRASTRUCTURE PROJECTS

CHAPTER OBJECTIVES

- Illustrate types of green stormwater infrastructure opportunities in the Permittees' jurisdictions, specifically in right-of-ways, parking lots, and public spaces;
- Provide GSI landscape design criteria;
- Identify considerations for GSI maintenance and post-construction performance.

OPPORTUNITIES TO INTEGRATE GREEN STORMWATER INFRASTRUCTURE

Opportunities abound to integrate Green Stormwater Infrastructure into the fabric of the urban landscape. From street corners and medians, to parking lots, and the rooftops of public buildings there is an opportunity to implement projects that provide a range of functions and benefits while reducing stormwater runoff volumes and making the stormwater that does runoff, cleaner.

One of the critical elements to create a cost effective balance of construction and O&M costs is to integrate GSI opportunities into projects that address multiples needs. For example, using GSI as a buffer to improve bicycle and pedestrian mobility and safety or using GSI to enhance public green space and the urban forest.

Green Stormwater Infrastructure Opportunities

Public buildings can showcase and educate the community about green stormwater infrastructure

Traffic calming and safety measures can also treat and manage stormwater

Rainwater harvesting can capture water for reuse and reduce stormwater runoff volumes

Retrofit or build new parking lots with green stormwater infrastructure.

Reduce impervious surfaces in parking lots by using permeable paving and landscaping.

3. Streetscape and Project Design Guidelines

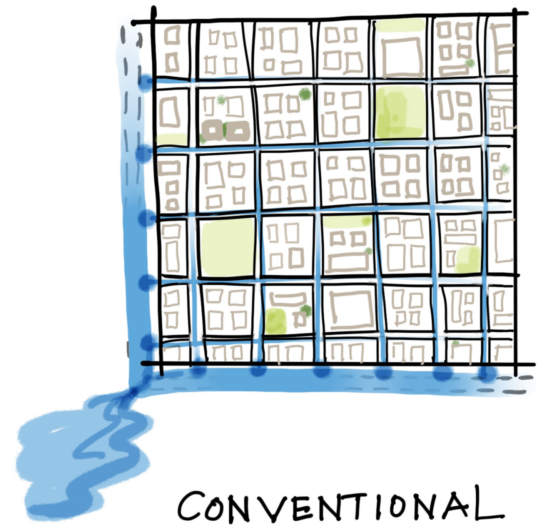
As dictated by the Green Stormwater Infrastructure Sizing Requirements described in Chapter 5, GSI will be installed on private parcels as new development and retrofit projects occur. There is also an opportunity to implement GSI projects in public spaces to showcase the aesthetic appeal of green stormwater infrastructure practices and provide a visual demonstration of how GSI can function. This every day interaction allows residents, businesses, and local governments to experience the additional benefits and values of green stormwater infrastructure practices—more walkable streets, traffic calming, green public spaces, improved aesthetics, shade, and enhanced foot traffic in retail areas.[3]

This chapter outlines guidelines to identify and maximize available GSI implementation opportunities, starting with the key Low Impact Development (LID) site design principles that every construction project should apply. Next we consider integration of GSI into Public Right-of-Way (ROW) Streets and Sidewalks, recognizing that regular ROW operation and maintenance activities open windows of opportunity to incorporate GSI. Retrofitting parking lots with GSI reduces runoff volumes, cleans stormwater runoff, and creates shade that reduces the urban heat island. Finally, integrating GSI into public spaces like plazas, parks, farmers market spaces, and schools provide the educational touch points to convey the multiple benefits green infrastructure brings into our communities.

3 Green Infrastructure Opportunities that Arise During Municipal Operations, EPA Office of Wetlands, Oceans and Watersheds, National Estuary Program, January 2015

LOW IMPACT DEVELOPMENT PRINCIPLES AND GREEN STORMWATER INFRASTRUCTURE

Low Impact Development (LID) is a water quality and stormwater management strategy concerned with maintaining or restoring the natural ecological and hydrologic functions of a community and/or site to protect and improve water quality, manage stormwater runoff, achieve natural resource protection objectives and fulfill environmental regulatory requirements. **LID employs a variety of natural and non-structural best management practices, such as green stormwater infrastructure, that reduce the rate of runoff, filter out its pollutants, and facilitate the infiltration of water into the ground.** By reducing water pollution and increasing groundwater recharge, LID and green stormwater infrastructure together improve the quality of receiving surface waters and stabilize the flow rates of nearby streams.



Why Use LID Practices?

Adopting better site design or LID techniques at the onset of a project can reduce non-point source pollution and the amount of stormwater runoff generated, and also reduce the cost of both the stormwater conveyance system and stormwater practices. Better site design stresses the principles of minimizing land disturbances, reducing runoff, increasing infiltration, filtering and adsorbing pollutants, retaining natural drainage and minimizing imperviousness. Several better site design goals can be applied early in the design process:

- Preservation of natural areas, stream and river buffers,
- Reducing impervious cover in site design
- Disconnecting and distributing runoff
- Utilizing landscaping as stormwater management features.

LID GUIDING PRINCIPLES[4]

LID Principle 1. Reduce Impervious Surfaces

Impervious surface areas associated with development can increase the speed, volume and frequency of stormwater flows resulting in flooding, erosion, and stream channel scour, down cutting of stream channels and costly washout of habitat and infrastructure (roads and pipelines). Less impervious surface reduces the volume of runoff needing treatment and infrastructure to safely convey it. Impervious cover reduces the amount of rainfall and runoff that directly infiltrates and recharges groundwater. Impervious land coverage greater than 10% has been shown to degrade water quality and the natural hydrology of a stream or river. Provision C.3 in the MRP requires site designs for new developments and redevelopments to minimize the area of new roofs and paving. Where feasible, pervious surfaces should be used instead of paving so that runoff can infiltrate to the underlying soil.[5]

- Minimize soil disturbance where feasible and improve soil quality by amending the soil thereby enhancing microbial health to improve landscape health and increase infiltration rates.
- Concentrate development on parts of the site with less permeable soils and preserve areas that can promote infiltration.
- To reduce impact of new impervious surfaces, capture stormwater for irrigation, toilet flushing, cooling towers, and other non-potable applications.

4 Edited from SFPUC, 2016, San Francisco Stormwater Management Requirements and Design Guidelines
5 http://www.ci.vallejo.ca.us/city_hall/departments___divisions/public_works/engineering_division/stormwater_regulatory_information/

A. Permeable pavers at UC Berkeley Botanical Garden (source: Blue Green Blog, Friends of Five Creeks) B. Pervious asphalt comparison (source: Water Research Center) C. Residential parking lot with pervious concrete (source: Fall Creek Engineering, Inc.)

LID Principle 2. Integrate Natural Landscaping

Vegetated landscapes filter and clean stormwater runoff and recharge groundwater with little effort. Stormwater that is treated and managed on-site reduces infrastructure for large scale stormwater management projects, thereby reducing initial development costs and long-term maintenance costs and needs. When stormwater management is integrated into the site, stormwater can be a beneficial resource or a functional amenity and can enhance livability through the creation of water features and green spaces.

- Prioritize the use of infiltration-based BMPs where soils, groundwater, and geology allow.
- Detain and retain runoff throughout the site to manage runoff as close to its source as possible.

Runoff from impervious surfaces like roads, sidewalks, and trails can be directed into bioswales through curb cuts and/or trench drains.

LID Principle 3. Preserve and Plant Trees

Preserving or planting trees and vegetation are key elements of LID. Trees and vegetation intercept rain, slowing and reducing stormwater runoff. The resulting runoff requires less treatment and minimizes downstream impacts. Trees and vegetation absorb and filter pollutants from soil, water and air, shade and cool air and water, and filter dust and airborne particles. Roots loosen soil increasing rainfall infiltration which reduces overland flows.

- Encourage planting of new trees and preservation of healthy established trees.
- Look at each site as an opportunity to protect, enhance, or create wildlife habitat.

Preserving and planting trees leads to a host of multi-benefits. For example, studies indicate urban trees promote retail shopping by stimulating more frequent visits to store fronts along with a willingness to pay more for goods and services.

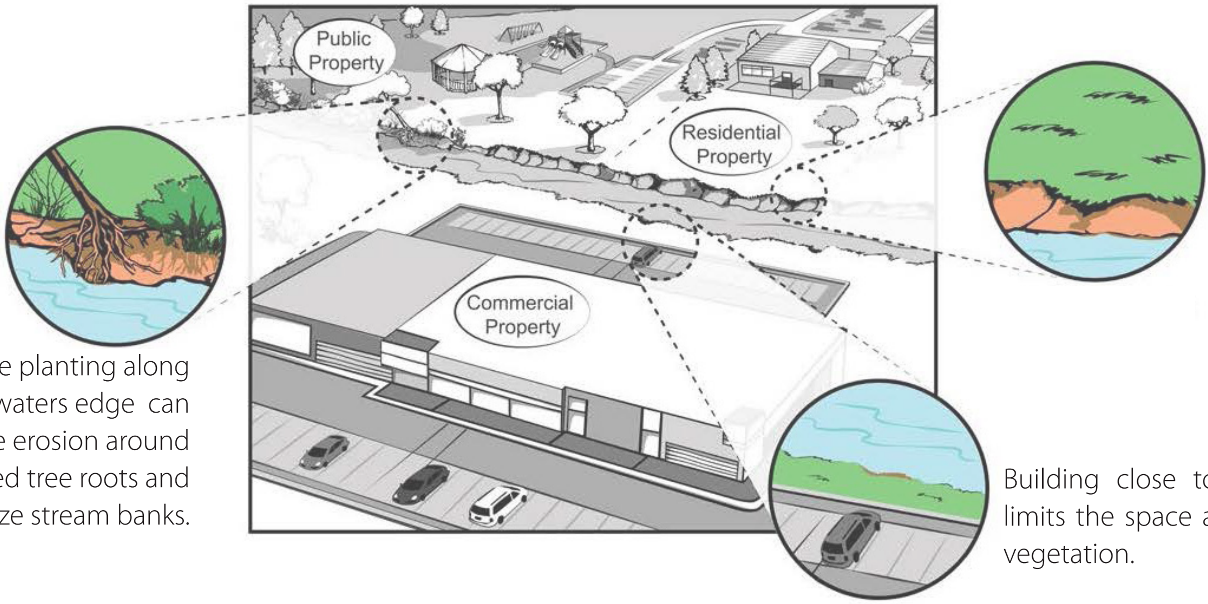
source: http://www.svrdesign.com/blog/2010/11/21st-street-in-paso-robles-ca-recommended-for-1m-grant

LID Principle 4. Create Vegetative Buffers

Natural vegetative corridors along rivers and streams filter pollutants, intercept rainfall and allow rain to infiltrate slowly to groundwater and streams. Buffers are important to accommodate natural shifts and widening of streams which provide space for flood flows and protect adjoining and nearby properties. Buffers provide open space corridors that can be used for passive recreation and exercise. Vegetated buffers protect and stabilize river and stream banks reducing the amount of erosion and property damage to roads and bridges.

- Incorporate creeks, wetlands, and existing vegetation into the site design. Develop setbacks to protect these areas.

The more space allowed for trees and shrubs along a stream leads to stronger banks, cleaner water, less flooding, and better habitat.



Sparse planting along the waters edge can cause erosion around exposed tree roots and destabilize stream banks.

Mowing to the waters edge prevents trees and shrubs from growing that would otherwise filter pollutants, and stabilize banks with their roots.

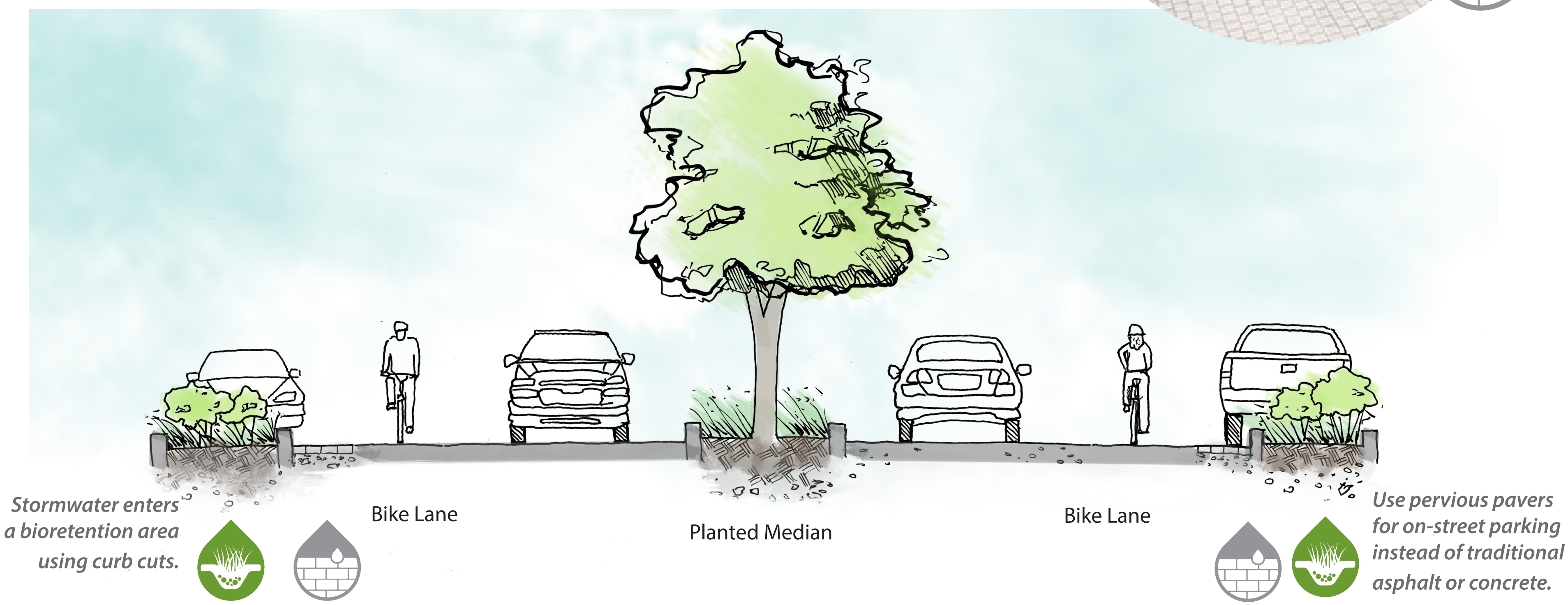
Building close to the waters edge limits the space available for riparian vegetation.

Commonly observed negative riparian conditions (source: adapted froom the Tennessee Urban Riparian Buffer Handbook, September 2015)

LID Principle 5. Make Green Streets, Parking Lots and Public Spaces

In developed areas streets and parking lots can make up to 25 to 30% of the land area and account for 50% of the total impervious cover. Street and parking lot runoff carries sediment, nutrients, oil, grease, heavy metals and other potential toxins. Green street and green parking lot design can reduce impervious coverage by 10 to 15% when compared to traditional street design.

- Use landscaping and pervious paving materials rather than traditional hardscape in plazas, sidewalks, driveways, streets, parking areas, and patios.
- Design multi-purpose projects that not only manage stormwater but also improve streetscape and public space design.
- Incorporate environmental education and interpretation into GSI where appropriate.
- Use GSI to amplify urban design and place using site-specific strategies.



PUBLIC RIGHT-OF-WAY (ROW) STREETS AND SIDEWALKS

With a changing climate bringing more frequent and intense extreme weather events we need alternatives to traditional "gray" stormwater management approaches that treat water as waste. Expanding existing gray stormwater infrastructure to add capacity is often financially untenable and squanders the benefits green stormwater infrastructure can do to reduce flooding risks and improve water quality. To build more resilient urban spaces we need to re-imagine our asphalt and concrete sidewalks and streets as sites for sustainable stormwater management.

By including green infrastructure, complete streets improve both mobility and stormwater management to make healthier, more resilient, and safer communities. Every realm in the public right-of-way is an opportunity to incorporate green stormwater infrastructure that also can calm traffic and make way for walking, biking, and public space. We can transition the management of stormwater as a nuisance to a resource in the Solano Permitees' arterial, commercial, and residential streets by using GSI tools like the ones described in this chapter; stormwater curb extensions, stormwater transit stops, floating island planters, and stormwater medians. These details and specifications will allow projects to provide a range of functions and benefits, such as stormwater management, bicycle and pedestrian mobility and safety, public green space, and urban forestry.

A challenge when identifying GSI opportunities both in new street design and in street retrofits is finding low points where it is also practical to incorporate GSI. Factors to consider include identifying existing and future gradient and drainage patterns. A cost effective GSI retrofit in a right-of-way will work with existing and/or proposed gradients and drainage patterns, the storm drain system, avoid utility conflicts, and maintain access for emergency and maintenance vehicles.

Green stormwater infrastructure implemented in the street right-of-way can be used to:

- **Reduce impervious area**
- **Infiltrate/filter runoff from the street and adjacent property**
- **Incorporate features of universal design to be made more accessible to people with disabilities.**
- **Provide shade using trees**
- **Improve air quality**
- **Reduce the urban heat island effect**
- **Create a sense of place**
- **Showcase public art**
- **Calm traffic**
- **Provide wildlife habitat**
- **Create a welcoming area**
- **Enhance aesthetics**

COMPLETE STREETS ARE GREEN STREETS

What is a Complete Street? A street that is safe for all users.

"Complete Streets are streets for everyone. They are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists and transit riders of all ages and abilities. Complete Streets make it easy to cross the street, walk to shops, and bicycle to work."

- Smart Growth America, National Complete Streets Coalition

What is a Green Street? A street where green stormwater infrastructure is capturing, slowing and treating all the runoff from the roadway.

"Green Streets are designed to capture, slow, and treat stormwater runoff. This approach stands in contrast to the traditional approach to stormwater management that uses "gray" infrastructure, designed to expediently collect stormwater runoff from streets through a system of storm drain inlets, pipes, culverts, and storage facilities that eventually dispose of the collected runoff in waterways or treatment facilities."[6]

- Sustainable Streets City of San Mateo, February 2015

Green Streets use green stormwater infrastructure to improve safety for all users while also introducing a host of environmental multi-benefits. Therefore an ideal Complete Street design is also a Green Street. Currently, not all Complete Streets are designed to be Green Streets and vice-versa. However, the Solano Permittees seek to incorporate Green Streets, and GSI features, into all future Complete Streets.

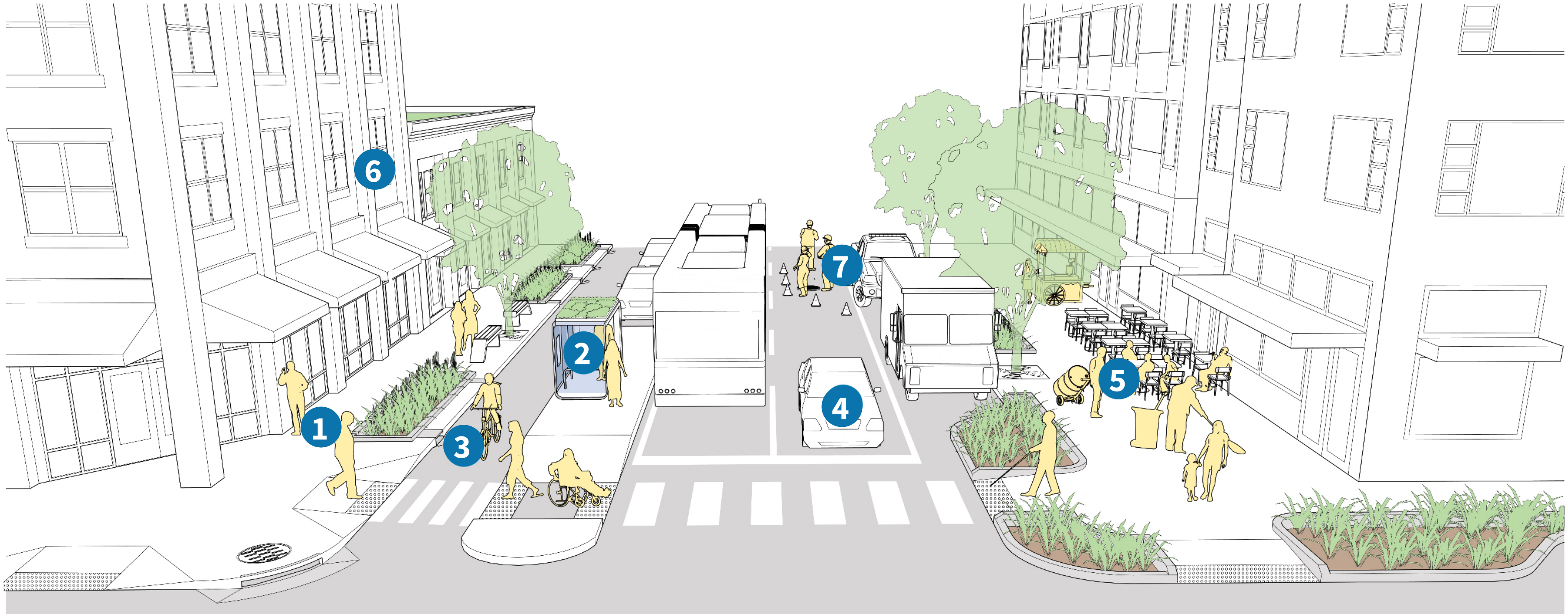
'Complete Streets' in Vallejo

In 2012, the City of Vallejo adopted a policy supporting the planning and installation of complete streets. Key features of the City's approach to complete streets are:

- **Multi-Modal.** Each complete street serves all users by balancing the needs of automobiles, buses, and trucks with those of pedestrians and cyclists. This is done in different ways depending upon the situation and ultimately will provide many options for moving throughout Vallejo.
- **Context Sensitive.** Each street is designed to accommodate the different users while working within the existing or intended physical context of the area to enhance the appeal of adjacent real estate.
- **Integral to Vallejo's Approach to Streets.** The City includes complete streets as part of its planning and review processes. Over time, each street is evaluated for the improvements it needs to become a complete street. As opportunities arise and funding is available, the improvements are systematically installed.

For additional information on Complete Streets, visit www.smartgrowthamerica.org/complete-streets

3. Streetscape and Project Design Guidelines



An exemple of a Complete Street integrated with green stormwater infrastructure to create a Green Street (source: National Association of City Transportation Officials (NACTO), Urban Street Stormwater Guide, 2017)

1. People Walking - Landscaped GSI makes walking more pleasant by providing shade the reduces temperatures, improving air quality, calming traffic, and creating valued community spaces.

2. People Using Transit - GSI incorporated into transit boarding bulbs and islands improves passenger comfort

3. People Bicycling - GSI can reduce nuisance ponding after storms, making bike paths safe for travel; landscaped GSI can create a protected bikeway buffer to increase biker safety and comfort.

4. People Driving Motor Vehicles - GSI can lead to reduced vehicle speeds and nuisance ponding after storms, making driving conditions safer.

5. 6. People Residing and Conducting Business - "Research has shown that street trees help create walkable environments that provide a positive impact to retail sales and rents. One study showed a 3% to 15% increase in home values and 9% to 12% more retail spending as shoppers spend more time in districts with a good canopy of street trees."7

7. People Working / Performing Maintenance - GSI must be implemented with consideration for existing or planned subsurface utilities, and designed so that maintenance crews can access and navigate equipment around GSI.

[7] Sustainable Streets City of San Mateo, February 2015

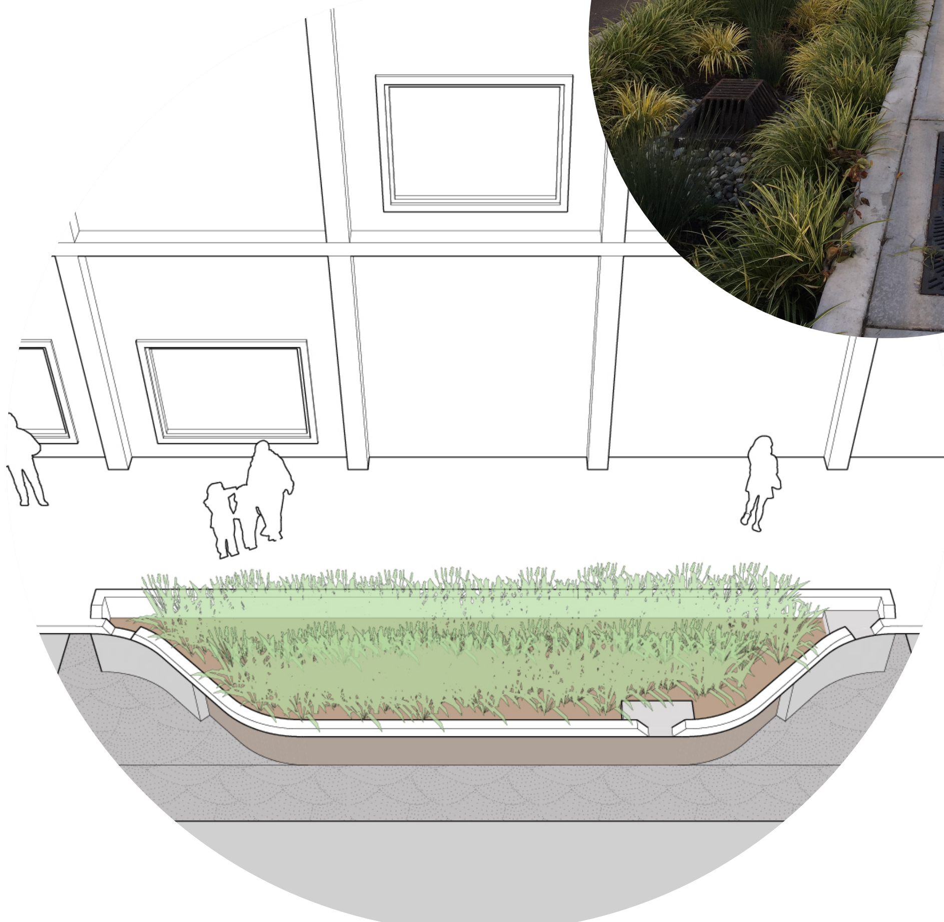
ROW GSI SOLUTION: STORMWATER CURB EXTENSION[8]

Stormwater curb extensions visually and physically narrow the roadway width, creating safer and shorter crossings for pedestrians and providing traffic calming on low-speed neighborhood streets and commercial corridors. The available space generated by curb extensions can be used for bioretention or biofiltration GSI, plantings, street furniture, benches, and street trees.

Stormwater curb extensions, also called "bulbs," "bump-outs," or "neckdowns", are typically located parallel to sidewalks and narrow the crossing distance for pedestrians crossing the street. Stormwater curb extensions also decrease curb radii, encouraging drivers to make slower turns.

Bioretention or biofiltration cells can be integrated into stormwater curb extensions depending upon drainage patterns to intercept runoff before it enters an existing catch basin. Curb extensions provide traffic calming benefits, can be combined with pedestrian crossings, and can intercept and infiltrate gutter flow, especially when cited along the downstream flow path.

Upgrading curb ramps and relocating signal poles and/or utility boxes can improve pedestrian mobility and make space available for GSI.



8 National Association of City Transportation Officials (NACTO), Urban Street Stormwater Guide, 2017)

Design Considerations

Stormwater curb extension sizing should allow for safe overflow during large storm events to minimize flooding into the roadway, which can create hazards for street users.

Plants in curb extensions should not grow taller than 24 inches above the sidewalk grade to maintain sight clearance in the right of way.

Curb extensions are typically recessed 1-2 feet from the outside edge of the right-most travel lane, though width may be adjusted based on site specific considerations.

The angle of the curb extension where it joins the original curb should be angled between 30 to 60 degrees to allow for mechanical street sweeping.

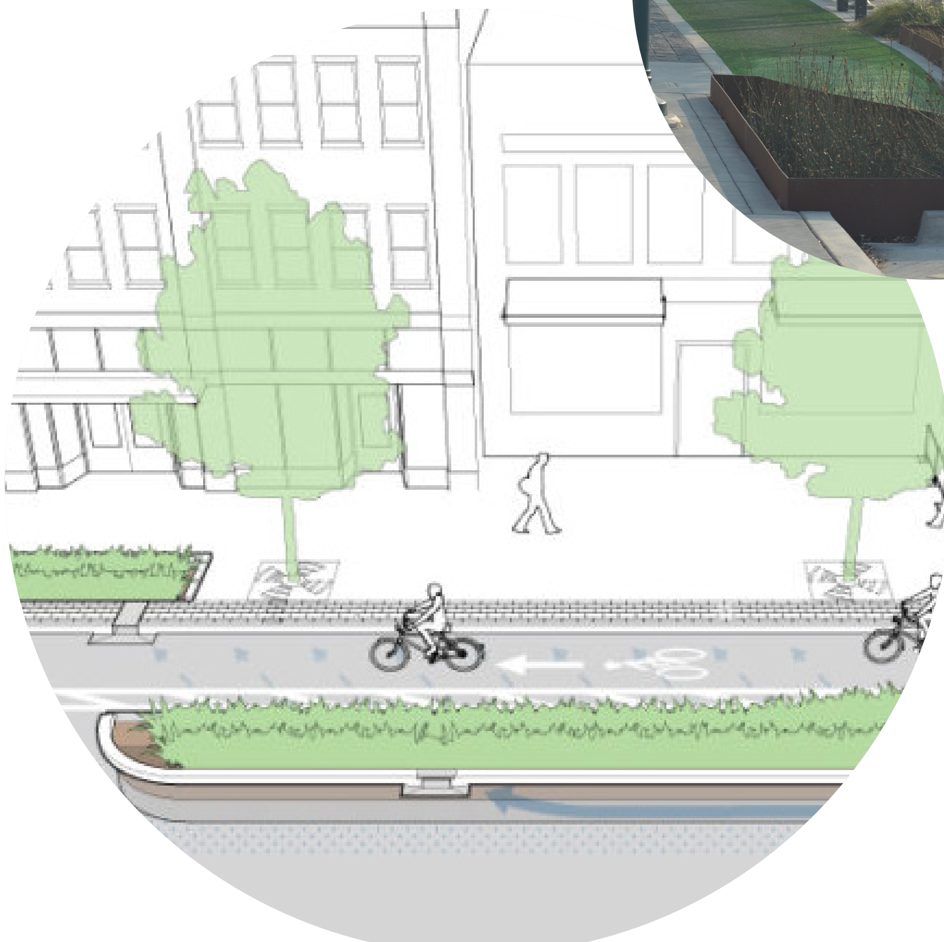
Inlets and outlets should be designed to avoid vehicle and bicycle wheels entering the openings.

A pre-settling zone, or energy dissipation area, should be incorporated at any locations where high energy flows are expected to enter the GSI.

While ensuring that emergency responders maintain adequate access, stormwater curb extensions can be located in areas where on-street parking is already prohibited, such as near fire hydrants or driveway setbacks.

ROW GSI SOLUTION: FLOATING ISLAND PLANTER[9]

Vegetated space on pedestrian refuge islands, bikeway buffers, transit boarding islands, or other constructed elements that are offset from the curb can improve the streetscape and provide space for street trees. With thoughtful design and suitable topography, GSI may be incorporated into islands.



Depending on the location, floating island planters provide mobility benefits by calming traffic, protecting cyclists, and shortening crossing distances for pedestrians, all while increasing the streetscape aesthetic and opening GSI opportunities.

Stormwater overflow from floating island planters can be directed to a second GSI treatment areas. For example, overflow from the floating island planter can enter a curbside GSI in a sidewalk area to maximize treatment and minimize ponding against the curb.

9 National Association of City Transportation Officials (NACTO), Urban Street Stormwater Guide, 2017)

Design Considerations

Bioretention or Biofiltration with walls are typically most appropriate in floating island planters due to space constraints.

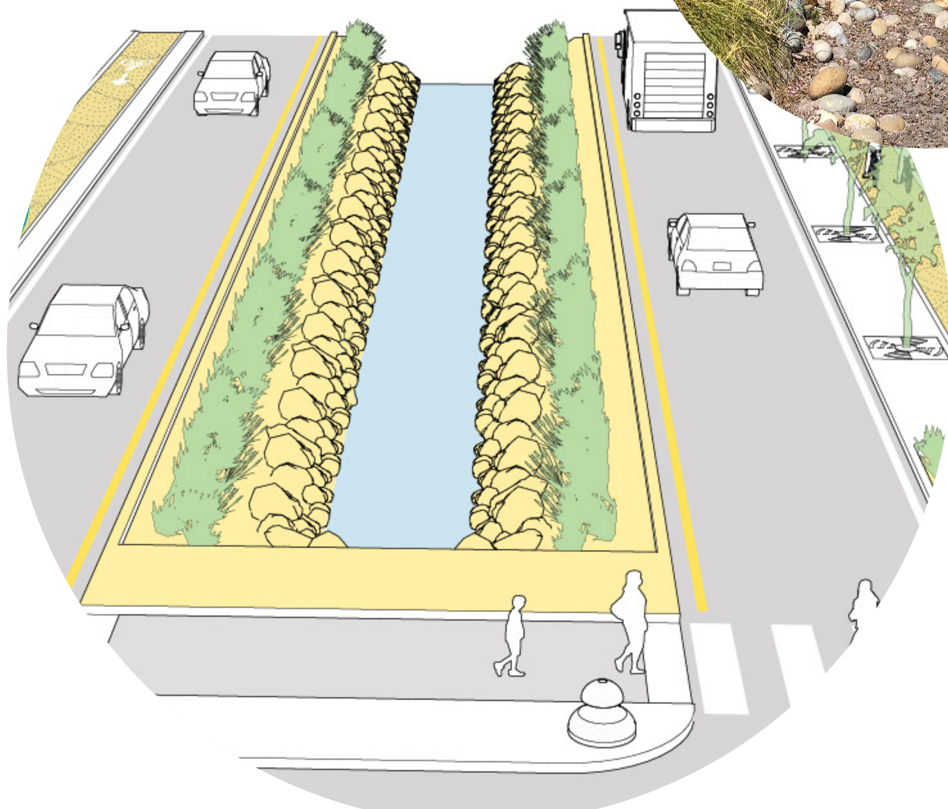
Runoff can enter the planter through cub cuts or trench drains. Overflow needs to managed to prevent ponding that creates unsafe conditions for bicyclists or motorists.

To allow adequate access by street sweepers, allow a minimum of 8 fee between the floating planter and the adjacent curb.

To maintain sight clearance plants should not grow taller than 24 inches abov the adjacent grade.

ROW GSI SOLUTION: STORMWATER MEDIAN[10]

Wide medians used to separate traffic directions can convey and infiltrate large amounts of water. On very wide streets and parkways, green stormwater infrastructure can be coupled with greenways for bicycling and walking, providing attractive public space adjacent to stormwater management.



Runoff from upstream and/or the adjacent roadways and impervious areas can be directed into a bioswale, bioretention, or biofiltration facility located in the median.

Stormwater medians transform a typically unused space in the right-of-way into a multi-functional GSI element that can provide a visual cue to drivers to reduce vehicle speeds. On wide parkways or boulevards, stormwater medians can provide distinctive walkways and inviting public spaces.

10 National Association of City Transportation Officials (NACTO), Urban Street Stormwater Guide, 2017)

Design Considerations

Streets are usually crowned, with runoff flowing away from a street centerline and towards the side curbs and gutters, therefore runoff does not typical flow towards the median. A right-of-way retrofit can capture runoff from upstream or from side streets or may require re-grading the street to convey runoff towards the median.

Capturing runoff from side streets can be achieved by daylighting the subsurface stormwater pipelines in the stormwater median.

Other utilities are often located in the right-of-way and their location may impact the stormwater median design.

To maintain sight clearance shrubs and ground cover should not grow taller than 24 inches above the adjacent grade. Trees should be pruned in standard form to maintain roadway views.

Identify if traffic lanes will need to be closed for maintenance and/or if refuge areas can be included for maintenance access.

Include an 10 to 24 inch wide level area on both sides of the median to allow maintenance workers to work safely within the median.

GUIDELINES BY STREET TYPE

Green stormwater infrastructure (GSI) can be integrated into many, if not all, of the street types located within the Solano Permittees' jurisdictions. Four specific street types have been identified as a high potential for incorporating GSI: arterial streets, commercial main streets, and high and low residential streets. These street types are found in a relatively high frequency throughout the Permittee areas and potential integration of GSI into the right-of-way, using specific GSI ROW solutions, such as stormwater curb extensions, transit stops, floating islands, and bioretention in planter strips and medians are proposed for each street type. Due to the predominance of soils with low infiltration capacity within the Solano Permittee, most GSI features won't infiltrate to a significant degree and in most cases will require an underdrain and overflow connected to the existing storm drain system.

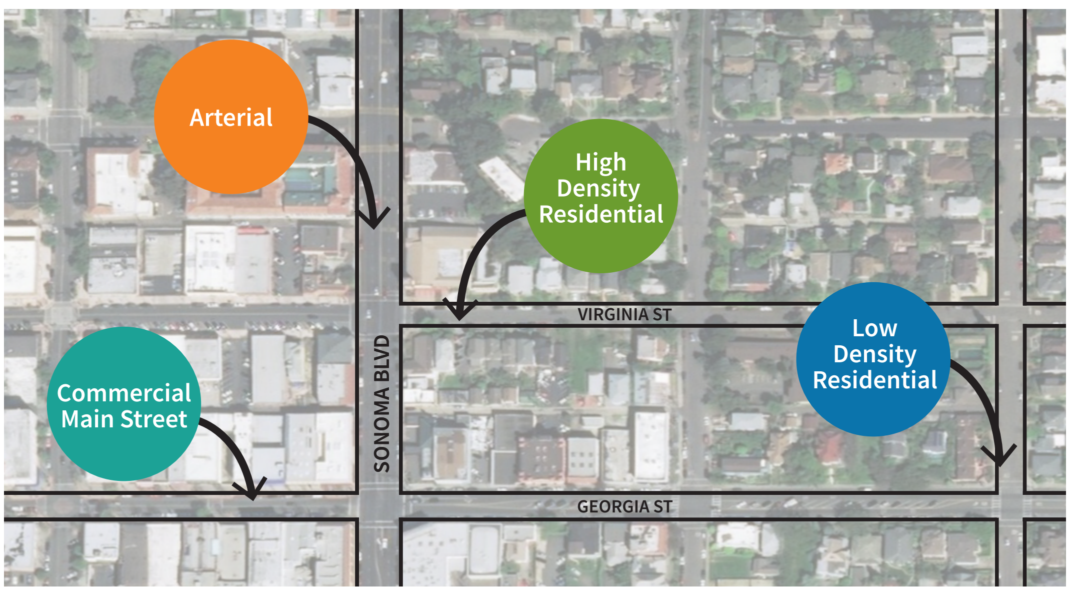
Modifying lane widths while maintaining safe travel and mobility can provide opportunity for GSI integration in the right-of-way. Importantly, wider lanes correlate to higher speeds, so reducing land widths to add GSI can correlate to improved stormwater management and safer streets.

Some lane width recommendations from the National Association of City Transportation Officials (NACTO):

- 10 foot lane widths in urban areas improve street safety without impacting traffic operations;
- Truck or transit routes can use one travel lane of 11 feet in each direction;
- Narrower travel lanes (9–9.5 feet) can be effective as through lanes in conjunction with a turn.

Other ROW elements where GSI can be incorporated:

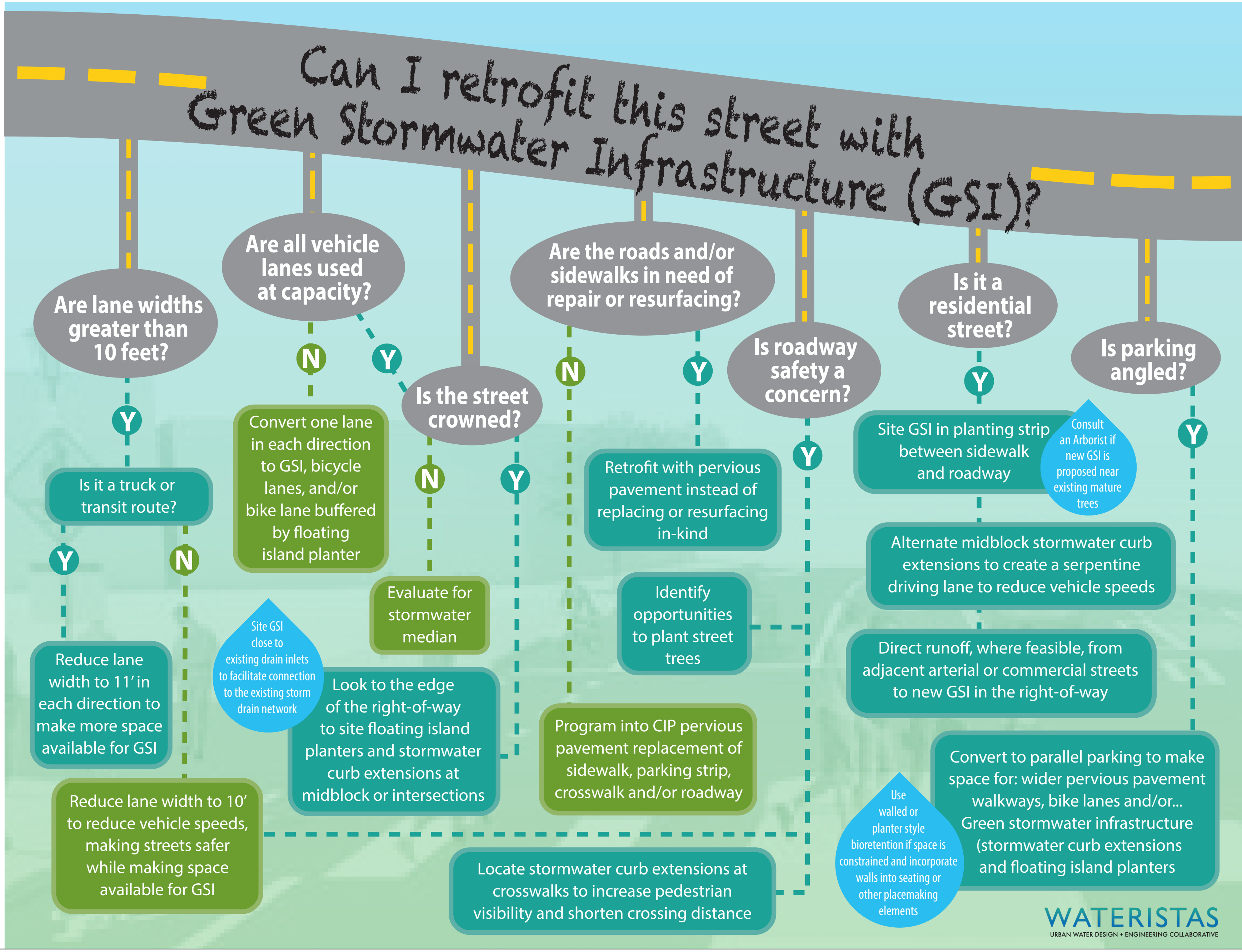
- Chicane
- Pinchpoint
- Gateway
- Pervious Pavement Within the Parking Lane, Crosswalks, and Sidewalks
- Tree well filters along sidewalks, in curb extensions, or medians
- Traffic Circles



This aerial image is from Vallejo, CA and depicts four common street types found within the Solano Permittee jurisdiction, each with unique GSI integration opportunities described in this Design Guidebook.

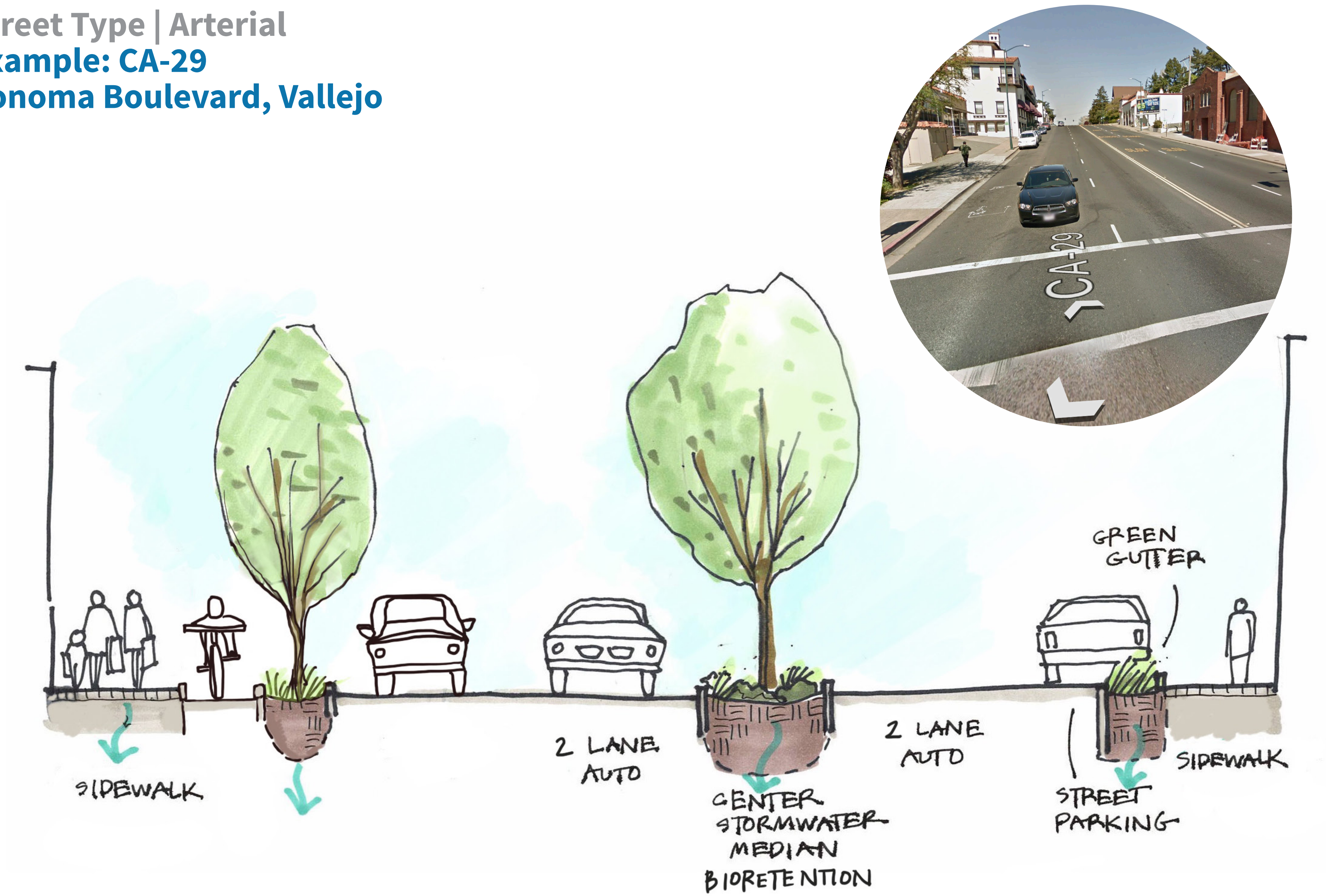
3. Streetscape and Project Design Guidelines

Use the questions in the decision tree to identify opportunities for adding green stormwater infrastructure into the street right-of-way.



3. Streetscape and Project Design Guidelines

Street Type | Arterial
Example: CA-29
Sonoma Boulevard, Vallejo



Example Arterial Street in Vallejo, CA

Guidelines by Street Type | Arterial

Arterial streets typically have a wide right-of-way with multiple travel lanes that generate significant amounts of stormwater runoff. Arterial street design also typically prioritizes vehicle traffic with little emphasis on walkability or bike transit. Travel lanes and paved shoulders are often oversized, which contributes to frequent speeding and unsafe vehicle operations.

The over-wide or redundant roadbeds in arterial streets present great opportunities for GSI integration. All of the ROW GSI solutions described previously can be applied in arterial street types: stormwater curb extensions, floating island planters, stormwater medians, and curb cuts to bioretention planter strips.

GSI can be a unifying theme for revitalizing arterial streets into vibrant corridors that provide safe multi-modal transportation alternatives while reducing stormwater runoff volumes, improving the quality of stormwater runoff, introducing ecosystem services into urban streets, and improving shade coverage.

For example, some arterial streets would benefit from replacing redundant travel lanes with bike lanes buffered by floating island planters. Similarly, existing landscape medians can be converted to medians with bioretention, or extra space available by reducing lane widths can be used to add stormwater curb extensions, or new medians with bioretention. Arterial streets are also the perfect place to introduce transit stops that integrate stormwater treatment and improve user experience and bus driver efficiencies, while providing the multiple benefits of GSI. Pervious pavement can replace impervious surfaces in sidewalks and in street parking areas, adding character and placemaking benefits while providing stormwater management services.

Design Considerations

Existing mature trees provide significant stormwater management benefits and valuable placemaking opportunities. GSI near existing mature trees along arterial streets needs to be designed to protect and promote the root structure of mature trees. A certified arborist should be consulted when designing around existing mature heritage trees.

The costs and benefits of stormwater medians should be carefully considered. Installing stormwater median retrofits can be an expensive GSI alternative because they may require changing existing topography (street drainage and cross slope) and create challenging maintenance conditions.

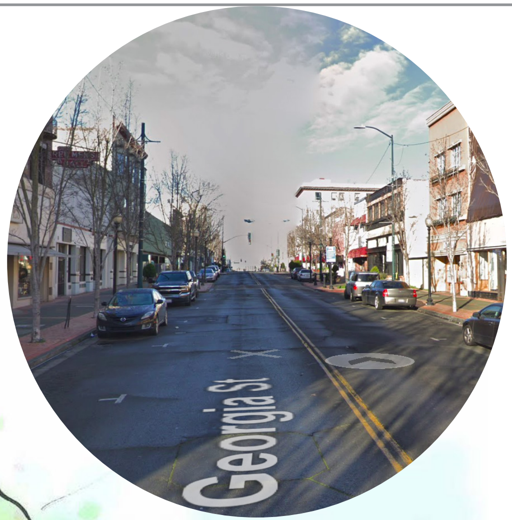
Proprietary biofiltration chambers with street trees, or street trees alone, could be a cost effective alternative to a stormwater median.

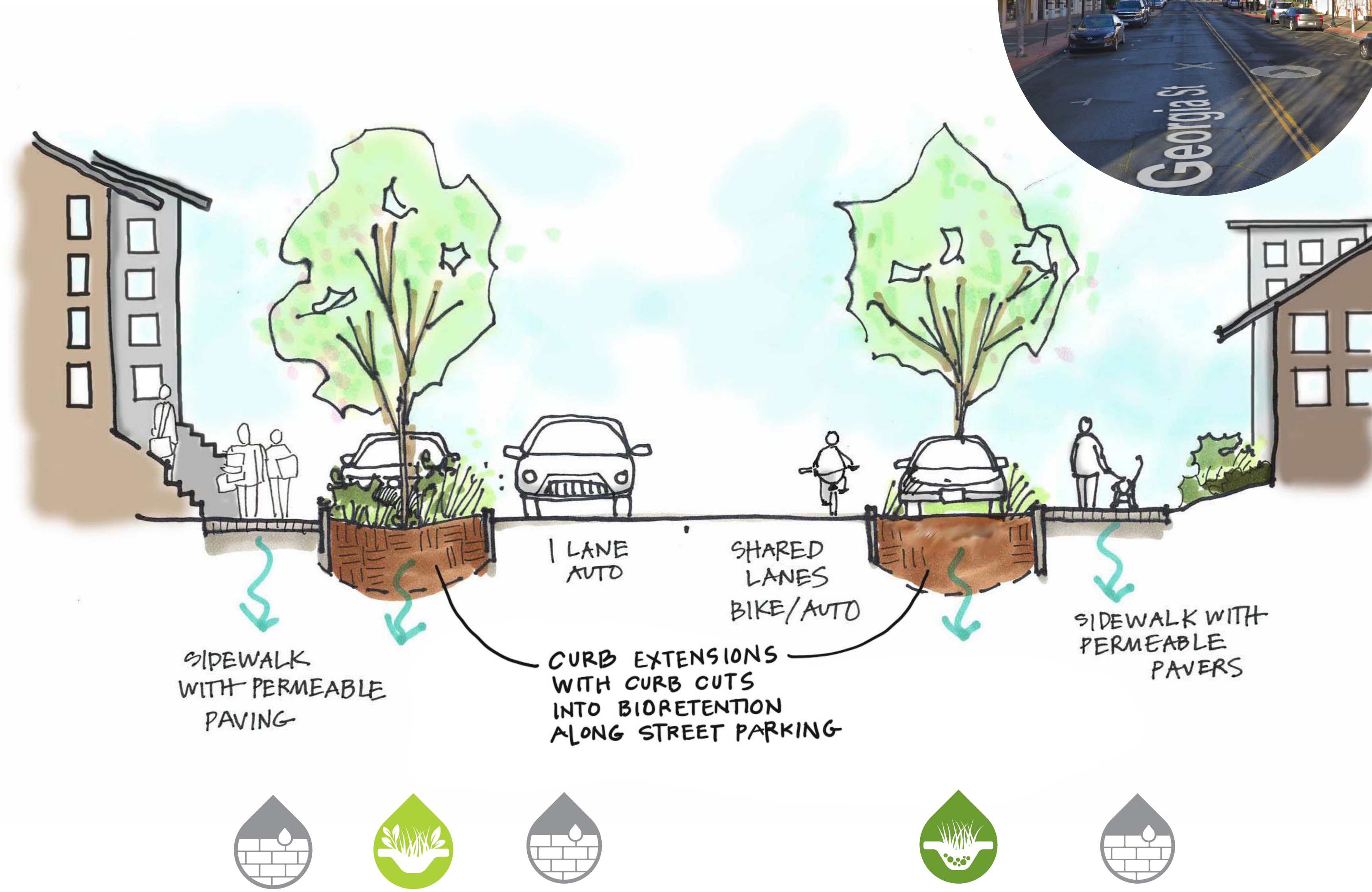
Pervious pavement can be used to designate bike lane; pervious concrete or porous asphalt are the more comfortable option for bicyclists.

Arterial streets generating amounts of sediment and debris, may require larger pre-settling zones at the entrance to bioretention or biofiltration facilities.

Street Type | Commercial Main Street

Example:
Georgia Street, Vallejo





GUIDELINES BY STREET TYPE | COMMERCIAL MAIN STREET

Example Commercial Main Street in Vallejo, CA

Downtown streets hold great potential for GSI integration, but require careful design to balance competition for space among on-street parking, pedestrians, street trees, and above ground/below ground utilities. One of the benefits introducing GSI into commercial downtowns is that landscaped GSI, like bioretention or biofiltration facilities, makes streets more inviting by improving the overall street aesthetic. GSI may help reduce flooding risks to downtown businesses and neighborhood main streets allowing them to more quickly return to service after extreme weather events.

Because they efficiently use available space and minimize sidewalk congestion, stormwater transit stops can be an excellent alternative to traditional pull-out bus stops in space-constrained commercial main streets.

Design Considerations

Reducing lanes through road diets, and reallocating road space to bicycling and/or walking increases mobility while also providing GSI opportunities like floating island planters or pervious pavement.

Stormwater curb extensions can be located midblock or at intersections to improve mobility and safety by shortening pedestrian crossing distances and calming vehicle traffic by narrowing the road. The walled, or planter style, biofiltration or bioretention facilities are often best suited in downtown areas because they require less space. The perimeter wall of these facilities can incorporate seating or other placemaking elements, which also reduce the risk of people stepping into the planters.

Biofiltration structures, with impermeable or concrete linings, may be preferred because they prevent groundwater infiltration which can negatively affect adjacent utilities and pavement.

GSI is often most effective at intersections or adjacent to existing drain inlets where it has the opportunity to capture, treat, and drain stormwater runoff.

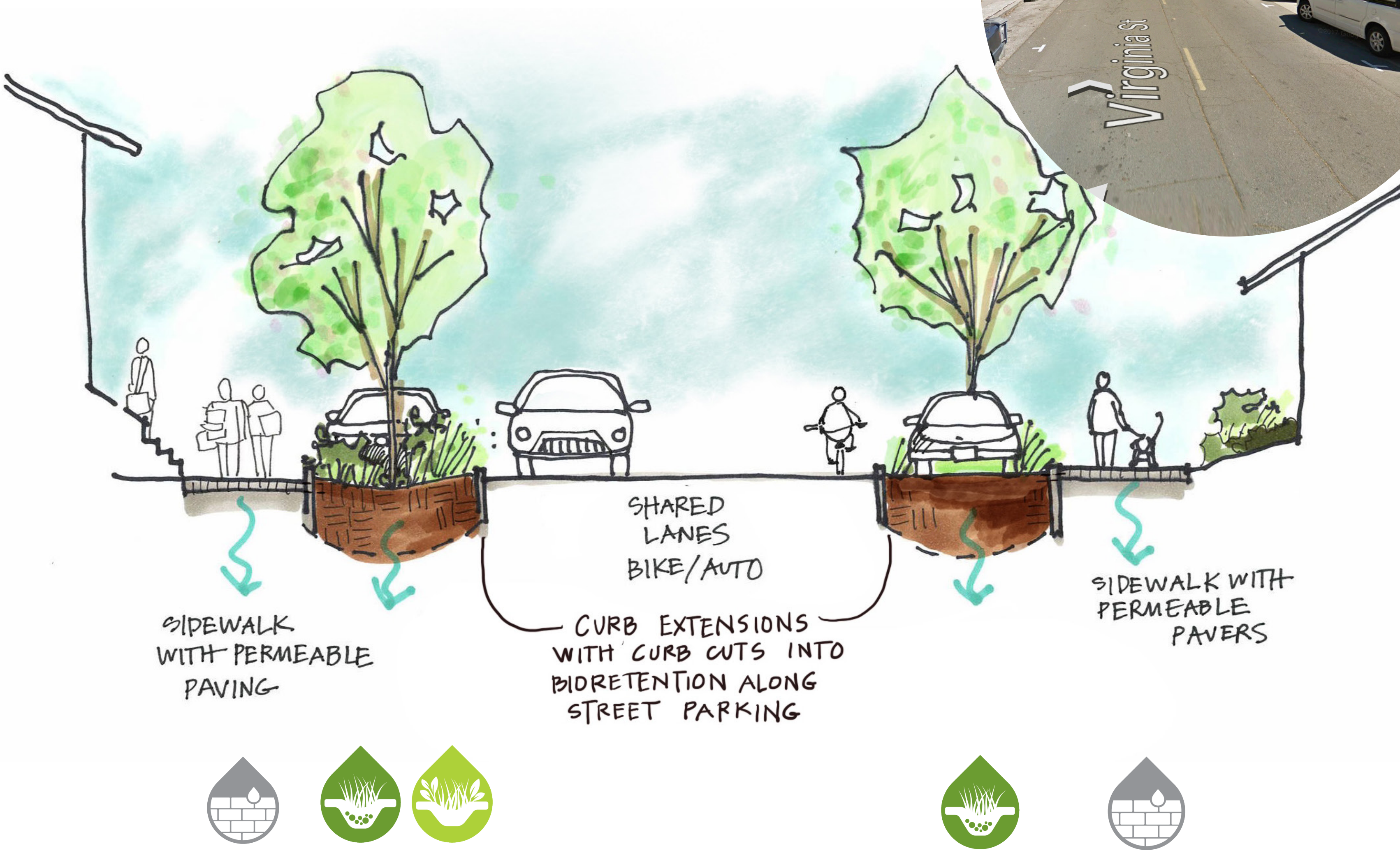
Many downtown streets use angled parking along the street frontage, which when converted to parallel parking creates additional space for wider walkways, bike lanes, and GSI with a relatively small loss in parking spaces.

GSI should include paths or be sited to allow for access to the sidewalk at frequent and regular intervals. GSI should be sited to prevent adversely affecting access to businesses. If access impacts are expected, they should be equally distributed across all storefronts.

To adjacent retailers GSI aesthetics are often more important that function. Provisions for regular maintenance, like debris removal and light weeding, can be coordinated with local businesses to reduce cost and improve performance.

Street Type | High Density Residential

Example:
Virginia Street, Vallejo



GUIDELINES BY STREET TYPE | HIGH DENSITY RESIDENTIAL

Example High Density Residential Street in Vallejo, CA

Green stormwater infrastructure can initiate opportunities to retrofit residential streets and create more pleasant conditions for people to walk, bike, and enjoy their neighborhoods.

The close proximity and frequency of driveway entrances, plus a higher demand for on-street parking, creates less space for GSI integration in high density residential streets as compared to low density residential streets. Pervious paving is a favorable GSI alternative in high-density residential streets because it can manage stormwater runoff without sacrificing high use parking spaces, sidewalk width, or drive lanes. For example, pervious paving in the parking lane can capture runoff from the street, with additional runoff directed into adjacent GSI.

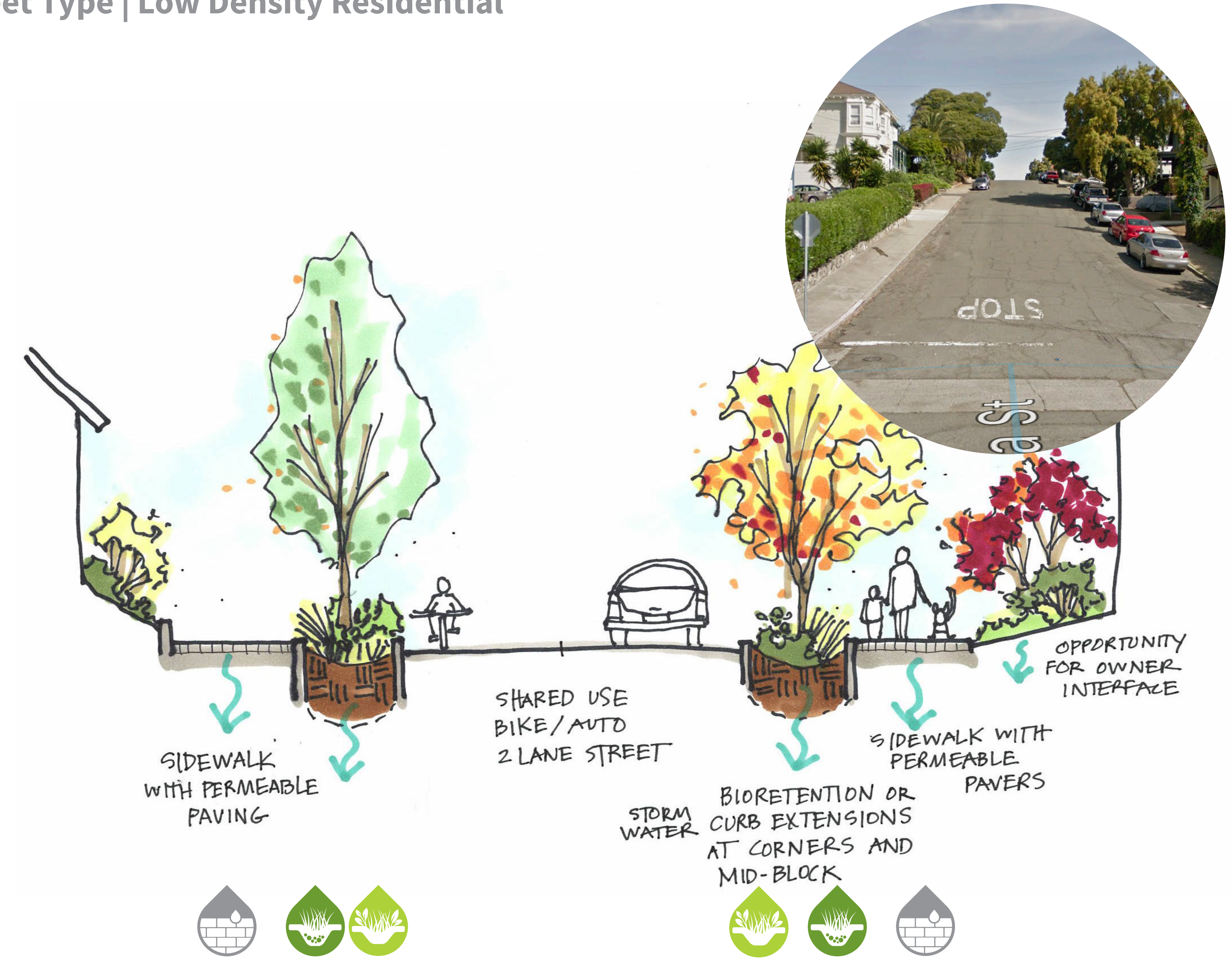
Design Considerations

Stormwater runoff from nearby arterial or downtown streets can be directed towards GSI on residential streets, which can avoid some of the potential maintenance conflicts on busier streets.

Alternating midblock stormwater curb extensions can create a curved, or serpentine, driving lane and maintain slow vehicle speeds. Curb extensions at cross walks also increase pedestrian visibility and shorten crossing distances.

Bioretention or biofiltration facilities can be sited in the planting strip between the sidewalk and the roadway.

Street Type | Low Density Residential



GUIDELINES BY STREET TYPE | LOW DENSITY RESIDENTIAL

Example Low Density Residential Street in Vallejo, CA

Low-density residential streets offer opportunities for GSI integration because they typically have the fewest conflicts with utilities and typically have under-used parking zones.[11]

GSI on low density residential streets can align with school routes, bike routes or delineate parks, schools or churches.

Design Considerations

Bioretention or biofiltration facilities can be sited in the planting strip between the sidewalk and the roadway, if the available width can be accessed by maintenance crews. Where space is a constrained, GSI facilities with walls may be appropriate.

Mature trees and frequent driveways can limit applications of stormwater curb extensions.

The lower traffic volumes on residential streets result in less sediment and debris, increasing opportunities for pervious pavement, biroetention, and biofiltration.

11 San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook, First Edition, January 2009

PARKING LOT OPPORTUNITIES FOR GREEN STORMWATER INFRASTRUCTURE INTEGRATION

Parking lot pavement makes up a substantial proportion of urban and suburban impervious surface areas. Parking lots, along with associated medians, curbs, and islands, present opportunities to integrate green stormwater infrastructure. New parking lot designs or existing parking lot retrofits can integrate green stormwater infrastructure to capture runoff from parking spaces, parking lanes, and buildings before it leaves the site. Parking lots with GSI can[12]:

- Reduce effective impervious area
- Infiltrate runoff from parking lanes and stalls
- Improve parking lot drainage
- Provide shade when trees are used
- Improve pedestrian safety with curb bump-outs to reduce crossing distances
- Improve aesthetics
- Provide wildlife habitat

When considering the design of new or retrofit parking lots, it is imperative to consider how much parking is needed on an "average day." For most of the year parking lots often have many empty parking spaces, especially shopping mall and large retail store parking lots. As municipal requirements allow, parking lots can provide spaces for average day versus peak conditions, incorporate principals of shared parking (for example between office buildings and movie theatres that have demand for parking at different times), or at a minimum, provide peak overflow parking zones with pervious paving.

Before

After

12 Green Infrastructure Opportunities that Arise During Municipal Operations, EPA Office of Wetlands, Oceans and Watersheds, National Estuary Program, January 2015

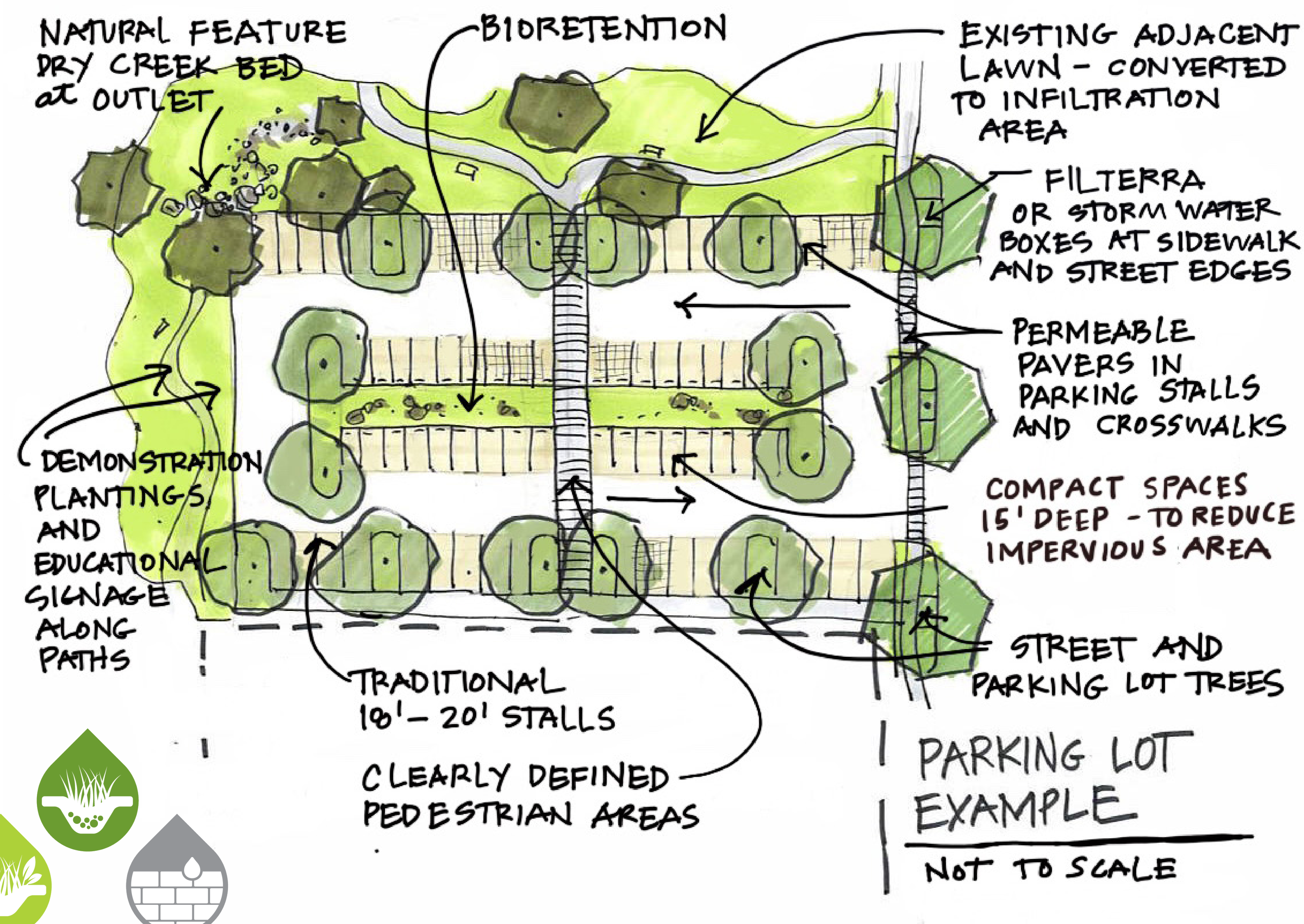
Balance Parking and Landscape Space

Impervious surfaces increase runoff and pollutant loads, and especially given the high cost of property in the Bay Area, parking lots are an opportunity for efficient design to make space available for other things, like green infrastructure. A variety of GSI tools can be applied in parking lots, starting with techniques to reduce impervious areas, which reduces runoff volumes and makes space available for GSI while meeting target parking space requirements.

Strategies to reduce imperviousness in parking lots include:

- Shortening parking stalls to create GSI planters in front of and/or next to angled parking. Shorten parking stall lengths to 15 feet and/or shorten the drive/back-up aisles to 22 feet. The shorter stalls can still accommodate SUVs, and the drive aisles can still allow cars to comfortably back-up and travel within the parking lot.[13]
- Create shallow depressions in medians, centerline safety strips, and roundabouts and plant with low-profile vegetation.
- Convert one or more street parking spaces to a micropark that serves as a seating area or gathering space while incorporating a bioretention facility to receive drainage from surrounding impervious areas.
- Choose pervious pavement for areas with low volume traffic, such as parking stalls, fire lanes, pedestrian walkways, and overflow parking.
- Install or convert areas between parking rows to bioswales.
- Install bioretention or biofiltration along the parking lot perimeter and in corners where cars cannot park. Use curb bump-outs with bioretention at the end of stalls to calm traffic and reduce pedestrian crossing distances.
- Plant trees between parking rows, in bump-outs, and along perimeters. Use stormwater tree boxes in wide sidewalks and entrance courts.
- For retrofits, redirect stormwater flow from storm drains to bioretention areas.

13 San Mateo County Sustainable Green Streets and Parking Lots Guidebook. Portland, Oregon and other cities have allowed even smaller parking lot dimensions within their city codes.


NATURAL FEATURE DRY CREEK BED at OUTLET
BIORETENTION
EXISTING ADJACENT LAWN - CONVERTED TO INFILTRATION AREA
FILTERRA OR STORM WATER BOXES AT SIDEWALK AND STREET EDGES
PERMEABLE PAVERS IN PARKING STALLS AND CROSSWALKS
COMPACT SPACES 15' DEEP - TO REDUCE IMPERVIOUS AREA
DEMONSTRATION PLANTINGS, AND EDUCATIONAL SIGNAGE ALONG PATHS
TRADITIONAL 18'- 20' STALLS
CLEARLY DEFINED PEDESTRIAN AREAS
STREET AND PARKING LOT TREES
PARKING LOT EXAMPLE
NOT TO SCALE

Green Parking Areas: Potential Project Partners and Funding Sources

- Seek input from business improvement districts, neighborhood associations, and the Chamber of Commerce regarding desired features and amenities of green parking areas.
- Solicit funding from business associations or grants to improve municipal parking areas serving a commercial district.

Design Considerations:

For GSI located between parking aisles, plant trees aligned with stripes to avoid being hit by cars.

Select plants that do not impede driver sight lines or hide pedestrians from view.

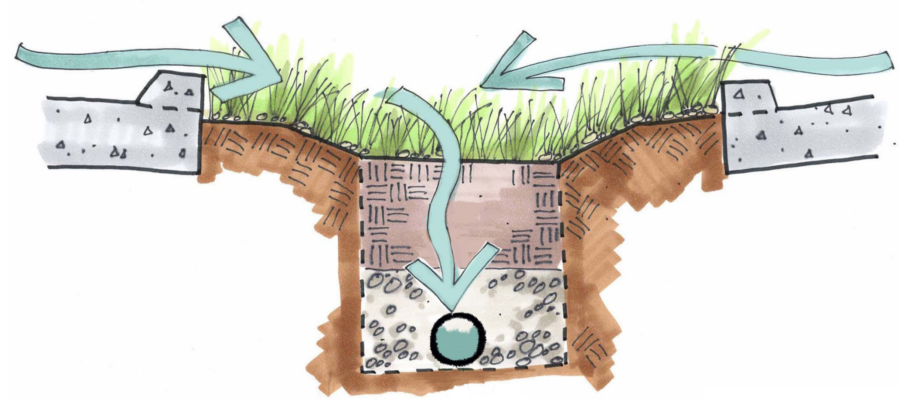
Design GSI with access and features that make maintenance easier, such as paved forebays for easy sediment removal.

Choose vegetation that is densely rooted to filter debris and pollutants.

Use wheel stops or curbs with cuts to ensure that cars do not drive over bioretention.

Grade drainage to slope toward bioretention areas or pervious pavement; avoid concentrated flows.

Design curb cuts and inflow areas to manage adequate flow.



PUBLIC PARKS, PUBLIC LANDSCAPE AREAS, AND OTHER PUBLIC OUTDOOR AREAS

Municipal buildings, libraries, public parking lots, schools, community centers and parks offer opportunities for highly visible green infrastructure retrofits. Projects can be undertaken as part of the capital improvement process, ideally in conjunction with other needed maintenance such as building additions and modifications, repaving, re-landscaping, or infrastructure repair or replacement.[14] Green stormwater infrastructure can enhance public spaces by:

Providing opportunities for signage describing the GSI philosophy;

Infiltrating runoff from paved areas and rooftops;

Creating wildlife habitat; and

Creating welcoming, park-like areas

Green Stormwater Infrastructure in Parks

The American Planning Association, through The City Parks Forum created a briefing paper on "How cities use parks for Green Infrastructure", which identifies the four key points:

- Key Point #1 Creating an interconnected system of parks and open space is manifestly more beneficial than creating parks in isolation.
- Key Point #2 Cities can use parks to help preserve essential ecological functions and to protect biodiversity.
- Key Point #3 When planned as part of a system of green stormwater infrastructure, parks can help shape urban form and buffer incompatible uses.
- Key Point #4 Cities can use parks to reduce public costs for stormwater management, flood control, transportation, and other forms of built infrastructure.

14 Green Infrastructure Opportunities that Arise During Municipal Operations, EPA Office of Wetlands, Oceans and Watersheds, National Estuary Program, January 2015

3. Streetscape and Project Design Guidelines

Consider the following actions to implement green stormwater infrastructure in parks and around public buildings like City Hall and the Library:[15]

- Convert turf areas with high maintenance requirements and potable water demands to landscape GSI or other naturalized areas to reduce maintenance and other costs associated with the management of turf;
- Decrease potable water demand by installing cisterns or rain barrels to collect roof runoff for irrigation;
- Install pervious pavement in parking lots and along walkways to reduce runoff and improve aesthetic;
- Install GSI in underutilized areas to improve aesthetics and reduce runoff and flooding;
- Include educational signage describing stormwater impacts and the benefits of GSI.

15 Adapted from Green Infrastructure in Parks: a Guide to Collaboration, Funding, and Community Engagement, EPA Office of Water, June 2017.

Green Stormwater Infrastructure in Schools

Integrating green stormwater infrastructure on school grounds provides an opportunity to connect kids, families, educators, and staff with environmental problems and solutions in tangible ways while also managing stormwater and achieving regulatory compliance.

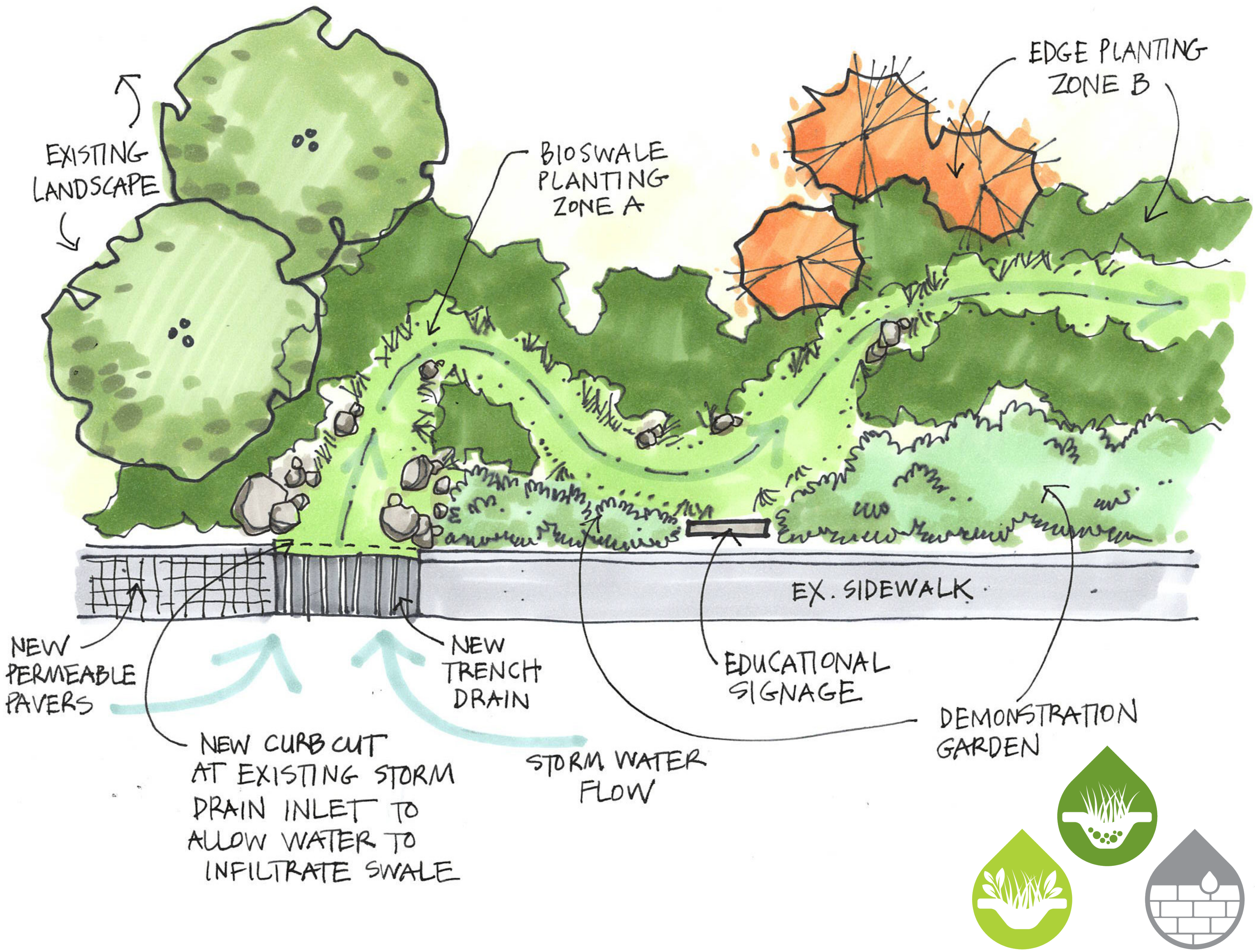
Students can study, monitor, and maintain water quality facilities on school grounds as part of their science curriculum.

GSI can be used to capture stormwater runoff from impervious surfaces adjacent to school rooftops, walkways, playgrounds, blacktops, and parking lots.

Rainwater harvesting can be used to collect rainfall from rooftops, and the captured water can be used for irrigation and with the proper treatment indoor uses like toilet flushing. Students can be a part of the collection and reuse process by using collected rainwater to irrigate school gardens.

Before

After


EXISTING LANDSCAPE
BIOSWALE PLANTING ZONE A
EDGE PLANTING ZONE B
EX. SIDEWALK
NEW PERMEABLE PAVERS
NEW TRENCH DRAIN
EDUCATIONAL SIGNAGE
DEMONSTRATION GARDEN
NEW CURB CUT AT EXISTING STORM DRAIN INLET TO ALLOW WATER TO INFILTRATE SWALE
STORM WATER FLOW

Create Stormwater Microparks

"Urban landscapes have many small-scale pockets of space that are underutilized and sometimes unsightly. These spaces often are located in triangles at junctions of diagonal streets, in spaces between buildings, in vacant lots, or in corners of parking lots. These underused areas are often paved or have high-maintenance turf that offers limited amenity value. They can be converted to a bioretention area or community garden with trees and attractive vegetation, and can accomplish the following:"

- Reduce impervious surface
- Infiltrate runoff from the right-of-way and adjacent property
- Protect and restore water quality
- Improve aesthetics
- Create park-like areas
- Provide shade
- Showcase public art
- Provide wildlife habitat
- Promote urban agriculture

Ensure that there is adequate light for plant growth, or select shade-tolerant plants for microparks surrounded by buildings.

For microparks adjacent to streets, consider enhanced pedestrian safety measures, such as wheelstops, railings, buffers, curb extensions, and painted crosswalks.

Review local codes (setback requirements, sidewalk widths, parking requirements, etc.) to ensure there is space for green infrastructure practices.

Identify possible conflicts with existing utilities." [16]

Design Considerations

Install pervious pavement in low traffic areas such as alleys, medians, sidewalks, fire lanes, and parking stalls.

Convert unused parking spaces into a micropark and/or install GSI. Overflow parking is fantastic application for pervious pavement.

Replace pavement in medians and traffic islands with vegetation. Larger under utilized spaces may be appropriate for community gardens.

Locate GSI in areas where runoff is already naturally flowing to avoid costly regrading.

Site and design GSI in consideration of maintenance requirements by providing adequate access and features to facilitate debris and sediment removal.

Include trees within site improvement plans to provide shade, stormwater and climate change benefits, and improve aesthetics.[17]

To prevent lateral migration of infiltrating stormwater, which can undermine building foundations and other structures, install lined biofiltration elements to capture rooftop runoff adjacent to, or close to, buildings.

16 Green Infrastructure Opportunities that Arise During Municipal Operations, EPA Office of Wetlands, Oceans and Watersheds, National Estuary Program, January 2015
17 Green Infrastructure Opportunities that Arise During Municipal Operations, EPA Office of Wetlands, Oceans and Watersheds, National Estuary Program, January 2015

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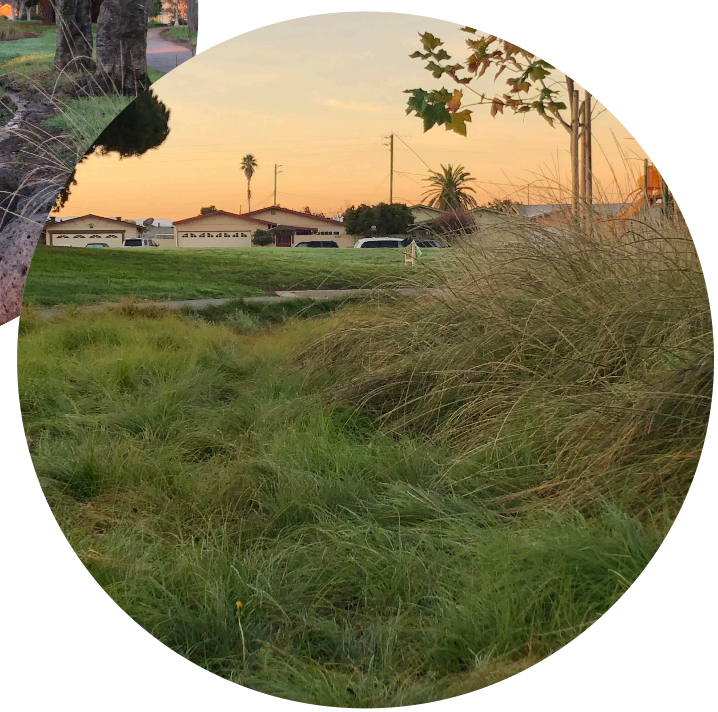
3. Streetscape and Project Design Guidelines

LANDSCAPE DESIGN CRITERIA

INTRODUCTION

Urban greening infrastructure improvements and low impact development projects should serve to improve the fabric and quality of life in our towns and cities. By making well informed and strategic landscape design and planting choices, engineered basins, swales and structures can be transformed into green jewels in a community!



Every project will be unique and will need to be thoughtfully considered. Urban sites designed to include bioretention planters and green gutters, or biofiltration planters surrounded by modern architecture lend themselves to a more structured approach with a less diverse plant palette while large stormwater facilities and bio-swales located within large sloping greenspaces may be more naturalistic and include a more diverse variety of plant species and textures.

Green street and parking lot projects may have an all-together different approach and include a mix of plantings that are tolerant of wet-zone conditions and severe drought and will almost always include large canopy tree plantings tolerant of these conditions as well as urban contaminants and pollution.

Climate

Solano County is located in the San Francisco Bay area, characterized as a Mediterranean climate is typified by warm dry summers and mild winters. Rainfall distribution is substantially affected by topography, with most of the rainfall concentrated along the western county border over the Vaca Mountains. Each of the three cities included in the project area have slight climactic differences. Vallejo is considered a waterfront city and subject to occasional fog and marine climate. Slightly further inland, Fairfield and Suisun City are also considered as having a mild climate with similar mild summers and winters.

PLANTING DESIGN

Tree Selection

Although not directly related to stormwater quality, adding tree canopy provides additional benefits including energy savings, air quality improvement and economic benefit to a community. Significant amounts of tree canopy have other important environmental benefits not directly related to stormwater management.

Existing healthy and mature trees should be preserved on a site whenever possible. Mature trees may influence the location of stormwater facilities and should be considered in the design of streetscape and stormwater treatment facilities. Often adjacent trees may be retained and can advantageously affect the uptake of water in a stormwater basin, thus providing an additional benefit.

Species of tree should be considered when placing new landscape as well, some species are highly sensitive to crown disturbance, root trimming, standing water or supplemental irrigation.

If a new tree planting is planned, it is important to consider if the tree species is well suited for the proposed location. For instance, in a parking lot island or street tree application species should be selected that have a large canopy, non-invasive roots, are pollution tolerant and tolerant of standing water (if planted in a biofiltration swale).

Each City within Solano County has developed tree selection criteria specific to their region and City Standards for Vallejo, Suisun City and Fairfield should be consulted in addition to this document.

Plant Selection

There are many conditions to consider when choosing plant species to be used in stormwater treatment drainage features. Many of the criteria are found in species that successfully tolerate the disparate conditions found in their native habitats. For example, the plant species need to tolerate periods of flooding as well as extended dry periods without supplemental irrigation. A mix of Mediterranean and California native plant species are highly recommended as they are best adapted to the local climate of wet winters and hot dry summers.

The plant palette is intended to serve as a baseline for plant species selection for LID drainage features. Other plant species may be proposed for use in stormwater drainage features and the individual Cities within Solano County will have the right to permit or deny their use. The following planting criteria and characteristics are to be considered when proposing other species for stormwater treatment features:

- The planting zones where the plant species are to be planted (Low, Mid, High, see Planting Zones)
- The size of the planting area and the size of the plant species at maturity
- California native or easily naturalized plant species are preferred
- Appropriate for the site, areas of high traffic and vandalism should be treated with sturdy more robust species
- Invasive species should not be used
- Ratio of 70% evergreen / 30% deciduous to minimize leaf collection in basins and maximize coverage year round.
- Drought tolerant / low-supplemental irrigation requirements
- Tolerant of flooding/inundation (when appropriate)
- Low maintenance requirements
- Proven success in Solano County

As an element of a drainage feature, plant selections should control erosion and draw water from soils. An ideal planting will have 100% coverage over a 1 year period to prevent sedimentation and erosion. Plantings should be installed with a higher coverage rate than in traditional applications.

If a planted LID drainage feature receives a concentrated flow, energy dispersion will be required at the entry point to deter damage or erosion to the planted areas. Examples of erosion protection/energy dissipation designs include large boulders, cobblestones or gabions. These natural dissipation features can enhance a stormwater feature by adding a natural character to what can be considered engineered site features.

Plant Layout

The following shall be considered when planting in stormwater features:

- The smallest practical area of land should be exposed at any one time during development. Mulching, erosion control blankets, native grass sod or other protective erosion control measures should be used to protect exposed areas.
- Vegetation should be installed immediately after the land is exposed, during construction.
- Plants should be planted in staggered rows to ensure that plants grow together for maximum soil coverage.
- Avoid compacting soils and maintain slopes less than 3:1

Hydrozones

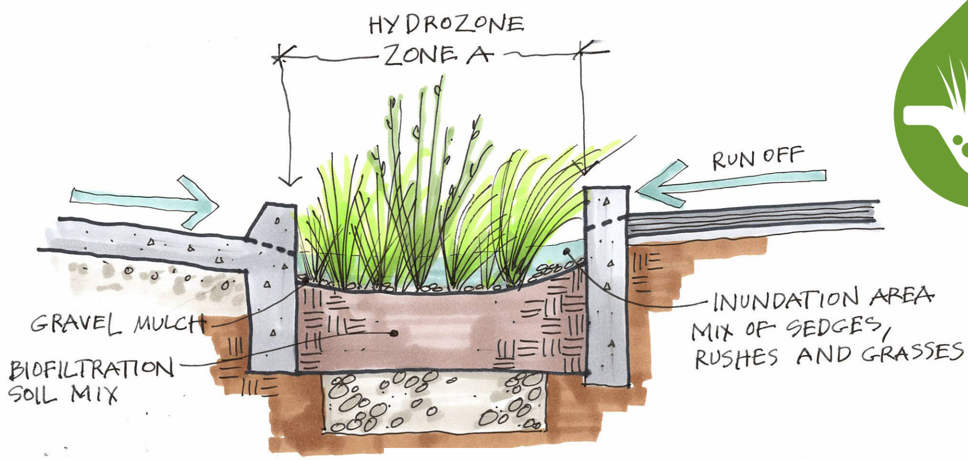
Planting zones refer to the planted areas in drainage features of Low Impact Development (LID) practices and stormwater control features. Plants are an integral element of the function of these stormwater features. The plants in these zones facilitate natural infiltration of surface runoff, increase evapotranspiration, reduce the heat-island effect of urbanized areas, and reduce the rate, volume, and pollutant loading of urban runoff that ultimately ends up in local streams, rivers, estuaries, Suisun Marsh, and Suisun Bay and the San Francisco Bay. For the drainage features to function optimally, numerous plant characteristics have been considered in indicating the appropriate plant species for the three plant zones such as: water requirements, tolerance for inundation, root and leaf structure and a species' ability to filter pollutants.

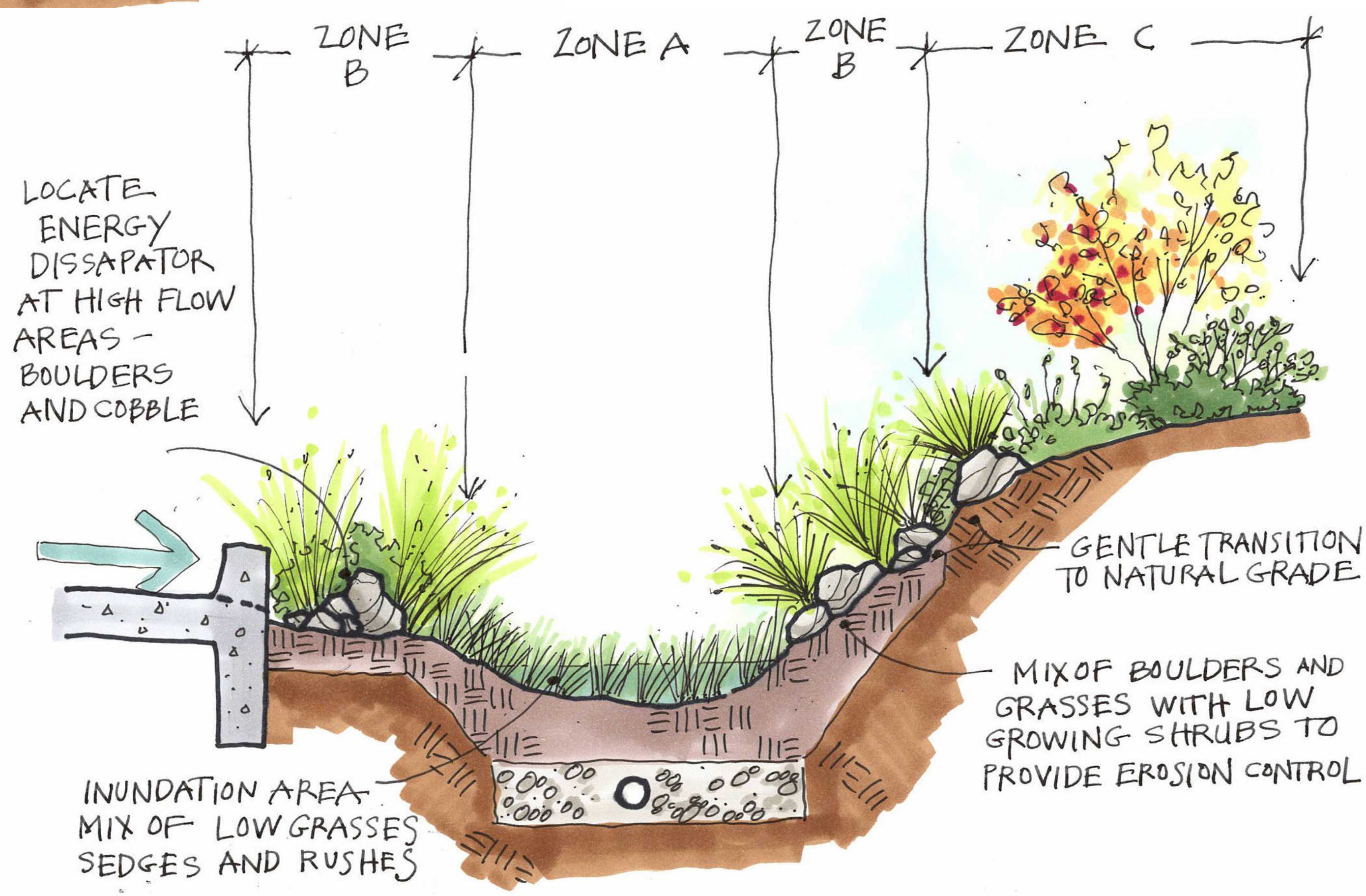
In all instances, a mix of drought tolerant Mediterranean and California native plant species are recommended since they are adapted to the San Francisco Bay and inland climate and generally require less water and fertilization. Invasive plant species are discouraged as water can quickly spread their occurrence and alter downstream habitats. Likewise, high water use turf grasses are discouraged for LID drainage features since they require large amounts of supplemental water, fertilizers and regular maintenance.

LOW ZONE A – The low zone is an area where runoff temporarily ponds in response to a rain event. The low zone should be designed to infiltrate at a rate of 5 inches per hour or greater, and to drain standing water in less than 72 hours. However, it may be inundated for extended periods of time during the rainy season. Water tolerant plants with dense root structure and/or vegetative cover provide maximum pollutant filtration, discourage erosion and slow water runoff velocities (in drainage features that cross-drain, such as biofiltration swales). Low growing sedges, rushes and grasses that quickly cover exposed soils (three months time) and are tolerant of very wet and intermittent flooding, are the best choices and low zone A. In some cases, a native grass sod may be selected and installed for immediate coverage in large basins subject to severe erosion or that need immediate coverage.

MID ZONE B – The mid zone is an area that slows the storm water runoff as it flows into the drainage feature, with side slopes 3:1 or less. Water passes through and saturates this area but will not stand there for extended periods of time during typical storm events. The plants for this zone must tolerate periods without water and periodic inundation. The plants in the mid zone should provide a root structure to prevent erosion of the side slope. Larger grasses and mixed species groundcovers may be used in the mid zone B where there are varied slopes, soil type, and drainage patterns (sheet flow, concentrated flow, or intermittent flooding). Select low-growing plant material (less than three feet in height). Low-growing plants tend to be more appropriate and functional in green street and parking lot applications.

HIGH ZONE C – The high zone is an area that creates the top of the bank of the drainage facility. Water will not stand in this zone. Deep roots give natural base structure to the edge of the drainage facility. These plants must be tolerant of extended periods without water and occasional saturation. Trees and small shrubs are best planted in the high zone C where their roots can absorb the infiltration and minimize debris collecting in the basin bottom. Plants chosen for wet zone conditions should also have some level of drought tolerance in order to minimize, or potentially eliminate, the need for supplemental irrigation and minimize maintenance.


HYDROZONE
ZONE A
RUN OFF
INUNDATION AREA
MIX OF SEDGES,
RUSHES AND GRASSES
GRAVEL MULCH
BIOFILTRATION
SOIL MIX


ZONE B
ZONE A
ZONE B
ZONE C
LOCATE ENERGY DISSAPATOR AT HIGH FLOW AREAS - BOULDERS AND COBBLE
GENTLE TRANSITION TO NATURAL GRADE
MIX OF BOULDERS AND GRASSES WITH LOW GROWING SHRUBS TO PROVIDE EROSION CONTROL
INUNDATION AREA MIX OF LOW GRASSES SEDGES AND RUSHES

SITE PREPARATION

Each site is different and stormwater treatment facilities and treatments may require specific soil mixes and soil preparation. It is important to consider the overall goal of the soil application and the requirements for drainage. Specific soil mixtures should be selected depending on the installation type and are detailed in the Engineering section of this Report.

LID retrofit sites and stormwater improvement projects are often located in sites with extremely compacted or mineral depleted soils. Because of this, the site preparation and soil amendment process is critical to the long-term and sustained health of plantings.

Generally new bioretention mixes should be fully incorporated into the top six inches of existing soil, well rototilled and lightly compacted (up to 75% compaction). Heavy compaction in large sites and paved areas is often the main cause of storm water facility failure.

Precise grading of stormwater facilities is critical for assuring the success of a green street or parking lot project and in most situations, adjustments to the grades will need to be made in the field. Finish elevations of biroetention soils shall be held 3 inches below final grade of the stormwater facility to account for a mulch layer.

Bioretention Soil Mix

In general, bioretention or biofiltration soil mixes shall be consistent with the BASMAA Regional Bioretention Soil Mix Specification (Appendix A). Soils for biotreatment or bioretention areas shall meet two objectives:

• Be sufficiently permeable to infiltrate runoff at a minimum rate of 5" per hour during the life of the facility, and

• Have sufficient moisture retention to support healthy vegetation.

Achieving both objectives with an engineered soil mix requires careful specification of soil gradations and a substantial component of organic material (typically compost).

Compost shall be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes or other organic materials not including manure or biosolids meeting the standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program).

Soil Testing For Non-Regulated Projects

A soils report should be prepared prior to planting. The report shall be prepared by a qualified soils laboratory. The report shall be submitted to the City as part of the landscape and irrigation plans for final approval. Soil samples should be collected after grading operations are complete. Since surface soils are highly variable within Solano County, a sufficient number of soils samples shall be collected to account for variations that may be present in the areas to be planted. The report should include:

- Native soil composition
- Infiltration rates
- A texture test
- Known or suspected toxins or infestations
- Exchange capacity
- An agricultural suitability analysis
- Recommended amendments for planted species to thrive

The selection of plant material, fertilizers, soil amendments, soil conditioners, and irrigation systems, shall address, in particular, the needs as indicated in the soils analysis report.

Amendments

Prior to planting the recommended amendments shall be added as described in the soils report. A copy of the soils report shall be attached to the irrigation schedule provided to the owner of the project.

Irrigation

Refer to the Individual City Standards (City of Vallejo, Suisun City and City of Fairfield) for a full list of irrigation materials, specifications and construction details. Specific irrigation standard materials may vary by City.

All irrigation systems and landscapes shall be designed using the Model Water Efficient Landscape Ordinance AB 1881 of the California Code of Regulations (or replacement bill) as a standard.

Ideally a sub-surface drip irrigation system or individual bubblers located in planting areas, are preferred choices in long narrow stormwater features such as green gutters and biofiltration swales and in engineered solutions such as biofiltration and infiltration features because they allow for maximum application of water without overspray, or emitter maintenance. This is an ideal solution in high traffic areas and where minimal irrigation is needed for establishment of a planting area.

Non irrigated landscapes should be maintained for a period of two full rainy seasons

Mulch

Mulch should be added to all stormwater features with the exception of Low Area A plantings that are densely planted. The mulch may be organic material (e.g., aged compost) or stone. Wood mulch is discouraged becuase it tends to float. Stone mulch is a good choice for stormwater facilities that experience high levels of runoff. Stone should be sized appropriately based on the expected sediment load of the runoff, larger rocks can collect sediment and be difficult to maintain. In green street and parking lot projects with a flat bottom, an ideal selection is pea gravel because it allows for easier removal and maintenance of sediment and debris.

When planning and designing stormwater facilities, finished grade should be left 3 inches below the desired finish grade to allow for a thick layer of mulch. If the finish grade of the stormwater facility is built without planning for a mulch layer, the stormwater facilities will be graded too high and water cannot get into the overflow.

After planting, exposed soils shall be covered with mulch to prevent erosion and for the purpose of retaining moisture and minimizing weed growth. New construction and retrofit is often subject to the State's Model Water Efficiency Landscaping Ordinance (or comparable local ordinance) will require at least three inches of mulch. Biodegradable coconut fiber erosion control blankets may also be used on slopes greater than 3:1 to provide same function as mulch.

Mulch should be large enough in size to be easily cleaned away from drain inlets and not fit through the openings of drain grates. Mulch shall be free of sticks and other debris. Always hold mulch away from root crown. Acceptable mulch types include:

- Redwood bark (1" to 2" diameter)
- Chipped gravel, crushed stone, (1" – 2 1/2" diameter) or cobbles (4" – 6" diameter)
- Aged compost

Maintenance

Native and well selected plant species naturally reduce the need for maintenance. Well selected plants and trees will minimize pests and disease problems, require less fertilizer, reduce the need for excessive pruning and conserve water.

Care requirements should be considered when choosing plant species for LID drainage features. Trash and debris should be cleaned out of LID planting areas periodically, especially after large storm events. Drain inlets shall be cleaned out monthly.

A 3" layer of composted mulch should be re-applied once a year, or as needed, to slopes and exposed soil, preferably in June following weeding.

Pesticide Use – Integrated Pest Management

Either by rain or irrigation, pesticides used on landscaping and gardens can be washed off the plants and soils upon which they have been applied. This stormwater runs off the land and flows to the nearest storm drain, which ultimately carries the stormwater to local creeks, the Suisun Marsh, and Suisun Bay without treatment. These pesticides may be harmful to fish and other organisms. Therefore, reducing the use of pesticides in landscape maintenance helps protect water quality, aquatic life and human health.

In planning and selecting plantings for a stormwater treatment project, consider pest resistant plants and promoting integrated pest management (IPM) methods of pest control. IPM is a decision-making process for managing pests. This approach uses monitoring to determine pest-caused injury levels and the most effective methods for pest control. To effectively control pests while minimizing pesticide usage, IPM uses a combination of biological controls (natural enemies or predators); physical or mechanical controls (hand labor or mowing); cultural controls (mulching, disking, or alternative plant type selection); and reduced risk chemical controls (soaps or oils).

Synthetic pesticides should not be used on bioretention facilities. Beneficial nematodes and non-toxic controls may be used. Acceptable natural pesticides include Safer® Aphid, Whitefly, and Mealybug Killer, Safer® Tree and Shrub Insect Attach, Safer® for Evergreens, and Neem oil. For more information on pesticide reduction in landscape maintenance and design, please refer to the Fairfield-Suisun Urban Runoff Management Program brochure entitled "Landscape Maintenance Techniques for Pest Reduction."

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WUCOLS IV, last modified January 2, 2014. http://ucanr.edu/sites/WUCOLS/

		Zone A	Zone B	Zone C	Swale or Filter Strip	Large Planters (> 5')	Tolerates Prolonged Saturation	Tolerates Periodic Flooding	Tolerates Prolonged Dry Periods	Tolerates Mowing	Street	Wind Tolerant	
Trees													
Alnus rhombifolia	White Alder			•				•	•		•	•	
Acer macrophyllum	Big Leaf Maple			•				•	•		•	•	
Acer rubrum	Red Maple			•					•		•	•	
Acer circinatum	Vine Maple			•				•	•		•	•	Select natural form - prefers some shade
Cercis occidentalis	Western Redbud			•					•		•		Select natural form in bioswale - std. for street tree
Cercis canadensis	Eastern Redbud			•					•		•		Select natural form in bioswale - std. for street tree
Platanus acerifolia 'Columbia'	London Plane Tree			•					•		•	•	** Do NOT use 'Yarwood'
Pyrus calleryiana	Flowering Pear			•							•		** Do NOT use in City of Suisun
Quercus agrifolia	Coast Live Oak			•					•		•	•	Allow ample room for canopy
Quercus lobata	Valley Oak			•					•		•		Allow ample room for canopy
Ulnus parvifolia	Chinese Elm			•				•					
Shrubs & Groundcovers													
Arctostaphylos species	Manzanita			•		•			•			•	Many sizes and species available
Baccharis pilularis	Coyote Brush			•		•			•			•	
Berberis aquifolium	Oregon Grape			•		•			•				
Ceanothus species	Ca. Wild Lilac			•		•			•			•	Many sizes and species available
Cornus stolonifera	Red Twig Dogwood	•	•	•	•	•	•	•	•			•	Clay tolerant
Heteromeles arbutifolia	Toyon		•	•		•			•			•	
Mimulus aurantiacus	Sticky Monkeyflower	•	•	•	•	•		•	•				
Myrica californica	Pacific Wax Myrtle			•		•		•	•			•	
Rhamnus californica	Coffeeberry			•		•		•	•			•	
Ribes species	Currant		•	•		•		•	•				Many sizes and species available - tolerates shade
Rosa californica	California Rose	•	•	•	•	•	•	•	•			•	
Rubus parvifolius	Thimbleberry		•	•		•		•	•				Shade tolerant
Sambucus species	Elderberry		•	•		•		•	•				Many sizes and species available - allow space

Sedges, Grasses and Herbaceous Perennials		Zone A	Zone B	Zone C	Swale or Filter Strip	Large Planters (> 5')	Tolerates Prolonged Saturation	Tolerates Periodic Flooding	Tolerates Prolonged Dry Periods	Tolerates Mowing	Street Tree	Wind Tolerant		
Achillea millefolium	Yarrow		●	●	●	●		●	●	●		●		Many colors available
Carex divulsa	Berkeley Sedge	●	●	●	●	●	●	●	●	●		●		Clay tolerant
Carex tumulicola	Foothill Sedge	●	●	●	●	●	●	●	●	●		●		
Carex species	Sedges	●	●	●	●	●	●	●	●	●		●		Many sizes and species available
Calamagrostis x "karl foester"	Feather Reedgrass		●	●		●		●	●			●		Should be pruned heavily annually
Deschampsia caespitosa	Tufted Hairgrass		●	●	●	●		●	●	●		●		
Elymus glaucus	Blue Wild Rye	●	●	●	●	●	●	●	●	●		●		
Festuca californica	California Fescue			●	●	●			●			●		
Festuca idahoensis	Idaho Fescue			●	●				●	●		●		
Festuca rubra	Red Fescue			●	●				●	●		●		
Fragaria chiloensis	Beach Strawberry		●	●	●			●	●			●		
Iris douglasiana	Douglas Iris			●					●			●		Keep out of Zone A and mulched areas
Juncus effusus	Pacific Rush	●	●		●	●	●	●	●			●		
Juncus patens	Blue Rush	●	●		●	●	●	●	●			●		Use sparingly, spreading habit can be aggressive
Lupinus species	Lupine		●	●		●		●	●			●		
Muhlenbergia rigens	Deer Grass		●	●	●	●		●	●			●		
Poystichum munitum	Western Sword Fern	●	●	●	●	●		●	●			●		plant in some shade
Leymus 'Canyon Prince'	California Wild Rye	●	●	●	●	●	●	●	●			●		Best in large planters - spreads quickly
Salvia species	Sage		●	●		●			●			●		Many sizes and species available

MAINTENANCE CONSIDERATIONS DURING DESIGN

Maintenance is critical to the longevity and effective function of green stormwater infrastructure. GSI projects need to strike a cost effective balance between construction and operation and maintenance (O&M) costs. Specific aspects of facility maintenance should be considered during the design phases, specifically who will be responsible for maintenance and if there is sufficient staffing capacity to support the additional work, how maintenance crews will access the facilities, and what special equipment or skills may be needed to perform the maintenance.

The access routes and temporary material storage areas that maintenance crews will use should be delineated during the project design phases. This will ensure that crews have safe access even in high traffic areas. The type and frequency of the required maintenance activities should be identified during the design phase to confirm with site managers that staffing, skills, and equipment will be in-place to perform the required maintenance once the facility is installed.

"Although green infrastructure may need more frequent maintenance, provided by a broader coalition of project partners, the aggregate costs can be less than that required for gray infrastructure, for which repairs and maintenance may be less frequent but much more disruptive and likely more costly."

- Sustainable Streets City of San Mateo, February 2015

POST-CONSTRUCTION

Post-Construction Verification[18]

Inspections and ongoing maintenance throughout the construction of a GSI facility is recommended and will streamline the post-construction verification process. After GSI construction, and an agreed upon plant grow-in period, a construction inspector should verify that the following items have been performed correctly and/or completed:

- Submit as-built drawings.
- Planter area(s) are free of construction-related sediment and debris.
- Plantings are healthy and rooted-in (pass pull test). Plant replacements should occur as required under the contract.
- Overall site is stabilized.
- Stormwater diversion and erosion and sediment control measures were maintained throughout the plant grow-in period.
- Good housekeeping measures were in place during the entire duration of the project.
- Monitoring wells, if any, have been installed properly.
- Irrigation system is functioning properly and irrigation head spray patterns are properly adjusted (if applicable).
- Plant grow-in and maintenance tasks are being performed.
- Flood tests were performed and approved for every bioretention planter.
- All punch list items/requested repairs have been addressed.

Flow diversion is required throughout the plant grow-in phase and until all adjacent construction is completed and stabilized. This ensures that plants are rooted firmly in place before they are inundated with stormwater runoff.

Post-Construction Maintenance

GSI maintenance can include watering, weeding, pruning, removal of invasive species, and plant replacement to support healthy plant establishment; plant debris and trash removal; and sediment removal from the forebay to maintain flow paths. If a facility is not functioning properly, maintenance may involve removing soil media and/or mulch to clean out sediment deposits.

Specific maintenance requirements, including frequency of each activity and length of contracted maintenance period, should be detailed in contract documents. Considerations during maintenance activities[19]:

- Ensure irrigation is functioning properly. Look for evidence of broken pipes or sprinklers.
- Follow recommended pruning practices by plant type for timing and amount to remove.
- Refer to the Planting Plan in the design documents to identify and remove invasive weeds.
- Ensure maintenance inspection takes place immediately following storms with rainfall of 0.25 inches or more.
- Complete and submit inspection checklists and maintenance logs based on the specification requirements.

18 Adapted from SFPUC, Green Infrastructure Construction Guidebook
19 Adapted from SFPUC, Green Infrastructure Construction Guidebook

CHAPTER 4
GREEN STORMWATER INFRASTRUCTURE STANDARD SPECIFICATION AND DESIGN DETAILS

CHAPTER OBJECTIVES

- Provide a suite of GSI details and specifications for integration into Permittee standards.

GREEN STORMWATER INFRASTRUCTURE STANDARD SPECIFICATION AND DESIGN DETAILS

These green stormwater infrastructure details and specifications have been selected to support integration of GSI into standard practices, for example in street design, municipal capital projects, and to support private development review. Implementation of a GSI strategy will require cross departmental coordination with planning, operations and maintenance. These details and specifications can support the design and construction of GSI practices in the Permittees jurisdictions.

How to use these GSI typical details[20]

These typical details and specifications were developed to be revised and customized as needed for each individual project by design professionals. They show typical configurations, rather than a required city standard configuration. This distinction is deliberate. We recognize that to create functional, contextual, and aesthetic green infrastructure projects, design professionals must use their professional judgment and creative thinking to be responsive to each site-specific condition.

AutoCAD drawings of these typical details are provided so that design professionals must modify the plan, sections, call-outs, and/or construction notes to address the projects site-specific conditions.

These typical details are formatted, organized, and developed with the necessary informational tools to guide the design professional through the proper selection, layout, and design of GSI best management practices (BMPs) and the selection of appropriate site-specific BMP component details (i.e., inlets, outlets, and edge treatments, etc.).

Design professionals using the AutoCAD drawings must review and adjust the details and construction notes to address their site-specific conditions . To allow for site-specific design adjustments the typical details are developed as "not for construction" drawings. Title blocks are provided for document organization and reference only.

Design Detail	Detail Number
Bioretention & Biofiltration Basins	
Designer Notes	1.0
Roadside Section	1.1
Parcel Section	1.2
Bioretention & Biofiltration Components - Underdrains	
Designer Notes	2.0
Underdrains	2.1
Bioretention & Biofiltration Components - Inlets	
Designer Notes	3.0
Curb Cut Inlet	3.1
Bioretention & Biofiltration Components - Outlets	
Designer Notes	4.0
Curb Cut Outlet	4.1
Outlet Curb Cut with Trench Drain	4.2
Overflow Structure	4.3
Permeable Plavement	
Designer Notes (1/2)	5.0
Designer Notes (2/2)	5.1
Key Map	5.2
Paver Section	5.3
Pervious Concrete Section	5.4
Porous Asphalt Section	5.5

SPECIFICATIONS

Specifications for Bioretention, Pervious Concrete, Porous Asphalt, and Permeable Pavers are located in Appendix A.

20 Adapted from Green Infrastructure Typical Details, SFPUC Stormwater Management Requirements and Design Guidelines, September 2016, Version 2.0

PURPOSE:

BIORETENTION BASINS CONTROL PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF BY PROVIDING SURFACE, SUBSURFACE STORAGE AND INFILTRATION INTO NATIVE SOIL. WATER IS ALSO TREATED AS IT FILTERS THROUGH THE BIORETENTION SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. FACILITY AREA, PONDING DEPTH, BIORETENTION SOIL DEPTH, AND AGGREGATE STORAGE DEPTH MUST BE SIZED TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS.
3. PONDING AND BIORETENTION SOIL DRAWDOWN TIME (I.E., TIME FOR MAXIMUM SURFACE PONDING TO DRAIN THROUGH THE BIORETENTION SOIL AFTER THE END OF A STORM) RECOMMENDATIONS:
   - 3 - 12 HOUR PONDING AND BIORETENTION SOIL DRAWDOWN (TYPICAL)
   - 24 HOUR MAXIMUM PONDING AND BIORETENTION SOIL DRAWDOWN
4. FACILITY DRAWDOWN TIME (I.E. TIME FOR SURFACE PONDING TO DRAIN THROUGH THE ENTIRE SECTION INCLUDING AGGREGATE STORAGE AFTER THE END OF A STORM) REQUIREMENTS:
   - 48 HOUR MAXIMUM FACILITY DRAWDOWN (I.E. ORFICE CONTROLLED SYSTEM OR EXTENDED STORAGE DEPTH WITHIN INFILTRATION SYSTEM).
5. THE FOLLOWING GUIDELINES APPLY TO RIGHT-OF-WAY APPLICATIONS:
   - BULB OUT CURB TRANSITIONS SHALL CONFORM TO CITY STANDARDS.
   - WHEN FACILITY CONSTRUCTION IMPACTS EXISTING SIDEWALK, ALL SAW CUTS MUST ADHERE TO CITY REQUIREMENTS. SAW CUTS SHOULD BE ALONG SCORE LINES AND ANY DISTURBED SIDEWALK FLAGS SHOULD BE REPLACED IN THEIR ENTIRETY.
   - DESIGNER TO SPECIFY TRANSITION OF PLANTER TO TOP OF CURB ELEVATION BETWEEN CURB CUTS OR CONTINUOUS 6 INCH REVEAL AT CURB EDGE.
6. UP TO TWO PLANTERS MAY BE CONNECTED IN SERIES, IN LIEU OF MULTIPLE INLETS, PROVIDED THE CONNECTION IS A TRENCH DRAIN OR EQUAL SURFACE CONVEYANCE AND IS ADEQUATELY SIZED TO CONVEY FLOWS.
7. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY ASSET PROTECTION STANDARDS AND OTHER UTILITY PROVIDERS REQUIREMENTS.

RELATED SPECIFICATIONS	CSI NO.
BIORETENTION: - BIORETENTION SOIL MIX - AGGREGATE STORAGE - MULCH - STREAMBED COBBLES	33 47 27

RELATED COMPONENTS		
UNDERDRAINS:	2.0 - 2.1	
INLETS:	3.0 - 3.2	
OUTLETS:	4.0 - 4.3	

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

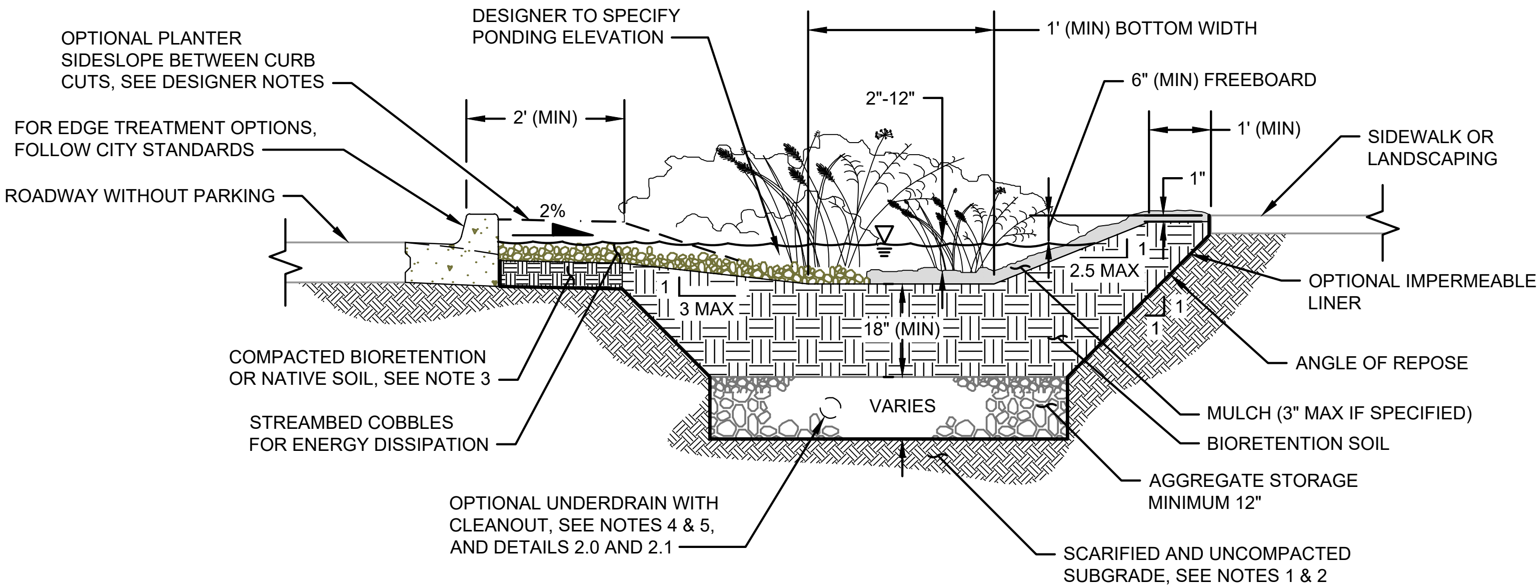
- [ ] FACILITY WIDTH, LENGTH, SLOPES (INCLUDING SIDE, CROSS, AND LONGITUDINAL), AND SHAPE
- [ ] DEPTH OF BIORETENTION SOIL
- [ ] DEPTH AND TYPE OF GRAVEL STORAGE, IF ANY
- [ ] PLANTER SURFACE ELEVATION (TOP OF BIORETENTION SOIL) AT UPSLOPE AND DOWNSLOPE ENDS OF FACILITY
- [ ] CONTROL POINTS AT EVERY CORNER OF FACILITY AND POINT OF TANGENCY
- [ ] DIMENSIONS AND DISTANCE TO EVERY INLET, OUTLET, SIDEWALK NOTCH, ETC.
- [ ] ELEVATIONS OF EVERY INLET, OUTLET, STRUCTURE RIM AND INVERT, AND SIDEWALK NOTCH
- [ ] TYPE AND DESIGN OF FACILITY COMPONENTS (E.G., EDGE TREATMENTS, INLETS/GUTTER MODIFICATIONS, UTILITY CROSSINGS, LINER, AND PLANTING DETAILS)

LAYOUT REQUIREMENTS:

1. FOR RIGHT-OF-WAY APPLICATIONS, REFER TO THE CITY STANDARD ACCESSIBILITY REQUIREMENTS FOR CONSTRUCTION OF COURTESY STRIP, THROUGHWAY, PARKING SPACE AND ACCESSIBLE PATH REQUIREMENTS.
2. LOCATE CURB CUTS AND GUTTER MODIFICATIONS TO AVOID CONFLICTS WITH ACCESSIBILITY REQUIREMENTS (E.G., LOCATE OUTSIDE OF CROSSWALKS).

BIORETENTION & BIOINFILTRATION BASINS DESIGNER NOTES	1.0

NOT FOR CONSTRUCTION

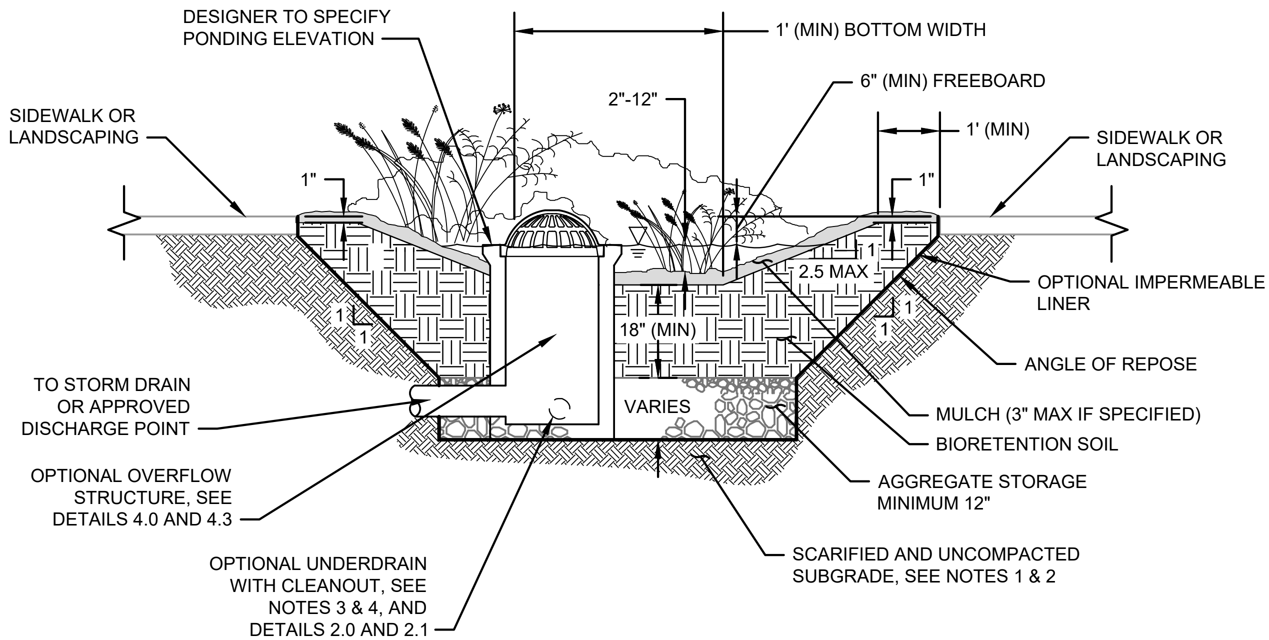


CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW BASIN.
2. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIORETENTION SOIL MATERIALS.
3. COMPACT BIORETENTION SOIL IMMEDIATELY BEHIND CURB TO 90% OF MAXIMUM DENSITY PER STANDARD PROCTOR TEST (ASTM D698).
4. UNDERDRAIN REQUIRED FOR ALL FACILITIES WITH IMPERMEABLE LINER.
5. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS. CLEANOUT MUST CONSIST OF A VERTICAL, RIGID, NON-PERFORATED PVC PIPE, WITH A MINIMUM DIAMETER OF 4-INCHES AND A WATERTIGHT CAP.
6. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

BIORETENTION & BIOINFILTRATION BASINS ROADSIDE SECTION	1.1

NOT FOR CONSTRUCTION



CONSTRUCTION NOTES:

1. AVOID COMPACTION OF EXISTING SUBGRADE BELOW BASIN.
2. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIORETENTION SOIL MATERIALS.
3. UNDERDRAIN REQUIRED FOR ALL FACILITIES WITH IMPERMEABLE LINER.
4. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS. CLEANOUT MUST CONSIST OF A VERTICAL, RIGID, NON-PERFORATED PVC PIPE, WITH A MINIMUM DIAMETER OF 4-INCHES AND A WATERTIGHT CAP.
5. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY STANDARDS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

BIORETENTION & BIOINFILTRATION BASINS PARCEL SECTION	1.2

NOT FOR CONSTRUCTION

PURPOSE:

UNDERDRAINS ARE USED TO COLLECT STORMWATER THAT HAS BEEN FILTERED THROUGH BIORETENTION SOIL AND CONVEY THAT TREATED STORMWATER TO A DESIGNATED OUTLET (E.G., PLANTER OVERFLOW STRUCTURE).

DESIGNER NOTES & GUIDELINES:

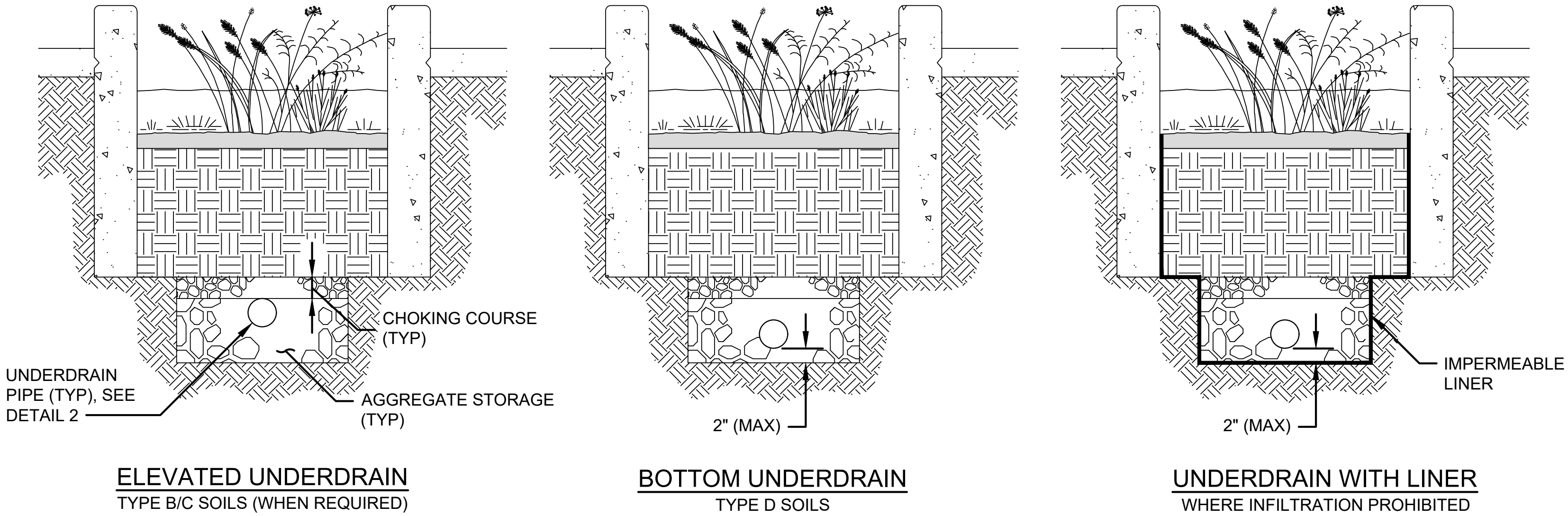
1. THE DESIGNER SHOULD INCLUDE UNDERDRAINS IN FACILITY DESIGN IN THE FOLLOWING SCENARIOS:
    - INFILTRATION IS PROHIBITED OR IMPRUDENT (E.G., FACILITY NEAR SENSITIVE INFRASTRUCTURE OR STEEP SLOPES, RISK OF CONTAMINATION IS HIGH OR SITE GROUNDWATER/SOILS ARE CONTAMINATED, THERE IS POOR INFILTRATION CAPACITY DUE TO SOILS OR HIGH GROUNDWATER).
    - SUBGRADE MEASURED (I.E., UNCORRECTED) INFILTRATION RATE IS LESS THAN 0.5 INCHES PER HOUR.
    - MAXIMUM SURFACE POOL DRAWDOWN PERIOD CANNOT BE ACHIEVED.
2. AN OUTLET STRUCTURE AND/OR CLEANOUT(S) TO ALLOW MAINTENANCE ACCESS TO ALL PIPES IS REQUIRED FOR FACILITIES WITH UNDERDRAINS.
3. UNDERDRAIN PIPE SHALL HAVE A SMOOTH INTERIOR WALL TO FACILITATE MAINTENANCE WITH PRESSURIZED WATER OR ROOT CUTTING EQUIPMENT.
4. DESIGNER SHOULD CONSIDER THE INSTALLED ELEVATION OF THE UNDERDRAIN PIPE WITHIN THE BIORETENTION FACILITIES AGGREGATE STORAGE LAYER TO PROMOTE INFILTRATION, BELOW THE UNDERDRAIN, WHEN FEASIBLE. DESIGNER SHOULD ALSO CONSIDER THE USE OF ORIFICES OR OTHER CONTROL STRUCTURES TO PROVIDE ADDITIONAL INFILTRATION AND FLOW CONTROL BENEFITS WHERE APPLICABLE.
5. PIPE MATERIAL SHALL BE DESIGNED PER CITY STANDARDS.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- [ ] UNDERDRAIN MATERIAL TYPE AND SIZE
- [ ] UNDERDRAIN ELEVATION, SLOPE, AND LOCATION WITHIN BASIN OR PLANTER
- [ ] PIPE BEDDING MATERIAL SPECIFICATION (I.E. AGGREGATE STORAGE LAYER)
- [ ] DISCHARGE LOCATION TO OVERFLOW STRUCTURE
- [ ] CLEANOUT LOCATIONS AND MAINTENANCE ACCESS
- [ ] ORIFICE FLOW CONTROL STRUCTURE(S), AS APPLICABLE

BIORETENTION & BIOINFILTRATION COMPONENTS UNDERDRAINS - DESIGNER NOTES	2.0

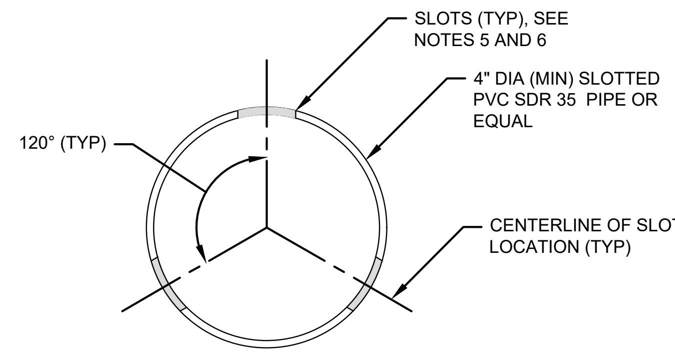
NOT FOR CONSTRUCTION



UNDERDRAIN PLACEMENT ALTERNATIVES

CONSTRUCTION NOTES:

1. UNDERDRAIN PIPE SHALL BE SLOTTED PVC SDR 35 OR ACCEPTABLE SUBSTITUTE MATERIAL PER ENGINEERS SPECIFICATION.
2. ALL MATERIAL AND WORKMANSHIP FOR UNDERDRAINS SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
3. SET CROWN OF UNDERDRAIN PIPE AT OR BELOW BOTTOM OF CHOKING COURSE. SEE DESIGNER NOTES FOR ADDITIONAL GUIDANCE ON LOCATING UNDERDRAIN PIPE IN GRAVEL STORAGE.
4. LONGITUDINAL SLOPE OF UNDERDRAIN PIPE SHALL BE 0.5% MINIMUM.
5. UNDERDRAIN PIPE SHALL BE SLOTTED PVC SDR 35 OR ACCEPTABLE SUBSTITUTE MATERIAL PER ENGINEERS SPECIFICATION. SINGLE WALL AND DUAL WALL CORRUGATED HDPE PIPE (AASHTO M252 AND M294 TYPES C, S, AND D) ARE NOT ACCEPTABLE.
6. UNDERDRAIN PIPE SHALL BE SLOTTED TYPE, MEASURING 0.032 INCH WIDE (MAX), SPACED AT 0.25 INCH (MIN), AND PROVIDING A MINIMUM INLET AREA OF 5.0 SQUARE INCH PER LINEAR FOOT OF PIPE.
7. SLOTS SHALL BE ORIENTED PERPENDICULAR TO LONG AXIS OF PIPE, AND EVENLY SPACED AROUND CIRCUMFERENCE AND LENGTH OF PIPE.



SLOTTED UNDERDRAIN PIPE 2

BIORETENTION & BIOINFILTRATION COMPONENTS UNDERDRAINS	2.1

NOT FOR CONSTRUCTION

PURPOSE:

CURB CUTS SERVE AS INLETS TO CONVEY STORMWATER RUNOFF TO A BIORETENTION FACILITY. CURB CUTS ARE TYPICALLY USED IN PLANTER APPLICATIONS WHEN THE FACILITY IS IMMEDIATELY ADJACENT TO THE ROADWAY (I.E. NO COURTESY STRIP), PROVIDING AN OPENING TO INTERCEPT AND CONVEY STORMWATER FROM THE GUTTER TO THE PLANTER. CURB CUT INLETS INCLUDE MODIFICATIONS TO THE GUTTER TO HELP DIRECT FLOW INTO THE FACILITY.

DESIGNER NOTES & GUIDELINES:

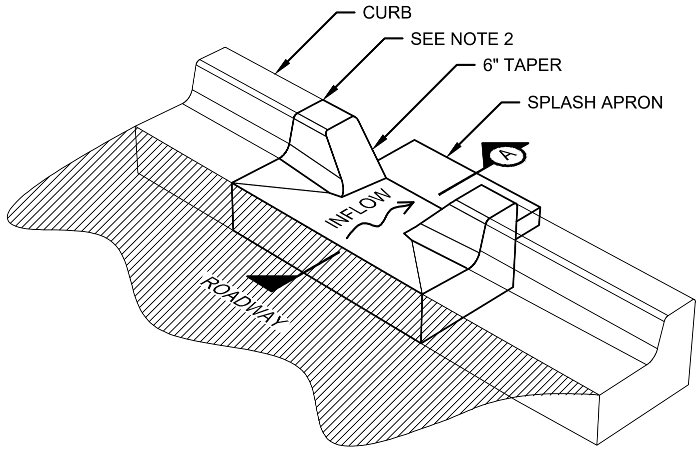
1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST ENSURE THAT CURB CUT INLETS ARE ADEQUATELY SIZED, SPACED, AND SLOPED TO SATISFY CITY HYDRAULIC REQUIREMENTS. THE CURB CUT OPENING WIDTH MUST BE SIZED BASED ON THE CATCHMENT AREA, LONGITUDINAL SLOPE ALONG THE CURB, AND THE CROSS SLOPE OF THE GUTTER OR ADJACENT PAVEMENT AT THE INLET. SEE SIZING EQUATIONS AND NOMOGRAPHS FOR CURB OPENING INLETS IN THE U.S. DEPARTMENT OF TRANSPORTATION HYDRAULIC ENGINEERING CIRCULAR NO. 22.

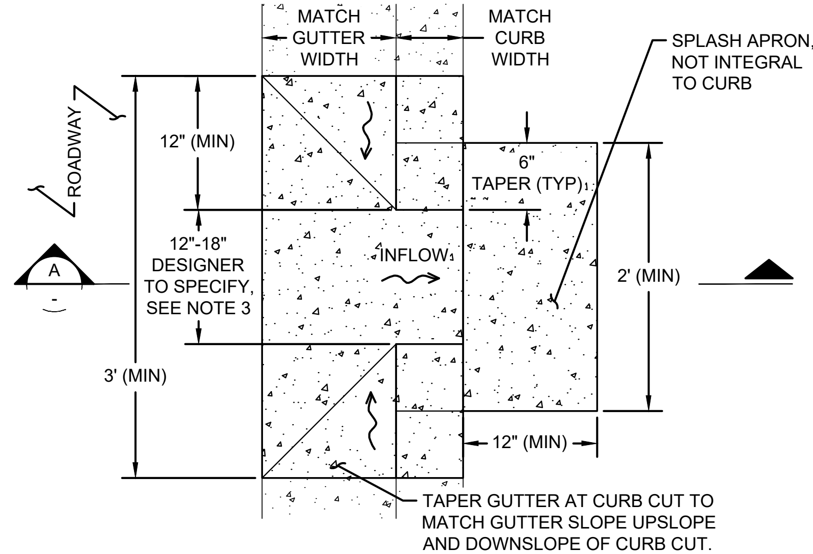
DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ CURB CUT DIMENSIONS
- ☐ FRAME AND GRATE TYPE/MATERIAL AND DIMENSIONS
- ☐ CHANNEL DIMENSIONS
- ☐ CONTROL ELEVATIONS FOR OPENINGS AT GUTTER AND PLANTER WALL

BIORETENTION & BIOINFILTRATION COMPONENTS INLETS - DESIGNER NOTES	3.0

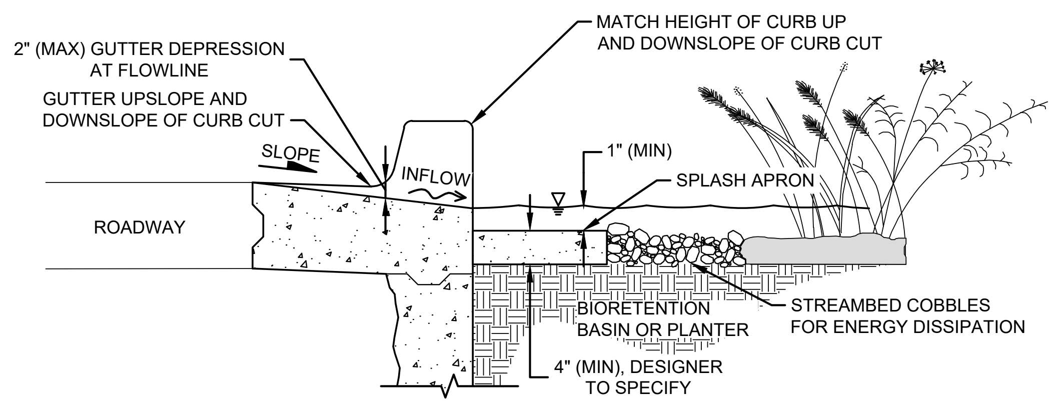
NOT FOR CONSTRUCTION





CONSTRUCTION NOTES:

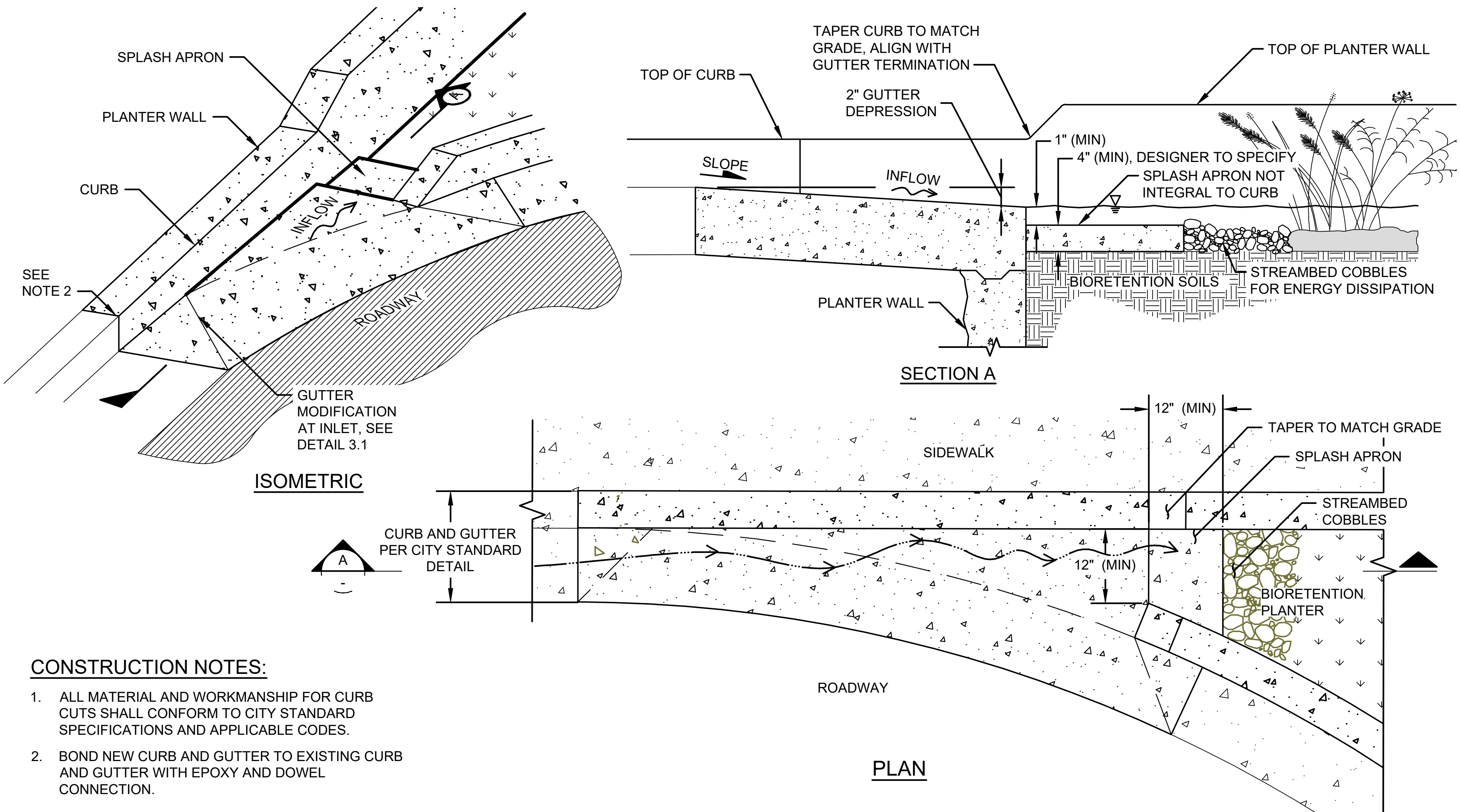
1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
3. INLET CURB CUT WIDTH SHALL BE 18" ON GUTTER SLOPES ≥ 5%.



INLET - CURB CUT TYPE 1 (1)

BIORETENTION & BIOINFILTRATION COMPONENTS INLETS - CURB CUT INLET	3.1

NOT FOR CONSTRUCTION



CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.

INLET - CURB CUT TYPE 2 (1)

BIORETENTION & BIOINFILTRATION COMPONENTS INLETS - CURB CUT INLET AT BULB OUT	3.2

NOT FOR CONSTRUCTION

PURPOSE:

BIORETENTION OUTLET STRUCTURES CONVEY SURFACE AND/OR SUBSURFACE OUTFLOWS FROM A BIORETENTION FACILITY TO AN APPROVED DISCHARGE LOCATION.

DESIGNER NOTES & GUIDELINES:

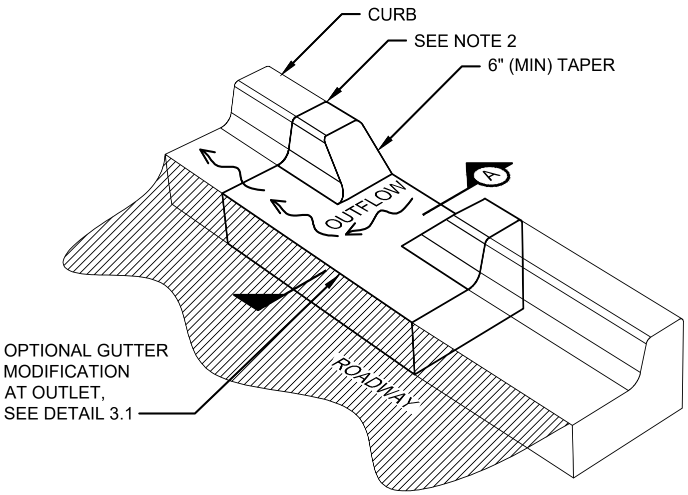
1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST SIZE CURB CUT, GRATE, AND OTHER OVERFLOW STRUCTURE FEATURES TO SATISFY CITY HYDRAULIC REQUIREMENTS.
3. AN OUTLET STRUCTURE OR CLEANOUT(S) THAT ALLOWS MAINTENANCE ACCESS TO ALL PIPES IS REQUIRED FOR FACILITIES WITH UNDERDRAINS.
4. IF SITE CONSTRAINTS NECESSITATE STORM DRAIN PIPE IN AN AREA SUBJECT TO VEHICULAR TRAFFIC OR OTHER LOADING, APPROPRIATE COVER DEPTH AND PIPE MATERIAL MUST BE SPECIFIED.
5. OUTLET PIPES MUST BE EQUIPPED WITH CLEANOUTS, SEE CITY STANDARD CLEANOUT DETAIL(S).
6. DESIGNER SHALL EVALUATE BUOYANCY OF STRUCTURES FOR SITE SPECIFIC APPLICATION AND SPECIFY THICKENED OR EXTENDED BASE / ANTI-FLOTATION COLLAR, AS NECESSARY.
7. SAND TRAP REQUIREMENTS (12 INCH SUMP AND CAST IRON HOOD/TRAP) MAY BE ELIMINATED WHEN OVERFLOW DIRECTLY DISCHARGES TO DOWNSTREAM (CITY) SAND TRAP.
8. LOCATE ALL OVERFLOW PIPES AT AN ELEVATION HIGHER THAN THE SEWER HYDRAULIC GRADE LINE TO PREVENT BACKFLOW INTO THE BIORETENTION FACILITY.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- [ ] OUTLET STRUCTURE TYPE/MATERIAL, DIAMETER, AND DEPTH
- [ ] ATRIUM GRATE MANUFATURER, MODEL NO., AND SIZE
- [ ] SAND TRAP COMPONENTS AND DIMENSIONS
- [ ] FRAME AND GRATE TYPE, MODEL NO., AND SIZE
- [ ] CONTROL ELEVATIONS FOR OUTLET STRUCTURE RIMS
- [ ] MATERIAL AND DIAMETER FOR ALL PIPES
- [ ] WATER TIGHT CONNECTOR TYPE FOR ALL WALL PENETRATIONS (E.G., GROUTED, COMPRESSION, BOOT)

BIORETENTION & BIOINFILTRATION COMPONENTS OUTLETS - DESIGNER NOTES	4.0

NOT FOR CONSTRUCTION



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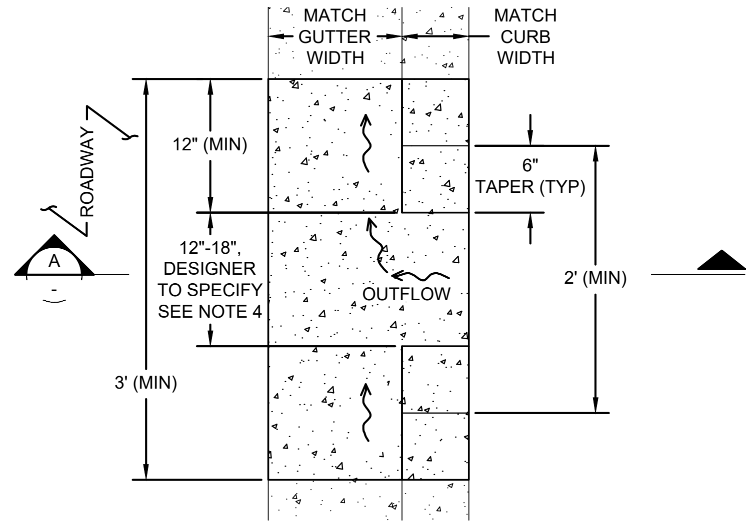
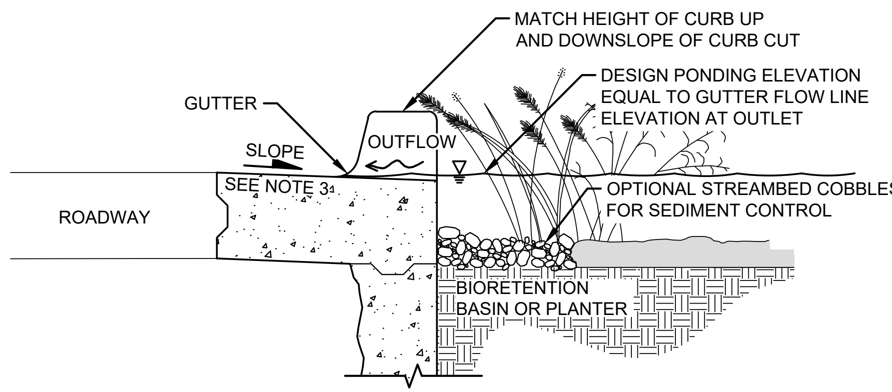


PLAN

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
3. MATCH GUTTER SLOPE UP AND DOWNSLOPE OF CURB CUT SLOPE SIMILAR TO INLET DETAIL 3.1 UNLESS MODIFYING GUTTER.
4. OUTLET CURB CUT WIDTH SHALL BE 18" ON GUTTER SLOPES ≥ 5%.

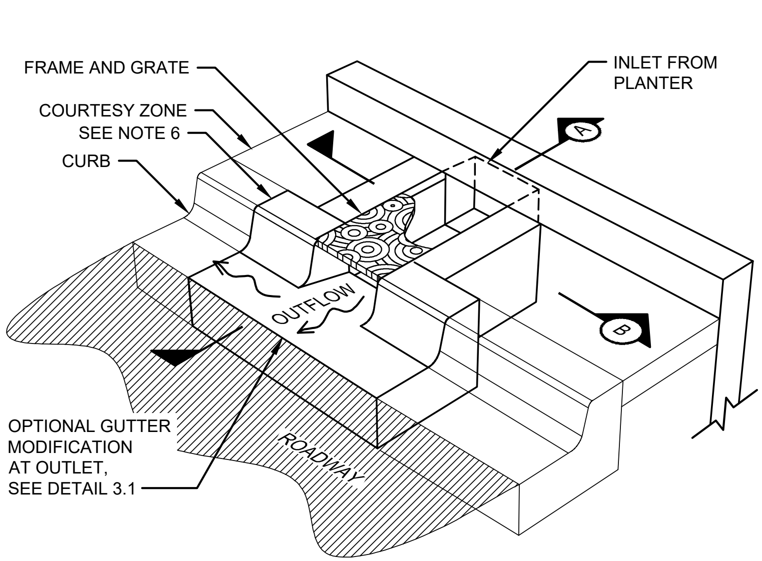


SECTION A

OUTLET - CURB CUT 1

BIORETENTION & BIOINFILTRATION COMPONENTS OUTLETS - CURB CUT OUTLET	4.1

NOT FOR CONSTRUCTION



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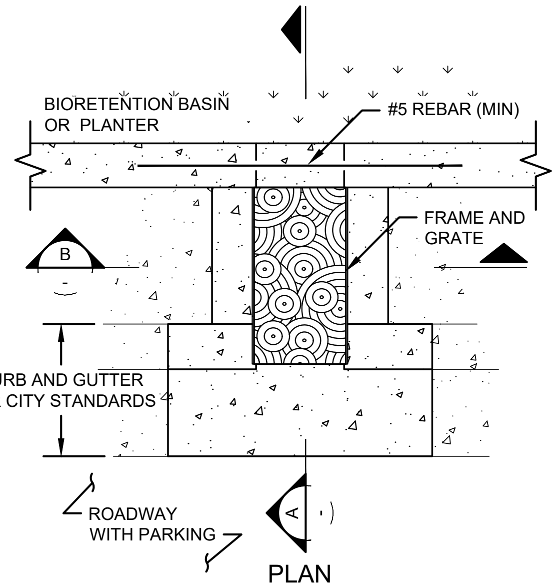
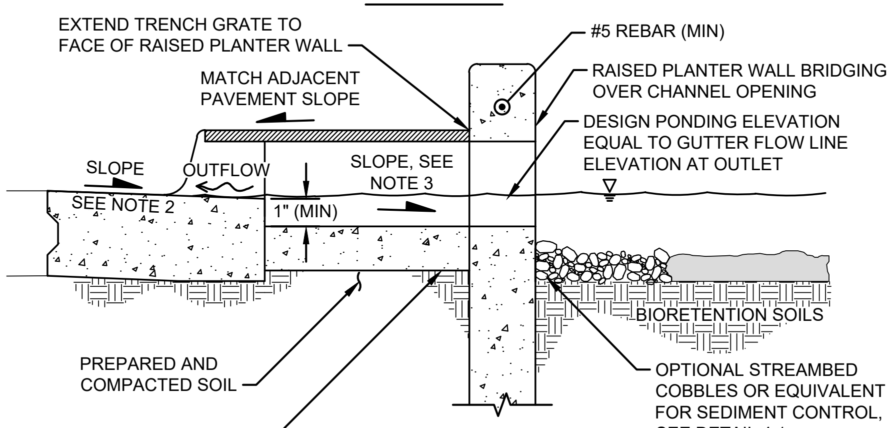


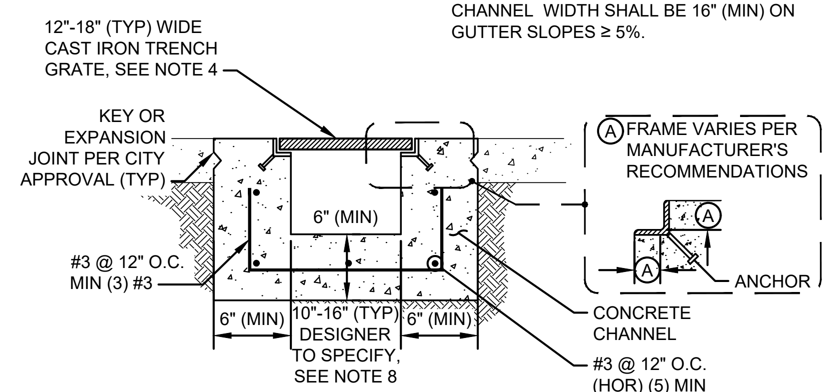
PLAN

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR TRENCH DRAIN ASSEMBLY SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. MATCH GUTTER SLOPE UP AND DOWNSLOPE (UNLESS MODIFYING GUTTER SLOPE SEE INLET DETAIL 3.1).
3. SLOPE TO PROVIDE AT LEAST 1 INCH DROP OVER LENGTH OF CHANNEL OR A MINIMUM OF 2 PERCENT, WHICHEVER IS LARGER.
4. ALL TRENCH GRATES SHALL BE REMOVABLE, RATED PER THE ANTICIPATED LOADING, AND BOLTED IN PLACE OR OUTFITTED WITH APPROVED TAMPER-RESISTANT LOCKING MECHANISM, FLUSH OR RECESSED IN GRATE.
5. HORIZONTAL CONTROL JOINTS SHALL BE PROVIDED EVERY 10 LINEAR FEET, OR PER MANUFACTURER'S RECOMMENDATIONS.
6. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
7. APPLY EPOXY BONDING AGENT AT ALL TRENCH DRAIN CONSTRUCTION COLD JOINTS.
8. INLET/OUTLET CURB CUT AND CONCRETE CHANNEL WIDTH SHALL BE 16" (MIN) ON GUTTER SLOPES ≥ 5%.



SECTION A



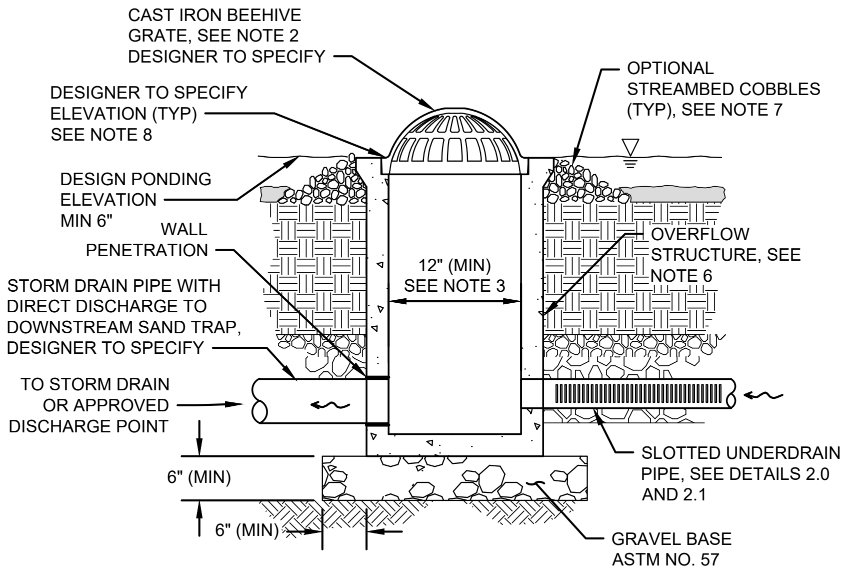
SECTION B

OUTLET - TRENCH DRAIN

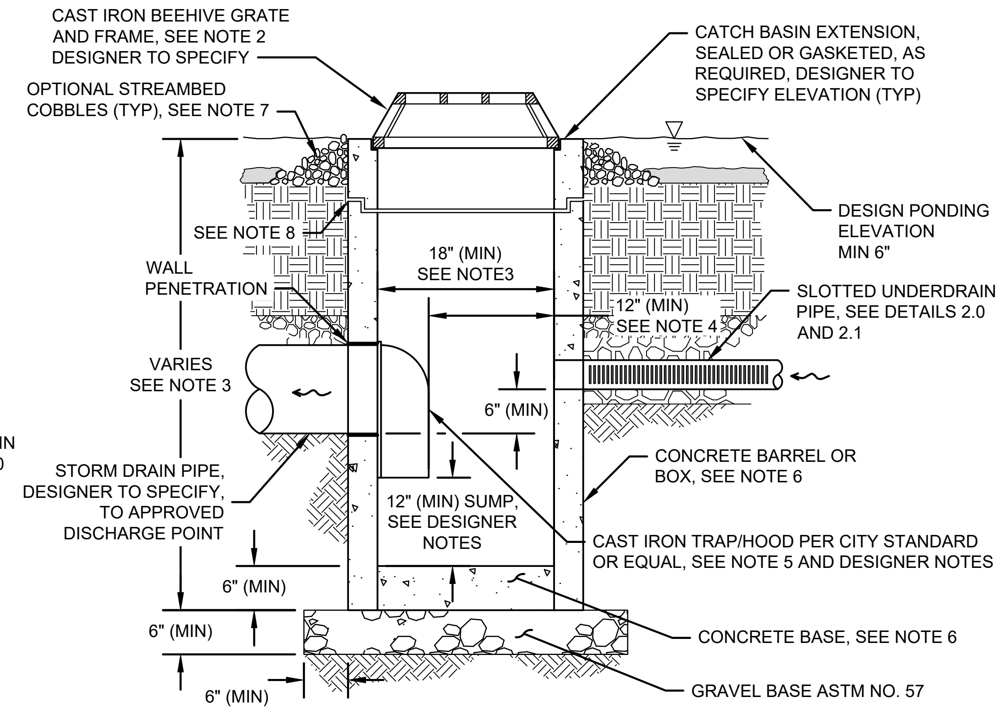
1

BIORETENTION & BIOINFILTRATION COMPONENTS OUTLETS - OUTLET CURB CUT WITH TRENCH	4.2

NOT FOR CONSTRUCTION



OVERFLOW STRUCTURE AREA DRAIN 1



OVERFLOW STUCTURE WITH INTERGAL SAND TRAP 2

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OVERFLOW STRUCTURES SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. SIZE OF ATRIUM GRATE SHALL MATCH SIZE OF RISER SPECIFIED IN PLANS, SHALL BE REMOVABLE TO PROVIDE MAINTENANCE ACCESS, AND SHALL BE BOLTED IN PLACE OR OUTFITTED WITH APPROVED TAMPER-RESISTANT LOCKING MECHANISM. MAXIMUM GRATE OPENING SHALL BE 4 INCHES.
3. IF INTERIOR DEPTH OF OVERFLOW STRUCTURE EXCEEDS 5 FEET, A PERMANENT BOLTED LADDER AND MINIMUM CLEAR SPACE OF 30 INCH BY 30 INCH SHALL BE PROVIDED FOR MAINTENANCE ACCESS.
4. 12 INCH (MIN) CLEARANCE WITHIN OVERFLOW STRUCTURE SHALL BE PROVIDED FOR MAINTENANCE ACCESS.
5. INSTALL CAST IRON TRAP/HOOD PER MANUFACTURER'S RECOMMENDATIONS.
6. BARREL/BOX AND BASE OF CATCH BASIN MAY BE PRE-CAST WITH REINFORCING STEEL PER MANUFACTURER'S RECOMMENDATIONS, POURED IN PLACE CONCRETE WITHOUT STEEL PER CITY STANDARD PLANS AND SPECIFICATIONS, OR NYLOPLAST DRAIN BASIN (2812AG OR EQUAL). ENGINEER TO SPECIFY.
7. MINIMUM STREAMBED COBBLE DIAMETER SHALL BE LARGER THAN MAXIMUM GRATE OPENING.
8. GROUT ALL PENETRATIONS, CRACKS, SEAMS, AND JOINTS WITH CLASS "C" MORTAR.

BIORETENTION & BIOINFILTRATION COMPONENTS OUTLETS - OVERFLOW STRUCTURE	4.3

NOT FOR CONSTRUCTION

PURPOSE:

PERVIOUS PAVEMENT (PAVEMENT) CONTROLS PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF VIA INFILTRATION THROUGH THE PAVEMENT SURFACE, STORAGE IN THE PAVEMENT SECTION, INFILTRATION INTO NATIVE SOIL, AND OVERFLOW THROUGH OPTIONAL SUBSURFACE OUTLETS. RUNOFF IS TREATED AS IT FILTERS THROUGH THE PAVEMENT SECTION, AND INFILTRATES INTO UNDERLYING NATIVE SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN, SECTION DRAWINGS, AND CALCULATE DEPTH TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. ALL PAVEMENT SYSTEMS MUST BE DESIGNED BY A LICENSED ENGINEER IN ACCORDANCE WITH THE AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES BASED ON SITE-SPECIFIC CONDITIONS INCLUDING TRAFFIC LOADS AND SUBGRADE CONDITIONS. PAVEMENT SECTIONS SET FORTH IN THESE TYPICAL DETAILS ARE PROVIDED TO REPRESENT THE ANTICIPATED RANGE OF DESIGN REQUIREMENTS, BASED ON "GOOD" AND "POOR" SOIL CHARACTERIZATIONS NORMALLY ENCOUNTERED IN THE CITY. **ACTUAL SECTION DEPTHS MUST BE DETERMINED AS DESCRIBED IN GUIDELINE #3, BELOW**. SEE TABLES BELOW FOR TRAFFIC LOADING AND EFFECTIVE ROADBED SOIL RESILIENT MODULUS ASSUMPTIONS USED IN DEVELOPING THESE TYPICAL SECTIONS.
3. TRAFFIC LOADING ASSUMPTIONS:

DESIGN ASSUMPTION	MODERATE VEHICULAR	LIGHT VEHICULAR	PEDESTRIAN
EQUIVALENT SINGLE AXLE LOADS*	2,000,000	40,000	800
TRAFFIC INDEX (TI)**	10	6.5	4
* SEE AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES FOR DEFINITIONS			
** SEE CALTRANS HIGHWAY DESIGN MANUAL FOR DEFINITIONS			

SUBGRADE ASSUMPTIONS:

DESIGN ASSUMPTION	GOOD SOILS	POOR SOILS
EFFECTIVE ROADBED SOIL RESILIENT MODULUS, M_R (PSI)*	6,800	3,700
CALIFORNIA R-VALUE **	33.3	15.6
DRAINAGE COEFFICIENT, m *	1.15	0.75
LAYER COEFFICIENT, a * FOR OPEN GRADED AGGREGATE BASE	0.08	
* SEE AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES FOR DEFINITIONS		
** SEE CALTRANS HIGHWAY DESIGN MANUAL FOR DEFINITIONS		

4. GEOTECHNICAL EVALUATION OF SUBGRADE SOILS TO VERIFY THEIR STRUCTURAL SUITABILITY FOR PERMEABLE PAVEMENT INSTALLATIONS IS REQUIRED. INFILTRATION TESTING REQUIREMENTS ARE SUBJECT TO DIFFERENT THRESHOLDS. REFER TO CITY STORMWATER MANAGEMENT REQUIREMENTS FOR GUIDANCE.
5. THE PERMEABLE PAVEMENT FACILITY MUST BE DESIGNED TO PROVIDE SUFFICIENT SUBSURFACE STORAGE IN THE PAVEMENT SECTION TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS. THE SECTION THICKNESS WILL BE A FUNCTION OF THE SUBGRADE INFILTRATION RATE (DRAINAGE COEFFICIENT), AND SUBGRADE SLOPE.
6. ENTIRE PAVEMENT BASE SECTION MAY BE USED TO MEET SUBSURFACE STORAGE REQUIREMENTS.
7. SUBSURFACE STORAGE DRAWDOWN TIME (I.E. TIME FOR MAXIMUM SUBSURFACE STORAGE VOLUME TO INFILTRATE INTO SUBGRADE AFTER THE END OF A STORM) SHOULD NOT EXCEED 48 HOURS. DRAWDOWN TIME IS CALCULATED AS THE MAXIMUM SUBSURFACE PONDING DEPTH DIVIDED BY THE NATIVE SOIL INFILRATION RATE.
8. THE DESIGNER MUST ENSURE THAT THE PAVEMENT EDGES ARE RESTRAINED AND THAT WATER IS CONTAINED IN THE PAVEMENT SECTION AS NEEDED TO PROTECT ADJACENT PAVEMENT SECTIONS OR STRUCTURES.
9. THE DESIGNER MUST EVALUATE UTILITY SURVEYS FOR POTENTIAL UTILITY CROSSINGS OR CONFLICTS.

RELATED SPECIFICATIONS	CSI NO.
PERMEABLE/POROUS UNIT PAVERS: - PERMEABLE /POROUS UNIT PAVERS - JOINT FILLER AGGREGATE - PAVEMENT BASE - EDGE RESTRAINTS - GEOTEXTILE FOR SOIL SEPARATION	32 14 43
PERVIOUS CONCRETE PAVEMENT: - PERVIOUS CONCRETE - PAVEMENT BASE - GEOTEXTILE FOR SOIL SEPARATION	32 13 43
POROUS ASPHALT PAVEMENT: - POROUS ASPHALT - PAVEMENT BASE - GEOTEXTILE FOR SOIL SEPARATION	32 12 43

PERMEABLE PAVEMENT DESIGNER NOTES (1/2)	5.0

NOT FOR CONSTRUCTION

LAYOUT REQUIREMENTS:

1. ALL PERMEABLE PAVEMENT APPLICATIONS SHALL CONFORM TO CITY STANDARDS. THE DESIGN MUST COMPLY WITH CITY STANDARD ACCESSIBILITY REQUIREMENTS.
2. THE PREFERRED AND ALLOWED CATCHMENT AREA CONTRIBUTING RUN-ON TO A PERMEABLE PAVEMENT FACILITY IS PROVIDED IN THE FOLLOWING TABLE:

WEARING COURSE	**PREFERRED RUN-ON RATIO**	**MAXIMUM RUN-ON RATIO** (AREA CONTRIBUTING RUN-ON: PERMEABLE PAVEMENT AREA)**
PERVIOUS CONCRETE AND POROUS ASPHALT	MINIMAL	3:1
PERMEABLE UNIT PAVERS (≥ 1/2" GAPS) [PARCEL ONLY]*	0:1	3:1
PERMEABLE UNIT PAVERS (≥ 3/8" GAPS)*	0:1	2:1
POROUS PAVERS	0:1	0:1 (NO RUN-ON)

*PAVERS WITH 3/8 INCH OR 1/2 INCH GAPS SHALL BE PERMEABLE INTERLOCKING CONCRETE PAVERS WITH INTEGRATED PRECAST INTERLOCKING SPACER.

**THE DESIGNER AND OWNER SHOULD CONSIDER THE INCREASED MAINTENANCE REQUIREMENTS ASSOCIATED WITH HIGHER RUN-ON RATIOS WHEN DESIGNING THE FACILITY.

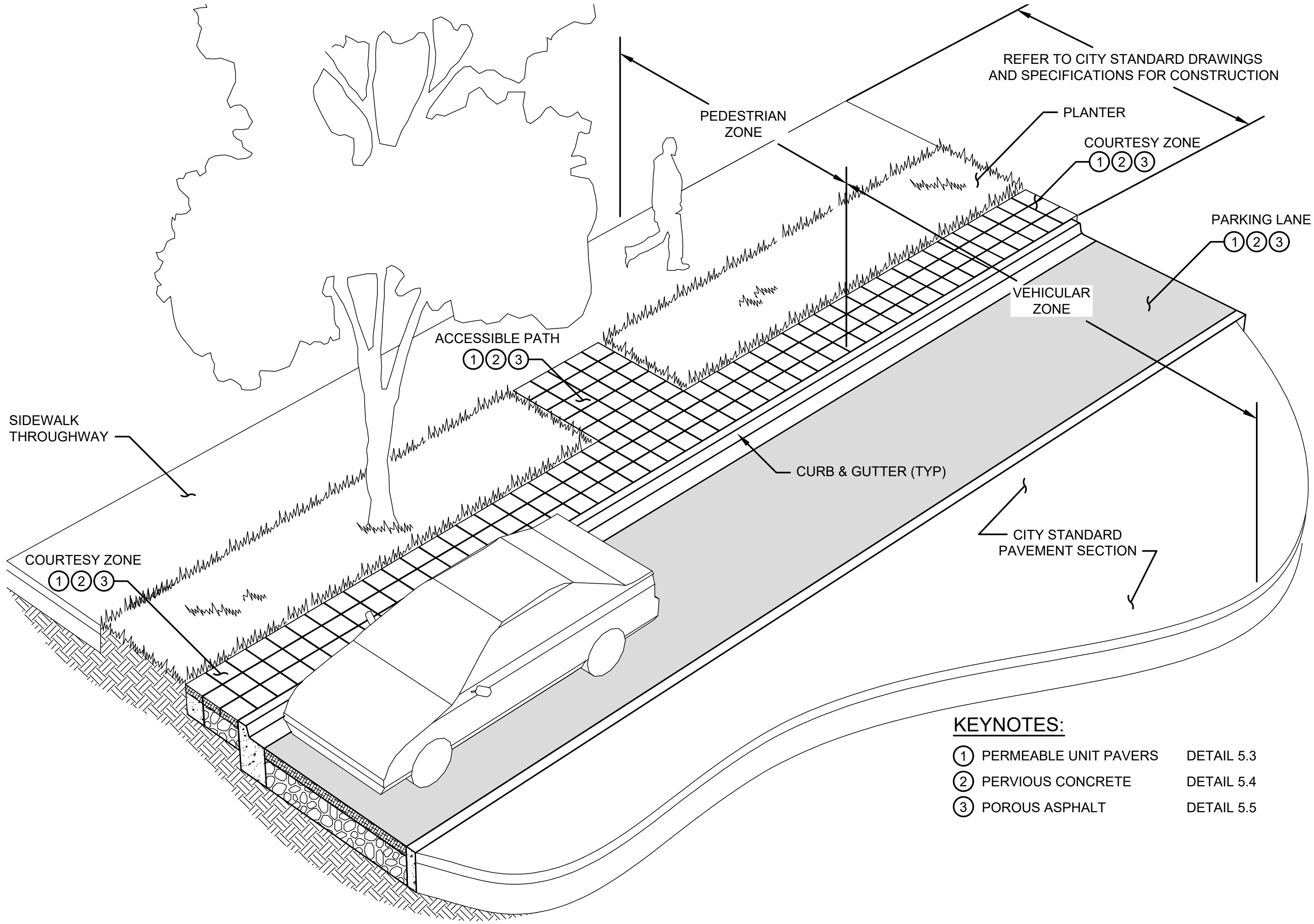
3. WHEN DESIGNED TO ACCEPT RUN-ON FROM OTHER CATCHMENT AREAS, PERMEABLE PAVEMENT AREAS MUST BE PROTECTED FROM SEDIMENTATION WHICH CAN CAUSE CLOGGING AND DIMINISHED FACILITY PERFORMANCE. THE FOLLOWING REQUIREMENTS APPLY FOR RUN-ON CONTRIBUTIONS:
   - RUN-ON FROM LAWN, LANDSCAPE OR OTHER ERODIBLE SURFACES IS DISCOURAGED. IF MINOR RUN-ON FROM LAWN OR LANDSCAPE AREAS IS UNAVOIDABLE, THOSE ERODIBLE AREAS MUST BE FULLY STABILIZED.
   - CONCENTRATED RUN-ON (E.G., DIRECT DISCHARGE FROM A DOWNSPOUT) SHOULD BE DISPERSED PRIOR TO DISCHARGE TO A PERMEABLE PAVEMENT FACILITY. ACCEPTABLE METHODS INCLUDE SHEET FLOW OR SUBSURFACE DELIVERY TO THE STORAGE RESERVOIR. IF SUBSURFACE DELIVERY IS USED, PRIMARY SETTLING IS REQUIRED (E.G., VIA SAND TRAP) FOLLOWED BY DISTRIBUTION TO STORAGE RESERVOIR (E.G., VIA PERFORATED PIPE).
4. WEARING COURSE SHALL BE SET FLUSH (± 3/16 INCH) WITH ADJACENT WALKING SURFACES.
5. WEARING COURSE SHALL HAVE A MINIMUM SURFACE SLOPE OF 0.5% TO ALLOW FOR SURFACE OVERFLOW AND A MAXIMUM SURFACE SLOPE AS LISTED BELOW:
   a. POROUS ASPHALT SURFACE: = 5 PERCENT SLOPE
   b. PERVIOUS CONCRETE SURFACE: = 10 PERCENT SLOPE
   c. PERMEABLE UNIT PAVERS: = 12 PERCENT SLOPE (PER MANUFACTURER'S RECOMMENDATION)

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ PERMEABLE PAVEMENT SPECIFICATIONS AND/OR PAVER TYPE AND GAP WIDTH
- ☐ PERMEABLE PAVEMENT WIDTH AND LENGTH
- ☐ ELEVATIONS AND CONTROL POINTS AT EVERY CORNER OR POINT OF TANGENCY
- ☐ THICKNESS OF EACH LAYER IN THE PAVEMENT SECTION
- ☐ JOINT SPACING AND TYPE
- ☐ SUBGRADE SLOPE
- ☐ ELEVATIONS OF EACH PIPE INLET AND OUTLET INVERT
- ☐ TYPE AND DESIGN OF PERMEABLE PAVEMENT COMPONENTS (E.G., EDGE TREATMENTS, OUTLETS, UNDERDRAINS, etc.)

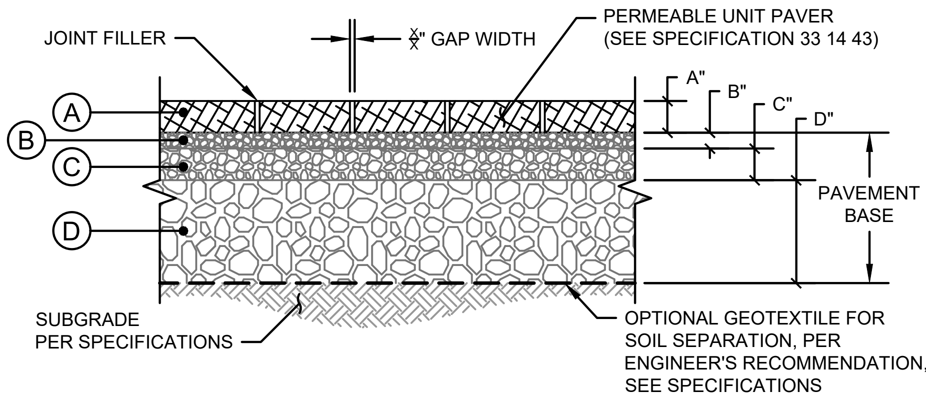
PERMEABLE PAVEMENT DESIGNER NOTES (2/2)	5.1

NOT FOR CONSTRUCTION



PERMEABLE PAVEMENT KEY MAP	5.2

NOT FOR CONSTRUCTION



PERMEABLE UNIT PAVERS 1

MINIMUM MATERIAL THICKNESS (IN):

LAYER	MATERIAL TYPE*	MODERATE VEHICULAR		LIGHT VEHICULAR		PEDESTRIAN	
		GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**
A	PERMEABLE UNIT PAVERS	3 1/8	3 1/8	3 1/8	3 1/8	3 1/8	3 1/8
B	LEVELING COURSE ASTM NO. 8	2	2	2	2	2	2
C	BASE COURSE ASTM NO. 57	6	6	6	4	4	4
D	RESERVOIR COURSE ASTM NO. 2, 3, OR 57	22	28	-	10	-	-

* MATERIAL FINER THAN NO. 100 SIEVE SHALL NOT EXCEED 2 PERCENT FOR ANY AGGREGATE LAYER (LICENSED PROFESSIONAL TO SELECT AGGREGATE).

** "GOOD" AND "POOR" SOIL CLASSIFICATIONS BASED ON AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES. SEE DESIGNER NOTES FOR SUBGRADE ASSUMPTIONS. (LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON SITE CONDITIONS).

TYPICAL JOINT FILLER AGGREGATE SIZE:

GAP WIDTH (IN)	JOINT FILLER AGGREGATE*
3/8 OR 1/2	ASTM NO. 8

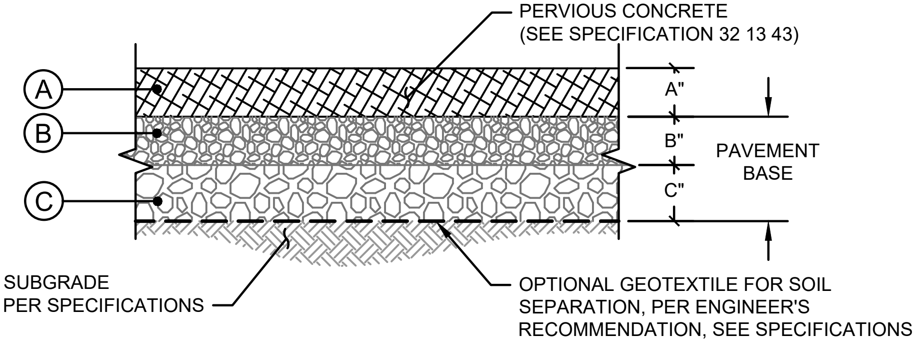
* PROVIDED FOR REFERENCE ONLY, FOLLOW MANUFACTURER'S RECOMMENDATIONS

CONSTRUCTION NOTES:

1. SEE PERMEABLE/POROUS UNIT PAVER SPECIFICATIONS FOR WEARING COURSE, PAVEMENT BASE, SUBGRADE, AND OTHER REQUIREMENTS FOR PERMEABLE/POROUS UNIT PAVER FACILITIES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSINGS AND UTILITY CONFLICTS.

PERMEABLE PAVEMENT PAVER SECTION	5.3

NOT FOR CONSTRUCTION



PERVIOUS CONCRETE 1

MINIMUM MATERIAL THICKNESS (IN):

LAYER	MATERIAL TYPE*	MODERATE VEHICULAR		LIGHT VEHICULAR		PEDESTRIAN	
		GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**
A	PERVIOUS CONCRETE	9	9.5	6.5	7	4.5	5
B	BASE COURSE ASTM NO. 3 OR 57	6	6	6	6	6	6
C	OPTIONAL RESERVOIR COURSE ASTM NO. 2, 3, OR 57	-	-	-	-	-	-

* MATERIAL FINER THAN NO. 100 SIEVE SHALL NOT EXCEED 2 PERCENT FOR ANY AGGREGATE LAYER (LICENSED PROFESSIONAL TO SELECT AGGREGATE).

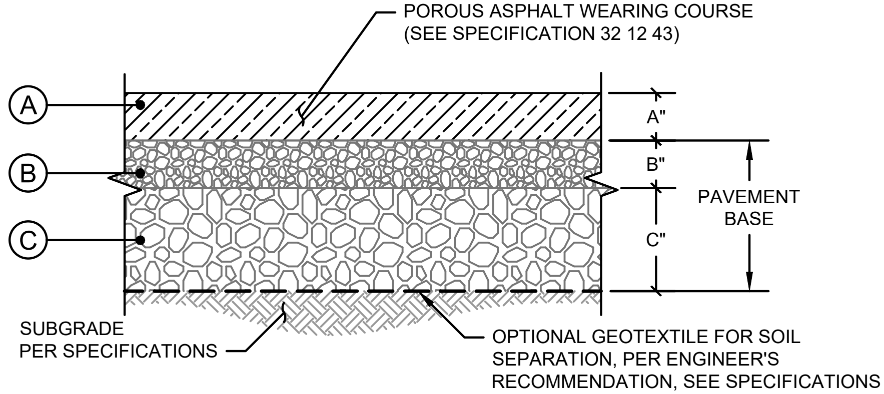
** "GOOD" AND "POOR" SOIL CLASSIFICATIONS BASED ON AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES. SEE DESIGNER NOTES FOR SUBGRADE ASSUMPTIONS. (LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON SITE CONDITIONS).

CONSTRUCTION NOTES:

1. SEE PERVIOUS CONCRETE SPECIFICATIONS FOR WEARING COURSE, PAVEMENT BASE, SUBGRADE, AND OTHER REQUIREMENTS FOR PERVIOUS CONCRETE FACILITIES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSINGS AND UTILITY CONFLICTS.

PERMEABLE PAVEMENT PERVIOUS CONCRETE SECTION	5.4

NOT FOR CONSTRUCTION



POROUS ASPHALT 1

MINIMUM MATERIAL THICKNESS (IN):

LAYER	MATERIAL TYPE*	MODERATE VEHICULAR		LIGHT VEHICULAR		PEDESTRIAN	
		GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**
A	POROUS ASPHALT	6	8	4	4	3	4
B	BASE COURSE ASTM NO. 57	6	6	5	4	6	4
C	RESERVOIR COURSE ASTM NO. 2, 3, OR 57	10	19	-	11	-	8

* MATERIAL FINER THAN NO. 100 SIEVE SHALL NOT EXCEED 2 PERCENT FOR ANY AGGREGATE LAYER (LICENSED PROFESSIONAL TO SELECT AGGREGATE).

** "GOOD" AND "POOR" SOIL CLASSIFICATIONS BASED ON AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES. SEE DESIGNER NOTES FOR SUBGRADE ASSUMPTIONS. (LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON SITE CONDITIONS).

CONSTRUCTION NOTES:

1. SEE POROUS ASPHALT SPECIFICATIONS FOR WEARING COURSE, PAVEMENT BASE, SUBGRADE, AND OTHER REQUIREMENTS FOR POROUS ASPHALT FACILITIES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY STANDARDS AND OTHER UTILITY PROVIDER REQUIREMENTS. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSINGS AND UTILITY CONFLICTS.

PERMEABLE PAVEMENT POROUS ASPHALT SECTION	5.5

NOT FOR CONSTRUCTION

CHAPTER 5

GREEN STORMWATER INFRASTRUCTURE SIZING REQUIREMENTS

CHAPTER OBJECTIVES

- Simply explain Green Stormwater Infrastructure sizing requirements

5. Green Infrastructure Sizing Requirements

The California Regional Water Quality Control Board for the San Francisco Bay Region reissued the MRP in November 2015. The MRP governs discharges from municipal storm drains operated by 76 local government entities, including those in the cities of Vallejo, Fairfield, and Suisun City.

Regulated Projects must comply with each Cities' C3 Guidance for specific LID and GSI requirements. All GSI measures must be designed to meet the same applicable treatment and hydromodification sizing requirements as Regulated Projects. However, if GSI measures cannot be designed to meet the standard sizing requirements due to constraints in the public right-of-way or other factors, the City may still wish to construct the measure to achieve other benefits (e.g., traffic calming, pedestrian safety, etc.) To address this situation, MRP Provision C.3.j.i.(2)(g) states that, for non-regulated projects, "Permittees may collectively propose a single approach with their Green Infrastructure Plans for how to proceed should project constraints preclude fully meeting the C.3.d requirements." Such a regional approach has been developed by BASMAA for use by Permittees in their GSI Plans and is described below, and included in Appendix B .

ALTERNATIVE SIZING

GSI measures should be located and sized to treat the C.3.d volume and/or flow of runoff from the contributing impervious surface area from the public right-of-way (street and sidewalk) where possible. Similarly, for GSI measures in parking lots and public parks, every attempt should be made to locate and size GSI measures to treat the C.3.d amount of runoff from the contributing impervious surface areas. Consideration should be given to the feasibility of treating impervious surface area from adjacent parcels, even if privately owned. If site constraints prevent locating and sizing GSI measures to meet C.3.d requirements, the alternative sizing methodology described below may be used.

In general GSI should be sized as large as feasible to meet the C.3.d. Criteria.

Regulated Projects

- Projects at auto service faciltiies, gas stations, restaurants, or standalong parking lots that create and/or replace 5,000 square feet or more of impervious area.
- Projects that create and/or replace 10,000 square feet or more of impervious area (excluding single family homs that area not apart of a larger housing developement.

Regulated Projects - Hydromodification Management

- Projects that create and/or replace one acre or more of impervious area.

Non-Regulated Projects

- Projects that create and/or replace between 2,500 square feet and 10,000 square feet of impervious area.
- Detached single family homes that create and/or replace 2,500 square feet or more of impervious area.

Source: City of Vallejo C.3. Compliance Information – Table 1

5. Green Infrastructure Sizing Requirements

Per the Bay Area Stormwater Management Agencies Association (BASMAA) Guidance for Sizing Green Stormwater Infrastructure Facilities, analysis completed by Dubin Environmental Consulting (in Appendix B) found that a bioretention facility with a standard cross-section that is sized to be equivalent to 4% of the impervious area draining to the feature will meet the sizing requirements for projects requiring hydromodification management. The standard bioretention facility cross-section is one that has 6-inch ponding depth, 2-inch freeboard, 18-inch treatment soil, and a 12-inch gravel layer below for water storage.

The hydrologic analysis report also provides minimum bioretention sizing criteria for projects to provide treatment of 80% of annual runoff (per MRP C.3.d,) based on the mean annual precipitation (MAP) of the project site:

For bioretention with 6-in surface reservoir configuration:

SizingFactor = 0.00060 x MAP (in) + 0.0086

Where:

SizingFactor is the ratio of the surface area of the bioretention facility to the impervious area contributing runoff

MAP is the mean annual precipitation of the project site

For example, the MAP for the Solano Permittees is approximately 24 inches per year. As a result, sizing factors for non-regulated GSI projects is 0.023 (or 2.3%). This indicates that GSI facilities in the street right-of-way can be sized with as low as a 2.3% sizing factor and still meet the C.3.d sizing requirements.

There are typically more constraints on the placement and sizing of GSI measures in a public right-of-way (street) than for parcel-based GSI projects, and there may be GSI opportunities for which the 2.3% sizing factor cannot be achieved. However, undersized GSI measures or GSI measures designed to only treat a portion of the runoff from the contributing drainage area may still have some water quality, runoff reduction, or other benefits.

The BASMAA Development Committee developed regional guidance on how to use the modeling results and what design approaches to use in specific situations when the C.3.d sizing requirements cannot be met. The regional guidance includes the following recommendations for sizing GSI facilities in green street projects:

1. Bioretention facilities in street projects should be sized as large as feasible and meet the C.3.d criteria where possible. Constraints in the public right-of-way may affect the size of these facilities and warrant the use of smaller sizing factors. Bioretention facilities in street projects may use the sizing curves in the BASMAA GSI Facility Sizing Report to meet the C.3.d criteria (see Appendix B). Local municipal staff involved with other assets in the public right of way should be consulted to provide further guidance to design teams as early in the process as possible.

2. Bioretention facilities in street projects smaller than what would be required to meet the Provision C.3.d criteria may be appropriate in some circumstances. As an example, it might be appropriate to construct a bioretention facility where a small proportion of runoff is diverted from a larger runoff stream. Where feasible, such facilities can be designed as "off-line" facilities, where the bypassed runoff is not treated or is treated in a different facility further downstream. In these cases, the proportion of total runoff captured and treated should be estimated using the results of the attached memorandum. In cases where "in-line" bioretention systems cannot meet the C.3.d criteria, the facilities should incorporate erosion control as needed to protect the facility from high flows.

3. Pollutant reduction achieved by GSI facilities in street projects can be estimated in accordance with the Interim Accounting Methodology or the applicable Reasonable Assurance Analysis [standard methodologies employed by BASMAA and the Solano Permittees].

5. Green Infrastructure Sizing Requirements

If it is determined that GSI measures in a City project are unable to be designed to meet the C.3.d sizing requirements, the following steps can be taken:

- Document the project constraints that preclude meeting the C.3.d sizing requirements. For example, if an underground utility is preventing installation at the appropriate depth, or the sidewalk planter area is inadequate for ideal sizing, or heritage trees and their root structures conflict with the desired GSI location, document those constraints.
- Use the sizing charts from the BASMAA GSI Facility Sizing Report to determine the smallest facility size that will meet the C.3.d sizing requirements (see Appendix B).
- If the minimum facility size is still infeasible, identify possible variations from the standard design. For example, determine whether the depth can be adjusted only in the area where a utility conflict exists. Using this alternative design, estimate the percent of the C.3.d volume that will be treated. Evaluate the cost-effectiveness of installing the GSI measure given the other benefits realized (e.g., pedestrian safety, traffic calming, reduced local flooding, etc.) and the amount of pollutant removal achieved.

APPENDICES

Appendix A

SPECIFICATIONS

Appendix B

Guidance for Sizing Green Infrastructure Facilities in Street Projects (BASMAA, 2018)