CITY OF
PALO ALTO

2025

GREEN STORMWATER INFRASTRUCTURE HANDBOOK

IMPLEMENTATION GUIDANCE AND DESIGN STANDARDS

Acknowledgements

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This City Handbook provides guidance through a specific, directed effort for projects carried out within the Palo Alto jurisdiction. It would not be possible without the experience, innovation, and vision put forth by other agencies and organizations moving forward the practice of GSI, including but not limited to, the San Francisco Public Utilities Commission, Central Coast Low Impact Development Initiative, City of Philadelphia, City of Portland, City of New York City, City of San Mateo, National Association of City Transportation Officials, and San Mateo Countywide Water Pollution Prevention Program. Watershed Protection is grateful for feedback from City staff from the following departments: Public Works, Utilities, Community Services, and Transportation, which helped to make this Handbook a successful product.

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1. How to Use This Handbook

This City of Palo Alto (City) Green Stormwater Infrastructure (GSI) Handbook is intended to be used by City staff and contractors when implementing all City GSI projects. The objective of this GSI Handbook is to establish City planning and design processes that will provide properly functioning GSI. Several technical resources developed by the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and other municipalities were used to develop this condensed GSI Handbook. These sources are referenced throughout this document where applicable for those seeking detailed background and guidance. They include:

- The City of Palo Alto Green Stormwater Infrastructure Plan (City of Palo Alto, 2020), which provides an overview of GSI planning and specific potential locations for future GSI in the City.
- SCVURPPP C.3 Stormwater Handbook (SCVURPPP, 2024), which summarizes regulatory requirements for GSI and stormwater treatment measures and describes methods for meeting those requirements.
- SCVURPPP Green Stormwater Infrastructure Handbook (SCVURPPP, 2019) and references cited therein, which includes GSI siting and design guidance.

This GSI Handbook provides background information about GSI, an overview of key GSI implementation steps, GSI details and specifications, and an explanation of the review and approval process (**Section 4.5**). The following six GSI implementation process steps, the first three of which may be conducted in a different order or in parallel depending on project types, are described in this Handbook:

1. Incorporating low impact development (LID) site design measures
2. Siting the GSI measure
3. Delineating the GSI measure drainage area
4. Selecting an appropriate GSI measure for the project
5. Sizing the GSI measure
6. Designing the GSI measure

GSI design details have been modified from regionally applied specifications developed by the San Francisco Utilities Commission (SFPUC) and other agencies and then edited for SCVURPPP's GSI Handbooks. Geosyntec then worked with the City to incorporate City-specific standards into designs pulled from the SCVURPPP Handbooks, which are provided in this Handbook. Although the GSI design details and specifications provided in this GSI Handbook include construction notes, GSI construction is not covered in detail in this Handbook. GSI projects costs and budgeting for GSI design, construction, and maintenance are also not included in this Handbook. The City is developing additional resources to complement this Handbook, including a GSI Maintenance and Monitoring Manual (City of Palo Alto, April 2025) and a guidance document regarding GSI inspections during and post-construction (May 2025). Definitions for many of the terms used in this GSI Handbook are provided in the Glossary in **Section 6**.

2. Green Stormwater Infrastructure

Stormwater runoff is generated when rain falls on impervious surfaces, such as roofs, roadways, and sidewalks that prevent water from infiltrating into the underlying soils. Development in our urban environment causes faster rates and larger volumes of stormwater runoff compared to natural pre-development conditions. Urban stormwater runoff often carries pollutants, such as hydrocarbons, metals, pesticides, nutrients, sediment, and bioaccumulative toxic chemicals that are present in urban infrastructure or applied to landscapes, into creeks and other natural bodies of water.

2.1. What is Green Stormwater Infrastructure?

Green stormwater infrastructure (GSI) is engineered infrastructure designed to use natural processes to manage and treat stormwater runoff from urban development. GSI is an alternative and a complement to "gray" storm drainage infrastructure (i.e., underground pipes that convey stormwater quickly away from the surface without treating it). GSI provides a pathway for stormwater to infiltrate to underlying soils, treat pollutants, and provide stormwater capture and use opportunities.

In addition to managing stormwater, GSI can provide other benefits such as increasing green space, providing urban cooling, and supporting habitat for native plants, insects, and other wildlife. GSI can also be designed into green street projects to provide traffic calming and pedestrian and bike safety features.

2.2. GSI Regulatory Requirements

The City is required to comply with the San Francisco Bay Municipal Regional Stormwater National Pollutant Discharge Elimination System (NPDES) Permit (MRP; Order No. R2-2022-0018 and future amendments). GSI measure implementation is primarily referenced in MRP Provision C.3.

Under the MRP's Provision C.3, new development and redevelopment projects on private and public property that exceed certain size thresholds (called "Regulated Projects") are required to mitigate stormwater quality impacts. Regulated Projects are defined as (see **Attachment A** for a detailed summary of Regulated Project thresholds):

- 5,000 square feet of new or replaced impervious area for most parcel-based projects and roads;
- 10,000 square feet of new or replaced impervious area for detached single-family homes; or
- 1 acre of road maintenance.

Regulated Projects are required to mitigate stormwater quality by incorporating low impact development (LID). The MRP states the goal of LID is to reduce runoff pollutant discharges and prevent increases in runoff from development projects. LID measures required for Regulated Projects by the MRP include:

(1) Site Design Measures – focus on conserving natural areas and reducing impervious surfaces;
(2) Source Control Measures – prevent stormwater from coming into contact with pollutants; and
(3) Stormwater Treatment Measures[1] – chemically, physically, or biologically remove

[1] The term Green Stormwater Infrastructure (GSI) is used interchangeably with Stormwater Treatment Measures in this Handbook.

pollutants from stormwater. Stormwater Treatment Measures include rainwater harvesting and use, infiltration, evapotranspiration, and biotreatment[2] (see **Section 2.3**).

In addition to Regulated Projects, the reissued MRP (Provision C.3.j) also requires the City to retrofit 3.92 acres of existing City impervious surface between 2022 and 2027 through installation of GSI measures (called "Retrofit Projects") and integrate GSI into City infrastructure projects to the maximum extent practicable. Retrofit Projects must meet the same requirements as Regulated Projects.

Under the MRP's Provision C.10, trash in stormwater must be managed. While there are non-GSI measures that capture trash, most GSI measures also provide trash removal benefits with proper maintenance. GSI measures that are implemented in accordance with C.3 and C.10.a.ii.(a) are considered "full trash capture devices"[3] (see **Glossary**).

Under the MRP's Provision C.12, the City must work collaboratively with other permittees in Santa Clara County to treat 664 acres across the County to remove polychlorinated biphenyls (PCBs) and Mercury by 2027. The City is also subject to the San Francisco Bay (Bay) PCBs and Mercury Total Maximum Daily Loads (TMDLs), which serve as water quality requirements that restrict the amount of these pollutants that can be discharged to the Bay. GSI measures can remove PCBs and mercury from stormwater and are an important tool in meeting TMDL load reduction goals.

To comply with these MRP requirements and to support protection of local creeks and the Bay, opportunities for GSI should be constantly considered, particularly when planning Capital Improvement Program (CIP) projects.

2.3. MRP-Compliant GSI Measures

This Handbook focuses on GSI measures that are compliant with the "Stormwater Treatment Measure" or "Site Design Measure" definitions in MRP Provision C.3.c. GSI measures compliant with the MRP LID Stormwater Treatment Measure requirements must provide specific treatment functions and can capture stormwater from a drainage area that may be 25 to 50 times larger than the GSI measure footprint area[4]. These treatment functions include retention, infiltration, evapotranspiration, capture and use, and biotreatment as defined below:

- **Retention** – The onsite storage of stormwater to prevent it from temporarily or permanently leaving the development site.

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[2] Refer to Attachment B for details on how GSI treats pollutants in stormwater.

[3] Per MRP Provision C.10.a.ii.(a), "the facility, including its maintenance, prevents the discharge of trash to the downstream MS4 and receiving waters and discharge points from the facility, including overflows, are appropriately screened or otherwise configured to meet the full trash capture screening specification for storm flows up to the full trash capture one-year, one-hour storm hydraulic specification."

[4] MRP compliant-GSI measure footprints are typically sized at 2% to 4% of the impervious portion of the drainage area. See Section 3.5 for more information.

- **Infiltration** – Infiltration of water to the subsurface, where it percolates through soils below the GSI measure and into groundwater. Infiltrated water has the additional benefit of reducing the overall quantity of water from the surface (i.e., retention of stormwater) and reducing erosion and other negative impacts of large stormwater flows.
- **Evapotranspiration** – A process by which water is returned to the air through plants. Plants installed in GSI measures uptake water from soil media into their roots and release this water as vapor through their leaves.
- **Capture and Use** – Capture and use entails collecting stormwater in storage facilities for later use. Because this water is typically used for irrigation, which enables infiltration and evapotranspiration of water, this is also considered a retention measure.
- **Biotreatment** – In GSI measures that contain soil and plants, biological processes can provide treatment of pollutants. These include soil microbes that ingest and transform chemical compounds, plants that uptake nutrients, and decomposition processes that change the chemical composition of the soil and transform pollutants. As required by MRP Provision C.3.c.i(2)(c)(ii), biotreatment systems must be designed to have a surface area no smaller than what is required to accommodate a 5.0 inches/hour stormwater runoff surface loading rate and use biotreatment soil media (BSM) as specified by BASMAA and in the MRP (specification provided in Attachment G) to maximize infiltration to the native soil.

GSI measures compliant with LID Site Design requirements are referred to as “self-treating areas” or “self-retaining areas” in this Handbook (See **Figure 1**). If these Site Design measures are designed to store and infiltrate the rainfall runoff volume per MRP Provision C.3.d., then they are also considered a stormwater treatment measure. These terms are defined in the SCVURPPP C.3 Stormwater Handbook, as provided below (SCVURPPP, 2024):

Self-treating areas prevent stormwater and pollutants from being discharged. These areas include natural spaces, landscaped areas (e.g., parks and gardens), green roofs, and areas paved with turf block. If designed correctly, self-treating areas can be routed directly to the storm drain system and do not need to be treated via other GSI measures. These areas may not receive or treat run-on (stormwater runoff draining from other adjacent areas). If runoff from self-treating areas co-mingles with other impervious areas of the site, then downstream GSI measures must be sized for both the impervious areas and the self-treating areas.

Self-retaining areas are also called zero discharge areas. These consist of depressed landscaped areas, pervious pavement, or artificial turf areas that do not discharge any portion of the MRP-required stormwater treatment volume (see **Section 3.5**). These areas must allow for infiltration into the underlying soil and not be lined with impervious materials or constructed over an impervious barrier. Self-retaining areas can treat themselves, along with impervious area up to two times the size of the self-retaining area. If a self-retaining area is designed to accept runoff from adjacent areas, it must be designed to manage the MRP-required stormwater treatment volume from the full drainage area.

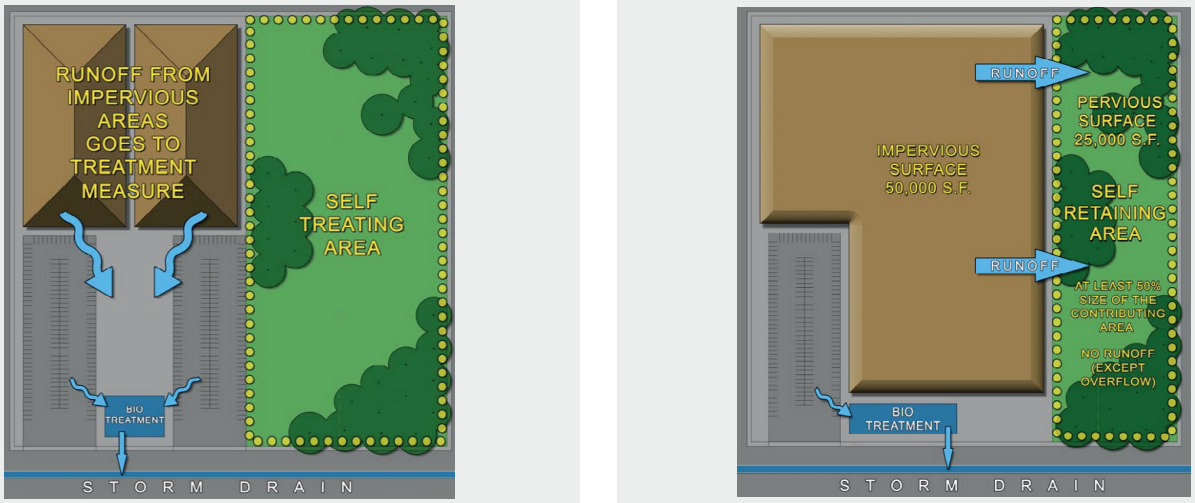


Figure 1: Schematic Diagrams of Sites with a Self-Treating Area and a Self-Retaining Area (Credit: SCVURPPP, 2024)

2.4. GSI Measure Types

This section describes GSI measure types in detail, including their treatment mechanism, benefits, constraints, appropriate application, and additional considerations. Although all GSI measures treat stormwater runoff, not all GSI measures are considered LID according to the MRP site design and stormwater treatment definitions, and therefore, may not meet C.3 requirements for both Regulated and Retrofit Projects. **Table 1** below summarizes which GSI types, when sized to comply with one of the hydraulic design criteria listed in MRP Provision C.3.d Numeric Sizing Criteria for Stormwater Treatment Systems, are considered LID and/or non-LID. **Table 1** also categorizes GSI measures as “self-retaining” and “self-treating” site design measures,

as applicable. **Sections 2.4.1a-f** and **2.4.2a-b** describe these GSI Measure Types in detail. Using these latter measures can help offset that area that needs to be addressed by a Stormwater Treatment Measure.

Table 1: GSI Measure Types
GSI measure types that are considered LID per the MRP when sized and designed correctly, described in **Sections 2.4.1a-f** and **2.4.2a-b**. Other non-LID (per the MRP) measures are described in **Section 2.5**.

GSI Measure	LID per MRP	Non-LID per MRP	Stormwater Treatment Measure	Self-Retaining or Self-Treating
Bioretention Area	x		x	
Flow-Through Planter	x		x	
Suspended Pavement System	x		x	
Tree Well Filter[1]	x	x	x	
Infiltration Trench	x		x	
Rainwater Harvesting and Use	x		x	
Green Roof[2]	x			x
Pervious Pavement	x		x	x
High-Flow Biofilter[3]		x	x	
Bioswale[4]		x	x	

[1] LID if biotreatment soil is used, non-LID if it is not used.

[2] Green roofs may be considered biotreatment systems that treat roof runoff only if they meet minimum specifications described in MRP C.3.c.i(2)(c)(iii).

[3] These measures do not yet have Water Board approval.

[4] Bioswales may only be used as pretreatment in combination with an allowed Stormwater Treatment Measure per the MRP but is no longer accepted as a single treatment measure.

2.4.1a Bioretention Area

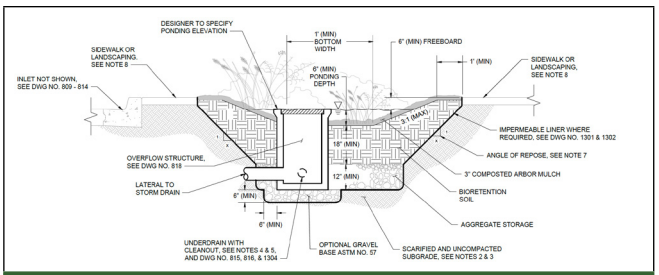
This GSI biotreatment measure is an engineered, depressed, landscaped area with biotreatment soil media composed of sand and compost and underlain by drain rock (aggregate). Bioretention areas are designed to retain runoff, filter the runoff through soil media and plant roots, then infiltrate to the underlying soil and/or discharge to the storm drain system (Palo Alto, 2019). When the area's underlying soil does not infiltrate water quickly, an overflow and an underdrain (a perforated pipe which conveys flow along the base of the bioretention) can connect the bioretention area to the municipal storm drain system. These areas can be designed to infiltrate or prevent infiltration using a waterproof lining.

- **LID Treatment Functions:** biotreatment, evapotranspiration, and (if unlined) infiltration.
- **Locations:** parking lot, driveway, along roadways, and on parcels away from buildings. They may be designed as an in-ground planter (flat media surface and vertical concrete walls within the step-out zone between the sidewalk and the roadway and requires modification of the curb and gutter), stormwater curb extension or bulb-out (extend into the roadway and require modification of the curb and gutter), or as a basin with sloped sides in larger installations.
- **Benefits:** traffic calming, decreased street widths and pedestrian crossing distance, aesthetic landscaped design element, and street greening.

The term "rain garden" is often used to describe bioretention-like facilities; however, rain gardens are typically not designed and installed per the specifications required in the MRP and often do not meet compliance requirements.

Southgate Neighborhood Bioretention area, City of Palo Alto

Bioretention Area adjacent to Palo Alto Junior Museum and Zoo, City of Palo Alto



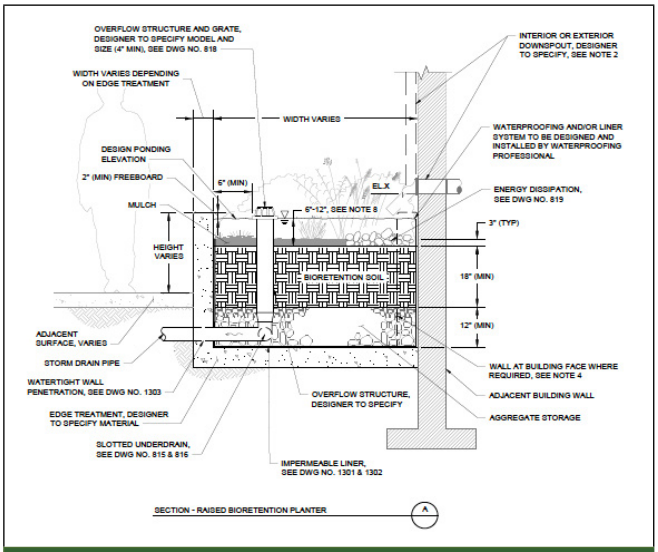
Bioretention Standard detail, CPA GSI Handbook Dwg. No. 808

2.4.1b Flow-Through Planter

This GSI biotreatment measure is an above ground concrete planter box with a waterproof membrane/liner, overflow, and an underdrain. Flow-through planters typically receive runoff via downspouts leading from the roofs of adjacent buildings (SCVURPPP, 2024).

- **LID Treatment Functions:** biotreatment and evapotranspiration.
- **Locations:** parking lot, roof, driveway, along roadways, and on parcels close to or away from buildings. They can be located where soil moisture is a potential concern.
- **Benefits:** can be installed adjacent to buildings and are aesthetic landscape design elements.

California Avenue Parking Garage Flow-Through Planter, City of Palo Alto



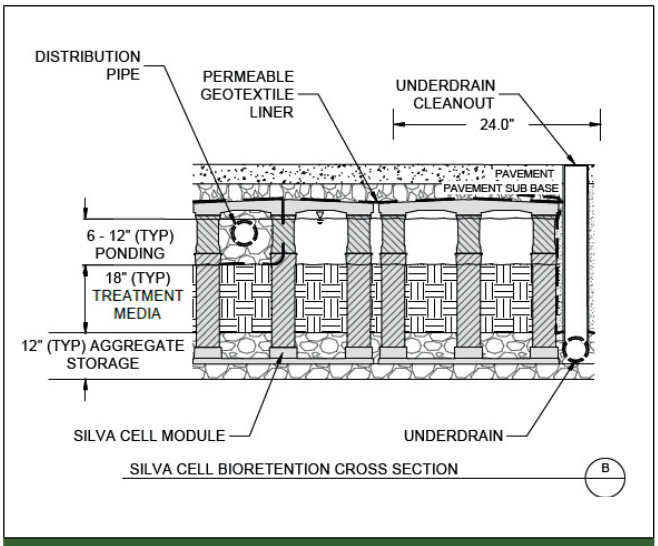
Flow-Through Planter, Raised Planter Section, Dwg. No. 826

2.4.1c Suspended Pavement Systems

This GSI measure consists of modular units containing uncompacted soil volume for urban tree roots to grow. They support pervious pavement areas or other surfaces (such as vegetation or grass) while creating a subsurface void for capturing and infiltrating stormwater through biotreatment soil media. These can be installed as open-bottom systems that promote infiltration or in closed-bottom systems where infiltration is undesirable or infeasible, such as sites with underlying soils that do not allow appreciable infiltration, groundwater contamination, or high groundwater levels. These are frequently constructed using modular proprietary suspended pavement system products, such as DeepRoot's Silva Cell, that can withstand roadway structural loads (adapted from SCVURPPP, 2024).

- **LID Treatment Functions:** biotreatment, evapotranspiration, and (if unlined) infiltration.
- **Locations:** under sidewalks, plazas, parking lots, or roadways. They are often along urban sidewalks or within parking lots.
- **Benefits:** provides efficient use of space and promotes large tree growth.

Junior Museum and Zoo Suspended Pavement System under Pervious Concrete Parking Spaces, City of Palo Alto



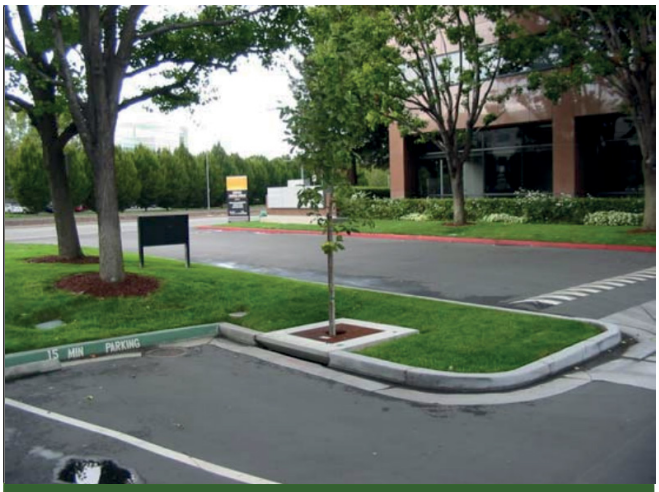
Suspended Pavement System Standard detail, CPA GSI Handbook Dwg. No. 1201

2.4.1d Tree Well Filters

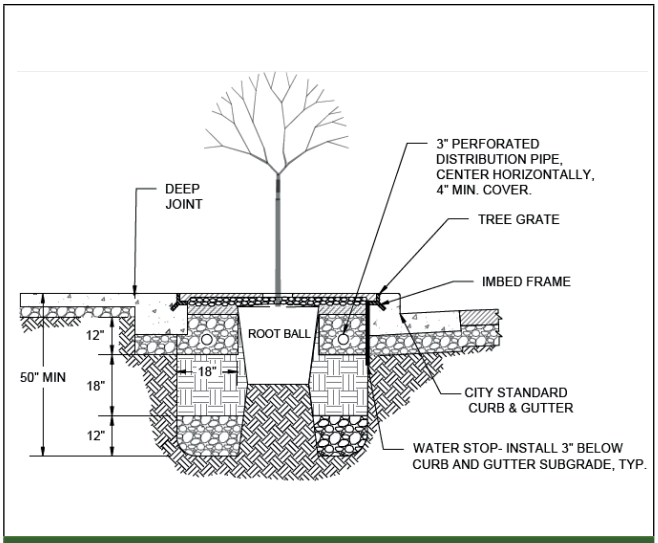
This GSI biotreatment measure consists of an excavated pit or vault filled with biotreatment soil media, planted with a tree, underlain with drain rock, and an underdrain, if needed. Tree well filters can be constructed in series and linked via a subsurface trench or underdrain. They can be integrated with suspended pavement systems and pervious pavement.

- **LID Treatment Functions:** biotreatment, evapotranspiration, and (if unlined) infiltration.
- **Locations:** parking lots, driveways, plazas, and along roadways where trees are desired.
- **Benefits:** requires less dedicated space than other bioretention areas and is an aesthetic landscape design element.

These facilities can be considered GSI compliant with the MRP if at least 18" of biotreatment soil media is provided to meet technical specifications and they are sized appropriately for the drainage area.



Tree well filter, City of San Jose (SCVURPPP C.3 Guidance, 2024).



Tree Well Filter Standard detail, CPA GSI Handbook Dwg. No. 1102

2.4.1e Infiltration GSI Measures

These systems capture stormwater and allow it to percolate into the subsurface soils. Infiltration facilities can be sited in areas with well-drained (Type A or B) existing soil and adequate depth to groundwater. Common types of infiltration GSI include:

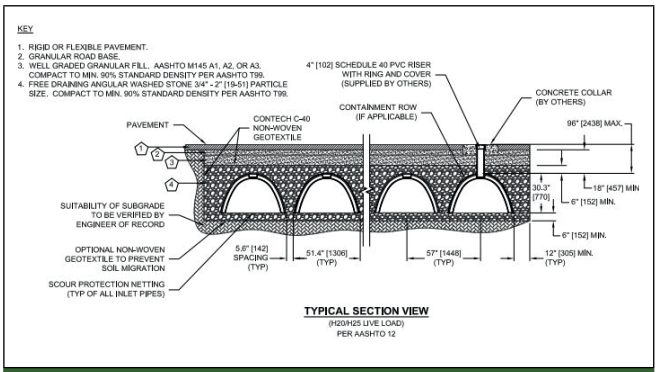
1. Subsurface infiltration systems
2. Infiltration trenches
3. Infiltration basins
4. Drywells

- **LID Treatment Function:** infiltration.
- **Locations:** parking lots, driveways, adjacent to other paved surfaces, and away from buildings.
- **Benefits:** may increase groundwater recharge, no surface outfalls.

There are few opportunities for infiltration GSI measures in the City of Palo Alto due to high groundwater, low soil infiltration rates, and areas of subsurface contamination.

Subsurface infiltration systems may be used to infiltrate larger quantities of runoff. These systems are underground vaults or pipes that store and infiltrate stormwater to the subsurface while preserving the use of the land surface above (e.g., parking lots, playing fields). They require pretreatment to remove sediment and other pollutants to maintain the infiltration capacity of the facility.

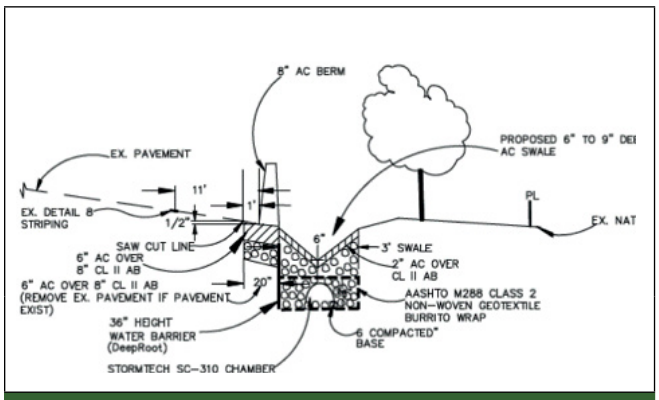
Example of a subsurface retention/ infiltration system installation under a parking lot (Conteches.com)



ChamberMaxx Stormwater Retention System Standard detail (Conteches.com)

Infiltration trenches are designed to store stormwater runoff in a linear narrow trench filled with permeable material (eg., gravel) and allow it to infiltrate through the bottom and sides into the surrounding and subsurface soil.

Example of an infiltration trench, Alma Street, City of Palo Alto



Drawing (Section View) of infiltration trench, Alma Street, City of Palo Alto

Infiltration basins are depressed or excavated areas that capture and store runoff for infiltration into the subsurface soils.

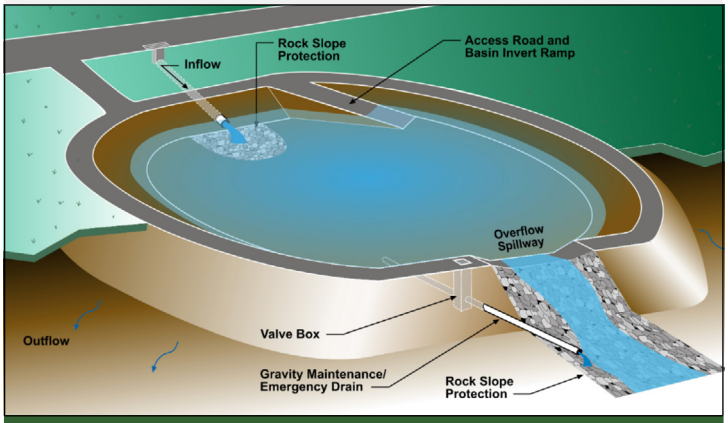
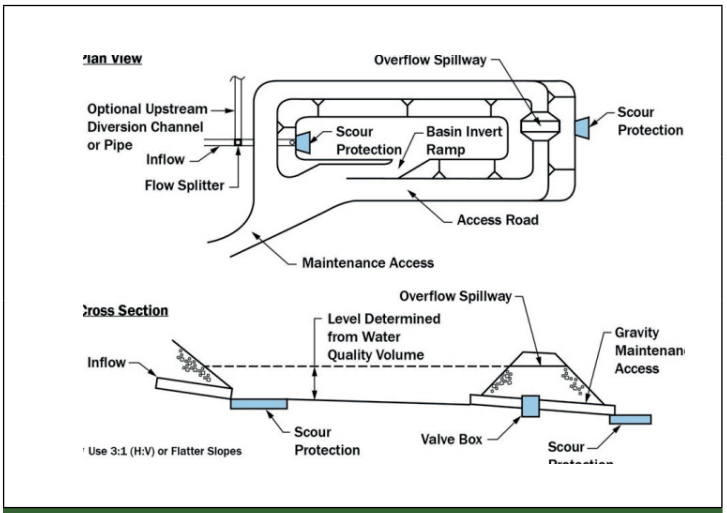


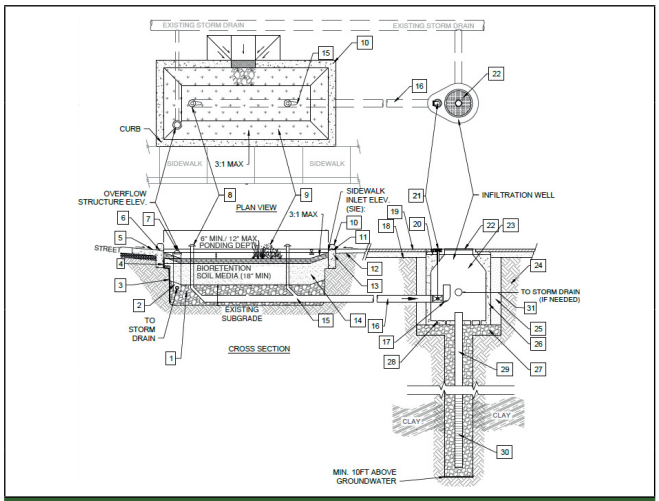
Image credit: Ken Euli



Schematic of an Infiltration Basin (Caltrans 2020)

Drywells are deep, relatively small diameter structures filled or surrounded by aggregate that are installed in the subsurface to infiltrate stormwater 15 to 40 or more feet below the surface.

Dry well located in a bioretention area in a corporation yard, Elk Grove, CA. (SCVURPPP GSI Handbook, 2019)

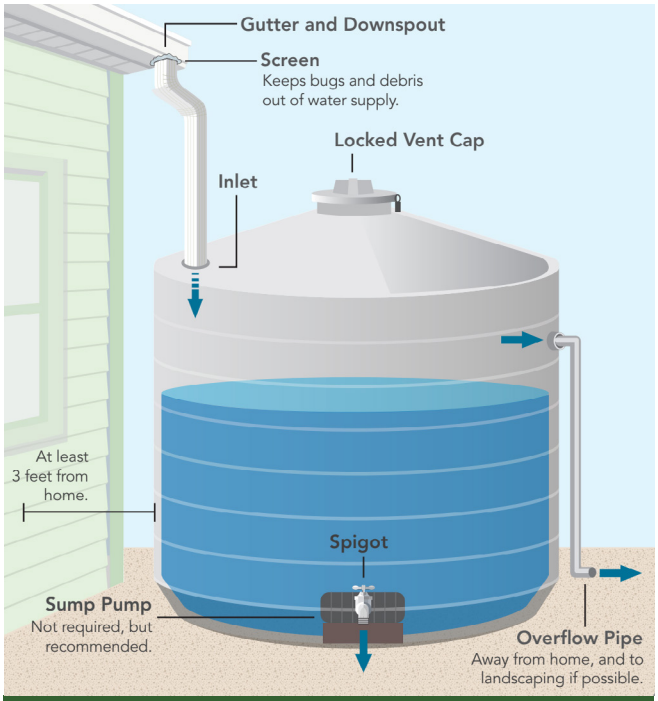


Standard detail of a dry well connected to a bioretention area, CPA GSI Handbook Dwg. No. 906

2.4.1f Rainwater Harvesting

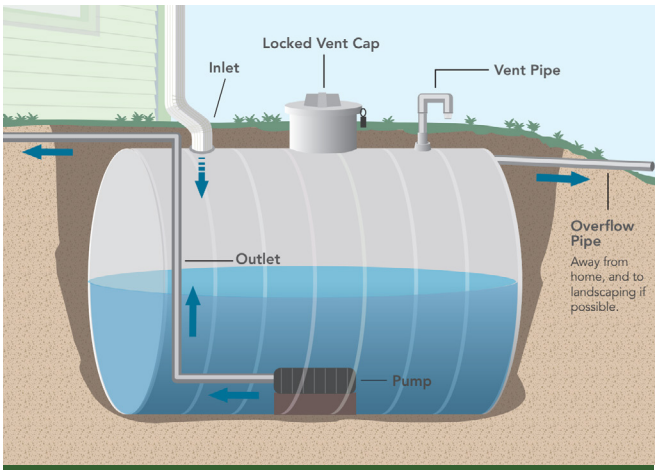
This GSI Measure is the process of collecting rainwater from impervious surfaces (roofs, paths, walkways, etc.) and storing it for later use. Rainwater harvesting systems are designed to store a specified volume of water with no discharge until this volume is exceeded. Storage facilities that can be used to harvest rainwater include rain barrels, above-ground or below-ground cisterns, open storage reservoirs (e.g., ponds), and various underground storage devices (tanks, vaults, pipes, and proprietary storage systems). The harvested water is then fed into irrigation systems or non-potable water plumbing systems, either by pumping or by gravity flow (SCVURPPP, 2024).

- **LID Treatment Function:** capture and use.
- **Locations:** roofs, adjacent to buildings, and underground.
- **Benefits:** non-potable reuse of captured stormwater for irrigation and other uses.



Above-Ground Cistern Schematic
(Image credit: SGA Marketing)

Heron's Head Eco Center Rainwater Harvesting, City of San Francisco (sfrecpark.org)



Below-Ground Cistern Schematic
(Image credit: SGA Marketing)

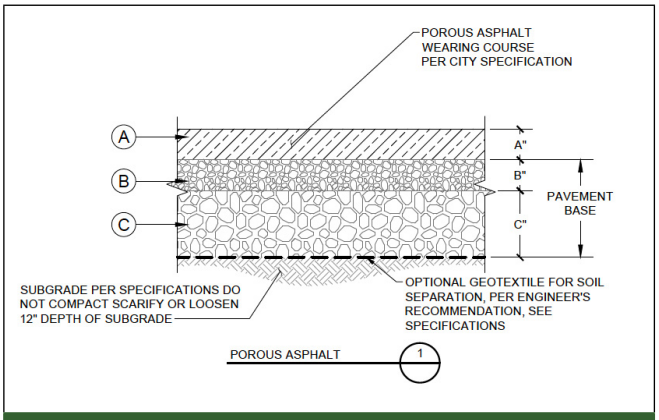
2.4.2a Pervious Pavement

This GSI Measure is a pavement system designed to allow stormwater to percolate through the surface material, aggregate filled spaces or turf, and into an underground storage area filled with various layers of compacted, open-graded aggregates before infiltrating into the underlying soils. Common pervious hardscape types include pervious concrete, porous asphalt, permeable pavers, interlocking concrete pavers with aggregate, and grid pavements (SCVURPPP, 2024).

- **LID Treatment Function:** infiltration.
- **Locations:** light traffic roads and alleys, parking lots, driveways, bike lanes, sidewalks, plazas and away from buildings.
- **Benefits:** reduces flow and treatment volume needed for other GSI measures.

This type of infiltration measure is defined as a self-treating or self-retaining area per the C.3 Stormwater Handbook. **To be considered LID, pervious pavement must be unlined and infiltrate into existing subsurface soil.** Pervious pavement may capture drainage from an area up to twice the receiving pervious pavement area and must be sized to capture the required water quality volume from these areas (see **Section 3.5.2**). GSI measures compliant with LID Site Design requirements are “self-treating areas” or “self-retaining areas” (see **Section 2.3** for definitions).

Junior Museum and Zoo Pervious Concrete, City of Palo Alto



Pervious asphalt standard detail, CPA GSI Handbook Dwg. No. 1006

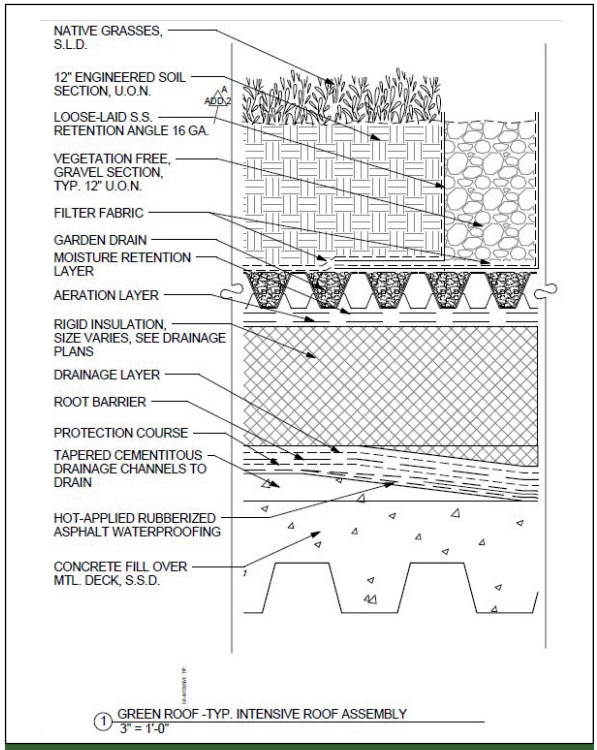
2.4.2b Green Roofs

These GSI Measures are vegetated roof systems that filter, absorb, and retain or detain the rain that falls on them. Green roof systems are comprised of a layer of planting media with vegetation, underlain by other structural components including waterproof membranes, synthetic insulation, and geofabrics (SCVURPPP, 2024).

- **LID Treatment Function:** evapotranspiration and biotreatment.
- **Locations:** roofs.
- **Benefits:** reduces "heat island" effect, provides habitat, has longer lifespan than conventional roofs, and reduces flow and treatment volume needed for other GSI measures.

GSI measures compliant with LID Site Design requirements are "self-treating areas" or "self-retaining areas" (see **Section 2.3** for definitions).

Mitchell Park Library Green Roof, City of Palo Alto



Green Roof Standard Detail, Mitchell Park Library Plans, Sheet 8.3.6

2.5. Other Stormwater Treatment Measures

Stormwater can be directed to flow through a series of different types of stormwater treatment measures. These groupings of stormwater treatment measures are called "stormwater treatment trains." In some cases, GSI measures may be paired with other non-GSI measures. Non-GSI measures can provide effective trash removal, legacy pollutant removal, or detention of larger flood flows, sometimes more cost effectively and in a smaller footprint than GSI. Non-LID stormwater treatment measures that can be used in treatment trains with GSI measures are listed in **Sections 2.5.1a-b**. Non-LID, non-GSI stormwater treatment measures that also can be used for pretreatment as part of a treatment train are listed in **Sections 2.5.2a-c**.

Extended Detention Basins, Media Filters, hydrodynamic separators, and debris-separating baffle boxes are also introduced in this Handbook; however, these stormwater treatment measures are not considered GSI.

2.5.1a Bioswales

These non-LID stormwater treatment measures are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff to downstream discharge points (SCVURPPP, 2024). In contrast to bioretention areas, which are designed to percolate vertically, bioswales convey flow laterally along the length of the swale, typically have a shallow biotreatment soil media layer and no underdrain.

- **Treatment Mechanism:** biotreatment, evapotranspiration, and (if unlined) infiltration.
- **Locations:** underground in accessible areas with overhead clearance.
- **Benefits:** aesthetic landscaped design element, street greening, and can be used to convey flow to other GSI measures or act as pretreatment.

Bioswales are no longer compliant with the MRP, because they do not meet the updated LID requirements. However, they can be used as pretreatment when needed.

Stanford/Palo Alto Community Playing Fields Bioswale, City of Palo Alto

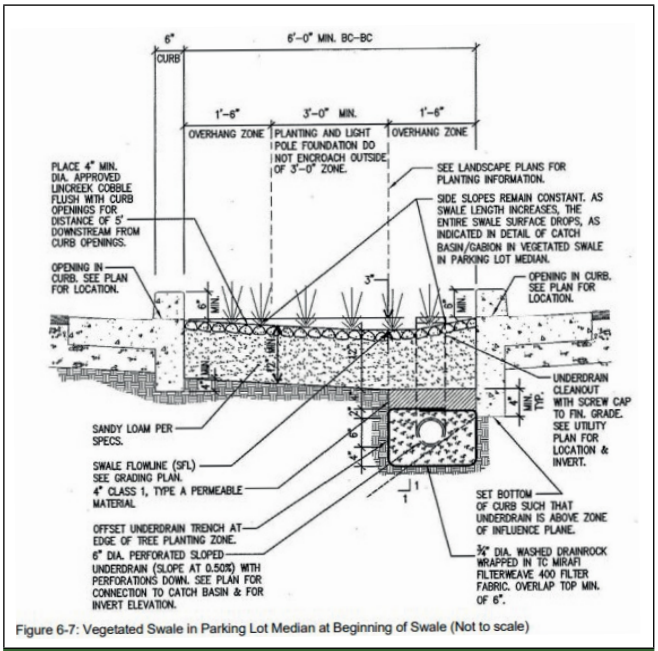


Figure 6-7: Vegetated Swale in Parking Lot Median at Beginning of Swale (Not to scale)

San Mateo Countywide Water Pollution Prevention Program C.3 Stormwater Technical Guidance

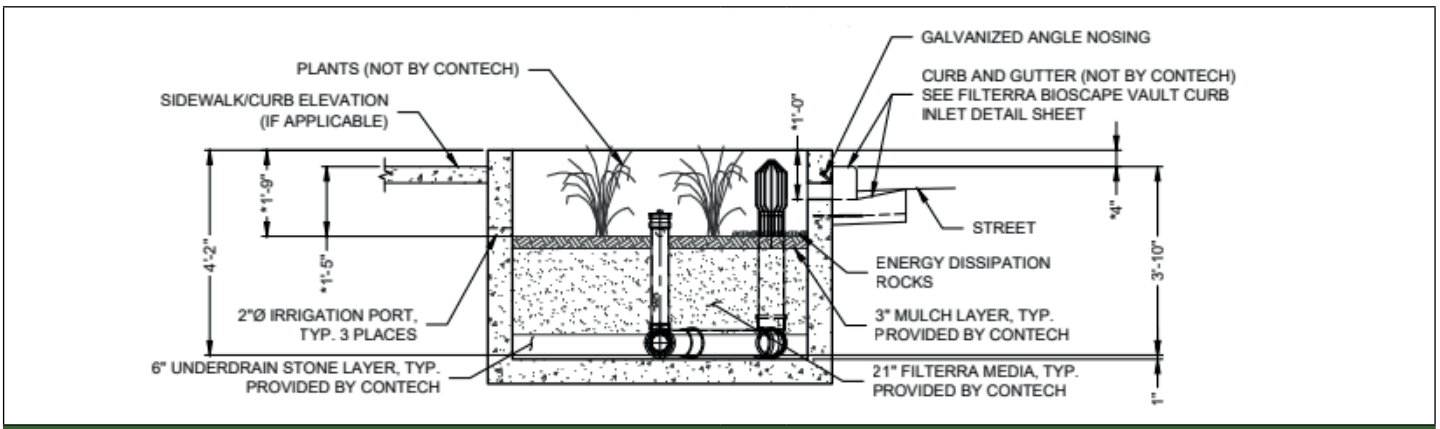
2.5.1b High-Flowrate Biofilters

These non-LID stormwater treatment measures are biotreatment measures that use an engineered media with a significantly higher infiltration rate than the MRP-specified biotreatment soil media to remove pollutants. The design of high-flowrate biofilters allow them to have smaller footprints than bioretention (Contech 2023).

- **Treatment Mechanism:** biotreatment, evapotranspiration, and (if unlined) infiltration.
- **Locations:** space-constrained areas including roadways, plazas, and near buildings.
- **Benefits:** aesthetic landscaped design element, street greening, and can act as pretreatment.

***Note: Use of high-flowrate biofilters requires special approval by the Regional Water Quality Control Board, Region 9.**

Open Top Planter – Filterra Bioscape (Conteches.com)



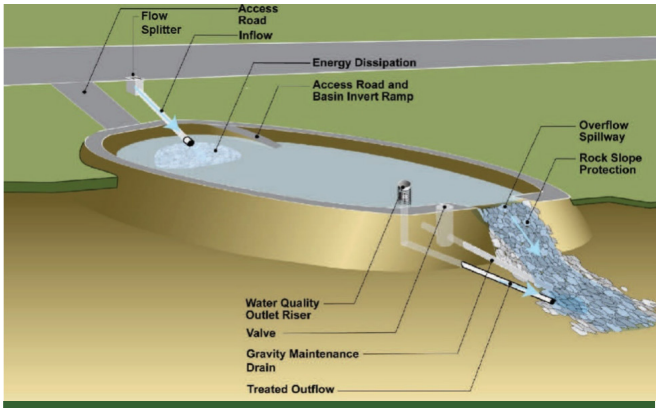
Contech Filterra Bioscape Vault Standard detail (Conteches.com)

2.5.2a Detention Measures

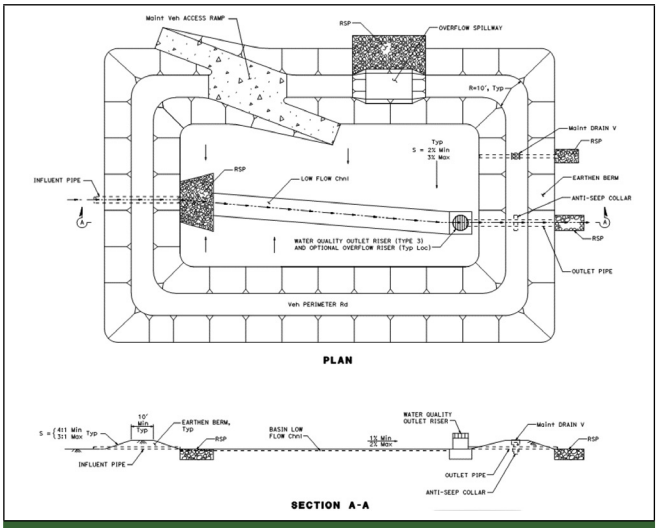
These non-LID, non-GSI stormwater treatment measures include above ground ponds or basins or underground temporary storage facilities. The outlets of detention measures have been designed to detain the stormwater runoff from a water quality design storm for a minimum of 48 hours to allow particles and associated pollutants to settle. They do not have a permanent pool of water and discharge directly to the storm drain system after the settling period. They can also be used to provide hydromodification management and/or flood control by including flow duration control and/or flood detention storage (adapted from SCVURPPP, 2024).

- **Treatment Mechanism:** settling.
- **Locations:** away from buildings and on large sites.
- **Benefits:** inexpensive to construct and low maintenance.

Under current MRP requirements, the use of detention measures as stand-alone treatment is not allowed.



Detention Basin Isometric View (Caltrans 2020)



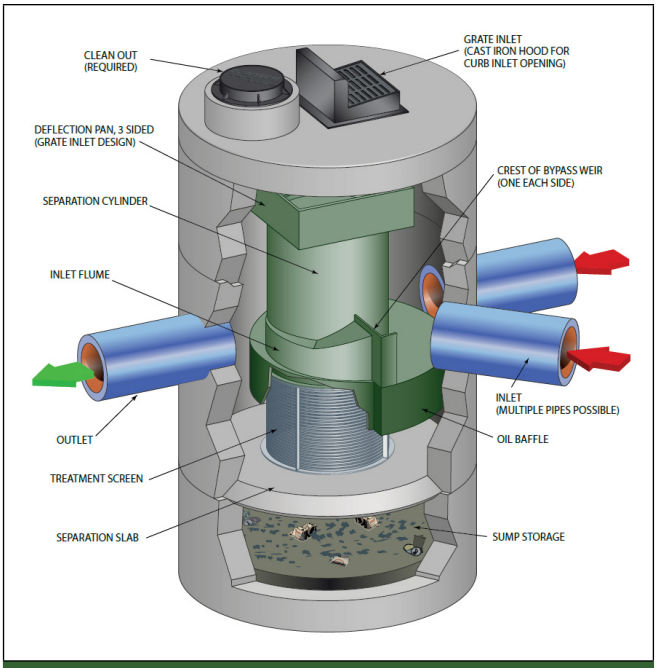
Detention Basin Schematic (Caltrans 2020)

2.5.2b Hydrodynamic Separators (HDS)

These non-LID, non-GSI stormwater treatment measures are flow-through structures that use centrifugal force (provided by the force of flowing water) to remove sediment, trash, and oil and grease (SCVURPPP, 2024).

- **Treatment Mechanism:** hydrodynamic separation.
- **Locations:** underground in accessible areas with overhead clearance.
- **Benefits:** trash (full capture certified device) and other pollutant removal, and act as pretreatment.

Under current MRP requirements, HDS units cannot be used as stand-alone for LID requirements.



Hydrodynamic Separator (Conteches.com)

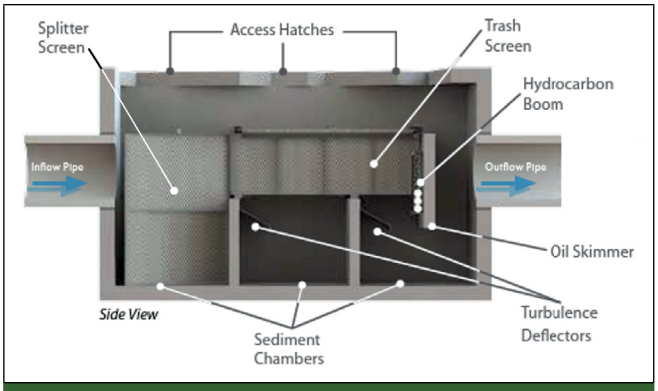
2.5.2c Debris Separating Baffle Box (DSBB)

This non-LID, non-GSI stormwater treatment measure is a rectangular chamber with a screening system suspended above sedimentation chambers to separate trash, debris, oil, and other pollutants from stormwater.

- **Treatment Mechanism:** settling and screening.
- **Locations:** underground in accessible areas with overhead clearance.
- **Benefits:** trash (full capture certified device) and other pollutant removal, and can act as pretreatment.

Under current MRP requirements, HDS units cannot be used as stand-alone for LID requirements.

This non-LID, non-GSI stormwater treatment measure is a rectangular chamber with a screening system suspended above sedimentation chambers to separate trash, debris, oil, and other pollutants from stormwater.



Debris Separating Baffle Box (Conteches.com)

2.6. GSI Measure Scales

GSI measures can be sized and designed to treat stormwater runoff from different drainage area sizes. Typical GSI measure implementation scales are described below:

- **Green streets** – GSI and other treatment controls may be installed on roadways and as part of public storm drain infrastructure to treat stormwater runoff in public rights-of way. Often, green streets are integrated with other sustainability features, such as traffic-calming, street trees, and bike lanes. These are typically Retrofit Projects treating existing urban area.
- **Parcel-based** – GSI installed on parcels which treat stormwater from a portion or all of the parcel. Typically, Regulated Projects use parcel-based treatment for a new or re-development project. Parcel-based treatment can also be used to treat existing urban parcels as a stormwater treatment Retrofit Project.
- **Regional** – GSI captures and treats stormwater runoff from a larger drainage area, often including streets and multiple parcels (e.g., multiple neighborhood blocks to an entire neighborhood). These are typically Retrofit Projects treating existing urban area and not associated with a Regulated Project.

Visual examples of different GSI scales are provided in **Section 2.7**.

2.7. Integrating GSI into Typical Urban Sites

A designer has many options for integrating GSI into typical urban sites. At the most basic level, GSI must be located where runoff can be intercepted. Inlets located at a sidewalk or street provide access for stormwater to enter the GSI measure. In **Figure 2a** (from SCVURPPP, 2019), curb cuts along both the street and the sidewalk allow stormwater runoff to enter a bioretention facility and be treated.

A three-dimensional image of how a streetside bioretention captures stormwater, filters it, and discharges to the storm drain system is shown in **Figure 2b** (included in SCVURPPP, 2019). Like the image above, inlets on the street and the sidewalk allow stormwater runoff to enter the bioretention facilities, which are placed in the right-of-way parkway. Pedestrian access is provided through crossing areas. Treated stormwater enters the underdrain (a perforated pipe which conveys flow along the base of the GSI measure) and/or is infiltrated to the subsurface if groundwater depth and underlying soil is suitable.

GSI measure underdrains, where provided, are hydraulically connected to the storm drain system, and convey treated runoff to the closest storm drainpipe.

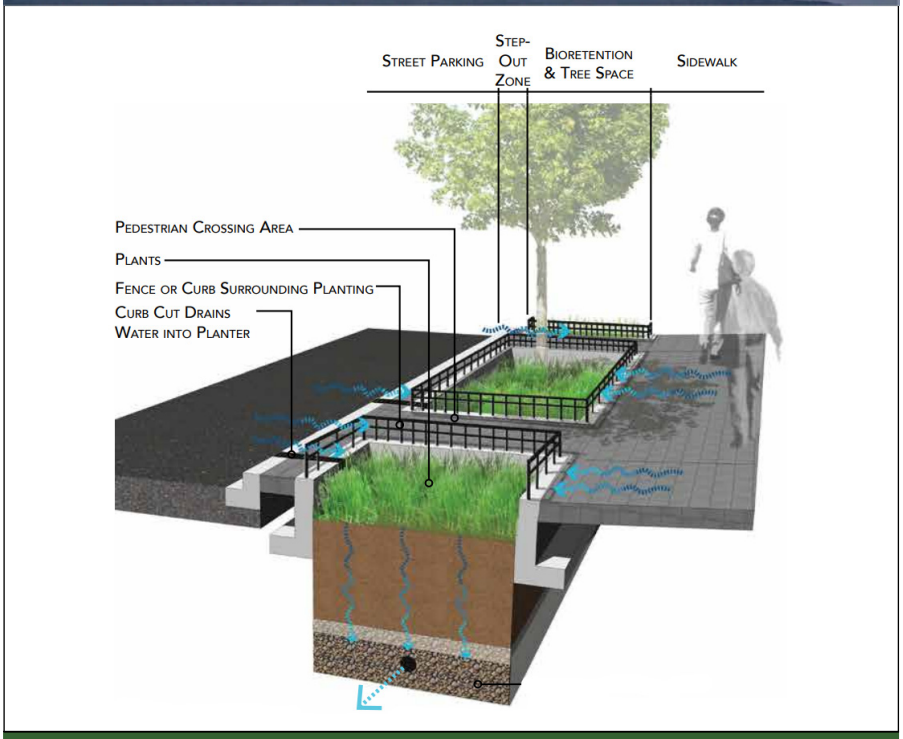


Figure 2: (a) Stormwater Curb Extension and Corner Bulb-Out in Southgate Neighborhood, City of Palo Alto (Credit: EOA), (b) Conceptual Stormwater Planter (Credit: DDOT)

2.7.1 Examples of Placement Options

Below are visual examples of GSI Measures in the urban environment for designers to reference when deciding where and how to place a GSI measure in their project. Most of the images show bioretention facilities, which meet MRP requirements for LID and are relatively easy to place in the urban settings shown. Although ease of maintenance is not considered in this section, designers should always consider GSI design with maintenance in mind due to cost constraints and logistical challenges in the right-of-way.

Typical Urban GSI Measure Applications

Bioretention bulb-out at Kellogg and Middlefield, City of Palo Alto

Bioretention with vertical walls located in parkway with step out zone for passengers exiting parked cars in El Cerrito (SFEI, 2012)

Bioretention bulb-out in Southgate neighborhood with parking not allowed, City of Palo Alto

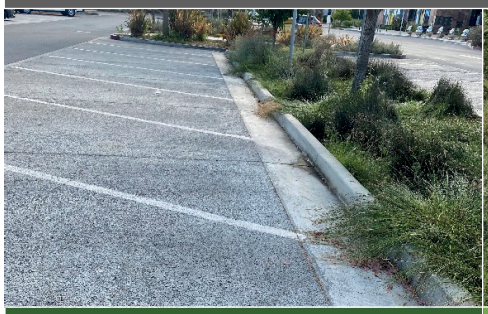
GSI Measures Integrated with Multi-Modal Transportation Features

Bioretention adjacent to bike lane located at Charleston-Arastradero, City of Palo Alto

Bioretention bulb-out integrated with ADA curb ramp crossing at Kellogg and Middlefield, City of Palo Alto

Bioretention curb extension and suspended pavement system integrated with bus stop, Castro Valley (from Google Earth)

Parcel-Based GSI Measures



Porous Concrete at Mitchell Library Parking Lot, City of Palo Alto

Parking Stall Pavers at Fire Station #3, City of Palo Alto

Infiltration GSI Measure under Mayfield Soccer Complex/ Stanford Playfield, City of Palo Alto (Image credit: BFS Landscape Architects)

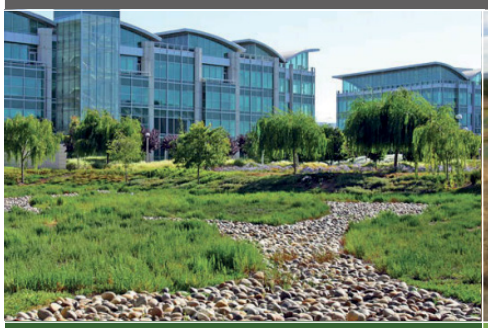
Parcel-Based GSI Measures on City Property

Fire Station #3 Bioretention area, City of Palo Alto

Flow-through Planter adjacent to California Avenue Parking Structure, City of Palo Alto

Green Roof on Mitchell Library, City of Palo Alto

Regional GSI Measures



Example of Regional Treatment Facility when Dry at Pacific Shores Center in Redwood City, California (DES Architects +Engineers)

Conceptual Rendering - Kelley Park Disc Course, City of San Jose

2.8. GSI and Climate Resilience

"Resilience," as defined by the U.S. Climate Resilience Toolkit, is "the capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption." GSI can be a valuable tool for communities to adapt to climate change and buffer against negative impacts. GSI designers should consider having projects address climate resilience when feasible to reap multiple benefits. The climate impacts that GSI could partially mitigate include:

- Urban heat, through implementation of cooling vegetation;
- Localized flooding, by retaining and detaining peak flows;
- Erosion, by reducing peak flows to downstream receiving waters;
- Water supply challenges, through capture and use of stormwater;
- Air quality, through implementation of vegetation; and
- Human health, through urban greening benefits.

There are limitations to using GSI to solve all community climate-related challenges. GSI is one of an extensive set of solutions to increase community resilience to climate change.

- The Climate Resilience Resource Guide was developed to explore the intersection of GSI and urban impacts from climate change and examines decision-making processes for planning and implementing GSI based on climate resilience, public engagement, and equity considerations. Refer to this guide for guidance regarding planning and implementation of GSI for climate resilience.

3. Siting, Selecting, and Sizing GSI Measures

This section provides an overview and step-by-step information on how to site, select, and size GSI measures. It assumes that more than one GSI measure may be installed to address the site's stormwater runoff due to site constraints, grade of the ground surface, and other criteria. These steps should be followed for each GSI measure. This GSI Handbook recommends the following GSI measure design process:

1. Incorporate LID site design measures

For Regulated Projects, identify locations within your project where site design measures can be incorporated to reduce the impervious surface GSI measures must treat.

2. Site the GSI Measure

Identify a location or locations within or adjacent to your project where the project runoff will drain, and there are no physical siting constraints. **Section 3.2** below provides specific requirements that must be followed in the City of Palo Alto.

3. Delineate the project drainage area

Outline the drainage management area(s) where runoff will drain into GSI measure(s).

4. Select a GSI Measure

Select one or more appropriate GSI measure type(s) for your site.

5. Size the GSI Measure

Size the GSI measure(s) per requirements.

Details of these steps are provided in this section. Steps 1 through 3 are an iterative process, and Steps 1 and 2 may be conducted in parallel. After the GSI measure(s) has been sited, selected, and sized, a design is developed for the GSI measure.

6. Design the GSI Measure

GSI measure design is covered in **Section 4**.

Details of these steps are provided in **Sections 3.1-3.5**. Steps 1 through 3 are an iterative process, and Steps 1 and 2 may be conducted in parallel. After the GSI measure(s) has been sited, selected, and sized, a design is developed for the GSI measure. GSI measure design (Step 6) is covered in **Section 4**.

3.1. Step 1: LID Site Design Measures

A project designer should incorporate LID site design measures in combination with GSI into their project to effectively treat the runoff and protect and increase the natural features of the site. This is specifically applicable to Regulated Projects but should be considered for parcel-based retrofits and some green street applications as well. A detailed summary of LID site design measures is provided in **Chapter 4** of the SCVURPPP C.3 Stormwater Handbook. Examples of LID site design measures to incorporate on the site include:

1. Designing or identifying self-treating areas and self-retaining areas.
2. Reducing the size of impervious features.
3. Implementing on-site stormwater capture and use.
4. Preserving and planting trees and avoiding soil compaction in areas without structures.

After these LID site design measures have been implemented, the designer may identify the remaining drainage area to be treated with GSI measures.

3.2. Step 2: City GSI Measure Siting Requirements

Several physical constraints must be considered when siting GSI measures. These include subsurface conditions, such as underlying groundwater depth, soil types, and existing contamination; existing infrastructure, such as utilities and foundations; existing street trees; and other site uses. When conducting Step 4 (GSI Measure Section for the Site) of the process, designers must consider regional and City siting constraints and requirements. **Table 2** provides a summary of Palo Alto-specific constraints. In addition to these constraints, best professional judgment should always be used when siting GSI.

Table 2: GSI Measure Siting Constraints and Requirements

Constraint	GSI Measure Siting Requirement	Reference
Depth to Groundwater	The base of unlined measures must be 10 feet from seasonal high groundwater. The base of lined measures must be at least 5 feet from seasonal high groundwater.	MRP C.3.d.iii, SCVURPPP C.3 Stormwater Handbook, Chapter 6
Underlying soil or groundwater contamination	Unlined measures must be at least 1,500 horizontal feet from underlying contamination. Distance from subsurface contamination for lined measures should be determined based on designer's best professional judgment.	SCVURPPP C.3 Stormwater Handbook, Appendix A, Table A-1

Constraint	GSI Measure Siting Requirement	Reference
Drinking water wells	Unlined measures must be at least 1,500 horizontal feet from drinking water wells. Distance from drinking water wells for lined measures should be determined based on designer's best professional judgment.	SCVURPPP C.3 Stormwater Handbook, Appendix A, Table A-1
Septic systems	Unlined measures must be set back at least 100 feet from septic systems. Distance from septic systems for lined measures should be determined based on designer's best professional judgment.	SCVURPPP C.3 Stormwater Handbook, Appendix A, Table A-1
Underground Storage Tanks (USTs)	Unlined measures must be set back at least 250 feet from USTs for depth to groundwater of 0-15 feet and at least 100 feet from USTs for depth to groundwater greater than 15 ft. Distance from drinking water wells for lined measures should be determined based on designer's best professional judgment.	SCVURPPP C.3 Stormwater Handbook, Appendix A, Table A-1. Specific Note H
Underlying soil infiltration rate	GSI measures (both lined and unlined) must include an underdrain when existing subsurface soils have an infiltration rate less than 0.5 inches per hour[1] and anytime when the GSI measure is lined.	SCVURPPP C.3 Stormwater Handbook, Section 5.4
Geotechnical hazards	Measures may not be sited overlying mapped geotechnical hazards without geotechnical engineer approval.	SCVURPPP C.3 Stormwater Handbook, Section 5.3
Building setbacks	Measures should be located at least 18 feet horizontal distance from building foundation for infiltrating facilities. GSI measures must be lined if they are less than 10 feet horizontal distance from building foundation.	SCVURPPP C.3 Stormwater Handbook, Sections 6.1, 6.4 & 6.5.

[1] Infiltration rate should be determined by available site-specific boring log or percolation test data, or through conducting a percolation test recommended by a geotechnical engineer (per SCVURPPP C.3 Stormwater Handbook section 5.3).

Constraint	GSI Measure Siting Requirement	Reference
Utilities	Measures should be located at least 5 feet horizontal separation from: • Primary utility pipelines, including concrete encased utility lines • Electrical vaults, unless City-approved water-tight material is installed to full extent of concrete encasement, in which 2 feet clearance is allowed • Concrete foundations (5 feet of native soil)	Communication with Palo Alto Utilities Department, November/ December 2021
	Maintain a minimum of 2 feet horizontal clearance between the edge of measure and outside wall of any electric, water, gas, and wastewater main/service pipes or electric duct banks, regardless of the elevation of the existing utility pipe or duct bank.	Communication with Palo Alto Utilities Department, April 2023
	Measures must have at least 10 feet vertical clearance from overhead utilities.	Communication with Palo Alto Utilities Department, November/ December 2021 California Public Utilities Commission General Order No. 95
	No electric, water, gas, or wastewater valves, manholes, and main/service pipes or electric duct banks and vaults are allowed within measure footprint.	Communication with Palo Alto Utilities Department, November/December 2021 and April 2023
Trees	Protection of existing trees requires a tree protection zone either 10 times the tree diameter or a 10-foot setback, whichever is greater.	City of Palo Alto Tree and Landscape Technical Manual, 2025
Street Widths	Minimum street widths must be maintained: • Major Arterial - 60 feet • Collector Street - 40 feet • Cul-De-Sac Street - 30 feet	Public Works City Standard Drawing No. 201: Minimum Street Standards

Constraint	GSI Measure Siting Requirement	Reference
Bike Lanes	Minimum bike lane width of 5 feet must be maintained.	City of Palo Alto Bicycle + Pedestrian Transportation Plan, Appendix A
Other Multi-Modal Transportation Requirements	Minimum bus lane widths must be maintained: • Curbside bus lanes - 11 feet • Offset bus lanes - 10 feet • Median Bus Lanes – 11 feet • Multi-use path – 12 feet	National Association of City Transportation Officials (NACTO) Urban Street Design Guide
Sidewalk (ADA) Requirements	Minimum sidewalk width of either the existing sidewalk width or five (5) feet, whichever is greater, must be maintained.	Public Works Technical Specifications Section 16 Public Works City Standard Dwg No. 141: Sidewalk Construction
Turning Radius	Allow a turning radius of 40 feet for waste management and street sweeping. Wall-to- wall turning radii of 29 feet should be provided for fire trucks.	Coordinate with GreenWaste, Public Works, and Fire Department for applicable truck turning templates and site review
Higher Speed Limit Street Setbacks	Set back measures on streets with higher speeds. Use reference to determine specifics.	Consult California Manual of Uniform Traffic Control Devices (MUTCD) and the Caltrans Highway Design Manual
Site Slopes	Measures should not be constructed on slopes greater than 4% unless constructed as a series of cells using check dams. Check dams should be placed every 4” to 6” of elevation change, the slope within a cell should not exceed 2% and cells are not recommended if the overall slope exceeds 8%.	SCVURPPP C.3 Stormwater Handbook, Chapter 6

3.3. Step 3: Drainage Area Delineation

GSI measures must be sited where they can capture the stormwater runoff generated from the desired drainage area. Several considerations must be made when a designer is conducting drainage delineation and siting for a project.

1. A designer should delineate the project drainage area using the topography of the site and consider where untreated stormwater flows.

    a. For **Regulated Projects**, site surveys or grading plans, which display site measurements and elevations on the surface and underground in a map format, are available to provide this information (typically in AutoCAD software). An engineer/designer can use the site survey to determine which direction stormwater runoff generated within the project boundary will flow along the ground surface (i.e., perpendicular to grade lines and downhill).

    b. For **Retrofit Projects**, detailed survey information is not always available (as with Regulated Projects). If detailed survey information is not available for the project, publicly available topography and storm drain data can be used to identify where the project area runoff will flow, and a designer can delineate the drainage area using geospatial information system (GIS) software (instead of AutoCAD).

    c. For **Regional (retrofit) GSI Projects**, drainage delineation may incorporate surface runoff and flows from existing storm drain pipes. As these projects capture runoff from a much larger area, typically stormwater collected through existing storm drain pipes is diverted to the regional project. To delineate the drainage area for a regional project, the surface tributary area to all of the storm drain pipes from which stormwater runoff will be diverted from, must be delineated. This can be done in GIS using geospatial storm drain data with flow direction and topography data.

2. After an initial drainage area is delineated at the desktop level (i.e., by using a computer), a field visit should be conducted to confirm the drainage area during a storm event, which will allow a visual check of the drainage area. In many cases, given the frequency of rain events, the field visit may need to take place in dry weather. Often visual observations of site slope are sufficient to check desktop delineation estimates. However, a construction laser level and rod can be used to help find high points in a project area for very flat drainage areas.

3. Once a project drainage area is delineated, it should be divided into drainage management areas (DMAs) based on where runoff drains. **One GSI measure must be sited for each DMA.** An example of a Stormwater Management Plan showing DMAs and the proposed GSI treatment (for Palo Alto Safety Building) is provided as **Attachment C**.[6]

4. Once the DMAs are identified, the location(s) they drain towards must be examined for GSI measure siting suitability. The siting requirements for GSI measures are provided in **Section 3.4**. If the location is not suitable for a GSI measure, the measure may need to be sited in a different location where physical constraints to siting are not present. **Project grading (if Regulated Project), drainage area delineation, and GSI measure siting may need to be conducted iteratively** until feasible GSI measure siting location(s) can be found that capture all project runoff.

[6] Refer to the SCVURPPP C.3 Handbook Chapter 3 Section 3.2 How to Prepare a Stormwater Management Plan

3.4. Step 4: GSI Measure Selection for the Site

After the DMA(s) is delineated and GSI measure location(s) is identified, GSI measure type(s) can be selected. The type(s) selected should be based on the physical site conditions and the intended or existing site uses. First, the subsurface conditions should be characterized to determine the infiltration feasibility underneath the GSI measure. There are many hydrologic and water quality benefits to infiltration and the volume of site stormwater infiltrated should be maximized where possible. There are three classes of infiltration feasibility defined in this GSI Handbook:

1. **Lined GSI Measure is Required** – If it is hazardous to infiltrate due to high groundwater or geotechnical concerns or steep slopes, underlying soil or groundwater contamination that could be mobilized, adjacent land uses with higher levels of water quality pollutants (e.g., industrial facilities, gas stations, etc.), or nearby structures, wells or other infrastructure, GSI measures must be lined.

2. **Unlined GSI Measure is Recommended** – If no infiltration hazards exist and the underlying infiltration rate is less than 0.5 inches per hour, the GSI measure should be installed with an underdrain but should remain unlined to maximize the infiltration below it. Pervious pavements that are designed to store the MRP-required water quality volume may be installed without an underdrain even in areas with low soil infiltration rates.

3. **Infiltrating GSI Measure is Recommended** – If no infiltration hazards exist and the underlying infiltration rate is at least 0.5 inches per hour determined by available site-specific boring log or percolation test data, or through conducting a percolation test recommended by a geotechnical engineer and applying an appropriate factor of safety, an infiltrating GSI measure is recommended for the site and is designed to fully infiltrate the MRP (Provision C.3.d) required water quality volume.

Flow charts are provided in **Attachment D** to provide recommendations for GSI measure types corresponding to specific site conditions and infiltration feasibility. These include whether the project is a parcel-based or roadway project, along with other characteristics. The flow charts provide the GSI measure names and detail numbers recommended for specific project conditions that can be referenced in **Attachment F**. These recommendations apply to general site conditions and may not result in the best GSI measure type in all cases. For any project, the designer should consider all site conditions and uses when selecting a GSI measure type for a specific project site. A more detailed GSI measure selection matrix is provided in **Attachment D** for reference and can also be found in the SCVURPPP GSI Handbook, **Chapter 2** (SCVURPPP, 2019).

The flow charts do not include recommendations for regional (retrofit) project sites as these projects vary considerably in terms of drainage area, site type, space availability, and other considerations and require a site-specific design. Also, the flow charts do not include recommendations for treatment trains, which are also site-specific. A treatment train is a multiple treatment system that uses two or more GSI measures in series. While treatment trains can refer to a pretreatment measure that drains to a GSI measure, often they are applied in specific situations where a site has distinct site uses. This could be as simple as a parcel with a building and a plaza, where a flow-through planter is installed to treat the building, and the treated runoff drains towards a second GSI measure that treats the plaza for hydrologic or hydraulic reasons. It could also include a site that implements a GSI measure that captures some portion of the required MRP C.3.d water quality volume (e.g., a rainwater harvesting system, which often must be very large to capture the full C.3.d water quality volume) and directs the remainder of the required MRP C.3.d water quality volume to a downstream GSI measure such as bioretention.

Pretreatment should be provided for infiltrating GSI measures if sediment migration from the drainage area

is a concern. The C.3 Stormwater Handbook provides additional details on pretreatment measure options (SCVURPPP, 2024).

3.5. Step 5: GSI Measure Sizing

All GSI measures must be sized to meet MRP Provision C.3.d sizing requirements. General guidance for proper sizing and design concepts are outlined in **Chapter 5** of the SCVURPPP C.3 Stormwater Handbook (SCVURPPP, 2024) and Technical Guidance for Stormwater Treatment and Site Design Measures is provided in the SCVURPPP C.3 Stormwater Handbook, **Chapter 6** (SCVURPPP, 2024). A summary of the sizing requirements for the GSI measures listed in **Section 2.3** are shown in **Table 3**. The sizing methods listed in the table will be discussed in this section.

Table 3: Summary of Sizing Requirements

GSI Measure Type	Sizing Requirement	Recommended Sizing Method
Bioretention Area	C.3.d Numeric Criteria	Simple Sizing Method (i.e., 4% of Impervious Drainage Area)
Flow-Through Planter	C.3.d Numeric Criteria	Simple Sizing Method
Suspended Pavement Systems	C.3.d Numeric Criteria	Simple Sizing Method
Tree Well Filters	C.3.d Numeric Criteria	Simple Sizing Method
Infiltration GSI Measures	C.3.d Numeric Criteria	Volume-Based Sizing
Rainwater Harvesting	C.3.d Numeric Criteria	SCVURPPP Rainwater Harvesting Method (SCVURPPP C.3 Handbook, Appendix I (2024)
Pervious Pavement	Self-Treating/Self-Retaining Area	Volume-Based Sizing (a maximum 2:1 ratio of impervious area to the receiving pervious area)
Green Roof	Self-Treating/Self-Retaining Area	Volume-Based Sizing

The sizing method may also be determined based on whether the GSI measure is a "flow-based" measure, or a "volume-based" measure. Flow-based measures treat pollutants from a constantly moving stream of water through infiltration, filtration, and other processes. Volume-based measures rely on storing or detaining stormwater for some length of time to allow for settling of pollutants before stormwater is subsequently infiltrated, filtered, or discharged.

3.5.1. Simple Sizing Method

The SCVURPPP C.3 Stormwater Handbook recommends a simplified sizing method for bioretention, flow-through planters, non-proprietary tree well filters, and suspended pavement systems. This sizing method entails sizing a volume-based biotreatment GSI measure such that its footprint is equal to 4% of the impervious drainage area. This assumes that the biotreatment measure is designed with a standard cross-section (see GSI details, **Section 4.2**) and biotreatment soil media (see **Section 4.3**) with a minimum infiltration rate of 5 inches per hour. Flow-through planters and bioretention areas can also use a sizing method based on a combination of flow and volume for stormwater treatment as they use both detention and filtration processes to treat stormwater.

3.5.2. Volume-Based Sizing

Infiltration GSI measures and rainwater harvesting systems should be sized using a volume-based approach. As summarized in the SCVURPPP C.3 Stormwater Handbook **Section 5.1** (2024, the MRP allows for two sizing methods for volume based GSI measures:

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

Worksheets for volume-based sizing using the URQM approach and California BMP Handbook approach are provided in Attachment F of this GSI Handbook and **Appendix B** of the SCVURPPP C.3 Stormwater Handbook (2024). Sizing of rainwater harvesting systems must consider use demand. If a rainwater harvesting system will be designed to fully meet Provision C.3.d stormwater requirements, there must be sufficient demand to use the water quality design volume, i.e., 80% of the average annual rainfall runoff, from the collection area. If the rainwater harvesting system is designed for less than the water quality design volume, the overflow must receive additional treatment, e.g., by infiltration in landscaping or by infiltration/biotreatment in a bioretention area to fully capture the required Provision C.3.d water quality design volume and be considered compliant with the MRP. **Attachment F of this GSI Handbook includes a method and worksheet for sizing rainwater harvesting systems which can also be found in the SCVURPPP C.3 Stormwater Handbook (2024), Appendix I.**

Pervious pavement and green roofs can be self-treating or self-retaining areas. Pervious pavement can be sized to treat its own area plus run-on from a drainage area two times the area of the pavement itself (i.e., a maximum 2:1 ratio of impervious area to the receiving pervious area is acceptable per the SCVURPPP C.3 Stormwater Handbook), providing that there is adequate storage volume. The volume provided in the

storage layer below the pervious pavement and the green roof needs to be sized to store the required C.3.d water quality design volume. The required storage volume can be calculated using the MRP volume-based sizing methods.

If the GSI measure is a public Retrofit Project that is in a space-constrained roadway location, an alternative sizing method may be used per the BASMAA Guidance for Sizing Green Infrastructure Facilities in Street Projects (BASMAA, 2019), which allows for a smaller footprint size while still providing the MRP C.3.d water quality volume through 80% capture of average annual runoff volume.

The SCVURPPP C.3 Stormwater Handbook recommends that when treatment trains are used, each GSI measure must be sized to meet the C.3.d numeric sizing criteria. When pretreatment is provided, the downstream GSI measure must be sized to capture the full MRP C.3.d water quality volume.

4. Designing GSI Measures

4.1. Overview of GSI Design

When designing GSI, compliance requirements, GSI measure function, and consistency with City standards (including protection of existing infrastructure) must be considered. Development of the GSI design must consider existing site uses, ease of maintenance, and the design parameters provided in the typical details. Issues can arise through design or installation that impact GSI measure functionality or the surrounding site uses. Examples of these design or installation issues, including inlets blocked from vegetation, outlet structures installed below inlets such that ponding is not possible, and other challenges, are further discussed in the City's Compendium of Lessons Learned – Observations and Recommendations (City of Palo Alto, 2021).

4.2. GSI Typical Details

GSI Details from several sources were compiled for the SCVURPPP GSI Handbook (Part 2). A selection of these details was identified to likely work best in the City of Palo Alto. They were then edited for consistency with City standards and are provided for reference in **Attachment E**. **Table 4** below provides a summary of the details included in this Palo Alto GSI Handbook.

City staff should refer to these details when installing GSI on City property and the right-of-way, particularly when carrying out Steps 4 and 5 of the GSI design measure process.

Table 4: City of Palo Alto GSI Handbook Details

City Detail Number	GSI Measure Type	Detail Name	Adapted From
801	Bioretention	Bioretention Planter Designer Notes	SFPUC BP 1.1 and BP 1.2
802	Bioretention	Bioretention Planter with Vertical Walls	SFPUC BP 2.1
803	Bioretention	Bioretention Planter with Vertical Wall Sections	SFPUC BP 2.2
804	Bioretention	Bioretention Planter Midblock Curb Extension	SFPUC BP 4.1
805	Bioretention	Bioretention Planter Corner Curb Extension	SFPUC BP 4.4
806	Bioretention	Bioretention Planter Midblock Bulb-Out with Raised Bike Lane and Pedestrian Crossing	BASMAA Urban Greening C-1.4
807	Bioretention	Bioretention Area Designer Notes	SFPUC BB 1.1
808	Bioretention	Bioretention Area Parcel Section	SFPUC BB 2.2
809	Bioretention	Bioretention Components - Inlet Designer Notes	SFPUC BC 2.1
810	Bioretention	Bioretention Components - Curb Cut at Bulb-Out	SFPUC BC 2.3

City Detail Number	GSI Measure Type	Detail Name	Adapted From
811	Bioretention	Bioretention Components - Curb Cut with Gutter Modification	SFPUC BC 2.2
812	Bioretention	Bioretention Components - Curb Cut with Wheel Guard	City of Dublin Public Works GI-6A (Originally SFPUC)
813	Bioretention	Bioretention Components - Curb Cut with Trench Drains	SFPUC BC 2.4
814	Bioretention	Bioretention Components - Curb Cut with Metal Trench Drain Cover	DC DOT 621.44
815	Bioretention	Bioretention Components - Underdrain Designer Notes	SFPUC BC 5.1
816	Bioretention	Bioretention Components - Underdrain	SFPUC BC 5.2
817	Bioretention	Bioretention Components - Overflow Structure Option #1	City of Dublin Public Works GI-4 (originally SFPUC)
818	Bioretention	Bioretention Components - Overflow Structure Option #2	LIDI SW-23 and SCVURPPP GSI Handbook Part 2
819	Bioretention	Bioretention Components - Rock Splash Pad	Philadelphia 4.1.1
820	Bioretention	Bioretention Components - Check Dam Designer Notes	SFPUC BC 6.1
821	Bioretention	Bioretention Components - Check Dam	SFPUC BC 6.2
822	Flow-Through Planter	Flow-Through Planter Designer Notes (1 of 2)	SFPUC BP 5.1
823	Flow-Through Planter	Flow-Through Planter Designer Notes (2 of 2)	SFPUC BP 5.2

City Detail Number	GSI Measure Type	Detail Name	Adapted From
824	Flow-Through Planter	Flow-Through Planter Setback from Structure	SFPUC BP 5.3
825	Flow-Through Planter	Flow-Through Planter Against Structure	SFPUC BP 5.4
826	Flow-Through Planter	Flow-Through Planter - Raised Planter Section	SFPUC BP 5.5
827	Flow-Through Planter	Flow-Through Planter - At-Grade Planter Section	SFPUC BP 5.6
828	Flow-Through Planter	Flow-Through Planter - On Structure Planter Section	SFPUC BP 5.7
901	Infiltration GSI Measure	Subsurface Infiltration - System Designer Notes (1 of 2)	SFPUC SI 1.1
902	Infiltration GSI Measure	Subsurface Infiltration - System Designer Notes (2 of 2)	SFPUC SI 1.2
903	Infiltration GSI Measure	Subsurface Infiltration System Infiltration Gallery - Large System Plan	SFPUC SI 2.1
904	Infiltration GSI Measure	Subsurface Infiltration System Infiltration Gallery - Large System Section	SFPUC SI 2.2
905	Infiltration GSI Measure	Drywell and Designer Notes	CASQA/LIDI SW-27
906	Infiltration GSI Measure	Drywell Specifications	CASQA/LIDI SW-27
1001	Pervious Pavement	Pervious Pavement Designer Notes (1 of 2)	SFPUC PP 1.1
1002	Pervious Pavement	Pervious Pavement Designer Notes (2 of 2)	SFPUC PP 1.2

City Detail Number	GSI Measure Type	Detail Name	Adapted From
1003	Pervious Pavement	Pervious Pavement Key Map	SFPUC PP 1.3
1004	Pervious Pavement	Pervious Pavement - Permeable Interlocking Concrete Pavers	SFPUC PP 2.1
1005	Pervious Pavement	Pervious Pavement - Pervious Concrete	SFPUC PP 3.1
1006	Pervious Pavement	Pervious Pavement - Porous Asphalt	SFPUC PP 4.1
1007	Pervious Pavement	Pavement Components - Edge Treatment Designer Notes	SFPUC PC 1.1
1008	Pervious Pavement	Pavement Components - Edge Treatment Key Map	SFPUC PC 1.2
1009	Pervious Pavement	Pavement Components - Edge Treatment Vehicular Applications	SFPUC PC 1.3
1010	Pervious Pavement	Pavement Components - Subsurface Underdrain Designer Notes	SFPUC PC 3.1
1011	Pervious Pavement	Pavement Components - Subsurface Underdrain Profile and Notes	SFPUC PC 3.3 and PC 3.4
1101	Tree Well	Tree Well Filter Plan and Notes	City of Fremont LSD-29
1102	Tree Well	Tree Well Filter Sections and Notes	City of Fremont LSD-30
1201	Suspended Pavement System	Suspended Pavement System - Silva Cell Components Bioretention Application	DeepRoot Figure 1
1202	Suspended Pavement System	Suspended Pavement System - Silva Cell[12] Components Plan and Section	DeepRoot Figure 2

City Detail Number	GSI Measure Type	Detail Name	Adapted From
1203	Suspended Pavement System	Suspended Pavement System - Silva Cell[12] Hydraulic Components – Plan and Sections	DeepRoot Figure 3
1204	Suspended Pavement System	Suspended Pavement System - Silva Cell[12] Inlet Details Sections	DeepRoot Figure 4
1301	General Detail	General Components - Liner Designer Notes	SFPUC GC 1.1
1302	General Detail	General Components - Liners and Attachments	SFPUC GC 1.2
1303	General Detail	General Components - Utility Crossings Wall Penetrations	SFPUC GC 2.10
1304	General Detail	General Components - Cleanouts	SFPUC GC 5.1
1305	General Detail	General Components - Observation Port Designer Notes	SFPUC GC 4.1
1306	General Detail	General Components - Observation Port, Bioretention	SFPUC GC 4.2
1307	General Detail	General Components - Observation Port, Pervious Pavement	SFPUC GC 4.3
1308	General Detail	General Components - Fencing	Moreland Australia SK007

4.3. GSI Measure Specifications

The following specifications should be used for City of Palo Alto projects. SFPUC specifications for (1) bioretention, (2) porous asphalt concrete, (3) pervious concrete, and (4) permeable/porous unit pavers were revised for the SCVURPPP GSI Handbook (2019) to include MRP requirements. These three specifications, which provide detailed information about GSI measure materials, installation practices, tests, and roles of installers and inspectors, are provided in **Attachment G** to this GSI Handbook to be used by the City of Palo Alto. Specifications are not available for the remainder of the GSI measure types included in this Handbook.

The bioretention specification provided in **Attachment G** includes specifications for biotreatment soil media (BSM) developed by the Bay Area Stormwater Management Agencies Association. A BSM verification

checklist developed by SCVURPPP follows the BSM specifications. For an up-to-date list of BSM suppliers, visit SCVURPPP's website on Biotreatment Soil Media and Mulch Guidance. **Attachment G** also includes a wood mulch specification prepared by SCVURPPP (EOA, Inc. and R. Alexander Associates, 2021).

4.4. City GSI Plant List

The City is developing a list of native plants that are better suited to the climate, soil, irrigation, and submersion conditions found in GSI measures. At this time, it is recommended that project managers refer to Appendix D of the SCVURPPP C.3 Stormwater Handbook for plant selection and planting guidance for GSI measures.

4.5. Project Plan Requirements

Once the above GSI design process is completed and details and specifications have been followed, detailed materials documenting the design and how it meets requirements should be developed for review by Stormwater Compliance staff. The Project Manager must include the information outlined below on the following civil drawing pages in the project plan: the Stormwater Management Plan [7], Stormwater Standard Details and Notes page, and Landscape Plan. In addition, the C.3 Data Form should be provided separately with the project plans. The project submittal should be submitted to Stormwater Compliance staff for review at or before the 35% design phase.

4.5.1 Stormwater Management Plan (See Attachment C)

- Drainage Management Areas, clearly delineated and labeled
- Stormwater Treatment Measure Summary Table (see **Attachment H** for an example template)
- C.3 Data Form Project Size Table (see page 2 of the C.3 Data Form)
- Stormwater Treatment Measures[8] (STM), clearly delineated, labeled, and numbered (e.g., STM #1, STM # 2, STM #3, etc.)

[7] Refer to the SCVURPPP C.3 Stormwater Handbook Chapter 3.2 for more guidance on preparation of the Stormwater Management Plan.

[8] Although Attachment C refers to Treatment Control Measures (TCM), the term Stormwater Treatment Measure (STM) is the preferred term in the City of Palo Alto.

4.5.2 Stormwater Standard Details and Notes Page

- City-Approved Standard Details for all Stormwater Treatment Measures and associated details (e.g., curb cuts, overflow, etc.) found in **Attachment E**. If a designer would like to use a detail not included in **Attachment E**, they should contact Stormwater Compliance staff. A detail needs to be shown for each type of STM (e.g., bioretention area, flow-through planter, pervious pavement, etc.) with the same label used in the Stormwater Management Plan. When providing a detail for duplicate STM types, label the detail with the numbers for each applicable STM as shown in **Figure 3** below (e.g., Flow-through Planter 1 lists that the detail applies to STM 1-23 & 32).
- At a minimum, include all relevant C.3 Development Standard Notes shown in **Figure 4**. Additional project relevant notes may be added as needed.
- Sizing Criteria Worksheets for the type of volume-based, flow based, or combination and flow volume approach sizing used for the STMs in the Stormwater Management Plan (See **Figure 5** for example template).

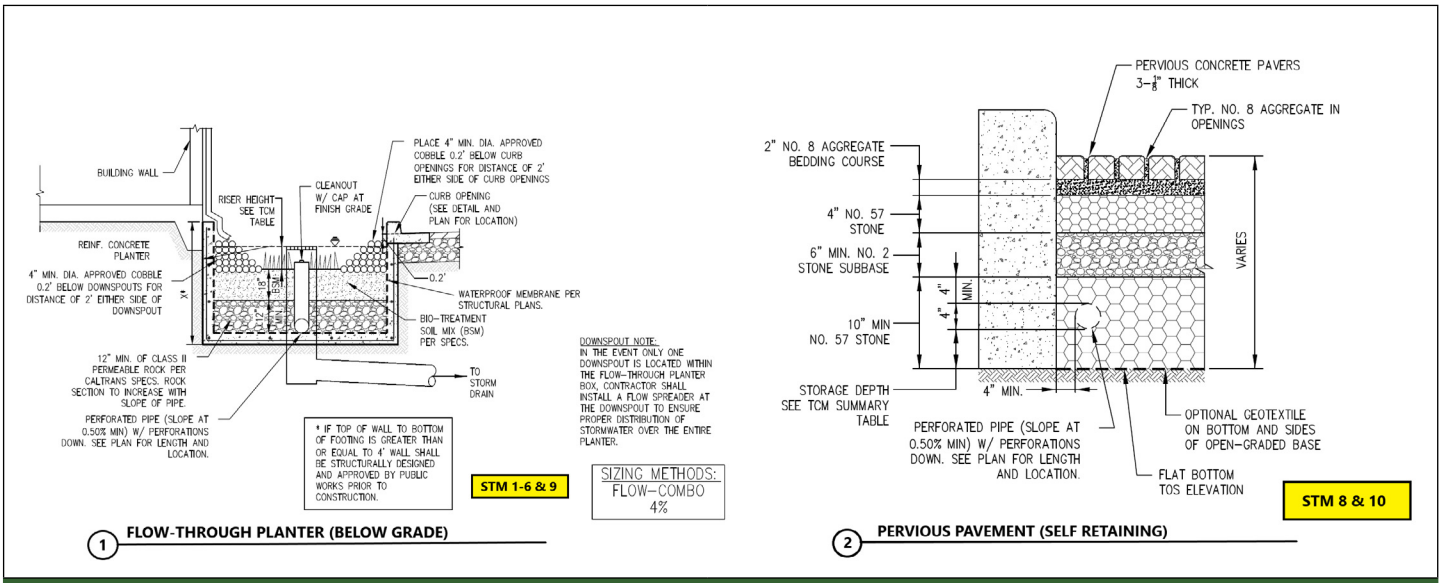


Figure 3: Standard Detail and STM Label example

Figure 4: C.3 Development Standard Notes

PROJECT SITE INFORMATION

1. SOIL(S) TYPE: _____
2. GROUNDWATER DEPTH: _____
3. NAME OF RECEIVING WATER: _____
4. FLOOD ZONE: _____
5. FLOOD ELEVATION (IF APPLICABLE): ___

STANDARD STORMWATER BEST MANAGEMENT PRACTICES (BMPs) NOTE

STORMWATER BEST MANAGEMENT PRACTICES (BMPs) ASSOCIATED WITH REFUSE MANAGEMENT (INCLUDING ACTIONS RELATED TO REFUSE PICK-UP AND THE ENCLOSURE ITSELF) SHALL BE FOLLOWED TO ENSURE POLLUTION PREVENTION AND PREVENT POTENTIAL DISCHARGES TO THE CITY'S STORM DRAIN SYSTEM. STORMWATER BMPs INCLUDE BUT ARE NOT LIMITED TO, POWER WASHING THE PAVEMENT ON BOTH THE PRIVATE PROPERTY AND IN THE RIGHT-OF-WAY AND SIDEWALK A MINIMUM OF ONCE PER YEAR BEFORE THE WET SEASON BEGINS ON OCTOBER 1ST; UTILIZING A POWER WASHING CONTRACTOR THAT IS A RECOGNIZED SURFACE CLEANER BY THE BAY AREA STORMWATER MANAGEMENT AGENCIES ASSOCIATION (BASMAA); DISPOSING OF WASH WATER ACCORDING TO THE RECOGNIZED SURFACE CLEANER CERTIFICATION REQUIREMENTS; AND REMOVING ANY POTENTIAL TRASH BUILD-UP ON A REGULAR BASIS.

STANDARD STORMWATER TREATMENT MEASURE NOTES

- STANDING WATER SHALL NOT REMAIN IN THE TREATMENT MEASURE FOR MORE THAN 5 DAYS TO PREVENT MOSQUITO GENERATION. SHOULD ANY MOSQUITO ISSUES ARISE, CONTACT THE SANTA CLARA COUNTY VECTOR CONTROL DISTRICT (DISTRICT) AT (408) 918-4770. MOSQUITO LARVICIDES SHALL BE APPLIED ONLY WHEN ABSOLUTELY NECESSARY, AS INDICATED BY THE DISTRICT, AND THEN ONLY BY A LICENSED PROFESSIONAL OR CONTRACTOR.
- DO NOT USE FERTILIZERS, PESTICIDES, HERBICIDES, OR OTHER CHEMICAL APPLICATIONS TO TREAT DISEASED PLANTS, CONTROL WEEDS, OR REMOVE UNWANTED GROWTH.
- DO NOT USE COMMERCIAL SOIL AMENDMENT. USE ORGANIC MATERIALS REVIEW INSTITUTE (OMRI) MATERIALS AND COMPOST. REFER TO THE BAY-FRIENDLY LANDSCAPE GUIDELINES: HTTP://WWW.STOPWASTE.ORG/RESOURCE/BROCHURES/BAY-FRIENDLY-LANDSCAPE-GUIDELINES-SUSTAINABLE-PRACTICES-LANDSCAPE-PROFESSIONAL AND RESCAPE.ORG FOR GUIDANCE.
- EMPLOY ONLY NON-CHEMICAL CONTROLS (BIOLOGICAL, PHYSICAL, CULTURAL CONTROLS) TO TREAT A PEST PROBLEM.
- PRUNE PLANTS PROPERLY AND AT THE APPROPRIATE TIME OF YEAR. PROVIDE ADEQUATE IRRIGATION FOR LANDSCAPE PLANTS AND DO NOT OVERWATER.
- AVOID COMPACTING SOIL IN AREAS THAT WILL BE UNPAVED.

SITE DESIGN MEASURES: (Only list measures that are part of site-specific design)

PROTECTION MEASURES

1. PROTECT EXISTING TREES, VEGETATION, AND SOIL
2. PROTECT RIPARIAN AND WETLAND AREAS/ BUFFERS
3. PRESERVE OPEN SPACE AND NATURAL DRAINAGE PATTERNS
4. EMPLOY RAINWATER HARVESTING AND USE (e.g., RAIN BARREL OR CISTERN CONNECTED TO ROOF DRAINS)

LANDSCAPE DESIGN MEASURES

1. DIRECT RUNOFF FROM ROOFS, SIDEWALKS, AND PATIOS TO LANDSCAPED AREAS
2. PLANT TREES ADJACENT TO AND IN PARKING AREAS AND ADJACENT TO OTHER IMPERVIOUS AREAS

DESIGN MEASURES TO MINIMIZE IMPERVIOUS SURFACE AREA

1. REDUCE EXISTING IMPERVIOUS SURFACES
2. CLUSTER STRUCTURES/PAVEMENT
3. CREATE NEW PERVIOUS AREAS (CHECK ALL THAT APPLY):
   A. LANDSCAPING
   B. PARKING STALLS
   C. WALKWAYS AND PATIOS
   D. EMERGENCY VEHICLE ACCESS
4. PARKING (CHECK ALL THAT APPLY:
   A. ON TOP OF OR UNDER BUILDINGS
   B. NOT PROVIDED IN EXCESS OF CODE
5. OTHER:

SOURCE CONTROL MEASURES: (Only list measures that are part of site-specific design)

1. CONNECTED TO THE SANITARY SEWER:
   A. COVERED TRASH/RECYCLING ENCLOSURES
   B. INTERIOR PARKING STRUCTURES
   C. WASH AREA/RACKS
   D. POOLS, SPAS, FOUNTAINS
   E. COVERED LOADING DOCKS AND MAINTENANCE BAYS
2. FUELING AREAS MUST (ALL REQUIRED):
   A. BE GRADED TO PREVENT PONDING
   B. USE A CONCRETE SURFACE
   C. BE SEPARATED FROM THE SITE BY A GRADE BREAK TO PREVENT RUN-ON AND RUNOFF
   D. HAVE A CANOPY COVER EXTENDING AT LEAST 10 FEET FROM EACH PUMP
3. INDUSTRIAL, OUTDOOR MATERIAL STORAGE AND RECYCLING FACILITIES (ALL REQUIRED):
   A. STOCKPILE MATERIAL ON AN IMPERVIOUS SURFACE OR UNDER A PERMANENT ROOF OR COVERING
   B. DIRECT PONDED WATER TO THE SANITARY SEWER, AN ON-SITE TREATMENT SYSTEM, OR OFF-SITE DISPOSAL. CONTACT CITY FOR APPROVAL.
   C. INSTALL BERMS OR CURBS TO PREVENT RUNOFF FROM THE STORAGE/ PROCESSING AREAS
   D. SEGREGATE POLLUTANT-GENERATING ACTIVITIES INTO A DISTINCT DRAINAGE MANAGEMENT AREA AND PROVIDE TREATMENT
4. BENEFICIAL LANDSCAPING
5. USE WATER EFFICIENT IRRIGATION SYSTEMS
6. GOOD HOUSEKEEPING (E.G., SWEEP PAVEMENT AND CLEAN CATCH BASIN, ETC.)
7. LABEL STORM DRAINS
8. OTHER:

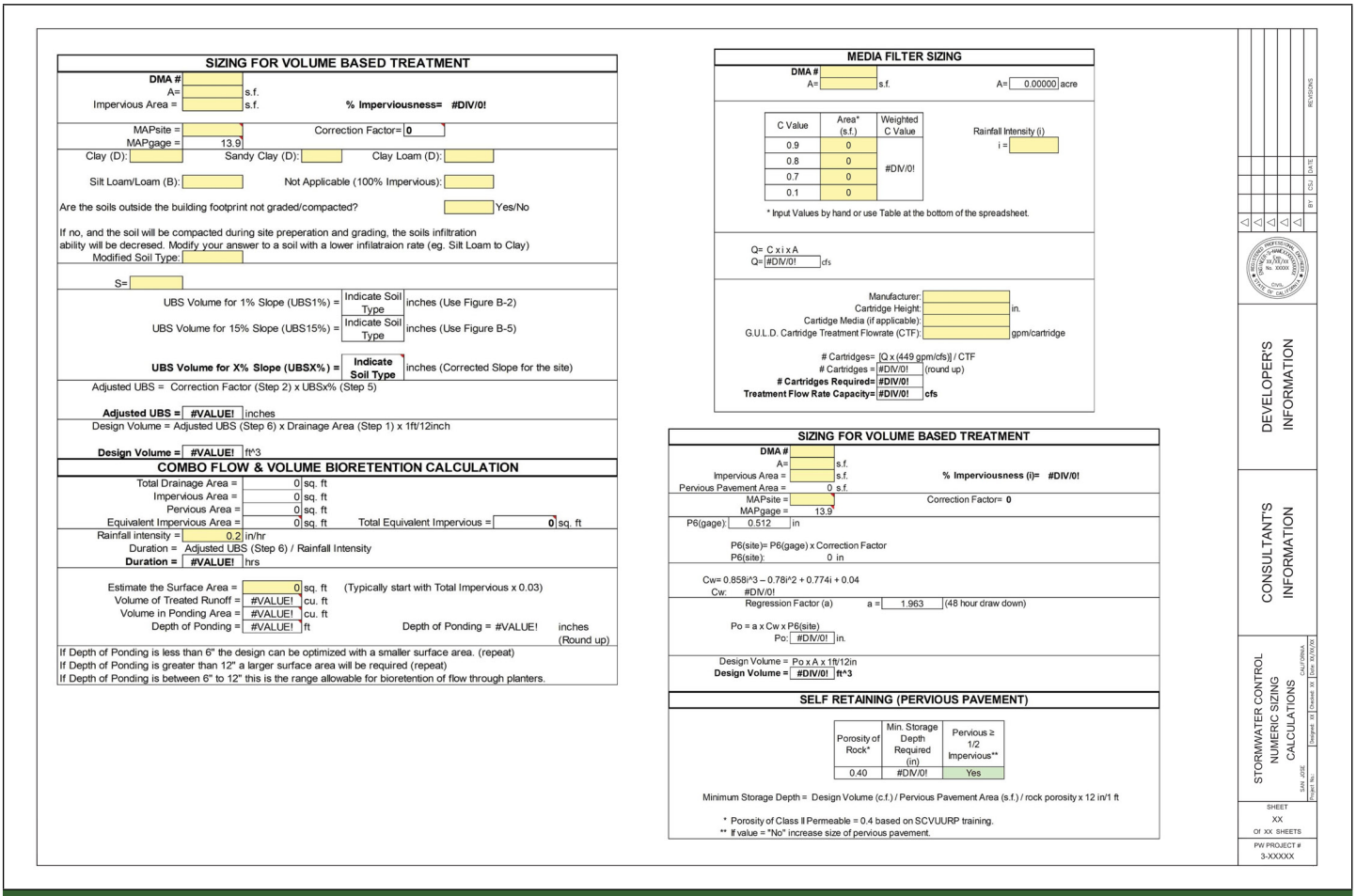
BIORETENTION & FLOW-THROUGH PLANTER NOTES

1. SEE GRADING PLAN FOR BASIN FOOTPRINT AND DESIGN EVALUATIONS.
2. PLACE 3 INCHES OF COMPOSTED, NON-FLOATABLE MULCH IN AREAS BETWEEN STORMWATER PLANTINGS.
3. SEE LANDSCAPE PLAN FOR MULCH, PLANT MATERIALS, AND IRRIGATION REQUIREMENTS.
4. CURB CUTS SHALL BE A MINIMUM OF 18" WIDE AND SPACED AT MAXIMUM 10' O.C. INTERVALS AND SLOPED TO DIRECT STORMWATER TO DRAIN INTO THE BASIN. CURB CUTS SHALL ALSO NOT BE PLACED INLINE WITH OVERFLOW CATCH BASIN. PROVIDE LOCATIONS OF CURB CUTS ON STORMWATER MANAGEMENT PLAN AND GRADING PLAN.
5. A MINIMUM 2" DROP BETWEEN STORMWATER ENTRY POINT (E.G., CURB OPENING, FLUSH CRUB, ETC.) AND ADJACENT SPLASH PAD AT LANDSCAPE FINISHED GRADE. SEE SPLASH PAD STANDARD DETAIL Dwg No. 819.
6. DO NOT COMPACT NATIVE SOIL/ SUBGRADE AT BOTTOM OF BASIN. LOOSEN SOIL TO 12" DEPTH.
7. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".

PERVIOUS CONCRETE AND PERVIOUS PAVER REQUIREMENTS

CONTRACTOR OR PERMITEE SHALL:

- PROVIDE CERTIFICATION FROM THE CONCRETE/PAVER MANUFACTURER THAT THE CONCRETE/PAVERS MEET THE REQUIREMENTS IN THE CITY GSI HANDBOOK FOR PERVIOUS PAVEMENT/PAVERS. THIS INCLUDES BUT IS NOT LIMITED TO HAVING A MINIMUM SURFACE INFILTRATION RATE OF 100"/HR. WHEN TESTED IN ACCORDANCE WITH ASTM C1701.
- ONLY CONTRACTORS HOLDING CERTIFICATION OF COMPLETION FROM THE NATIONAL READY MIX CONCRETE ASSOCIATION (NRMA) OR INTERLOCKING CONCRETE PAVEMENT INSTITUTES PICP INSTALLER TECHNICIAN COURSE SHALL INSTALL THE CONCRETE/ PAVERS AND AT LEAST ONE FOREMAN WITH THIS CERTIFICATION MUST BE ON THE JOB SITE AT TIMES DURING CONCRETE/CONCRETE PAVER INSTALLATION.
- PROTECT THE EXCAVATED AREA FOR PERVIOUS CONCRETE/PAVERS FROM EXCESSIVE COMPACTION DUE TO CONSTRUCTION TRAFFIC AND PROTECT THE FINISHED PAVEMENT FROM CONSTRUCTION TRAFFIC.



SIZING FOR VOLUME BASED TREATMENT

DMA #
A= s.f.
Impervious Area = s.f. % Imperviousness= #DIV/0!

MAPsite = Correction Factor= 0
MAPgage = 13.9
Clay (D): Sandy Clay (D): Clay Loam (D):
Silt Loam/Loam (B): Not Applicable (100% Impervious):
Are the soils outside the building footprint not graded/compacted? Yes/No
If no, and the soil will be compacted during site preperation and grading, the soils infiltration ability will be decresed. Modify your answer to a soil with a lower infilatraion rate (eg. Silt Loam to Clay)
Modified Soil Type:
S=
UBS Volume for 1% Slope (UBS1%) = Indicate Soil Type inches (Use Figure B-2)
UBS Volume for 15% Slope (UBS15%) = Indicate Soil Type inches (Use Figure B-5)
UBS Volume for X% Slope (UBSX%) = Indicate Soil Type inches (Corrected Slope for the site)
Adjusted UBS = Correction Factor (Step 2) x UBSx% (Step 5)
Adjusted UBS = #VALUE! inches
Design Volume = Adjusted UBS (Step 6) x Drainage Area (Step 1) x 1ft/12inch
Design Volume = #VALUE! ft^3

COMBO FLOW & VOLUME BIORETENTION CALCULATION

Total Drainage Area = 0 sq. ft
Impervious Area = 0 sq. ft
Pervious Area = 0 sq. ft
Equivalent Impervious Area = 0 sq. ft Total Equivalent Impervious = 0 sq. ft
Rainfall intensity = 0.2 in/hr
Duration = Adjusted UBS (Step 6) / Rainfall Intensity
Duration = #VALUE! hrs
Estimate the Surface Area = 0 sq. ft (Typically start with Total Impervious x 0.03)
Volume of Treated Runoff = #VALUE! cu. ft
Volume in Ponding Area = #VALUE! cu. ft
Depth of Ponding = #VALUE! ft Depth of Ponding = #VALUE! inches (Round up)
If Depth of Ponding is less than 6" the design can be optimized with a smaller surface area. (repeat)
If Depth of Ponding is greater than 12" a larger surface area will be required (repeat)
If Depth of Ponding is between 6" to 12" this is the range allowable for bioretention of flow through planters.

MEDIA FILTER SIZING

DMA #
A= s.f. A= 0.00000 acre

C Value	Area* (s.f.)	Weighted C Value
0.9	0	#DIV/0!
0.8	0	
0.7	0	
0.1	0	

Rainfall Intensity (i)
i =
* Input Values by hand or use Table at the bottom of the spreadsheet.
Q= C x i x A
Q= #DIV/0! cfs
Manufacturer:
Cartridge Height: in.
Cartidge Media (if applicable):
G.U.L.D. Cartridge Treatment Flowrate (CTF): gpm/cartridge
Cartridges= [Q x (449 gpm/cfs)] / CTF
Cartridges = #DIV/0! (round up)
Cartridges Required= #DIV/0!
Treatment Flow Rate Capacity= #DIV/0! cfs

SIZING FOR VOLUME BASED TREATMENT

DMA #
A= s.f.
Impervious Area = s.f. % Imperviousness (i)= #DIV/0!
Pervious Pavement Area = 0 s.f.
MAPsite = Correction Factor= 0
MAPgage = 13.9
P6(gage): 0.512 in
P6(site)= P6(gage) x Correction Factor
P6(site): 0 in
Cw= 0.858i^3 – 0.78i^2 + 0.774i + 0.04
Cw: #DIV/0!
Regression Factor (a) a = 1.963 (48 hour draw down)
Po = a x Cw x P6(site)
Po: #DIV/0! in.
Design Volume = Po x A x 1ft/12in
Design Volume = #DIV/0! ft^3

SELF RETAINING (PERVIOUS PAVEMENT)

Porosity of Rock*	Min. Storage Depth Required (in)	Pervious ≥ 1/2 Impervious**
0.40	#DIV/0!	Yes

Minimum Storage Depth = Design Volume (c.f.) / Pervious Pavement Area (s.f.) / rock porosity x 12 in/1 ft
* Porosity of Class II Permeable = 0.4 based on SCVUURP training.
** If value = "No" increase size of pervious pavement.

REVISIONS | BY | CSJ | DATE
DEVELOPER'S INFORMATION
CONSULTANT'S INFORMATION
STORMWATER CONTROL NUMERIC SIZING CALCULATIONS
SAN JOSE CALIFORNIA
Project No. | Designed XX | Checked XX | Date XX/XX/XX
SHEET XX Of XX SHEETS
PW PROJECT # 3-XXXXX

Figure 5: Sizing Criteria Worksheet examples

4.5.3 Landscape Plan/Page

- Provide a separate stormwater plant list/table or identify in the plant list which plants are used in the STMs. Refer to **Appendix D** of the C.3 Stormwater Handbook for approved plants.
- Identify plants in the STMs and show appropriate spacing is provided. Required plant spacing should take into account sizes of plants at full growth and maturity.
- Ensure plants are not planted such that they will block the inlets/outlets (e.g., curb cuts) or overflow risers.
- Clearly delineate and identify all STMs on the Landscape plan with the same labels used in Stormwater Management Plan (e.g., STM #1, STM #2, STM #3, etc.).

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6 . Glossary

Bay Area Municipal Stormwater Collaborative (BAMSC)	A consortium of nine San Francisco Bay Area municipal stormwater programs. This collaborative was organized following the dissolution of the Bay Area Stormwater Management Agencies Association (BASMAA) and is continuing the information sharing and permittee advocacy functions of BASMAA in an informal manner.
Bay-Friendly (ReScape) Landscaping	A holistic approach to landscaping that works in harmony with the natural conditions of the San Francisco Bay Watershed. Bay-Friendly (ReScape) practices foster soil health and protect water resources while reducing waste and preventing pollution. ReScape California has expanded and revised the Bay-Friendly principles into eight Regenerative Principles. These can be found on the ReScapeCA website at: www.rescapeca.org
Best Management Practice (BMP)	Any program, technology, process, siting criteria, operational method or measure, or an engineered system, which when implemented, prevents, controls, removes or reduces pollution. Includes schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce water pollution. BMPs include treatment requirements, operating procedures, and techniques to control site runoff, spillage or leaks, litter or waste disposal, or drainage from raw material storage.
Biotreatment Soil Media (BSM)	An engineered soil media meeting the requirements detailed in the BASMAA Biotreatment Soil Media specification as required by the Municipal Regional Stormwater NPDES Permit (MRP). The current specification is provided in the bioretention specification in Attachment G of this City GSI Handbook.
C.3	The provision of the Municipal Regional Stormwater NPDES Permit (MRP) that requires each Permittee to control the flow of stormwater and stormwater pollutants from land development projects (C.3 Regulated Projects or Regulated Projects). Provision C.3 also requires municipalities to develop and implement Green (Stormwater) Infrastructure Plans, thereby expanding the applicability of the provision to public projects that have not historically been considered Regulated Projects but that may be needed to achieve the goals in the MRP. Also referred to as Provision C.3.

C.3 Regulated Projects (Regulated Projects)	Development projects as defined by Provision C.3.b.ii of the Municipal Regional Stormwater NPDES Permit (MRP). This includes new public and private projects and redevelopment projects that create and/or replace 5,000 square feet or more of impervious surface and single-family homes that create and/or replace 10,000 square feet or more of impervious surface. Roadway reconstruction and certain roadway maintenance works are also included (see Attachment A for details).
C.3.d sizing requirements or C.3.d required water quality volume	The amount of stormwater runoff from C.3 Regulated Projects that must receive stormwater treatment, as described by hydraulic sizing criteria in Provision C.3.d of the Municipal Regional Stormwater NPDES Permit (MRP).
California Association of Stormwater Quality Agencies (CASQA)	"A professional member association that advances sustainable stormwater management protective of California water resources" and publisher of the California Stormwater Best Management Practices Handbooks, available at www.casqa.org/resources.
Caltrans	The California Department of Transportation, the department that manages the public transportation network throughout the State and publisher of the Caltrans Standards Specifications Manual.
Class 2 Permeable Material (Class 2 Perm)	Class 2 Permeable Material is a Caltrans specification for a mix of rock and fines that is placed around underdrains, provides storage in biotreatment measures, and does not require filter fabric, unlike open-graded aggregate.
Clean Water Act (CWA)	The Federal Water Pollution Prevention and Control Act, or Clean Water Act (33 U.S. Code 1251 et seq.), is intended to control or eliminate surface water pollution and establishes the National Pollutant Discharge Elimination System of permits to regulate surface water discharges from municipal storm drains, publicly-owned treatment works, industrial discharges, and construction sites (> 1 acre).
Cistern	A storage GSI measure that is used to harvest (collect) and store rainwater and/or stormwater for subsequent use. Cisterns can be located above or below ground. Water stored in this way can be used to supplement or replace potable water for irrigation, toilet flushing, or other uses.

Cobbles	Natural stones of various sizes generally consisting of larger granular material ranging from 3 to 24 inches in diameter set on soil or set in concrete.
Collector Street	A street that connects a neighborhood, a Local Street, or an area of homogenous land use, to a Minor Arterial or Principal Arterial roadway.
Conduit/Conveyance System/Culvert	Channels or pipes for collecting and directing the flow of water. Types of conduits and conveyance systems include open channels, covered channels, and pipes. Culverts are covered channels or large diameter pipes that allow water to flow under a road, railroad, trail, or similar obstruction.
Design Storm	A hypothetical rainstorm defined by rainfall intensities and durations for which a GSI measure is designed.
Detention	The temporary storage of stormwater runoff in ponds, vaults, within berms, or in depressed areas to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates. See “Infiltration” and “Retention.”
Discharge	A release or flow of stormwater or other substance from a conveyance system or storage container.
Drawdown Time	The time required for a stormwater detention or infiltration best management practice (BMP) to drain and return to the dry-weather condition. For detention BMPs, drawdown time is a function of basin volume and outlet orifice size. For infiltration BMPs, drawdown time is a function of basin volume and infiltration rate.
Dry Weather Flow	Flows that occur during periods without rainfall. In a natural setting, dry weather flows result from precipitation that infiltrates into the soil and slowly moves through the soil to the creek channel. Dry weather flows in storm drains may result from human activities, such as over-irrigation.
Erosion	The wearing away of land surface by wind or water. Erosion occurs naturally from weather or runoff but can be intensified by land-clearing practices related to residential, commercial, or industrial development, road building, farming, or timber cutting.

Evapotranspiration	Evaporation of water through plant transpiration.
Filter Fabric	Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (pervious); or (b) prevent both runoff and sediment from passing through (impervious).
Flow-based Treatment Measures	Stormwater treatment measures that treat pollutants from a moving stream of water through filtration, infiltration, sedimentation and/or biological processes.
Full Capture Device or System	Per the Municipal Regional Stormwater NPDES Permit (MRP) Provision, C.10. Trash Load Reduction, C.10.a.ii.(a): "A full capture device or system is a treatment control, or series of treatment controls, including, but not limited to, a multi-benefit project (as defined in the Trash Amendments) or a low-impact development control that traps all particles that are 5 mm or greater, and has a design treatment capacity that is either: a) of not less than the peak flow rate, Q, resulting from a one-year, one-hour storm in the subdrainage area, or b) appropriately sized to, and designed to carry at least the same flows as, the corresponding storm drain. The device(s) must also have a trash reservoir large enough to contain a reasonable amount of trash safely without overflowing trash into the overflow outlet between maintenance events."
Grading	The excavation and/or filling of the land surface to a desired shape or elevation.
Green Stormwater Infrastructure (GSI)	Stormwater infrastructure that uses vegetation, soils, and/or natural processes to manage water and create healthier urban environments. At the scale of a city or county, green stormwater infrastructure (GSI) refers to the patchwork of natural and landscaped areas that provides habitat, flood control, cleaner air, and cleaner water. At the scale of a neighborhood, street, or site, GSI refers to stormwater management systems that mimic nature by soaking up, storing, and/or improving the quality of water.
Groundwater	Subsurface water that occurs in pervious geologic formations that are fully saturated.

Head	In hydraulics, energy represented as a difference in water elevation. In slow-flowing open systems, the difference in water surface elevation, e.g., between an inlet and outlet.
Heritage Tree	An individual tree of any size or species given the 'heritage tree' designation due to its unique value as defined by the municipality's tree ordinance or other section of the Municipal Code.
High-Flow Bypass	In stormwater treatment measures or green stormwater infrastructure (GSI), a pipe, outlet, or other structure designed to convey flood flows directly to the storm drain systems without entering the measure.
Hydrograph	Runoff flow rate plotted as a function of time.
Hydromodification	"Hydrograph modification," or more generally, the changes in natural watershed hydrological processes and runoff characteristics caused by urbanization or other land use changes that result in increased stream flows and sediment transport. Hydromodification is managed through a set of techniques focused on retaining, detaining, or infiltrating runoff to prevent erosion problems caused by increased stream flows and sediment transport downstream of a watershed.
Hydrologic Soil Group	Classification of soils by the Natural Resources Conservation Service into A, B, C and D groups according to infiltration capacity. Group A and B soils have high infiltration rates (sand) while Group C and D soils have slow infiltration rates (clay).
Imperviousness	A term applied to surfaces (roads, sidewalks, rooftops, and parking lots) that prevent or inhibit rainfall from infiltrating into native soils and groundwater.

Impervious surface	A surface covering or pavement of a developed parcel of land that prevents the land's natural ability to absorb and infiltrate rainfall/ stormwater. Impervious surfaces include, but are not limited to, roof tops; walkways; patios; driveways; parking lots; storage areas; impervious concrete and asphalt; and any other continuous watertight pavement or covering. Landscaped soil and pervious pavement, including pavers with pervious openings and seams, underlain with pervious soil or pervious storage material, such as a gravel layer sufficient to hold at least the Municipal Regional Stormwater NPDES Permit's (MRP) Provision C.3.d water quality volume are not impervious surfaces as long as infiltration into native soil can occur. Open, uncovered retention/detention facilities are not considered impervious surfaces for purposes of determining whether a project is a Regulated Project under Provisions C.3.b and C.3.g or for purposes of runoff modeling and meeting the Hydromodification standard.
Infiltration	Downward entry of runoff into the soil.
Inlet	An entrance into a GSI measure, storm drain, or waterway.
Local Street	A street that is designed to provide access from the immediately adjacent land use area or neighborhood to a Collector Street.
Low Impact Development (LID)	A land planning and engineering design approach with a goal of reducing stormwater runoff and mimicking a site's predevelopment hydrology by minimizing disturbed areas and impervious cover and then infiltrating, storing, detaining, evapotranspiring, and/or biotreating stormwater runoff close to its source, or onsite.
Minor Arterial	A street that acts as a distributor in urban areas, connects Local Streets and Collector Streets to Principal Arterials and provides service for moderate length trips.
Municipal Regional Stormwater Permit (MRP)	The Phase I municipal stormwater NPDES permit under which discharges are permitted from municipal separate storm sewer systems throughout the San Francisco Bay Region (including the City of Oakland). The current version is available at Municipal Regional Stormwater NPDES Permit (ca.gov)

New Development	Land disturbing activities, including construction or installation of a building or structure, creation of impervious surfaces; and/or land subdivision, on a previously undeveloped site.
Non-Stormwater Discharge	Any discharge to a municipal storm drain system that is not composed entirely of stormwater. Some types of non-stormwater discharges may be authorized by NPDES permits and others are prohibited.
NPDES Permit	An authorization, license, or equivalent control document issued by the Federal Environmental Protection Agency (EPA) or an approved State agency to implement the requirements of the National Pollutant Discharge Elimination System (NPDES) program. As part of the 1972 Clean Water Act, Congress established the NPDES permitting system to regulate the discharge of pollutants from municipal sanitary sewers and industries. The NPDES program was expanded in 1987 to incorporate permits for stormwater discharges as well. In California, Regional Water Quality Control Boards issue stormwater NPDES Permits to local government agencies placing provisions on allowable discharges of municipal stormwater to waters of the State.
Numeric Sizing Criteria	Sizing requirements for stormwater treatment controls or green stormwater infrastructure (GSI) established in Provision C.3.d. of the Municipal Regional Stormwater NPDES Permit (MRP).
Operation and Maintenance (O&M)	Refers to requirements in the Municipal Regional Stormwater NPDES Permit (MRP) to inspect stormwater treatment and hydromodification management measures and implement preventative and corrective maintenance in perpetuity.
Operational Source Control Measures	Low technology, low-cost activities, procedures, or management practices designed to prevent pollutants associated with site functions and activities from being discharged with stormwater runoff. Examples include good housekeeping practices, employee training, standard operating practices, Bay-Friendly landscaping practices, and integrated pest management.
Outfall/Outlet	The point where stormwater discharges from a pipe, channel, ditch, or other conveyance to a waterway.

Percentile Rainfall Intensity	A method of designing flow-based treatment controls that ranks long-term hourly rainfall intensities and selects the 85th percentile value, and then doubles this value.
Percolation	The movement of water through pores in soil or permeable rock.
Permeability	A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.
Pervious Surface	A natural, landscaped, or permeable hardscape that allows surface runoff to infiltrate into underlying soils.
Pollutant	A substance introduced into the environment that adversely affects or potentially affects the beneficial use of the receiving water.
Precipitation	Any form of rain or snow.
Principal Arterial	A street that carries the highest traffic volumes in urban areas. It carries most of the trips to and from major urban areas and most of the traffic through urban centers.
Provision C.3	Refer to C.3 definition.
Rational Method	A method of calculating runoff peak flows based on rainfall intensity, acreage of drainage area, and land use characteristics.
Redevelopment Project	A project on a previously developed site that adds, replaces, and/or removes impervious surface on the site. The Municipal Regional Stormwater NPDES Permit (MRP) excludes interior remodels and routine maintenance or repair, including roof or exterior surface replacement, pavement resurfacing, repaving and road pavement structural section rehabilitation within the existing footprint, and any other reconstruction work within a public street or road right-of-way where both sides of the right-of-way are developed, from the definition of a Regulated Redevelopment Project.

Regional Water Quality Control Board, San Francisco Bay Area Water Board (RWQCB)	One of nine California Regional Water Quality Control Boards, the Regional Water Board for the San Francisco Bay Region is responsible for implementing pollution control provisions of the Clean Water Act and California Water Code within the area that drains to San Francisco Bay. Also referred to as the Water Board.
Retention	The storage of stormwater to prevent it from leaving the development site.
Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)	Per scvurppp.org, SCVURPPP is an association of thirteen cities and towns in Santa Clara Valley, the County of Santa Clara, and the Santa Clara Valley Water District that are permittees under the local National Pollutant Discharge Elimination System stormwater permit. SCVURPPP and member agencies implement pollution prevention, source control, monitoring and outreach programs aimed at reducing pollution in stormwater runoff, protecting water quality and beneficial uses of San Francisco Bay and Santa Clara Valley creeks and rivers.
Sedimentation	The process of depositing soil particles, clays, sands, or other sediments.
Sediments	Soil, sand, and minerals washed from land, roofing material, and pavements into water usually after rain, which accumulate in reservoirs, rivers, and harbors.
Self-Retaining Area	A portion of a development site designed to retain the first one inch of rainfall (by ponding and infiltration and/or evapotranspiration) without producing stormwater runoff and may receive runoff from adjacent impervious areas. Self-retaining areas may include graded depressions with landscaping or pervious pavement.
Self-Treating Area	A portion of a development site in which infiltration, evapotranspiration and other natural processes remove pollutants from stormwater. Self-treating areas may include conserved natural open areas, areas of landscaping, green roofs and pervious pavement. Self-treating areas treat only the rain falling on them and do not receive stormwater runoff from other areas.

Site Design Measures	Site planning techniques used to conserve natural spaces and/or limit the amount of impervious surface at new and redevelopment projects to minimize runoff and the transport of pollutants in runoff.
Source Control Measures	Any schedules of activities, structural devices, prohibitions of practices, maintenance procedures, managerial practices or operational practices that aim to prevent stormwater pollution by reducing the potential for pollution at its source. There are two types: Structural and Operational Source Control Measures.
Special Projects	Certain types of smart growth, high density and transit-oriented development projects that are allowed, under Provision C.3.e.ii of the Municipal Regional Stormwater NPDES Permit (MRP), to receive low impact development (LID) treatment reductions.
Storm Drain System or Storm Drains	Above and below-ground structures for transporting stormwater to creeks or outfalls for flood control purposes.
Storm Event	A rainfall event that produces more than 0.1 inch of precipitation and is separated from the previous storm event by at least 72 hours of dry weather.
Stormwater	Stormwater runoff, snow-melt runoff, surface runoff, and drainage, excluding infiltration and irrigation tailwater.
Stormwater Runoff	Flow that is created when precipitation falls on Impervious Surfaces or compacted Pervious surfaces that do not allow water to infiltrate into the ground.
Stormwater Pollution Prevention Plan (SWPPP)	A plan describing the temporary best management practices used to prevent erosion and control sediment and other pollutants during construction of a project.
Stormwater Treatment Measures	Engineered systems designed to remove pollutants by gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process. This Handbook and City of Palo Alto prefers the use of the Green Stormwater Infrastructure (GSI) in place of this term.

Structural Source Control Measures	Permanent features that are designed and constructed as part of a project to prevent pollutants from coming in contact with stormwater runoff, such as sanitary sewer connections for roofed washing areas or design features that reduce the need for polluting practices.
Treatment	The application of engineered systems that use physical, chemical, or biological processes to remove pollutants. Such processes include, but are not limited to, filtration, gravity separation, media adsorption, biodegradation, biological uptake, and infiltration.
Treatment Train	A treatment train is a multiple treatment system that uses two or more stormwater treatment measures in series, for example, a settling basin/ infiltration trench combination.
Underdrain	Perforated or slotted pipe that allows water in GSI measures to enter the pipe and flow to the storm drain system. They prevent the accumulation of standing water.
Vector Control	Any method to limit or eradicate the carriers of pathogens (e.g., viruses or parasites) related to vector-borne diseases, such as mammals, birds, and insects or other arthropods. For the purposes of this document, vector control refers to mosquito control.
Volume-Based Stormwater Treatment Measures	Stormwater treatment measures that are designed to detain the design volume of stormwater for a certain period and treat primarily through sedimentation and/or infiltration.

ATTACHMENT A:

Municipal Regional Permit Regulated Projects Summary

MRP 3.0: Development Projects Requiring LID Treatment for Stormwater

(Spreadsheet prepared by the Contra Costa Clean Water Program and distributed regionally)	Impervious surface area created or replaced				
Project Type/Description	**Threshold Area**	**MRP 2.0**	**MRP 3.0**	**Notes**	**Subprovision**
Parcel-Based Requirements					
Detached single-family home not part of a larger plan of development	Cumulative	Exempt	**10,000 SF**	1, 2, 3	C.3.b.ii.(6)
Public/private development (e.g. new library on previously undeveloped site)	Cumulative	10,000 SF	**5,000 SF**	1, 2, 4	C.3.b.ii.(1), (2)
Public/private redevelopment project (e.g. renovated hospital)	Cumulative	10,000 SF	**5,000 SF**	1, 2, 4	C.3.b.ii.(3)
Renovation of existing public/private parking lots and other pavement (see applicable activities below)	Cumulative	Exempt	**5,000 SF**	1, 2, 4, 5	C.3.b.ii.(1)
Roads, Sidewalks, and Trails					
New roads, including sidewalks and bike lanes	Contiguous	10,000 SF	**5,000 SF**	1, 6	C.3.b.ii.(4)
Adding traffic lanes to an existing road	Contiguous	10,000 SF	**5,000 SF**	1, 6	C.3.b.ii.(4)
New stand-alone trail projects 10 feet wide or wider with impervious surface	Contiguous	10,000 SF	**5,000 SF**	1, 7	C.3.b.ii.(4)
Sidewalk gap closures, sidewalk replacement, ADA curb ramps not associated with a parcel-based project	Contiguous	10,000 SF	**5,000 SF**	1	C.3.b.ii.(3)
Road Maintenance Projects					
Reconstructing existing roads, including sidewalks and bicycle lanes (see applicable activities below)	Contiguous	Exempt	**1 acre**	1, 8, 9	C.3.b.ii.(5)
Extending roadway edge (e.g., lane widening, safety improvement, paving a graveled shoulder)	Contiguous	Exempt	**1 acre**	1, 8, 9, 10	C.3.b.ii.(5)
Utility trenching projects ≥ 8 feet wide on average over entire length of project	Contiguous	Exempt	**1 acre**	1, 8, 9	C.3.b.ii.(5)
Specific Activities: Work Included or Exempt When Calculating Threshold Area of Project (e.g. 5,000 SF, 1 acre)					
Upgrade from dirt to gravel (exempt if built to spec for pervious pavement)		Included	Included	1	C.3.b.ii.(1)(b)(iii)
Upgrade from dirt/gravel to pavement (exempt if built to spec for pervious pavement)		Included	Included	1	C.3.b.ii.(1)(b)(iii)
Removing/replacing asphalt or concrete to top of base course or lower		Exempt	**Included**	1	C.3.b.ii.(1)(b)(iii)
Repair of pavement base (i.e. base failure repair)		Exempt	**Included**	1	C.3.b.ii.(1)(b)(iii)
Extending the pavement edge or paving graveled shoulders		Exempt	**Included**	1	C.3.b.ii.(1)(b)(iii)
Interior Remodels		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Repair of roof or exterior wall surface		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Pothole and square cut patching		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Overlay gravel on existing gravel		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Overlay asphalt or concrete on existing asphalt or concrete (no increase in area)		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Upgrade from chip seal or cape seal to asphalt or concrete (no increase in area)		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Shoulder grading		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Reshaping/regrading drainage		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Crack sealing		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Pavement preservation that does not expand road prism		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)
Vegetation maintenance		Exempt	Exempt		C.3.b.ii.(1)(b)(ii)

Notes:

1. Change effective July 1, 2023, per Provision C.3.b.iii.
2. Projects that fall under the planning and building authority of the Permittee
3. Includes addition of an ADU within a lot
4. "Project" includes any frontage improvements
5. Prior to MRP 3.0, implementation of stormwater treatment for renovated pavement has varied by jurisdiction and by project.
6. Caltrans highway projects are excluded
7. Work may be excluded if runoff is directed to a vegetated area
8. Acreage treated with road maintenance projects can count towards minimum Green Infrastructure numeric requirement (Provision C.3.j.ii.).
9. Alternative minimum sizing criteria for bioretention facilities (typically 2% or less of tributary area) may apply
10. These activities were moved from Provision C.3.b.ii.(1) during the May 11, 2022 adoption hearing

ATTACHMENT B:

GSI Pollutant Removal Processes

How GSI Treats Pollutants in Stormwater

GSI treats and removes or transforms pollutants in stormwater runoff through several different processes. Pollutants are often categorized based on their size and chemical properties and require different treatment mechanisms depending on these characteristics. Typical pollutant categories include:

1. Gross solids – These include larger pollutant particles such as trash or vegetative debris such as leaf litter. Trash management requirements define these as particles 5 mm or greater.
2. Sediment – Large quantities of stormwater can cause erosion of sediment. In large amounts, sediment can be considered a pollutant, as it clogs stream beds and impacts other habitats. Additionally, sediment in urban environments often contains sediment-bound pollutants, which can cause other toxic effects.
3. Sediment-bound pollutants – Many pollutants have chemical properties that make them more likely to adsorb, or attach, to sediment rather than remain free-floating in water. These include but are not limited to toxic chemicals such as PCBs and many metals, including total mercury, pesticides, hydrocarbons, and other organic compounds. Many nutrient contaminants[1] are also sediment-bound.
4. Dissolved pollutants – Dissolved pollutants include metals, some nutrients, and other contaminants that are not sorbed to sediment. These pollutants are quite small.

Based on empirical studies, different amounts of these pollutants are associated with different urban land use types (see, e.g., the National Stormwater Quality Database (Pitt, 2015)). For example, residential properties typically have lower quantities of all stormwater pollutants but can discharge pesticides and nutrients from landscaping activities. Commercial areas often have higher levels of trash, transportation land uses have high quantities of hydrocarbons and other pollutants associated with cars, and industrial land uses may have high levels of metals and other toxic chemicals produced from manufacturing and using heavy equipment.

Typical removal mechanisms for the pollutant categories defined are described, as well as how GSI and other stormwater treatment measures provide these removal mechanisms.

1. Screening – Typically used for removing gross solids, screening involves forcing stormwater to flow through a material (such as metal mesh) that has openings that only allow smaller particles to pass through.
2. Settling – In still water, larger, heavier particles naturally sink. Detention of water allows for these larger particles and the pollutants that are attached to them to settle out of the water column, where they can be removed through maintenance activities. Detention by itself is not considered GSI, however, areas of detention can be incorporated into GSI measures and treatment trains. Capture and use facilities utilize settling and other processes as needed to remove pollutants before using the water for non-potable demand such as irrigation.
3. Hydrodynamic separation – When flowing water is mechanically swirled, settling processes can be enhanced by taking advantage of varying particle weights to separate larger particles from water. This process is employed in hydrodynamic separator units (HDS units), which are

[1] While nutrients are beneficial in moderate quantities, they can cause ecological impacts in large quantities, including eutrophication and low dissolved oxygen in receiving waters.

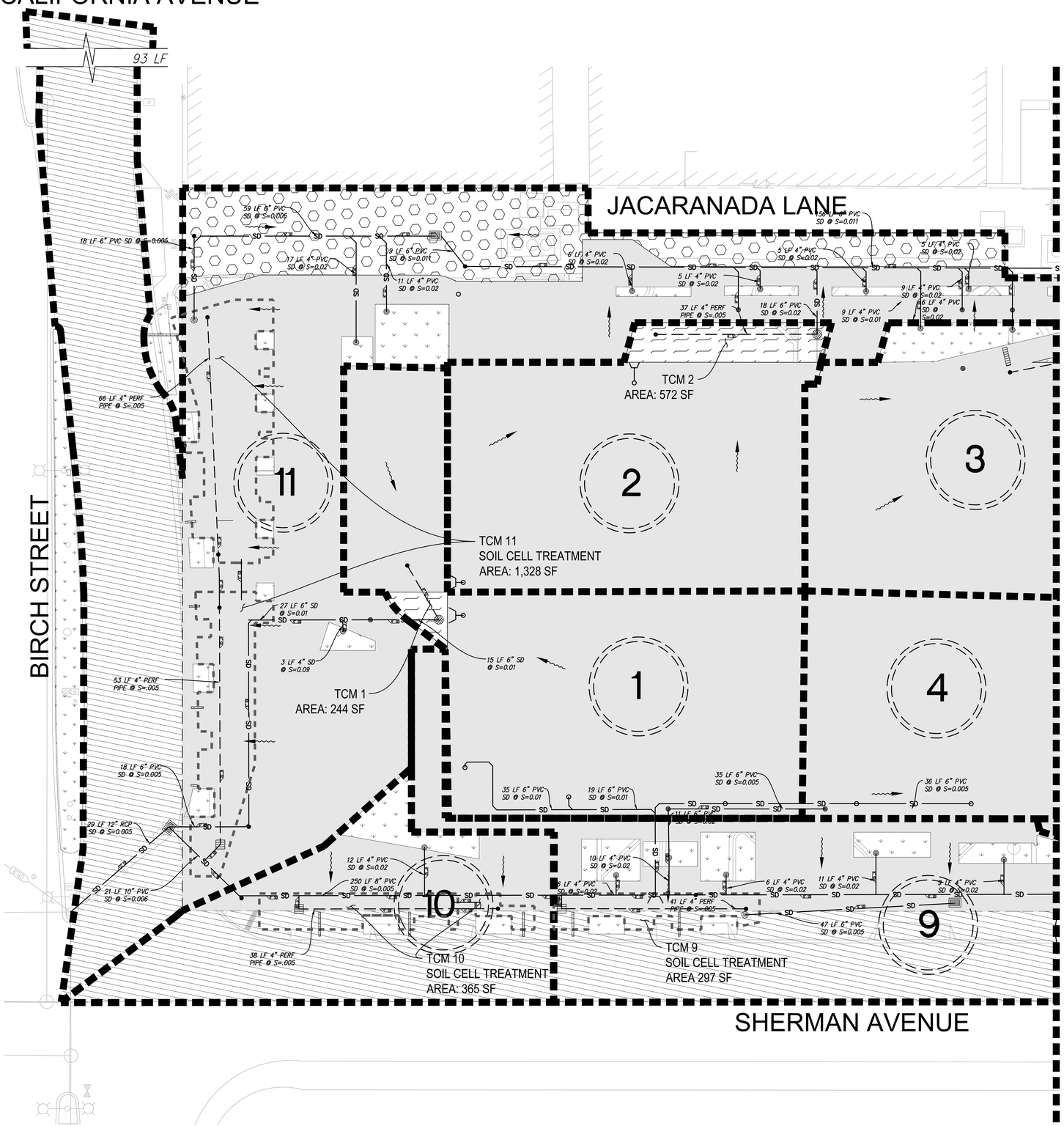
frequently cleaned out to collect and dispose of larger separated particles. HDS units are not considered GSI but can be used in combination with GSI measures as described in Section **2.3**.

4. Filtration – Many GSI measures utilize filtration to remove pollutants. Filtration entails running stormwater through filter media, which pollutants adsorb to, and removing them from water. For typical GSI measures in the City, the filter media used is biotreatment soil media, which is specified in the MRP. Amendments, including but not limited to, biochar, activated carbon, compost, and other materials, may be added to biotreatment soil media to enhance filtration. These types of additives are often characterized by having a large internal and/or external surface area, allowing for more locations for pollutants to adsorb to.
5. Biological Treatment – In GSI measures that contain soil and plants, biological processes can provide treatment of pollutants. These include soil microbes that ingest and transform chemical compounds, plants that uptake nutrients, and decomposition processes that change the chemical composition of the soil and transform pollutants.
6. Infiltration – Infiltration to the subsurface is a type of filtration treatment process. When water is infiltrated, it is not discharged back to surface water or storm drains; instead, it percolates through the subsurface and into groundwater. Non-amended native soil in the subsurface removes pollutants similar to filter media. Infiltrated water has the additional benefit of reducing the overall quantity of water, reducing erosion and other negative impacts of large stormwater flows.
7. Abiotic chemical transformation – Treating pollutants through abiotic (or non-biological) chemical transformation is most often associated with "active" treatment, i.e., treatment that involves energy or chemical (such as flocculant) inputs. Wastewater treatment plants use active treatment to treat sanitary sewage. In passive treatment devices such as GSI, other design features can be incorporated to encourage abiotic chemical transformation, which entails changing the chemistry of a pollutant so that it can settle or be filtered out. These design features include creating zones of low or no oxygen (i.e., anaerobic zones). Abiotic chemical transformation may be needed to remove some kinds of dissolved contaminants from stormwater.

In addition to water quality treatment processes, additional processes remove or retain stormwater. These include evapotranspiration, a process by which water is returned to the air through plants, and capture and use, which is the storage of water for later use. In most cases capture and use would require other treatment before using the captured stormwater.

ATTACHMENT C:

Example Stormwater Management Plan



SANDIS — SILICON VALLEY — SCALE: 1"=10'

LEGEND

PROPOSED IMPERVIOUS AREA

PROPOSED PERVIOUS AREA

MAINTENANCE AREA

BIO-TREATMENT AREA (7/C-7.2, 1/C-7.6)

OFFSITE IMPERVIOUS AREA

DRAINAGE AREA BOUNDARY

SOIL CELL BOUNDARY (1/C-7.5)

THRU CURB INLET INTO SOIL CELLS (1/C-7.4)

BMP Area Calculation Table - Public Safety Building

Drainage Area	ONSITE TOTAL AREA sq. ft.	ONSITE TOTAL AREA Ac.	ONSITE IMPERVIOUS sq. ft.	ONSITE IMPERVIOUS Ac.	ONSITE PERVIOUS AREA sq. ft.	ONSITE PERVIOUS AREA Ac.	Onsite Percent Impervious	Treatment Area Required (sf)	Treatment Control Method	Treatment Control Method	Treatment Provided (sf)	Adequate Sizing	Offsite Impervious Area (sf)	Offsite Impervious Area Treated	Offsite Percent Treated
DMA-1	5,249	0.12	5,147	0.12	102	0.01	98.1%	296	RBA	2C. Flow: 4% Method **	744	OK	0	N/A	N/A
DMA-2	4,456													N/A	N/A
DMA-3	4,655													N/A	N/A
DMA-4	5,313													N/A	N/A
DMA-5	4,726													N/A	N/A
DMA-6	9,910													350	5%
DMA-7	2,200													781	100%
DMA-8	3,801													406	100%
DMA-9	3,014													591	100%
DMA-10	1,200													890	100%
DMA-11	10,646	0.24	9,945	0.23	701	0.02	93.4%	398	Soil Cells	2C. Flow: 4% Method **	1,328	OK	6,791	6,791	100%
TOTAL	**55,164**	**1.27**	**49,992**	**1.15**	**5,172**	**0.12**	**90.6%**	**1,872**			**4,487**		**21,483**	**14,809**	

ATTENTION: The Stormwater Treatment Measure (STM) Summary Table has been updated. Please use the Table 8 Template for the STM Summary Table.

ATTENTION: The Required Stormwater Notes have been updated. Please refer to Figure 4. C.3 Standard Development Notes for minimum required notes and Sizing Criteria Worksheets.

HYDROMODIFICATION NOTE:

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SITE TREATME...

THIS PROJECT IS REPLACING MORE T... THEREFORE MUST TREAT THE ENTIRE...

STORMWATER MANAGEMENT NOTES:

1. *THIS PLAN PRESENTS METHODS AND CALCULATIONS FOR COMPLYING WITH THE REQUIREMENTS OF PROVISION C.3 OF THE MUNICIPAL REGIONAL STORMWATER PERMIT IN ACCORDANCE WITH THE SANTA CLARA COUNTY PROGRAM AND THE CITY OF PALO ALTO REQUIREMENTS.*
2. *THE FOLLOWING TREATMENT MEASURES ARE PROPOSED TO REGULATE THE QUALITY OF STORM WATER LEAVING THE SITE*
   - 2.1. *FLOW-THROUGH PLANTER – RUNOFF IN THIS AREA IS DIRECTED TO A FLOW-THROUGH PLANTER AREA FOR FILTRATION, INFILTRATION AND EVAPOTRANSPIRATION PRIOR TO EXITING THE SITE. PLANTING AND SOIL REQUIREMENTS APPLY.*
   - 2.2. *SILVA CELL – RUNOFF IN THIS AREA IS DIRECTED TO A SILVA CELL SYSTEM WITH A BIOTREATMENT SOIL MIX FOR FILTRATION PRIOR TO EXITING THE SITE.*
3. *A 3RD PARTY INSPECTION OF THE BIORETENTION AREAS WILL BE REQUIRED DURING INSTALLATION AND PRIOR TO OCCUPANCY. CONTACT 3RD PARTY INSPECTOR PRIOR TO THE PLACEMENT OF BIORETENTION SOIL.*
4. *INSTALLATION VENDOR SPECS SHOULD BE FOLLOWED AND PROVIDED TO THE CITY STAFF.*
5. *STAFF FROM STORMWATER PROGRAM (WATERSHED PROTECTION DIVISION) MAY BE PRESENT DURING INSTALLATION OF STORMWATER TREATMENT MEASURES. CONTACT PAM BOYLE RODRIGUEZ, PROGRAM MANAGER, AT (650) 329-2421 BEFORE INSTALLATION.*
6. *DO NOT USE CHEMICALS FERTILIZERS, PESTICIDES, HERBICIDES OR COMMERCIAL SOIL AMENDMENT. USE ORGANIC MATERIALS REVIEW INSTITUTE (OMRI) MATERIALS AND COMPOST. REFER TO THE BAY-FRIENDLY LANDSCAPE GUIDELINES: HTTP://WWW.STOPWASTE.ORG/RESOURCE/BROCHURES/BAY-FRIENDLY-LANDSCAPE-GUIDELINES-SUSTAINABLE-PRACTICES-LANDSCAPE-PROFESSIONAL FOR GUIDANCE.*
7. *AVOID COMPACTING SOIL IN AREAS THAT WILL BE UNPAVED.*
8. *TRASH AND RECYCLING CONTAINERS SHALL BE COVERED TO PROHIBIT FLY-AWAY TRASH AND HAVING RAINWATER ENTER THE CONTAINERS.*
9. *DRAIN DOWNSPOUTS TO LANDSCAPING (OUTWARD FROM BUILDING AS NEEDED).*
10. *DRAIN HVAC FLUIDS FROM ROOFS AND OTHER AREAS TO LANDSCAPING.*
11. *CREATE A CONTAINED AND COVERED AREA ON THE SITE FOR THE STORAGE OF BAGS, CEMENT, PAINTS, OILS, FERTILIZERS, PESTICIDES, OR OTHER MATERIALS USED ON THE SITE THAT HAVE THE POTENTIAL OF BEING TRANSPORTED VIA ANY OTHER TRANSPORT METHOD, OR IN THE EVENT OF A MATERIAL SPILL.*
12. *FOR DMA'S 6,7,8 REFER TO DETAIL 1/C-7.6.*

LIST OF POTENTIAL POLLUTANTS

THIS FOLLOWING ARE LIST OF POTENTIAL POLLUTANTS PRESENT AT THE SITE AFTER DEVELOPMENT: OIL, GAS AND ANTIFREEZE.

STORM DRAIN LABELING

STORM DRAIN INLETS SHALL BE CLEARLY MARKED WITH THE WORDS "NO DUMPING – FLOWS TO MATADERO CREEK" OR EQUIVALENT.

ATTENTION: For consistency in the City of Palo Alto, use the term Stormwater Treatment Measure (STM) instead of Treatment Control Measure (TCM).

CITY OF PALO ALTO

PALO ALTO PUBLIC SAFETY BUILDING

250 Sherman Avenue, Palo Alto, CA

REVISIONS

No.	Description	Date
1	Plan Check Responses	03/18/2020
3	Plan Check Responses	06/29/2020
9	Plan Check Responses	12/04/2020
13	Plan Check Responses	03/10/2021

PERMIT SUBMITTAL #6

STORMWATER MANAGEMENT PLAN

DATE 04/16/2021

REGISTERED PROFESSIONAL ENGINEER — CHAD J. BROWNING — No. C68315 — Exp. 9/30/21 — CIVIL — STATE OF CALIFORNIA

CHAD J. BROWNING
R.C.E. NO. C68315, EXPIRES 9-30-21

Drawn By: NT
Checked By: CB

Scale: 1" = 10'

Date: 04/16/2021

Project No. 10040

C-6.0
Drawing No.

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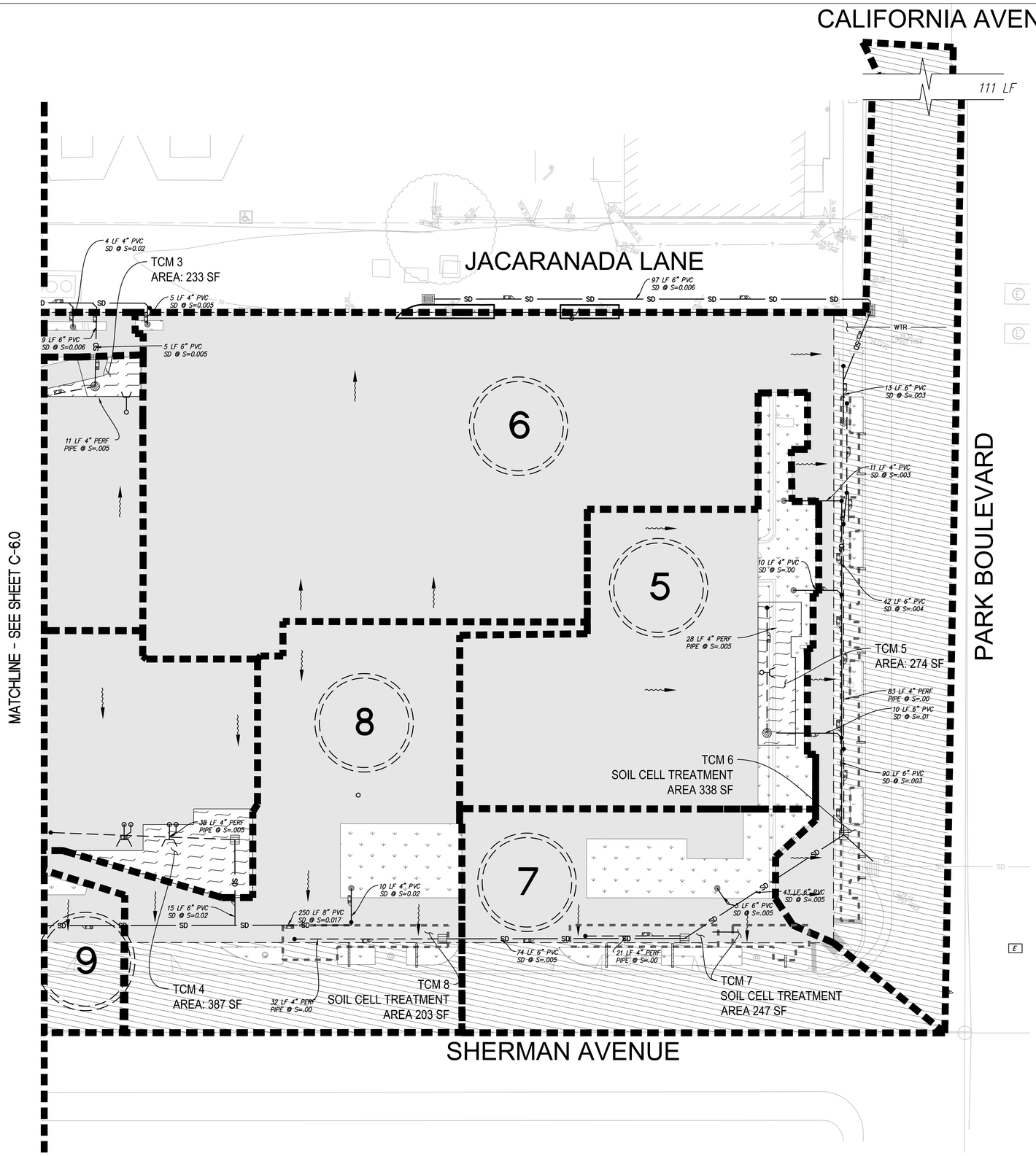
SACRAMENTO EAST BAY/ SF



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SANDIS SILICON VALLEY — SCALE: 1"=10'

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- PROPOSED PERVIOUS AREA
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- BIO-TREATMENT AREA (7/C-7.2, 1/C-7.6)
- OFFSITE IMPERVIOUS AREA
- DRAINAGE AREA BOUNDARY
- SOIL CELL BOUNDARY (1/C-7.5)
- THRU CURB INLET INTO SOIL CELLS (1/C-7.4)

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4. *FOR ALL C.3 FEATURES, VENDOR SPECIFICATIONS REGARDING INSTALLATION AND MAINTENANCE SHOULD BE FOLLOWED AND PROVIDED TO CITY STAFF. COPIES MUST BE SUBMITTED TO PAM BOYLE RODRIGUEZ AT PAMELA.BOYLERODRIGUEZ@CITYOFPALOALTO.ORG.*
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PERMIT SUBMITTAL #6

STORMWATER MANAGEMENT PLAN

DATE 04/16/2021

REGISTERED PROFESSIONAL ENGINEER CHAD J. BROWNING No. C68315 Exp. 9/30/21 CIVIL STATE OF CALIFORNIA

CHAD J. BROWNING
R.C.E. NO. C68315, EXPIRES 9-30-21

Drawn By: NT
Checked By: CB

Scale: 1" = 10'

Date: 04/16/2021

Project No. 10040

C-6.1
Drawing No.

ATTACHMENT D:

Stormwater Treatment Measure Summary Table Example Template

STORMWATER TREATMENT CONTROL MEASURE SUMMARY TABLE

											Bioretention			Self Retaining / Treating[6]		Media Filter					
DMA #	STM #	Location[1]	Treatment Type[2]	LID or Non-LID	Sizing Method	Drainage Area (s.f.)	Impervious Area[4] (s.f.)	Pervious Area (Permeable Pavement) (s.f.)	Pervious Area (Other) (s.f.)	% Onsite Area Treated by LID or Non-LID TCM	Bioretention Area Required (s.f.)	Bioretention Area Provided (s.f.)	Overflow Riser Height (in)	Storage Depth Required (ft)	Storage Depth Provided (ft)	# of Cartridges Required	# of Cartridges Provided	Media Type	Cartridge Height (inches)	Treatment Credit (s.f.)	Comments
1										-											
2										-											
3										-											
4										-											
5										-											
6										-											
7										-											
8										-											
9										-											
10										-											
11[5]										-											Being equivalently treated by EQ-1
EQ-1[5]										-											Equivalent Treatment for DMA 11
					Totals:	0	0	0	0	0.00%											

Footnotes:

1 Per the Municipal Regional Stormwater Permit, sidewalks and other parts of the right-of-way should be included in the new and/or replaced impervious surface calculation and treated as required

2 "Lined" refers to an impermeable liner placed on the bottom of a Bioretention basin or a concrete Flow-Through Planter, such that no infiltration into native soil occurs.

3 2C. Flow: 4% Method - Sizing for Bioretention Area Required calculated using the 4% Method (Impervious Area x 0.04)

4 Gravel layers are considered impervious, excluding gravel layers included in pervious pavement systems.

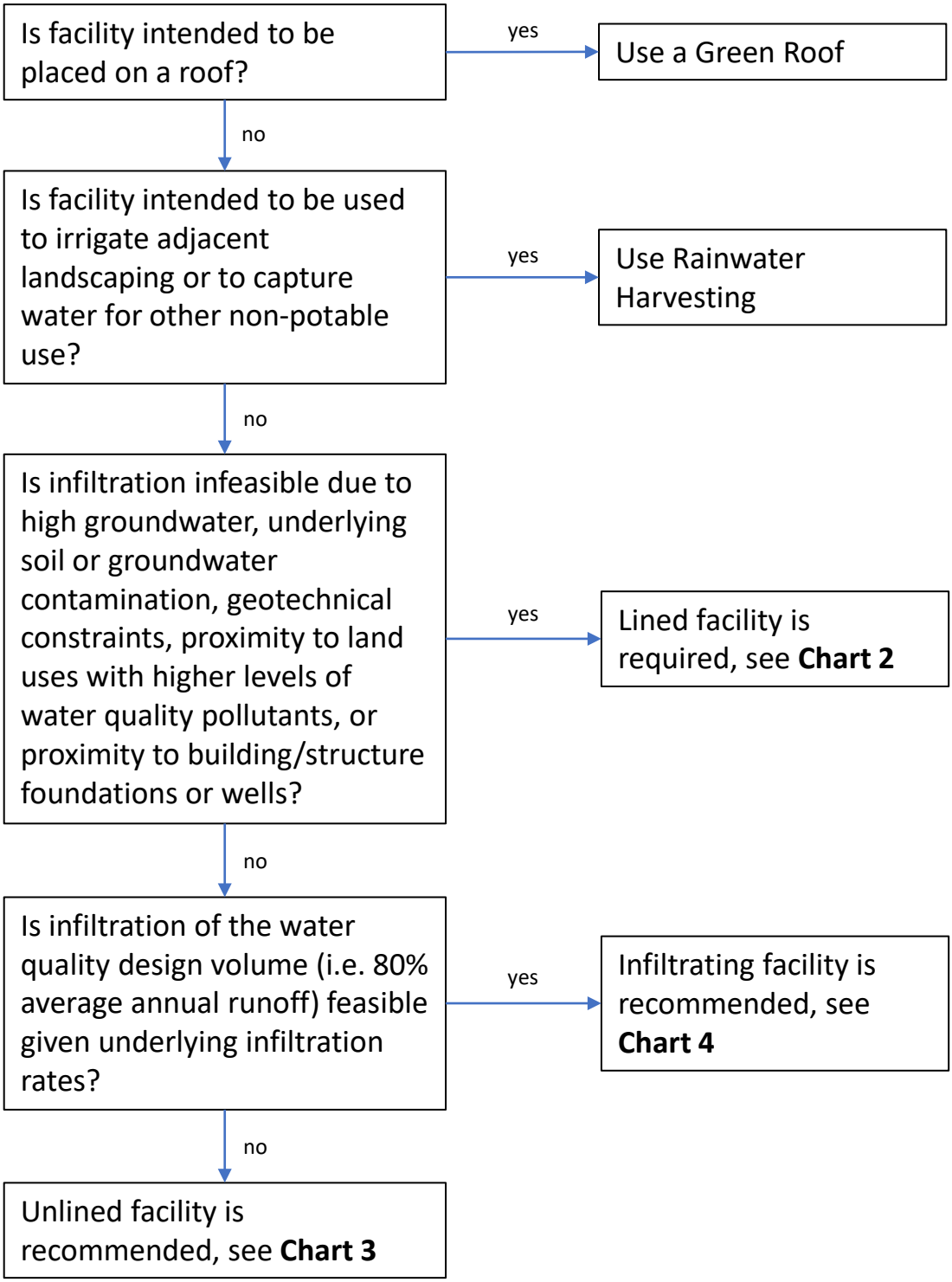
5 DMA XX is not being treated but will be treated by Equivalent Treatment Area EQ-1. Area EQ-1 is equal to or greater than the required treatment area of DMA XX. EQ-1 is not required to be treated as it is [insert reason here]

6 Treatment type of Self-Treating or Self-Retaining should only be used with landscape based treatment. If previous pavement is proposed for Self-Treating or Retaining, use the Pervious Pavement selection.

ATTACHMENT E:

GSI Measure Selection Flow Charts

Chart 1 – GSI Measure Selection



Regional Projects should be designed on a site-specific basis

Chart 2 – Lined Facility is Required

GSI measure types are recommended based on the typical project conditions described. In all cases, the designer should consider the local site conditions when selecting or designing a GSI measure type.

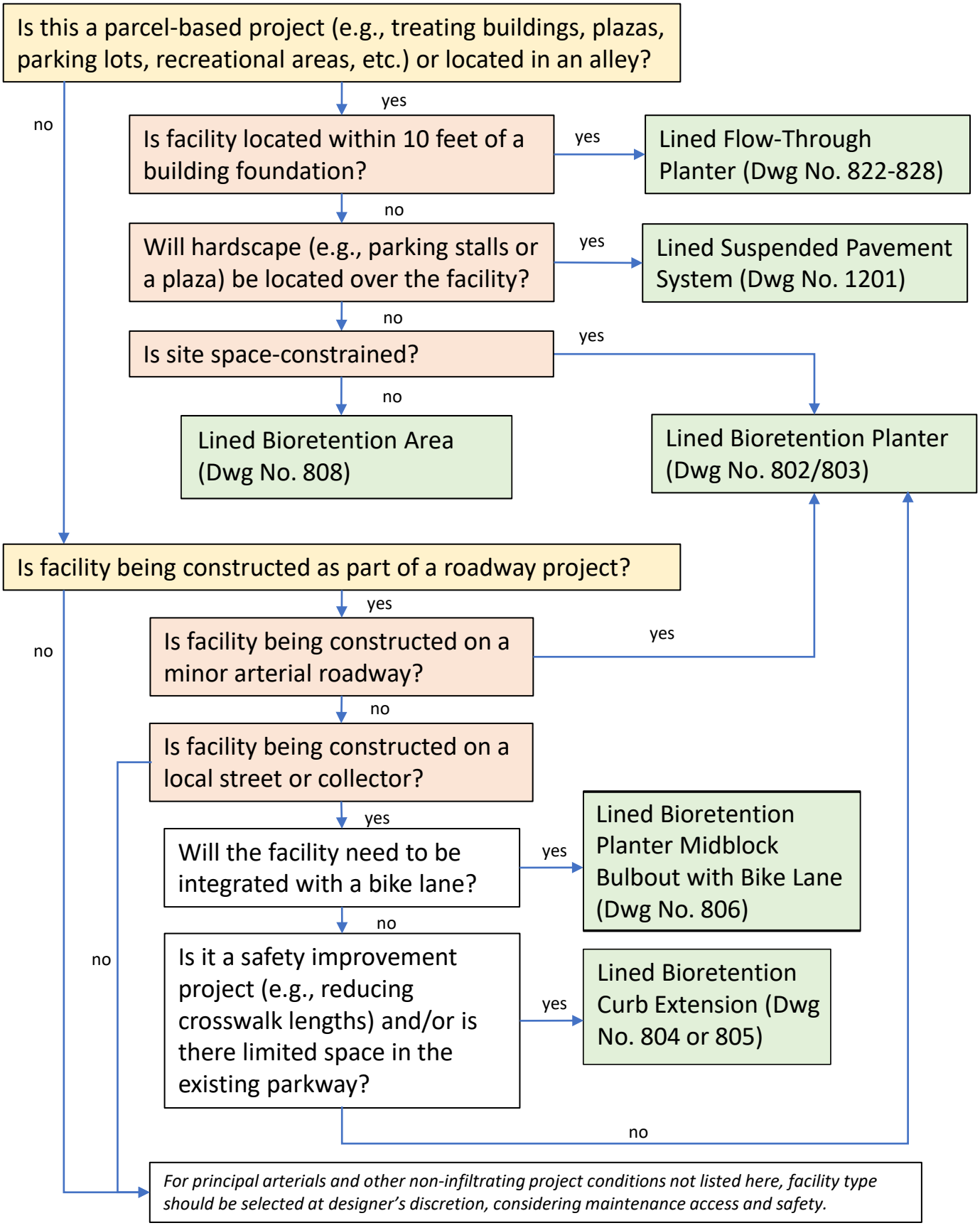


Chart 3 – Unlined Facility is Recommended

GSI measure types are recommended based on the typical project conditions described. In all cases, the designer should consider the local site conditions when selecting or designing a GSI measure type.

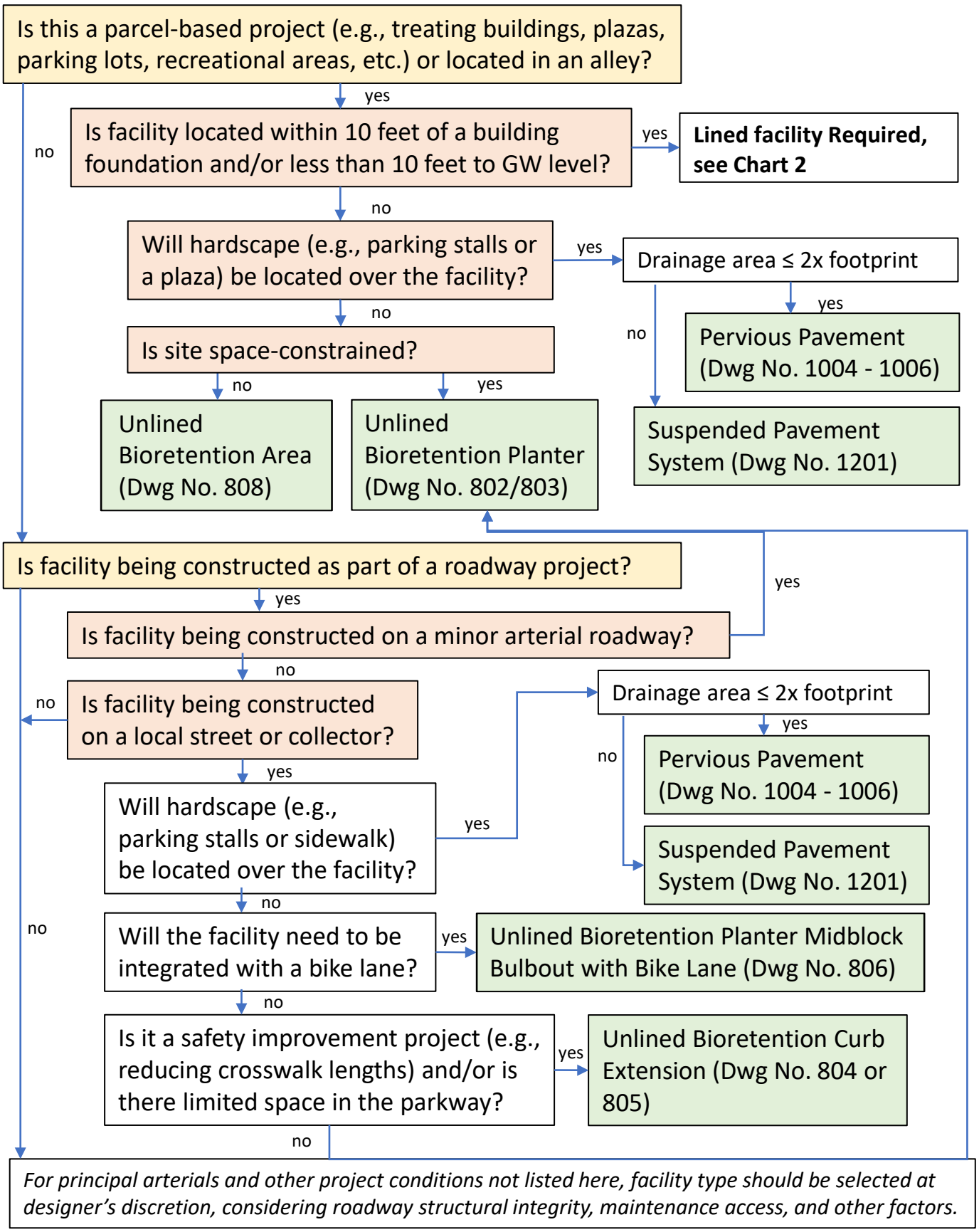
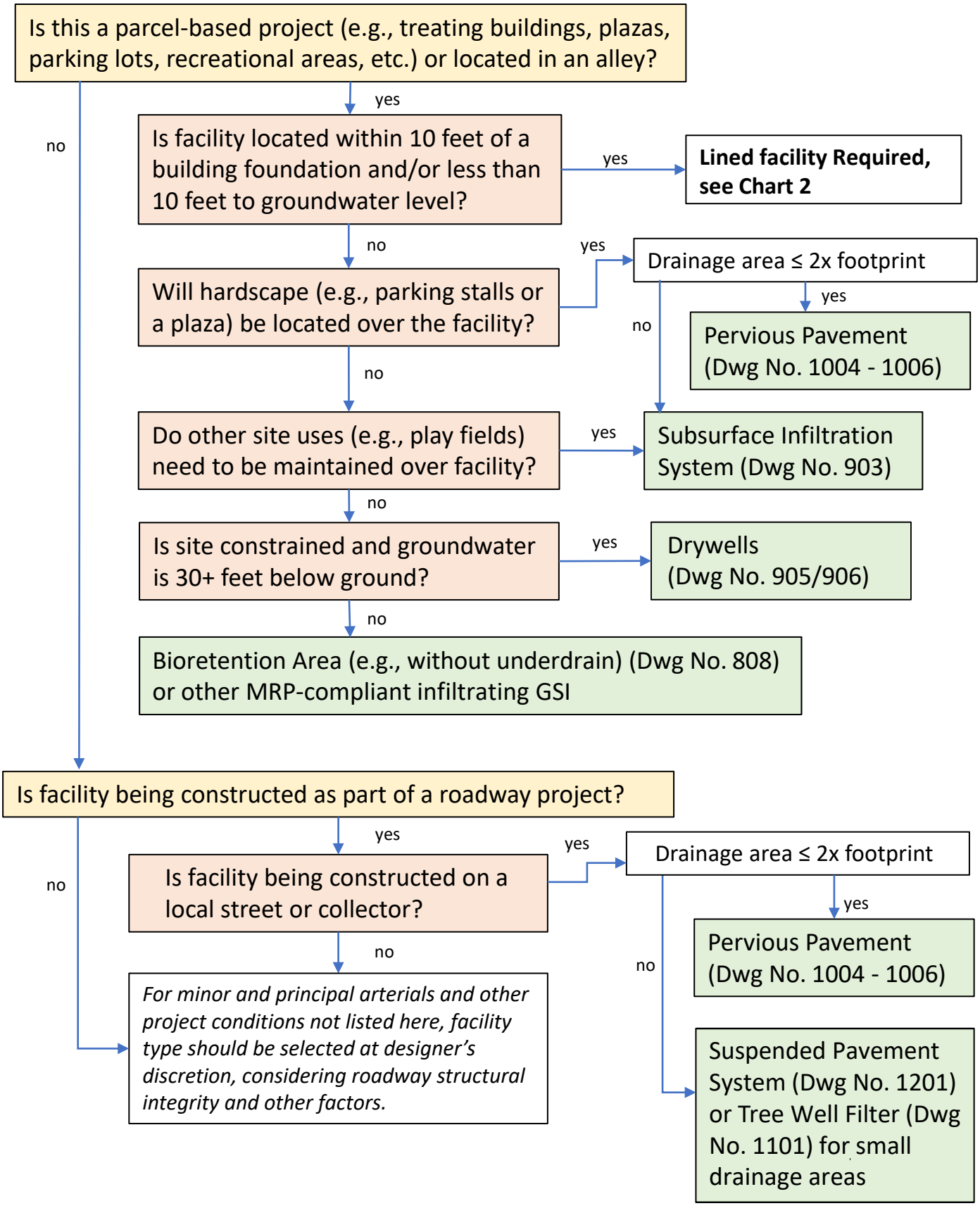


Chart 4 – Infiltrating Facility is Recommended

GSI measure types are recommended based on the typical project conditions described. In all cases, the designer should consider the local site conditions when selecting or designing a GSI measure type.



Summary of Recommended GSI Measure Types Depending on Parcel(s) Land Use and Adjacent Road Type (Source: SCVURPPP 2019).

Legend: ☒ = Not Recommended ○ = Potential ☑ = Recommended

Street Type:	Local Streets				Collectors	Minor Arterials	Principal Arterials	Parking Lots
Land Use Type:	**Alley**	**Low Density Residential**	**High Density Residential**	**Commercial**	**Commercial**	**Commercial/ Industrial**	**Commercial/ Industrial**	
Flow-Through Planter	○	☑	☑	☑	☑	☑	○	☑
Bioretention Planter - Midblock Curb Extension	☒	☑	○	○	☑	○	○	☒
Bioretention Planter -Corner Curb Extension	☒	☑	☑	☑	☑	○	☒	☒
Tree Well Filter	☒	☑	☑	☑	☑	○	○	☑
Pervious Pavement	☑	☑	☑	☑	☑	○	☒	☑
Infiltration Trench	☑	○	○	○	☒	☒	☒	☑
Dry Well/Infiltration Well	☑	○	○	○	☒	☒	☒	☑
Subsurface Infiltration System	☒	☒	☒	☒	☒	☒	☒	☑
Land Use Type Characteristics:	Narrow roadway; no sidewalks; consider heavy loads and passage of garbage trucks.	Low to moderate demand for street parking; Light pedestrian traffic; moderate vehicle traffic; sidewalks of varying sizes; driveways and underground utilities may be limitations.	Moderate to high demand for street parking; moderate pedestrian traffic; moderate vehicle traffic; sidewalks of varying sizes; driveways and underground utilities may be limitation.	Moderate to high pedes-trian traffic; sidewalks likely to be wide; moderate to high parking demand; underground utilities may be limitation.	Moderate to high pedes-trian traffic; sidewalks likely to be wide; moderate to high parking demand; underground utilities may be limitation; may be able to reduce width of roadways.	Low pedes-trian traffic; high vehicle traffic; possible opportunity for road diet; pervious pavement may only be possible in sidewalk areas.	Low pedes-trian traffic; high vehicle traffic; medians are possible locations for GSI; heavy vehicles, sediment loads and large turning radii may limit GSI options.	Lighter traffic loads and volumes; more flexibility on space and design; tree soil volumes; have fewer utility conflicts.

ATTACHMENT F:

Standard GSI Measure Details

PURPOSE:

BIORETENTION PLANTERS CAPTURE AND TREAT STORMWATER RUNOFF VIA SURFACE AND SUBSURFACE STORAGE, FILTRATION THROUGH BIOTREATMENT SOIL, AND INFILTRATION INTO NATIVE SOIL WHERE FEASIBLE. BIORETENTION PLANTERS TYPICALLY HAVE VERTICAL SIDES, AND MAY HAVE UNDERDRAINS AND IMPERMEABLE LINERS ON THE SIDES AND/OR BOTTOM OF FACILITY IF NEEDED, BASED ON SOIL CONDITIONS AND GEOTECHNICAL CONSIDERATIONS. BIORETENTION PLANTERS MAY ALSO BE REFERRED TO AS STORMWATER PLANTERS OR STORMWATER CURB EXTENSIONS (ALSO KNOWN AS BULB-OUTS) DEPENDING ON THEIR LOCATION IN THE STREETSCAPE.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. PLANTER SURFACE AREA AND PONDING DEPTH MUST BE SIZED TO MEET SAN FRANCISCO BAY MUNICIPAL REGIONAL STORMWATER PERMIT (ORDER NO. R2-2022-0018 OR CURRENT) PROVISION C.3.D
3. 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 (PREFERRED) TO 72 HOUR MAXIMUM FACILITY DRAWDOWN
4. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
5. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.
6. THE PLANTER WALL SLOPE IS TYPICALLY DESIGNED TO MATCH THE LONGITUDINAL SLOPE OF THE ADJACENT ROADWAY/SIDEWALK. THE FACILITY SUBGRADE, HOWEVER, SHOULD BE FLAT. CHECK DAMS MAY BE USED TO TERRACE FACILITIES TO PROVIDE SUFFICIENT PONDING FOR HIGHER-SLOPED INSTALLATIONS. DESIGNER MUST SPECIFY CHECK DAM HEIGHT AND SPACING. REFER TO DWG NO. 820 & 821 FOR GUIDANCE ON CHECK DAM DESIGN.
7. THE DESIGN SHALL MINIMIZE THE HEIGHT OF EXPOSED PLANTER WALLS BETWEEN THE TOP OF SOIL AND TOP OF CURB WALL AND CONSIDER PEDESTRIAN AND VEHICLE SAFETY, ACCESSIBILITY REQUIREMENTS, AND OVERALL AESTHETICS. DEPENDING ON THE HEIGHT OF THE PROPOSED PLANTER WALL, ADDITIONAL STRUCTURAL CONSIDERATIONS MAY BE REQUIRED TO ADDRESS WALL LOADING.
8. 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.
9. 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.
9. PLANTERS IN PUBLIC RIGHT OF WAY SHALL BE DESIGNED WITH EMERGENCY OVERFLOW TO THE STREET IN THE EVENT THE PLANTER OUTLET IS OBSTRUCTED OR CLOGGED. IN THE EVENT THE PLANTER OVERFLOW DRAIN IS OBSTRUCTED OR CLOGGED, THE INUNDATION AREA SHALL BE CONTAINED WITHIN THE STREET AND SHALL NOT BE WITHIN ADJACENT PRIVATE PROPERTIES.
10. PLANTER VEGETATION MUST BE SPECIFIED BY DESIGN PROFESSIONAL PER CITY VEGETATION PALLET OR APPENDIX D OF THE SCVURPPP C.3 STORMWATER HANDBOOK FOR GUIDANCE. LANDSCAPE ARCHITECT SHOULD APPROVE DESIGN/PLANTING PALETTE IF PONDING IS OVER 6".
11. THE DESIGNER MUST EVALUATE UTILITY SURVEYS FOR POTENTIAL UTILITY CROSSINGS OR CONFLICTS. UTILITIES ARE NOT ALLOWED IN BIORETENTION AREAS. REFER TO THE CITY'S UTILITY CROSSING DETAILS AND UTILITY CROSSING CONFLICT DETAILS AND CONTACT PUBLIC WORKS AND UTILITIES FOR GUIDANCE.
12. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY ASSET PROTECTION STANDARDS. IN THE ABSENCE OF THESE STANDARDS, THE DESIGNER SHALL REFER TO CITY'S GSI HANDBOOK FOR GUIDANCE. FREEBOARD REQUIREMENTS SHOWN SHOULD BE USED AS GUIDELINES.
13. THESE BIORETENTION PLANTER DETAILS ADAPTED FROM STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES (SAN FRANCISCO PUBLIC UTILITIES COMMISSION), 2016, INCLUDING APPENDIX B GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.
14. REFER TO CITY'S GUIDANCE AND SPECIFICATIONS FOR STEP OUT ZONE, PEDESTRIAN ZONE, PARKING SPACE AND ACCESSIBLE PATH REQUIREMENTS.
15. LOCATE CURB CUTS AND GUTTER MODIFICATIONS TO AVOID CONFLICTS WITH ACCESSIBILITY REQUIREMENTS (E.G., LOCATE OUTSIDE OF CROSSWALKS).

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ PLANTER WIDTH AND LENGTH
- ☐ DEPTH OF PONDING
- ☐ DEPTH OF FREEBOARD
- ☐ DEPTH OF BIOTREATMENT SOIL
- ☐ DEPTH AND TYPE OF AGGREGATE STORAGE
- ☐ PLANTER SURFACE ELEVATION (TOP OF BIOTREATMENT SOIL) AT UPSLOPE AND DOWNSLOPE ENDS OF FACILITY
- ☐ CONTROL POINTS AT EVERY PLANTER WALL CORNER AND POINT OF TANGENCY
- ☐ DIMENSIONS AND DISTANCE TO EVERY INLET, OUTLET, CHECK DAM, SIDEWALK NOTCH, ETC.
- ☐ ELEVATIONS OF EVERY INLET, OUTLET, STRUCTURE RIM AND INVERT, CHECK DAM, PLANTER WALL CORNER, AND SIDEWALK NOTCH
- ☐ TYPE AND DESIGN OF PLANTER COMPONENTS (E.G., EDGE TREATMENTS, INLETS/GUTTER MODIFICATIONS, UTILITY CROSSINGS, LINER, AND PLANTING DETAILS)

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BIORETENTION PLANTER DESIGNER NOTES

City of Palo Alto Standard

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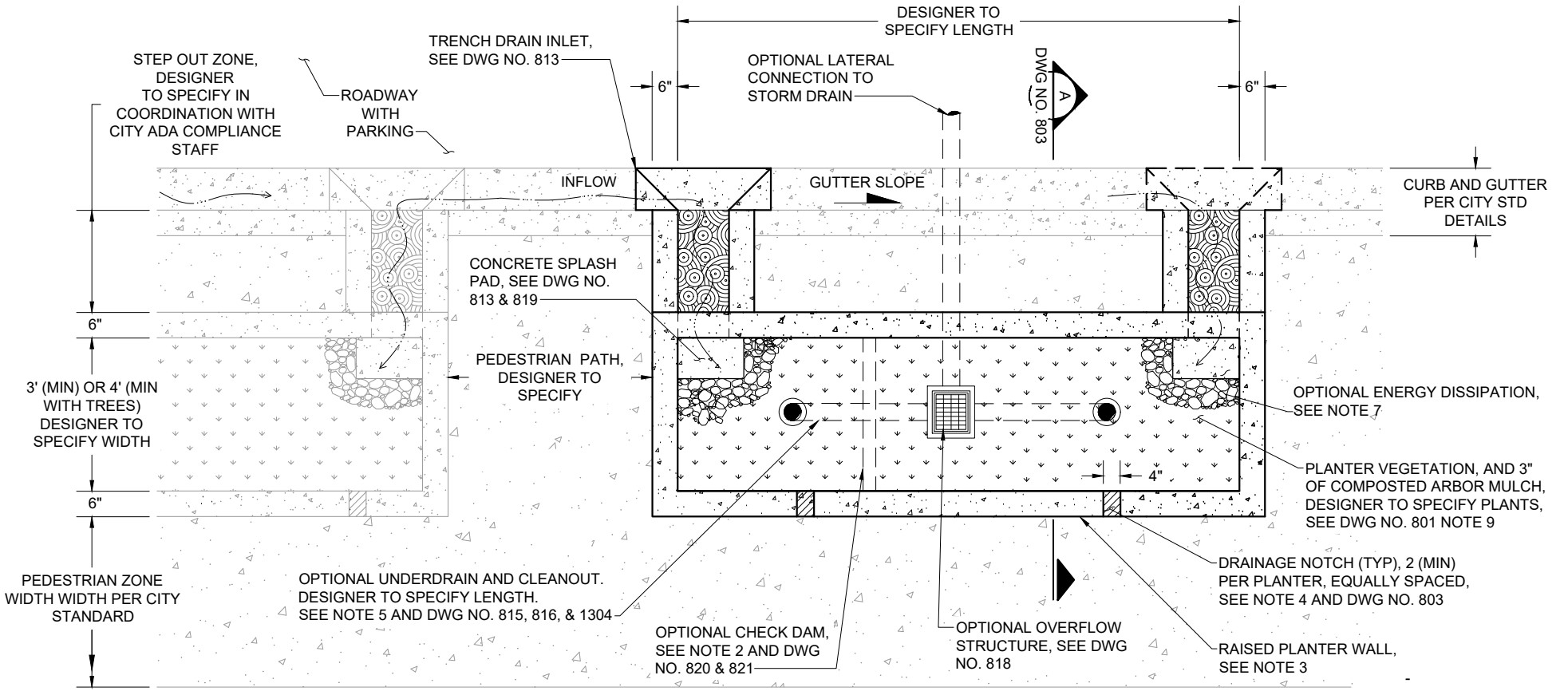
Dwg No. **801**



CONSTRUCTION NOTES:

1. REFER TO DWG NO. 801 FOR GUIDELINES AND CHECKLIST.
2. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
3. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.
4. CHECK DAMS (IF NEEDED) SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
5. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.PLANTER WALL MUST CONFORM TO LOCAL ADA REQUIREMENTS.
6. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
7. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
8. REFER TO SITING REQUIREMENTS FOR UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK TABLE 6. COORDINATE WITH PROJECT MANAGER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
9. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.

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BIORETENTION PLANTER WITH VERTICAL WALLS

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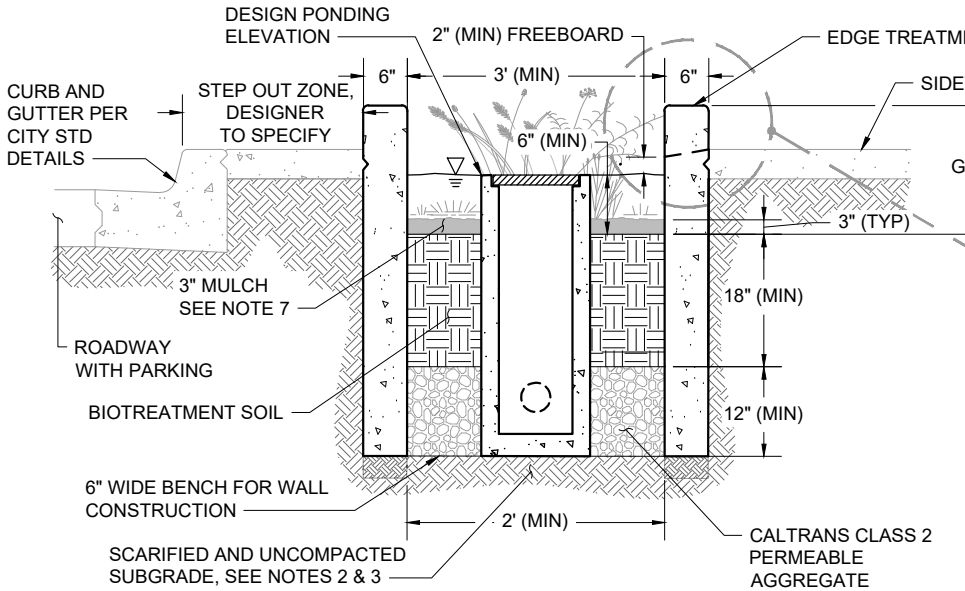
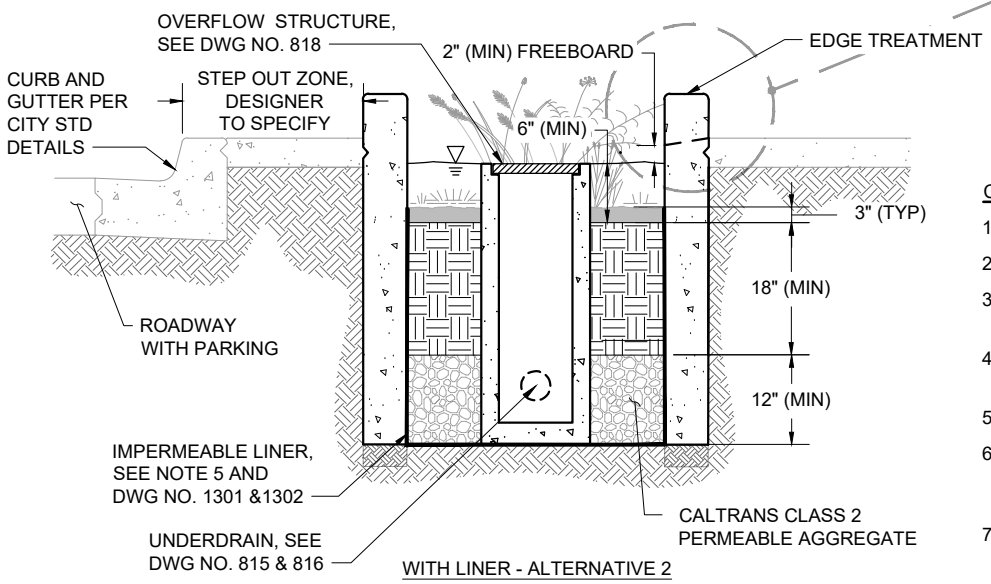
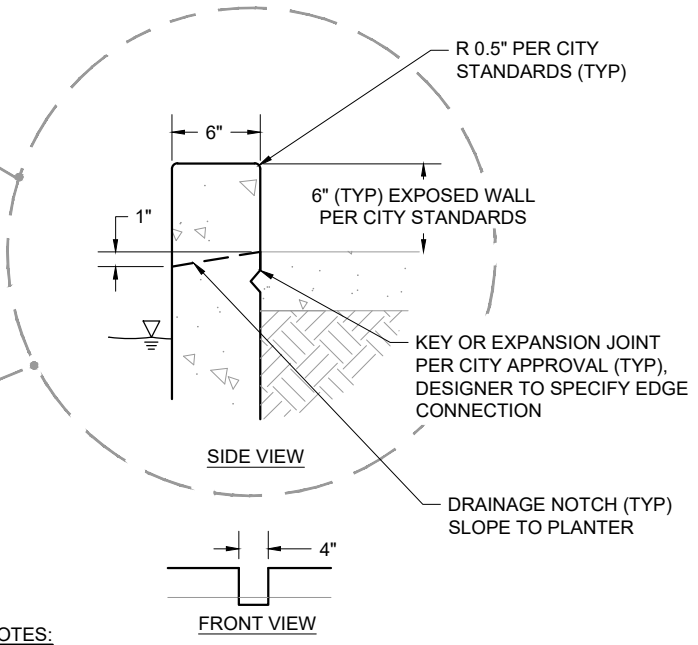


NO LINER - ALTERNATIVE 1



WITH LINER - ALTERNATIVE 2

TYPICAL DRAINAGE NOTCH DETAIL



CONSTRUCTION NOTES:

1. REFER TO DWG NO. 801 FOR GUIDELINES AND CHECKLIST.
2. AVOID COMPACTION OF EXISTING SUBGRADE BELOW PLANTER DURING CONSTRUCTION.
3. SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF CALTRANS CLASS 2 PERMEABLE AGGREGATE AND BIOTREATMENT SOIL MATERIAL.
4. MAXIMUM DROP FROM TOP OF CURB TO TOP OF BIOTREATMENT SOIL SHALL INCLUDE CONSIDERATIONS FOR BIOTREATMENT SOIL SETTLEMENT.
5. IMPERMEABLE LINER SHALL ONLY BE USED WHEN SITE CONDITIONS REQUIRE USE.
6. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
7. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.

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BIORETENTION PLANTER WITH VERTICAL WALL SECTIONS

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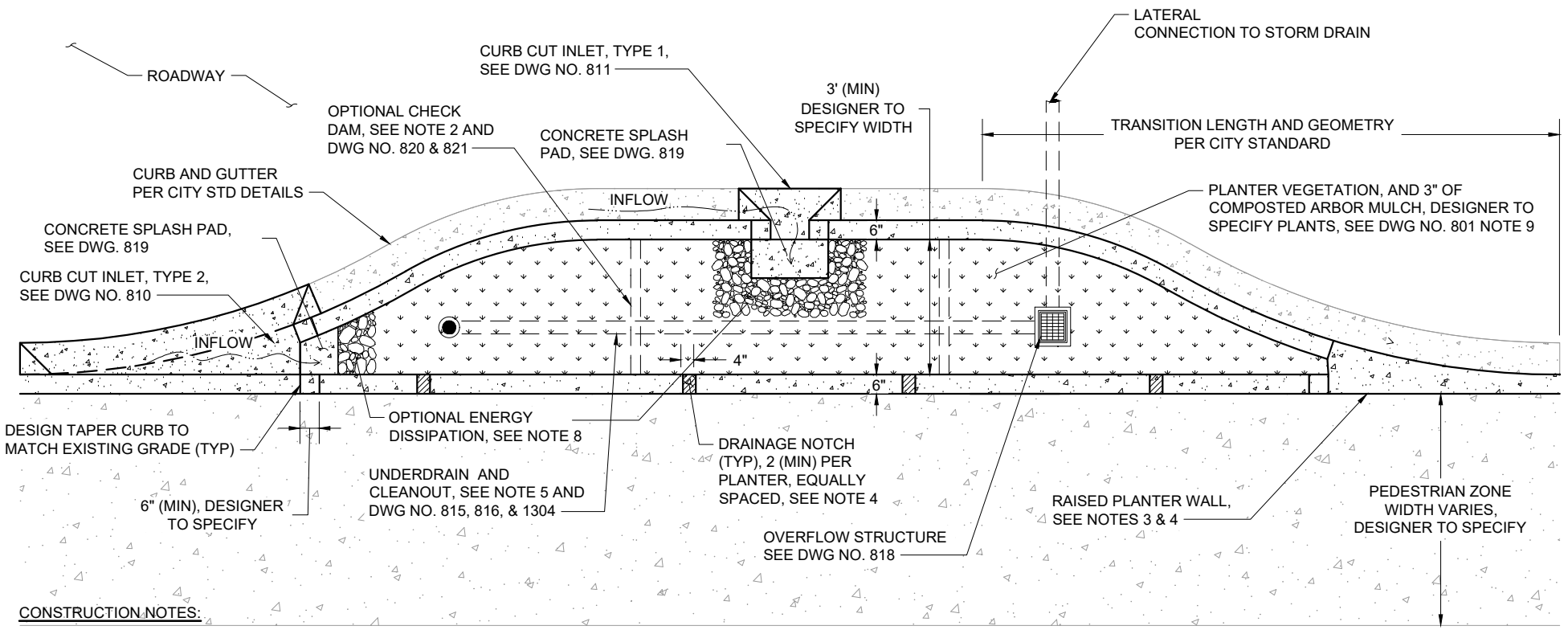

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 801 FOR GUIDELINES AND CHECKLIST.
2. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
3. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.
4. CHECK DAMS (IF NEEDED) SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
5. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
6. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
7. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
8. REFER TO SITING REQUIREMENTS FOR UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK TABLE 6. COORDINATE WITH PROJECT MANAGER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
9. REFER TO SECTION A OF DWG NO. 810 FOR INLET CURB CUT TYPE CROSS SECTION.
10. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.

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BIORETENTION PLANTER
MIDBLOCK CURB EXTENSION

City of Palo Alto Standard

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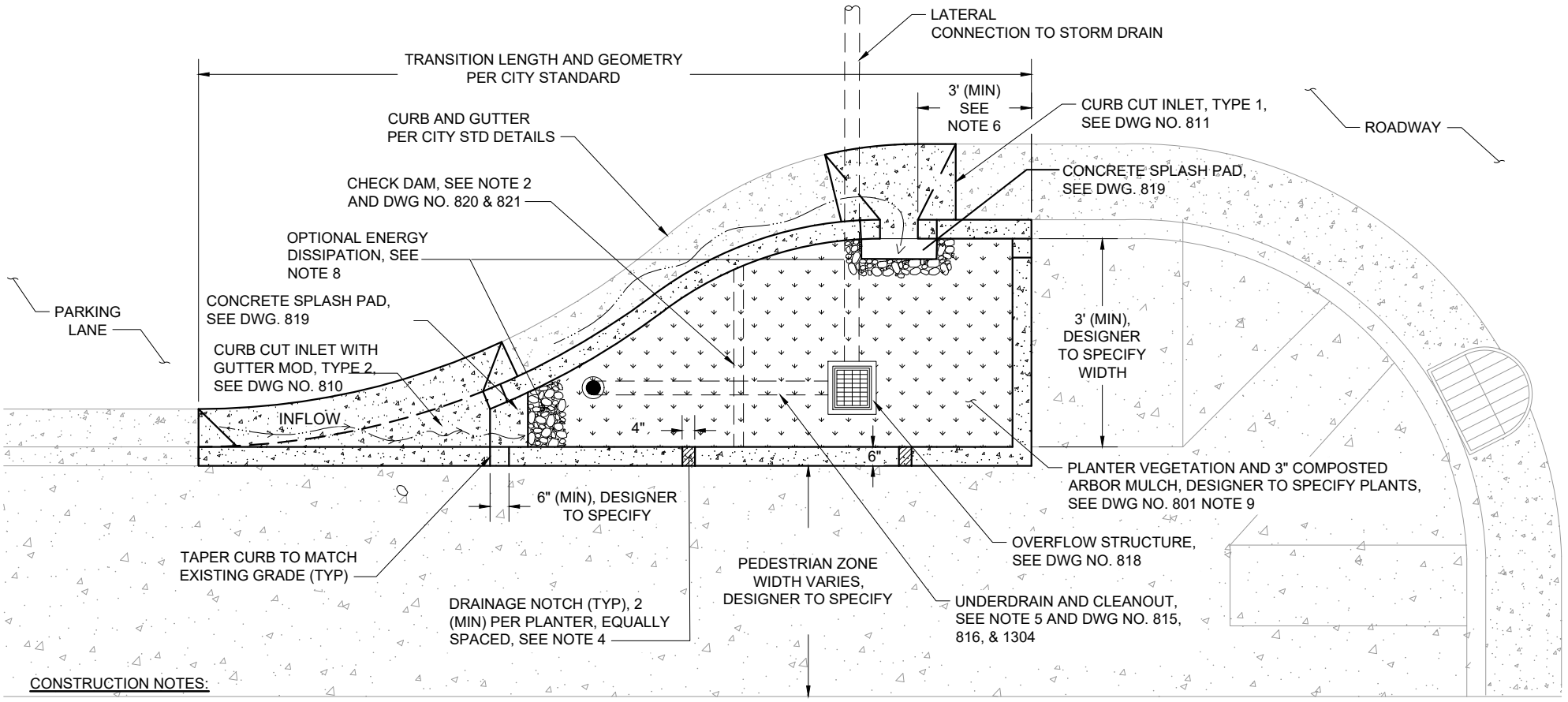
Date _____

Dwg No. **804**



CONSTRUCTION NOTES:

1. REFER TO DWG NO. 801 FOR GUIDELINES AND CHECKLIST.
2. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
3. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.
4. CHECK DAMS (IF NEEDED) SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
5. SLOPE TOP OF PLANTER WALL TO MATCH LONGITUDINAL SLOPE OF ADJACENT SURFACE.
6. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
7. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
8. REFER TO SITING REQUIREMENTS FOR UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK TABLE 6. COORDINATE WITH PROJECT MANAGER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
9. REFER TO SECTION A OF DWG NO 810 FOR INLET CURB CUT TYPE CROSS SECTION.
10. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.

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Scale: NTS

BIORETENTION PLANTER
CORNER CURB EXTENSION

City of Palo Alto Standard

Approved by: _____

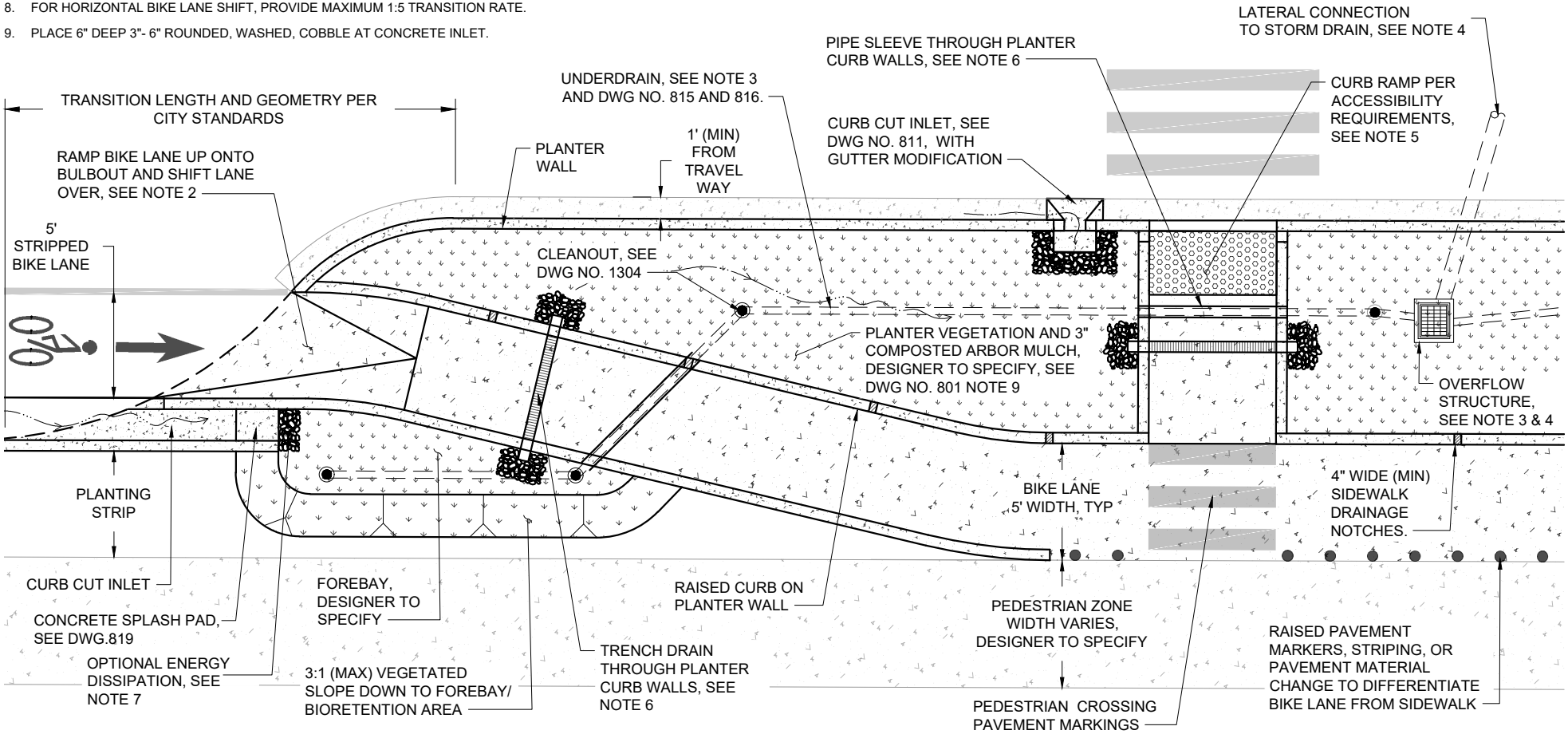
PE No. _____

Date _____

Dwg No. **805**

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 801 FOR GUIDELINES AND CHECKLIST.
2. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
3. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.
4. PROVIDE UNDERDRAIN WHERE REQUIRED TO MEET THE MINIMUM SURFACE WATER DRAWDOWN TIME. LONGITUDINAL SLOPE OF PIPE SHALL BE 0.5%MINIMUM. PROVIDE CLEANOUT AT UPSTREAM END AND ANGLE POINTS EXCEEDING 45 DEGREES.
5. DESIGNER TO SPECIFY OVERFLOW STRUCTURE SIZE AND MATERIAL (SEE DWG NO. 818). WHERE FEASIBLE, CONNECT TO THE EXISTING STORM DRAIN LATERAL SERVING THE CORNER CATCH BASIN BEING REMOVED, IF ANY.
6. PROVIDE TRENCH DRAINS THROUGH PLANTER CURB WALLS TO ALLOW FOR THE HYDRAULIC CONNECTION OF SEPARATED BIORETENTION PLANTERS AND PIPE SLEEVES FOR THE PASSING OF SOLID UNDERDRAIN CONNECTOR PIPES.
7. ADHERE TO ALL CITY AND FEDERAL ACCESSIBILITY REQUIREMENTS FOR THE SIDEWALK AND CURB RAMP DESIGNS.
8. FOR HORIZONTAL BIKE LANE SHIFT, PROVIDE MAXIMUM 1:5 TRANSITION RATE.
9. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.



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BIORETENTION PLANTER
MIDBLOCK BULB-OUT
WITH RAISED BIKE LANE AND PEDESTRIAN CROSSING

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **806**

PURPOSE:

BIORETENTION AREAS CAPTURE AND TREAT STORMWATER RUNOFF VIA SURFACE AND SUBSURFACE STORAGE, FILTRATION THROUGH BIOTREATMENT SOIL, AND INFILTRATION INTO NATIVE SOIL WHERE FEASIBLE. BIORETENTION BASINS MAY HAVE UNDERDRAINS AND IMPERMEABLE LINERS ON THE SIDES AND/OR BOTTOM OF FACILITY IF NEEDED, BASED ON SOIL CONDITIONS AND GEOTECHNICAL CONSIDERATIONS.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. FACILITY SURFACE AREA, PONDING DEPTH, AND BIORETENTION SOIL DEPTH MUST BE SIZED TO MEET MRP PROVISION C.3.d SIZING REQUIREMENTS.
3. 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 (PREFERRED) TO 72 HOUR MAXIMUM FACILITY DRAWDOWN.
4. AN AGGREGATE COURSE IS REQUIRED UNDER THE BIOTREATMENT SOIL. AGGREGATE SHALL BE CALTRANS CLASS 2 PERMEABLE MATERIAL.
5. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
6. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.
7. CHECK DAMS MAY BE USED TO TERRACE FACILITIES TO PROVIDE SUFFICIENT PONDING FOR HIGHER-SLOPED INSTALLATIONS. DESIGNER MUST SPECIFY CHECK DAM HEIGHT AND SPACING. REFER TO DWG NO. 820 & 821 FOR GUIDANCE ON CHECK DAM DESIGN.
8. THE FOLLOWING GUIDELINES APPLY TO RIGHT-OF-WAY APPLICATIONS:
   - BULBOUT 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 BIORETENTION AREA TO TOP OF CURB ELEVATION BETWEEN CURB CUTS OR CONTINUOUS 6 INCH REVEAL AT CURB EDGE, CONFIRMING WITH CITY ADA REQUIREMENTS.
9. BIORETENTION AREAS IN PUBLIC RIGHT OF WAY SHALL BE DESIGNED WITH AN EMERGENCY OVERFLOW. IN THE EVENT THE BIORETENTION AREA OVERFLOW DRAIN IS OBSTRUCTED OR CLOGGED, THE INUNDATION AREA SHALL BE CONTAINED WITHIN THE STREET AND SHALL NOT BE WITHIN ADJACENT PRIVATE PROPERTIES. UP TO TWO BIORETENTION AREAS 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.
10. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY ASSET PROTECTION STANDARDS. IN THE ABSENCE OF THESE STANDARDS, THE DESIGNER SHALL REFER TO CITY'S GSI HANDBOOK FOR GUIDANCE.
11. FREEBOARD REQUIREMENTS SHOWN SHOULD BE USED AS GUIDELINES .
12. BIORETENTION AREA VEGETATION MUST BE SPECIFIED BY DESIGN PROFESSIONAL PER CITY VEGETATION PALLETTE OR APPENDIX D OF THE SCVURPPP C.3 STORMWATER HANDBOOK FOR GUIDANCE. LANDSCAPE ARCHITECT SHOULD APPROVE OF DESIGN/PLANTING PALETTE IF PONDING IS OVER 6"
13. THESE BIORETENTION PLANTER DETAILS ADAPTED FROM STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES (SAN FRANCISCO PUBLIC UTILITIES COMMISSION), 2016, INCLUDING APPENDIX B GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ FACILITY WIDTH, LENGTH, SLOPES (INCLUDING SIDE, CROSS, AND LONGITUDINAL), AND SHAPE
- ☐ DEPTH OF BIOTREATMENT SOIL
- ☐ DEPTH AND TYPE OF AGGREGATE STORAGE, IF ANY
- ☐ BIORETENTION AREA SURFACE ELEVATION (TOP OF BIOTREATMENT SOIL) AT UPSLOPE AND DOWNSLOPE ENDS OF FACILITY (I.E., PROVIDE SPOTS AND/OR CONTOURS AS NEEDED)
- ☐ CONTROL POINTS AT EVERY CORNER OF FACILITY AND POINT OF TANGENCY
- ☐ DIMENSIONS AND DISTANCE TO EVERY INLET, OUTLET, CHECK DAM, SIDEWALK NOTCH, ETC.
- ☐ ELEVATIONS OF EVERY INLET, OUTLET, STRUCTURE RIM AND INVERT, CHECK DAM, AND SIDEWALK NOTCH
- ☐ TYPE AND DESIGN OF FACILITY COMPONENTS (E.G., EDGE TREATMENTS, INLETS/GUTTER MODIFICATIONS, UTILITY CROSSINGS, LINER, AND PLANTING DETAILS)
- ☐ DEPTH AND TYPE OF MULCH

LAYOUT REQUIREMENTS:

1. FOR RIGHT-OF-WAY APPLICATIONS, REFER TO THE CITY STANDARD ACCESSIBILITY REQUIREMENTS DRAWINGS AND SPECIFICATIONS FOR CONSTRUCTION FOR STEP OUT ZONE, PEDESTRIAN ZONE, PARKING SPACE AND PEDESTRIAN PATH REQUIREMENTS.
2. LOCATE CURB CUTS AND GUTTER MODIFICATIONS TO AVOID CONFLICTS WITH ACCESSIBILITY REQUIREMENTS (E.G., LOCATE OUTSIDE OF CROSSWALKS).

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BIORETENTION AREA DESIGNER NOTES

City of Palo Alto Standard

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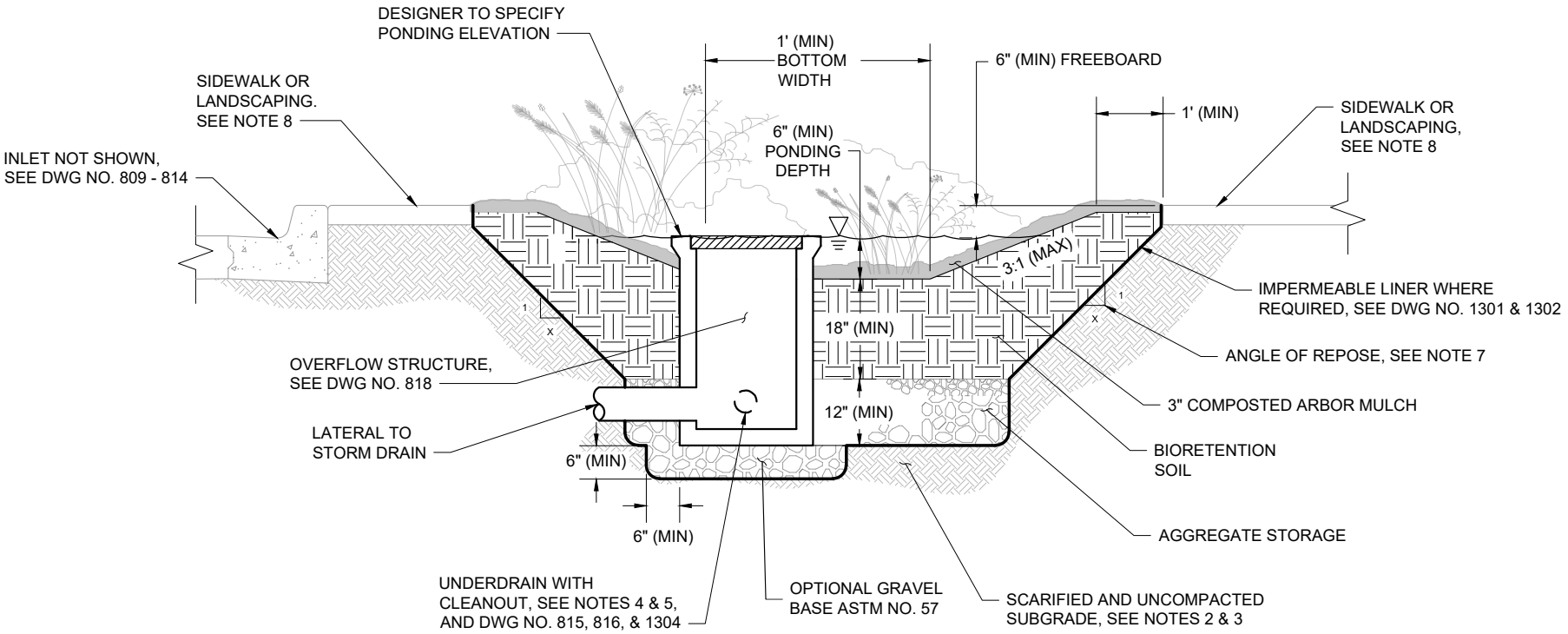
Date _____

Dwg No. **807**



CONSTRUCTION NOTES:

1. REFER TO DWG NO. 807 FOR GUIDELINES AND CHECKLIST.
2. FOR UNLINED BIORETENTION AREAS, AVOID COMPACTION OF EXISTING SUBGRADE BELOW BASIN.
3. FOR UNLINED BIORETENTION AREAS, SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIORETENTION SOIL MATERIALS.
4. INSTALL BIOTREATMENT SOIL MEDIA (BSM) IN EITHER TWO 10" LIFTS AND THEN WETTED TO ACCOMMODATE AN EXPECTED 2" OF SETTLING OR THREE 6" LIFTS THEN WETTED WITH ADDITIONAL BSM ADDED TO THE SURFACE AS NEEDED TO ACHIEVE A FINAL DEPTH OF 18".
5. REFER TO COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS IN ATTACHMENT G OF CITY GSI HANDBOOK.
6. UNDERDRAIN REQUIRED FOR ALL FACILITIES WITH IMPERMEABLE LINER.
7. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
8. REFER TO SITING REQUIREMENTS FOR UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK TABLE 6. COORDINATE WITH PROJECT MANAGER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
9. ANGLE OF REPOSE VARIES PER GEOTECHNICAL ENGINEER RECOMMENDATIONS.
10. REFER TO CITY STANDARDS FOR SIDEWALK DETAILS.

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Scale: NTS

BIORETENTION AREA PARCEL SECTION

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PE No. _____

Date _____

Dwg No. **808**

PURPOSE:

CURB CUTS AND TRENCH DRAINS 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. WITH NO STEP OUT ZONE), PROVIDING AN OPENING TO INTERCEPT AND CONVEY STORMWATER FROM THE GUTTER TO THE PLANTER. TRENCH DRAIN SYSTEMS ARE MOST COMMONLY USED TO CONVEY STORMWATER FROM A GUTTER THROUGH THE STEP OUT ZONE TO A BIORETENTION PLANTER; PROVIDING A CONTINUOUS SURFACE FOR PEDESTRIAN ACCESS WHILE MINIMIZING ELEVATION LOSSES AT THE FACILITY INFLOW LOCATIONS. CURB CUT AND TRENCH DRAIN 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 CUTS AND TRENCH DRAIN INLETS ARE ADEQUATELY SIZED, SPACED, AND SLOPED TO SATISFY CITY HYDRAULIC REQUIREMENTS.
3. TRENCH DRAIN GRATES AND ASSEMBLIES MUST COMPLY WITH CITY STANDARDS.
4. DESIGNER MAY SPECIFY CURB CUT INLET/OUTLET MODIFICATION WITH METAL PLATE TOP WHEN ADJACENT TO VEHICLE PARKING AND LOADING AREAS WITH APPROVAL FROM CITY.
5. ENERGY DISSIPATION AT INLET STRUCTURES SPECIFIED BY DESIGNER. EXAMPLES INCLUDE STREAMBED COBBLE EMBEDDED IN CONCRETE SPLASH PAD, STREAMBED COBBLE APPROVED BY ENGINEER, OR EQUIVALENT. REFER TO DWG. 819.
6. CURB CUT INLETS SHALL BE ADEQUATELY SIZED, SPACED, AND SLOPED TO MEET HYDRAULIC REQUIREMENTS. THE CURB CUT OPENING WIDTH SHALL BE SIZED BASED ON THE CATCHMENTS 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. 27.

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

Rev	By	Date
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Scale: NTS

BIORETENTION COMPONENTS
INLET DESIGNER NOTES

City of Palo Alto Standard

Approved by: _____

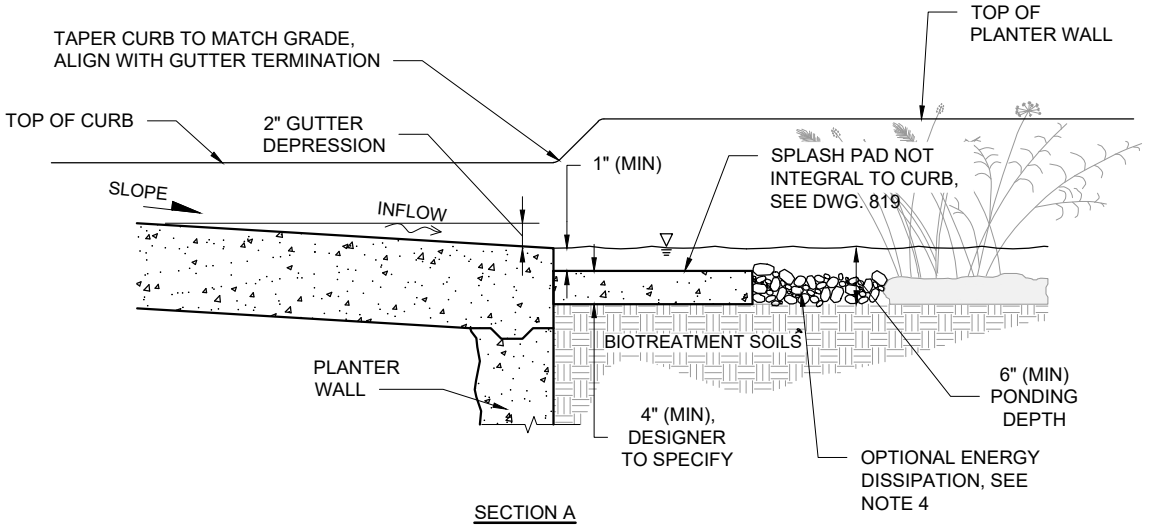
PE No. _____

Date _____

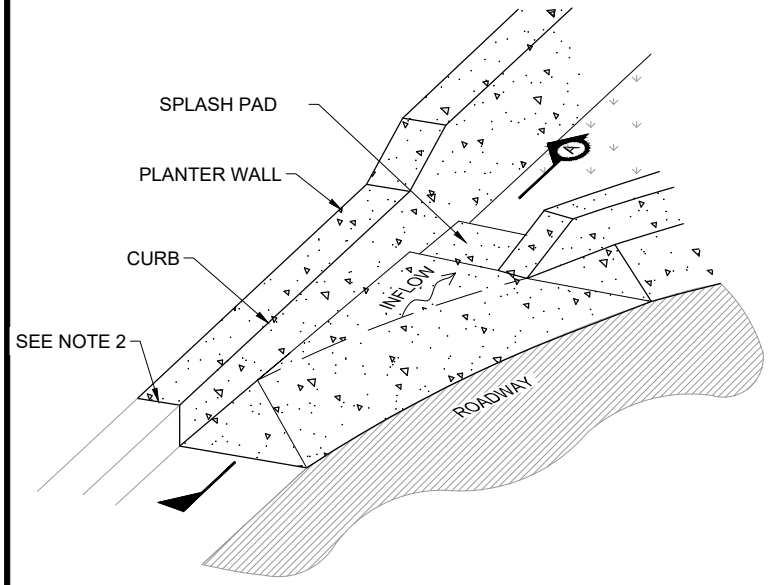
Dwg No. **809**

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. OPTIONAL CHAMFERED OR FILLET EDGES AT CURB CUTS MAY BE USED.
4. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.



SECTION A



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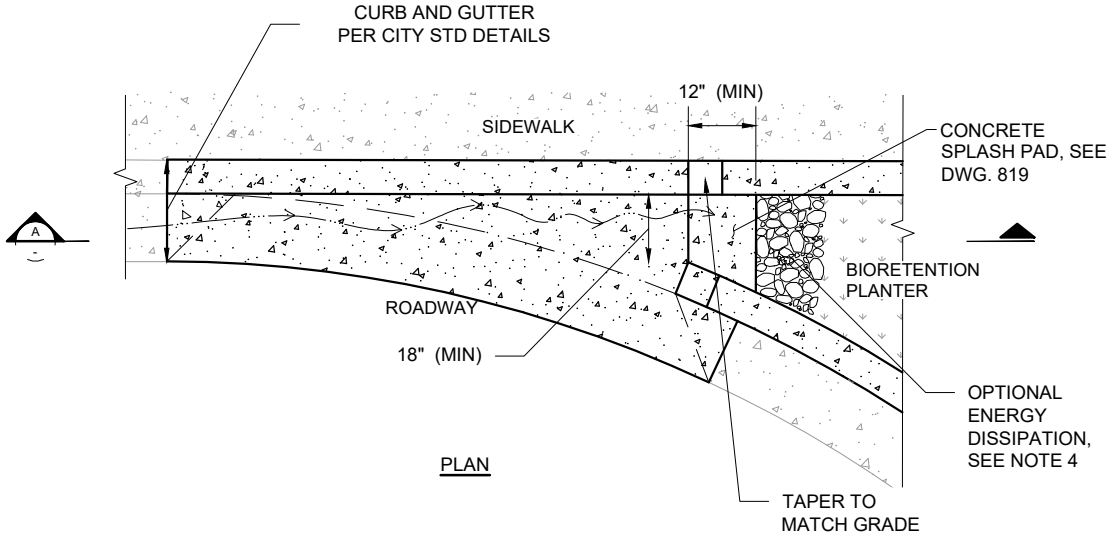

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INLET - CURB CUT TYPE 2 — 1

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Scale: NTS

BIORETENTION COMPONENTS
CURB CUT AT BULB-OUT

City of Palo Alto Standard

Approved by: _____

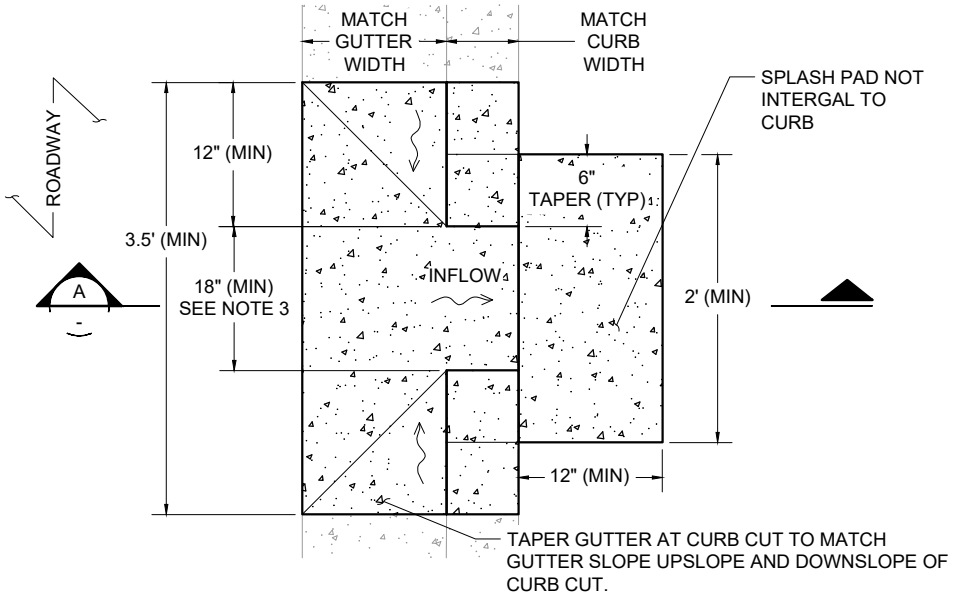
PE No. _____

Date _____

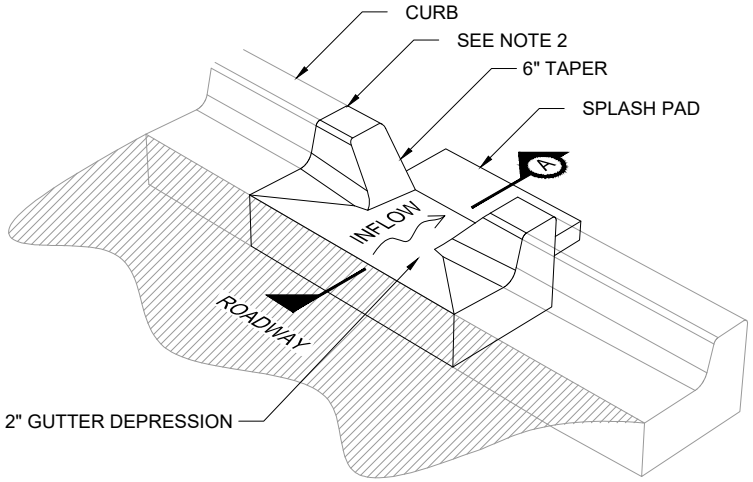
Dwg No. **810**

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 MAY BE INCREASED ON STEEPER GUTTER SLOPES. DESIGNER TO SPECIFY.
4. OPTIONAL CHAMFERED OR FILLET EDGES AT CURB CUTS MAY BE USED.
5. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.



PLAN



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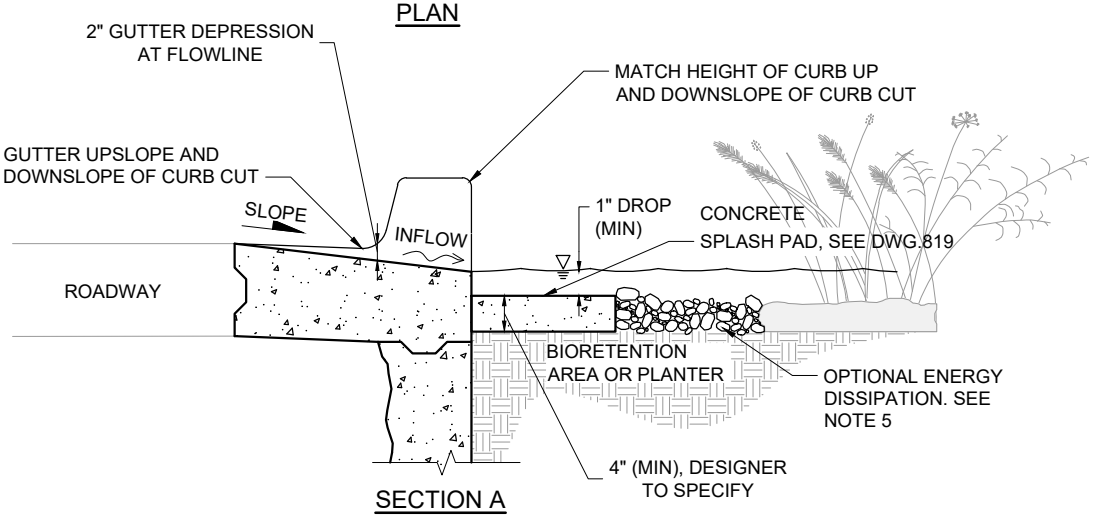

SECTION A

INLET - CURB CUT TYPE 1 (1)

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BIORETENTION COMPONENTS
CURB CUT WITH GUTTER MODIFICATION

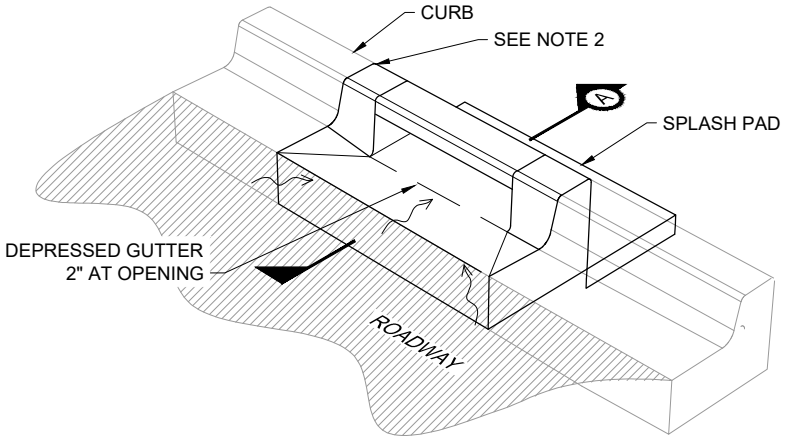
City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **811**



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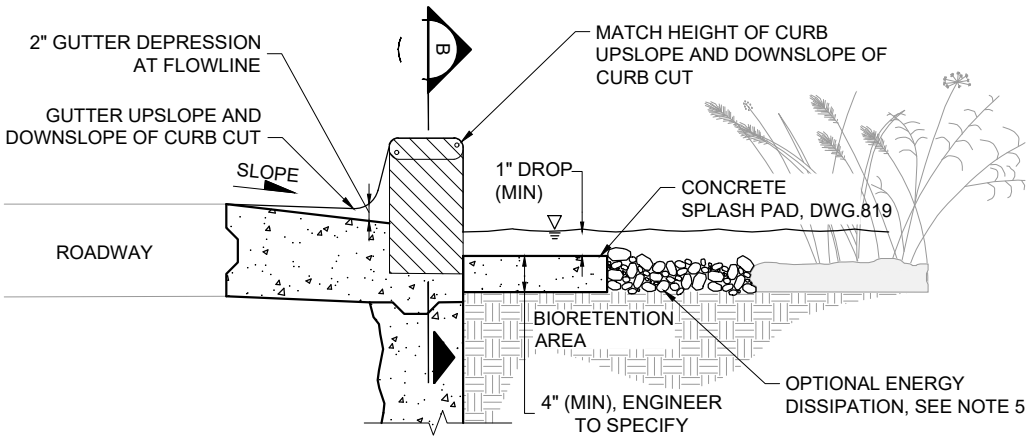
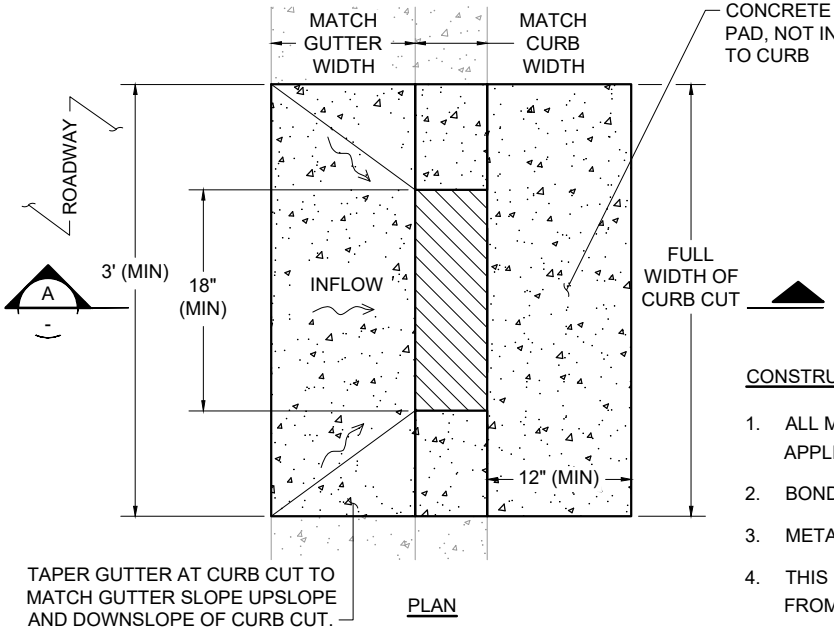
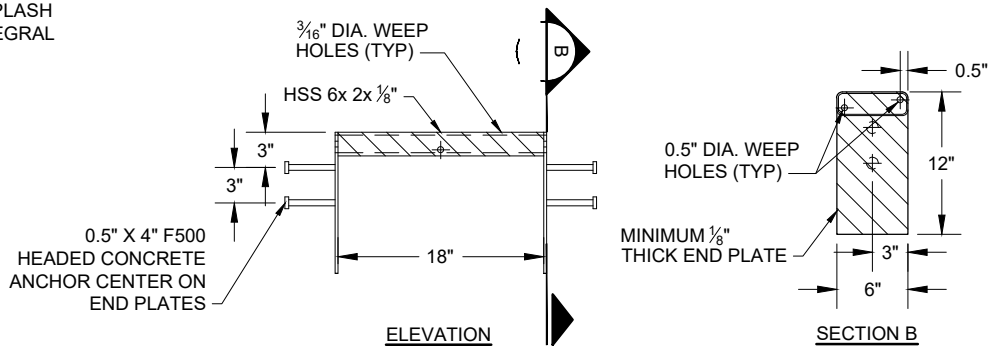


SECTION A



PLAN

METAL INLET ASSEMBLY



ELEVATION

SECTION B

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR CURB CUTS SHALL CONFORM TO MUNICIPAL STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION,
3. METAL INLET ASSEMBLY SHALL BE HOT-DIP GAVANIZED IN ACCORDANCE WITH ASTM A-123.
4. THIS DETAIL IS ADAPTED FROM THE CITY OF DUBLIN PUBLIC WORKS GREEN INFRASTRUCTURE TYPICAL DETAILS AND FROM SFPUC GREEN INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS.
5. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.

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BIORETENTION COMPONENTS
CURB CUT WITH WHEEL GUARD

City of Palo Alto Standard

Approved by: _____

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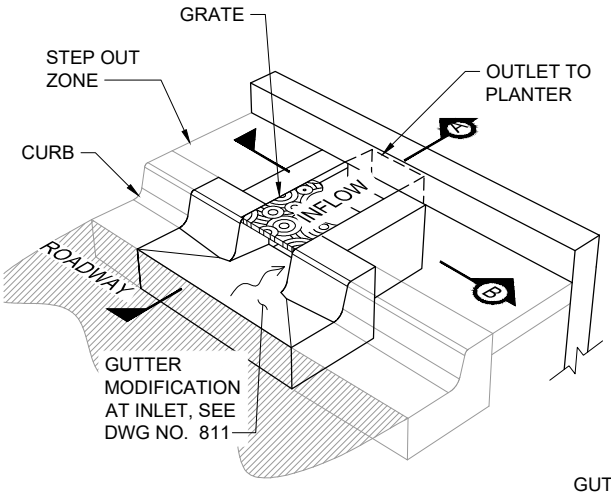
Date _____

Dwg No. **812**



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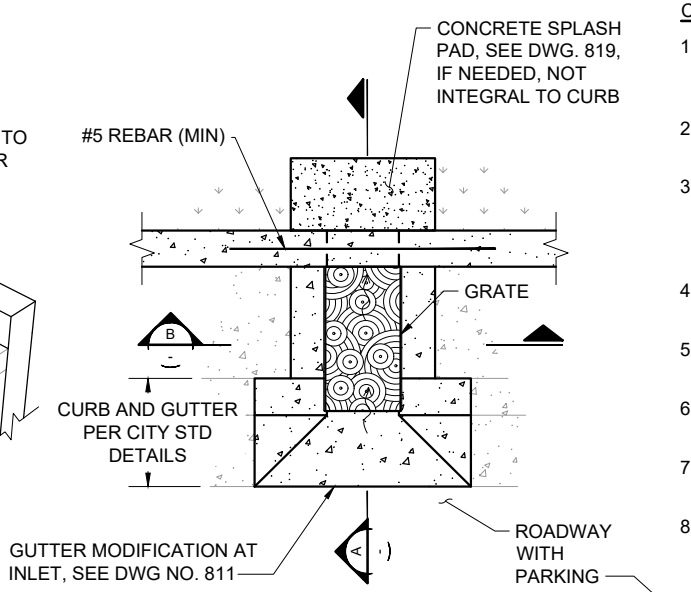
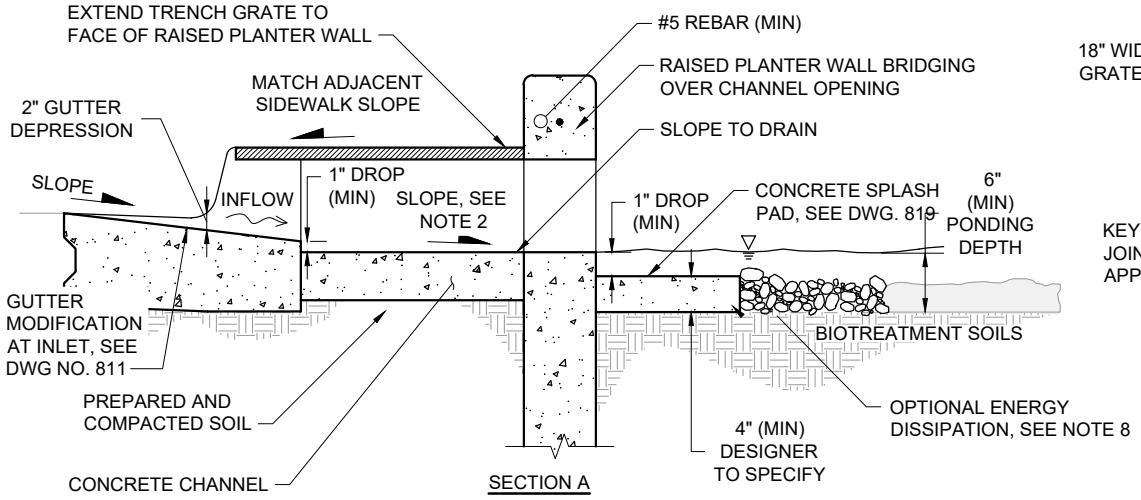


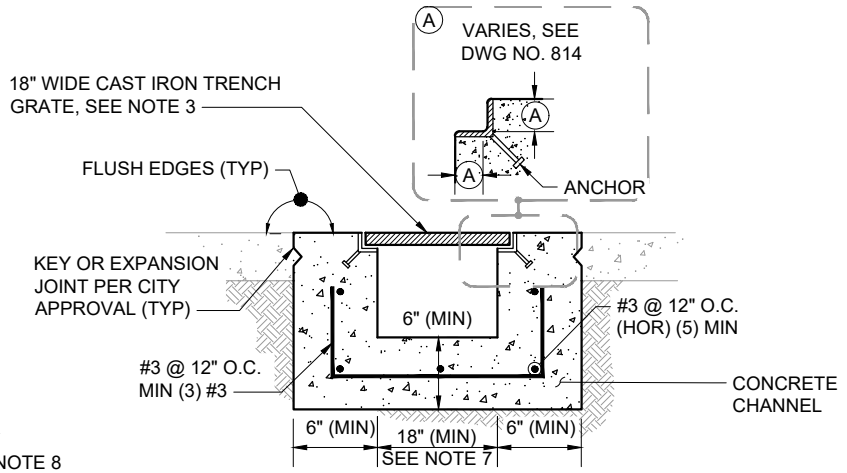
PLAN

CONSTRUCTION NOTES:

1. ALL MATERIAL, REINFORCEMENT, AND WORKMANSHIP FOR TRENCH DRAIN ASSEMBLY SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. SLOPE TO PROVIDE AT LEAST 1 INCH DROP OVER LENGTH OF CHANNEL OR BE A MINIMUM OF 2%, WHICHEVER IS LARGER.
3. 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.
4. BOND NEW CURB AND GUTTER TO EXISTING CURB AND GUTTER WITH EPOXY AND DOWEL CONNECTION.
5. HORIZONTAL CONTROL JOINTS SHALL BE PROVIDED EVERY 10 LINEAR FEET, OR PER MANUFACTURER'S RECOMMENDATIONS.
6. APPLY EPOXY BONDING AGENT AT ALL TRENCH DRAIN CONSTRUCTION COLD JOINTS.
7. CURB CUT AND CONCRETE CHANNEL WIDTH SHALL BE INCREASED ON STEEPER GUTTER SLOPES. DESIGNER TO SPECIFY.
8. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AT CONCRETE INLET.



SECTION A



SECTION B

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BIORETENTION COMPONENTS
CURB CUT WITH TRENCH DRAINS

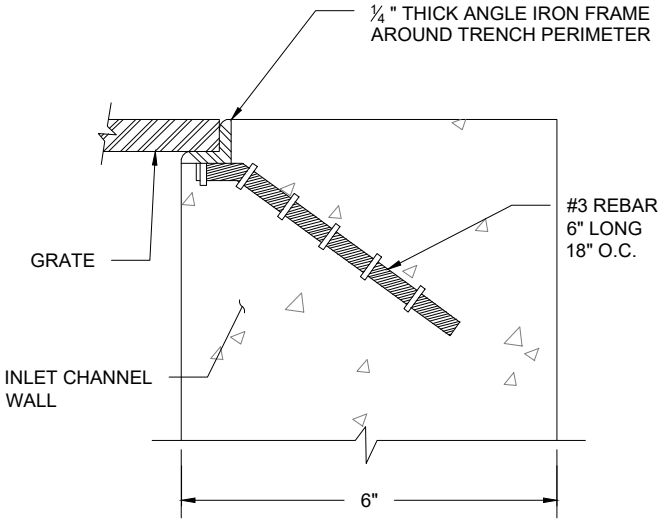
City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **813**



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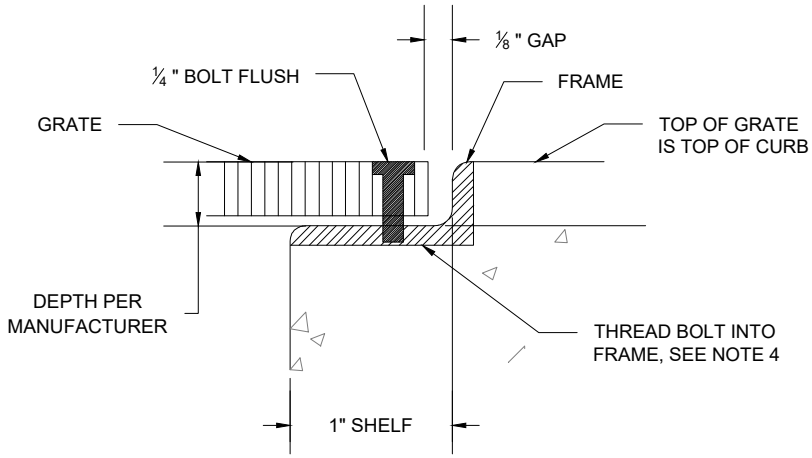

GRATE ATTACHMENT DETAIL

CONSTRUCTION NOTES

1. CAST IRON NATURAL FINISH, SEE DWG NO. 813 FOR BIORETENTION COMPONENT CURB CUT WITH TRENCH DRAIN.
2. NO OPENING GREATER THAN ⅜ ".
3. PROTECT THREADED HOLES IN FRAME FROM CLOGGING DURING FRAME INSTALLATION.
4. GRATE TO BE RATED FOR H-20 LOADING WITH A NON-SLIP SURFACE HAVING A STATIC COEFFICIENT OF FRICTION BETWEEN 0.60 AND 1.0 PER ASTM CI030. GRATES ON INCLINES GREATER THAN 4 % SHALL HAVE A COEFFICIENT OF 0.80 TO 1.0.
5. THIS CURB CUT METAL TRENCH DRAIN COVER BIORETENTION COMPONENT DETAIL IS ADAPTED FROM THE DISTRICT OF COLUMBIA DEPARTMENT OF TRANSPORTATION CURB CUT METAL TRENCH DRAIN COVER -2, OBTAINED SEPTEMBER 2022.

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Scale: NTS

BIORETENTION COMPONENTS
CURB CUT
METAL TRENCH DRAIN COVER

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **814**

PURPOSE:

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

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER SHOULD INCLUDE UNDERDRAIN IN FACILITY DESIGN IN THE FOLLOWING SCENARIOS:
   - MAXIMUM DRAWDOWN PERIOD CANNOT BE ACHIEVED (SEE DWG NO. 818).
   - SUBGRADE MEASURED (I.E., UNCORRECTED) INFILTRATION RATE IS LESS THAN 0.5 INCHES PER HOUR.
   - INFILTRATION 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).
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 SPECIFY 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 CODE.
6. UNDERDRAIN PIPE SHALL BE SLOTTED HDPE SDR 17 OR ACCEPTABLE SUBSTITUTE (E.G. PERFORATED PVC) PER ENGINEERS SPECIFICATIONS. TO HELP PREVENT CLOGGING, TWO ROWS OF PERFORATION MAY BE USED ALONG THE UNDERSIDE OF THE UNDERDRAIN PIPE. THE NOMINAL ROCK DIAMETER SIZE USED IN THE ROCK LAYER SHOULD BE LARGER THAN THE DIAMETER OF THE PERFORATIONS.
7. UNDERDRAIN INVERT SHALL BE LOCATED TO ENSURE THAT THE FULL BIORETENTION SECTION (BIORETENTION SOIL MEDIA AND FULL AGGREGATE SECTION INCLUDING AGGREGATE BELOW UNDERDRAIN) DRAINS WITHIN 48 HOURS.
8. THESE BIORETENTION PLANTER DETAILS ADAPTED FROM STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES (SAN FRANCISCO PUBLIC UTILITIES COMMISSION), 2016, INCLUDING APPENDIX B GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.

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

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BIORETENTION COMPONENTS
UNDERDRAIN
DESIGNER NOTES

City of Palo Alto Standard

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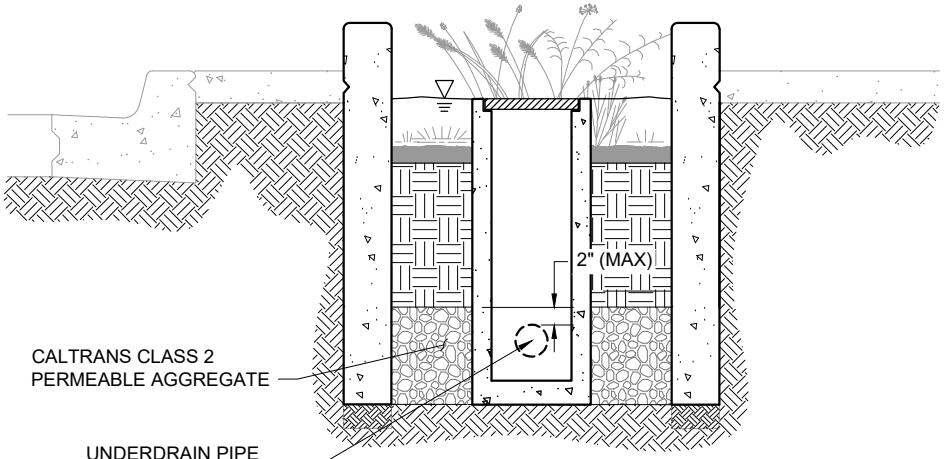
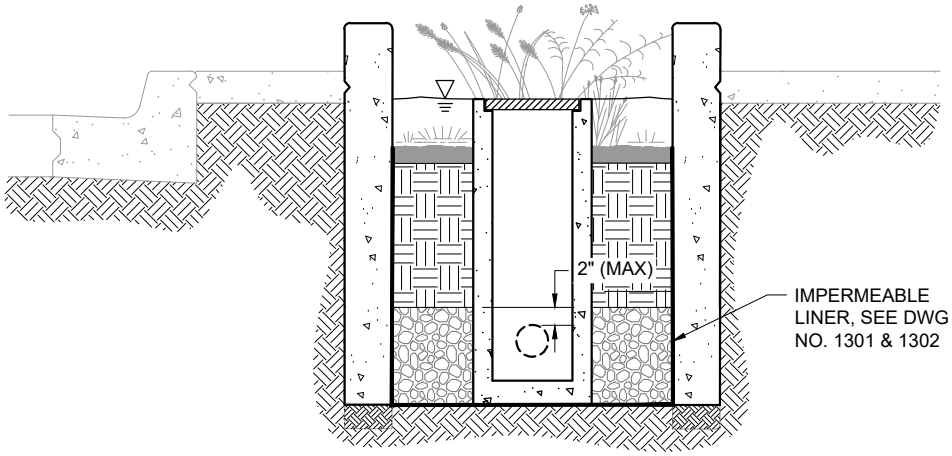
Date _____

Dwg No. **815**



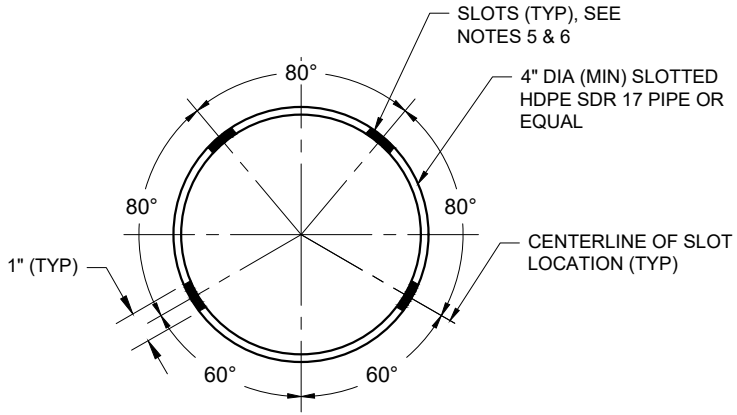
ELEVATED UNDERDRAIN



UNDERDRAIN WITH LINER
WHERE INFILTRATION PROHIBITED

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 815 FOR GUIDELINES AND CHECKLIST.
2. ALL MATERIAL AND WORKMANSHIP FOR UNDERDRAINS SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
3. LONGITUDINAL SLOPE OF UNDERDRAIN PIPE SHALL BE 0.5% MINIMUM.
4. UNDERDRAIN PIPE SHALL BE SLOTTED HDPE SDR 17 OR ACCEPTABLE SUBSTITUTE (E.G. PERFORATED PVC PIPE) PER ENGINEERS SPECIFICATION. SINGLE WALL AND DUAL WALL CORRUGATED HDPE PIPE (AASHTO M252 AND M294 TYPES C, S, AND D) ARE NOT ACCEPTABLE.
5. UNDERDRAIN PIPE SHALL BE SLOTTED TYPE, MEASURING 0.064 INCH WIDE (MAX), SPACED AT 0.30 INCH ON CENTER, AND PROVIDING A MINIMUM INLET AREA OF 10.0 SQUARE INCHES PER LINEAR FOOT OF PIPE. OTHER SLOT CONFIGURATIONS PROVIDING A MINIMUM INLET OF 10.0 SQUARE INCHES PER LINEAR FOOT OF PIPE MAY BE SUBMITTED FOR CITY APPROVAL.
6. SLOTS SHALL BE ORIENTED PERPENDICULAR TO LONG AXIS OF PIPE, AND EVENLY SPACED AROUND CIRCUMFERENCE AND LENGTH OF PIPE.



SLOTTED UNDERDRAIN PIPE 2

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BIORETENTION COMPONENTS
UNDERDRAIN

City of Palo Alto Standard

Approved by: _____

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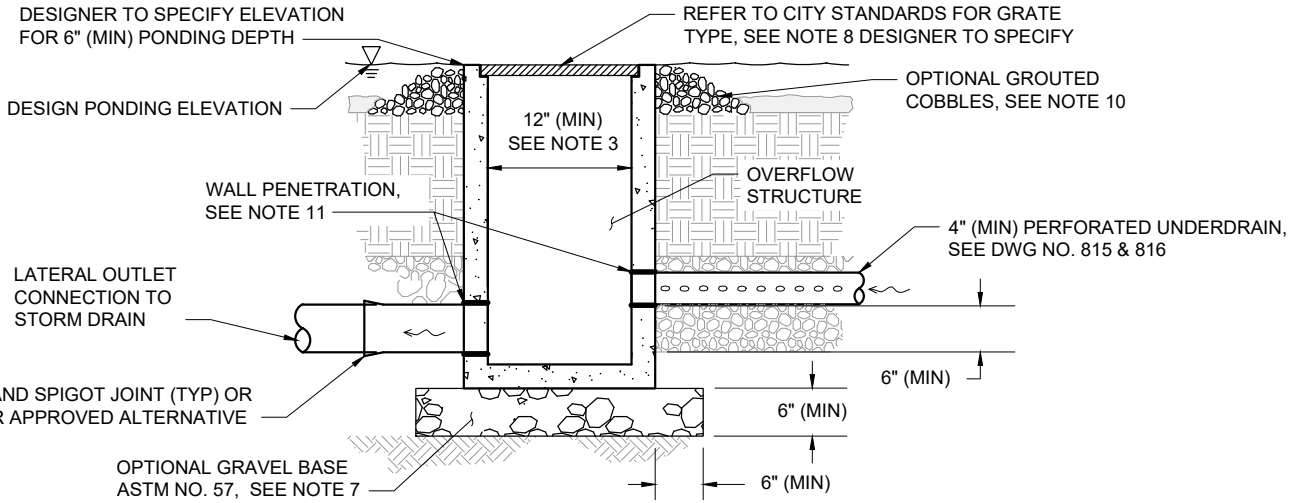
Date _____

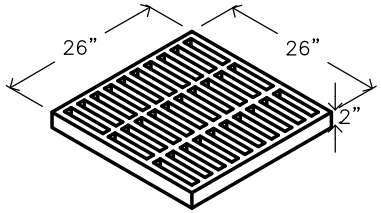
Dwg No. **816**

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 818 ADDITIONAL CONSTRUCTION NOTES.
2. ALL MATERIAL AND WORKMANSHIP FOR OVERFLOW STRUCTURES SHALL CONFORM TO CITY STANDARDS.
3. DESIGN OVERFLOW STRUCTURE AND OUTLET PIPE TO CONVEY 10-YR, 24-HR STORM FLOW OR DESIGN INLET TO DIVERT FLOWS LARGER THAN THE DESIGN STORM DIRECTLY TO THE STORM DRAIN SYSTEM. LOCATE ALL OVERFLOW PIPES AT AN ELEVATION HIGHER THAN THE STORM DRAIN SYSTEM HYDRAULIC GRADE LINE TO PREVENT BACKFLOW INTO THE BIORETENTION FACILITY.
4. STORM DRAIN OUTLET PIPES SHALL BE SIZED TO MEET HYDRAULIC REQUIREMENTS WITH APPROPRIATE COVER DEPTH AND PIPE MATERIAL.
5. PERFORATED UNDERDRAINS WITH CLEANOUT PIPES ARE REQUIRED (SEE DWG NO. 815 & 816).
6. MAINTENANCE ACCESS IS REQUIRED FOR ALL OUTLET STRUCTURES AND CLEANOUT FACILITIES. 12" (MIN) CLEARANCE WITHIN OVERFLOW STRUCTURE SHALL BE PROVIDED FOR MAINTENANCE ACCESS.
7. DESIGNER SHALL REFER TO CITY STANDARDS AND/OR ASSESS NEED FOR GRAVEL BASE. DESIGNER SHALL EVALUATE BUOYANCY OF STRUCTURES FOR SITE SPECIFIC APPLICATION AND SPECIFY THICKENED OR EXTENDED BASE / ANTI-FLOATATION COLLAR, AS NECESSARY.
8. SIZE OF 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 2".
9. IF INTERIOR DEPTH OF OVERFLOW STRUCTURE EXCEEDS 5', A PERMANENT BOLTED LADDER AND MINIMUM CLEAR SPACE OF 30" BY 30" SHALL BE PROVIDED FOR MAINTENANCE ACCESS.
10. MINIMUM DIAMETER OF OPTIONAL GROUTED COBBLES SHALL BE LARGER THAN MAXIMUM GRATE OPENING.
11. GROUT ALL PENETRATIONS, CRACKS, SEAMS, AND JOINTS WITH CLASS "C" MORTAR.
12. THIS DETAIL IS ADAPTED FROM THE CITY OF DUBLIN PUBLIC WORKS GREEN INFRASTRUCTURE TYPICAL DETAILS AND FROM SFPUC GREEN INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS.



GRATE



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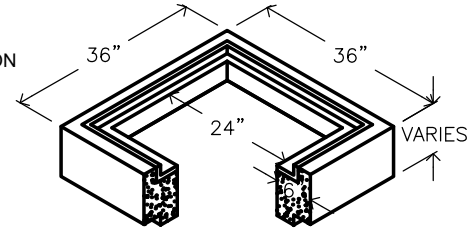

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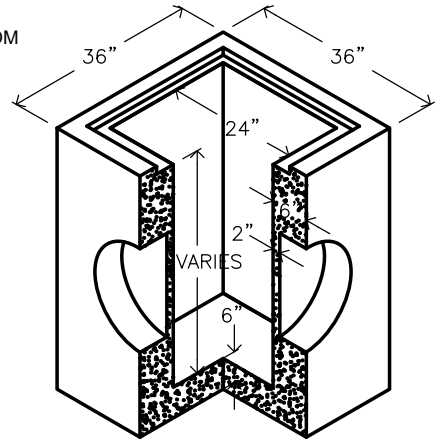

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BIORETENTION COMPONENTS
OVERFLOW STRUCTURE
OPTION #1

City of Palo Alto Standard

Approved by: _____

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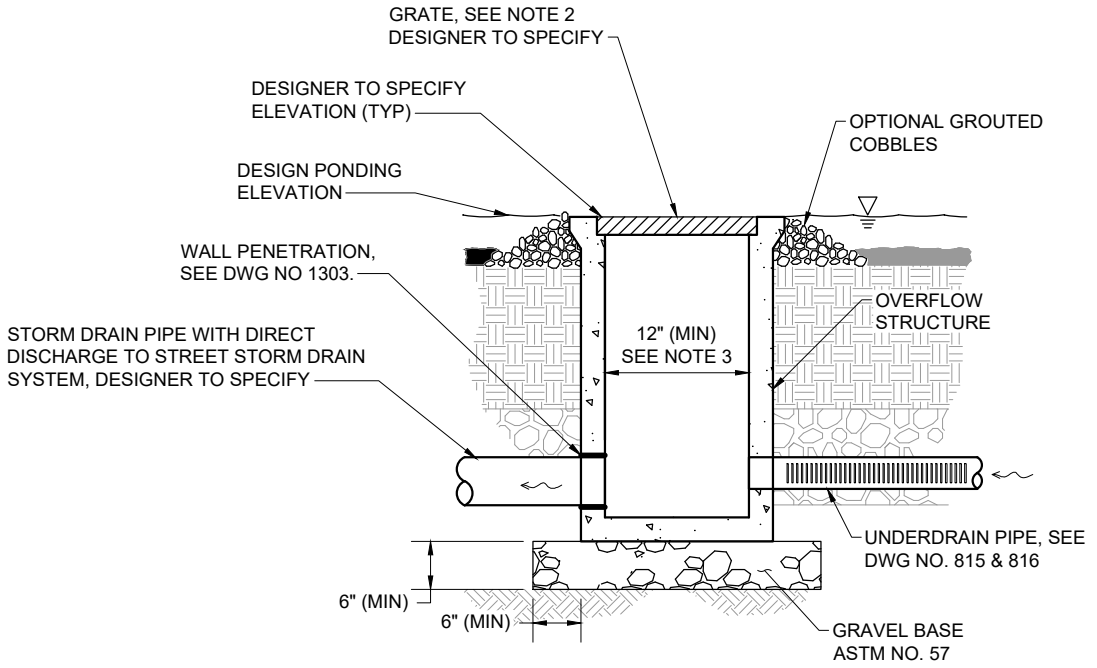
Date _____

Dwg No. **817**

CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OVERFLOW STRUCTURES SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. SIZE OF 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. GRATE MATERIAL SPECIFICATIONS SHALL CONSIDER SITE CONDITIONS, E.G. PUBLIC VS. PRIVATE SETTING, TRAFFIC LOADING, UV EXPOSURE, AND PROXIMITY TO BAY. GRATE MODEL MUST MEET MUNICIPAL APPROVAL FOR RIGHT OF WAY PROJECTS.
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. DESIGNER TO SPECIFY WATERTIGHT OVERFLOW STRUCTURAL MATERIAL, MODEL, AND SIZE. 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.
5. GROUT ALL PENETRATIONS, CRACKS, SEAMS, AND JOINTS WITH CLASS "C" MORTAR.
6. THIS OUTLET OVERFLOW STRUCTURE BIORETENTION COMPONENT DETAIL IS ADAPTED FROM THE BIORETENTION ENGINEERING STANDARDS: DETAILS AND TECHNICAL SPECIFICATIONS (CENTRAL COAST LOW IMPACT DEVELOPMENT INITIATIVE), 2017, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.
7. MINIMUM DIAMETER OF OPTIONAL GROUTED COBBLES SHALL BE LARGER THAN MAXIMUM GRATE OPENING.



OVERFLOW STRUCTURE AREA DRAIN 1

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Scale: NTS

BIORETENTION COMPONENTS
OVERFLOW STRUCTURE
OPTION #2

City of Palo Alto Standard

Approved by: _____

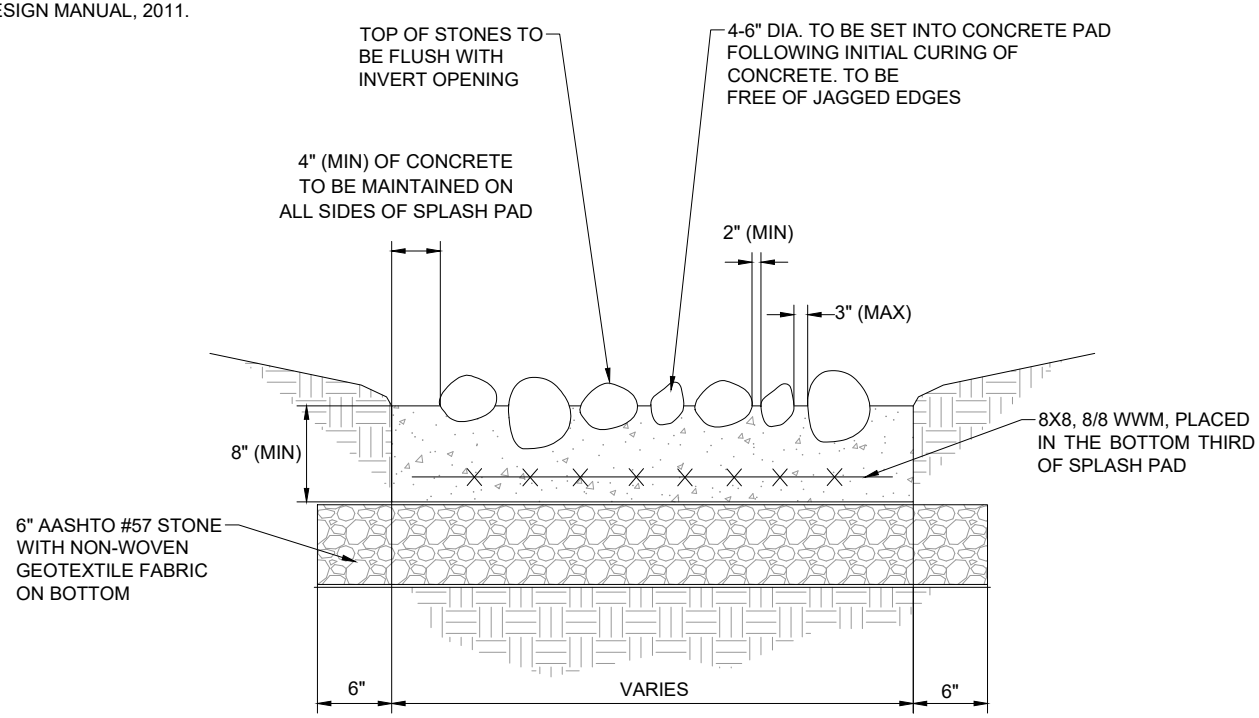
PE No. _____

Date _____

Dwg No. **818**

CONSTRUCTION NOTES:

1. THIS SPLASH PAD BIORETENTION COMPONENT DETAIL IS ADAPTED FROM THE PHILADELPHIA WATER DEPARTMENT (PWD) GREEN STREETS DESIGN MANUAL, 2011.



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Scale: NTS

BIORETENTION COMPONENTS
ROCK SPLASH PAD

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **819**

PURPOSE:

CHECK DAMS ARE OFTEN USED IN BIORETENTION FACILITIES AT SLOPED LOCATIONS (ALIGNED PERPENDICULAR TO THE LONGITUDINAL SLOPE OF THE FACILITY) TO REDUCE FLOW VELOCITIES (AND EROSION) THROUGH THE FACILITY AND TO PROMOTE SURFACE PONDING, SUBSURFACE STORAGE, AND INFILTRATION OF STORMWATER. CHECK DAMS CAN BE CONSTRUCTED OF A VARIETY OF MATERIALS INCLUDING CONCRETE, WOOD, METAL, ROCK, OR COMPACTED SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST ESTABLISH THE HEIGHT AND SPACING OF CHECK DAMS BASED ON THE PONDING DEPTH REQUIRED TO MEET PROJECT HYDROLOGIC PERFORMANCE GOALS AND THE MAXIMUM DESIRED DROP FROM THE SURROUNDING GRADE TO THE FACILITY BOTTOM.
3. FOR BIORETENTION SWALES (SLOPED BOTTOM), THE AVERAGE DEPTH OF PONDING ACROSS THE FACILITY AREA MUST MEET THE REQUIRED STORAGE DEPTH.
4. CONCRETE CHECK DAM SHALL MEET STRUCTURAL REQUIREMENTS FOR LATERAL BRACING WHEN USED AS LATERAL BRACING.
5. MATERIALS OTHER THAN CONCRETE MAY BE ALLOWED FOR CHECK DAM WITH CITY APPROVAL. MUST BE DESIGNED BY STRUCTURAL ENGINEER. PROVIDE ALL CONNECTION DETAILS.
6. THESE CHECK DAM DETAILS ADAPTED FROM STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES (SAN FRANCISCO PUBLIC UTILITIES COMMISSION), 2016, INCLUDING APPENDIX B GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.

THE DESIGNER SHALL SPECIFY THE FOLLOWING, AS APPLICABLE:

- ☐ CHECK DAM TYPE AND MATERIAL
- ☐ CHECK DAM HEIGHT, WIDTH, AND ELEVATION
- ☐ CHECK DAM SPACING

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BIORETENTION COMPONENTS
CHECK DAM
DESIGNER NOTES

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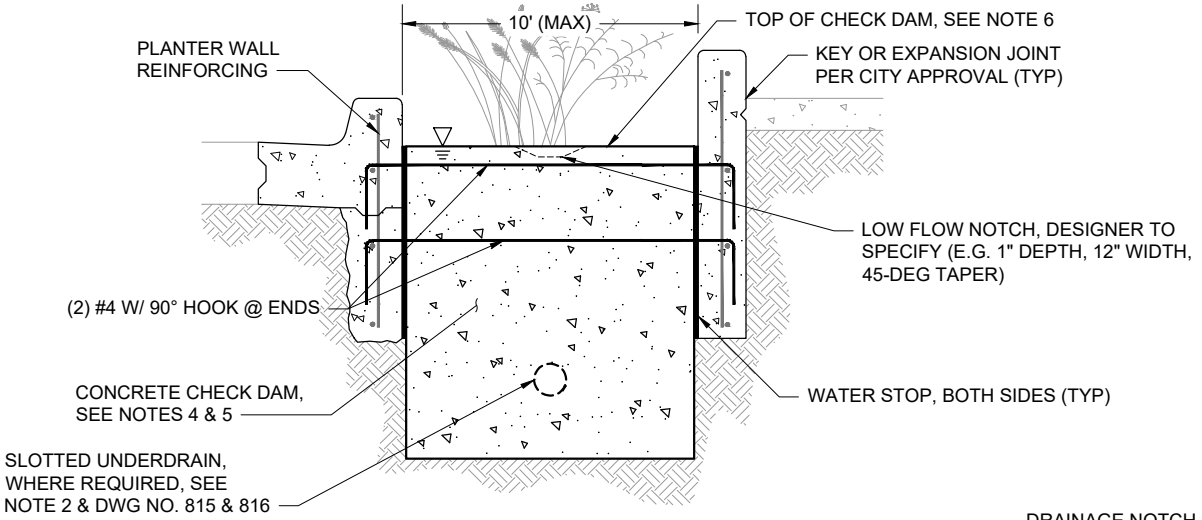
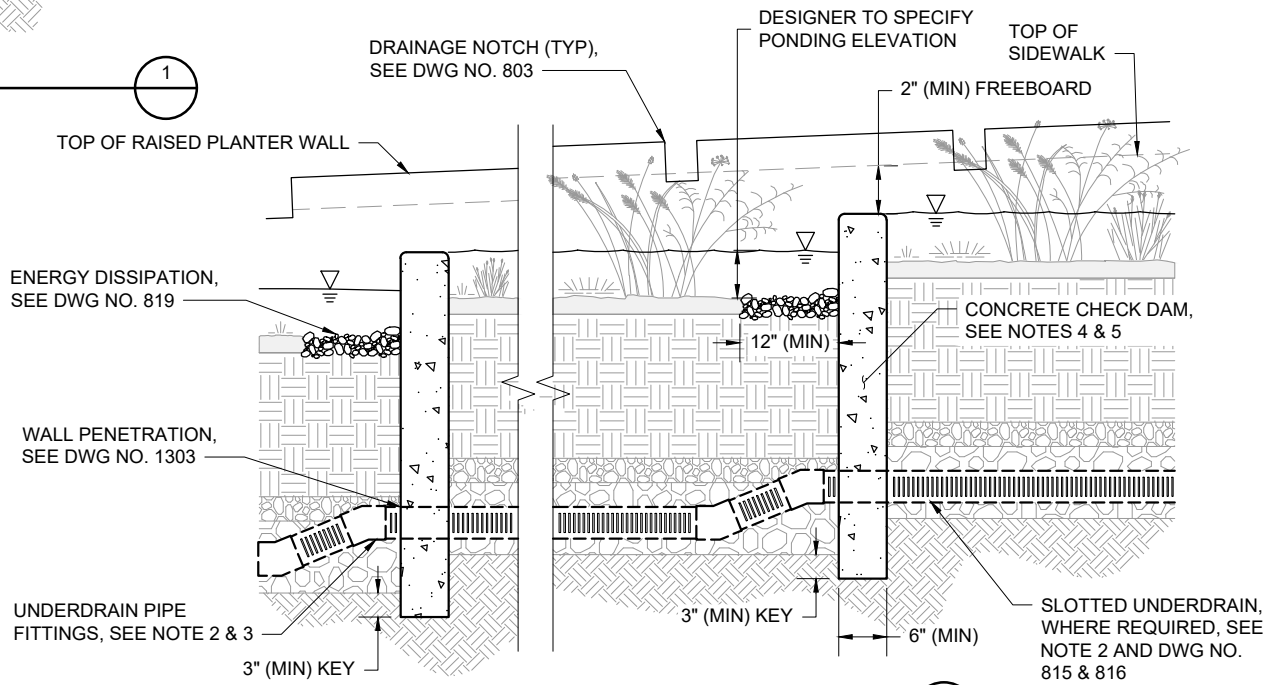
Dwg No. **820**



SECTION - CONCRETE CHECK DAM 1



PROFILE - CONCRETE CHECK DAM 2

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 820 FOR GUIDELINES AND CHECKLISTS.
2. UNDERDRAIN TO PASS THROUGH CHECK DAM IS NON-PERFORATED.
3. PIPE FITTINGS SHALL BE USED TO ACCOMMODATE CHANGES IN GRADE, AS NEEDED.
4. CONCRETE CHECK DAM SHALL BE CONTINUOUS (NO JOINTS) AND REINFORCED WITH #4 BAR, PLACED AT 18 INCHES ON CENTER, EACH WAY.
5. CONCRETE CHECK DAM SHALL MEET STRUCTURAL REQUIREMENTS FOR LATERAL BRACING WHEN USED AS LATERAL BRACING. COORDINATE WITH ENGINEER.
6. TOP OF CHECK DAM TO BE LEVEL WITH CREST ELEVATION MATCHING PONDING ELEVATION UNLESS NOTCH SIZED TO CONVEY DESIGN FLOWS PROVIDED.
7. CONCRETE CHECK DAM TO EXTEND 3" MIN BEYOND SIDE AND BOTTOM EDGES OF AGGREGATE PER ENGINEER GUIDANCE.

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BIORETENTION COMPONENTS
CHECK DAM

City of Palo Alto Standard

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Dwg No. **821**

PURPOSE

FLOW-THROUGH PLANTERS CAPTURE AND TREAT STORMWATER RUNOFF VIA SURFACE AND SUBSURFACE STORAGE AND FILTRATION THROUGH BIOTREATMENT SOIL. FLOW-THROUGH PLANTERS MUST HAVE UNDERDRAINS AND BE COMPLETELY LINED AND SURROUNDED WITH CONCRETE OR OTHER STRUCTURAL PLANTER BOX WALLS WITH IMPERMEABLE LINER. THEY TYPICALLY RECEIVE RUNOFF VIA DOWNSPOUTS LEADING FROM THE ROOFS OF ADJACENT BUILDINGS. HOWEVER, THEY CAN ALSO BE SET LEVEL WITH THE SURROUNDING GRADE AND RECEIVE RUNOFF AS SHEET FLOW.

DESIGNER NOTES & GUIDELINES

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS BUILDING- AND SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER MUST COMPLY WITH ALL APPLICABLE SITE AND BUILDING CODE REQUIREMENTS FOR ON-SITE ACCESSIBILITY AND SAFETY INCLUDING, BUT NOT LIMITED TO, CURBS, PEDESTRIAN SURFACING, AND GUARDRAILS/FALL HEIGHTS.
3. PLANTER AREA, PONDING DEPTH, BIORETENTION SOIL DEPTH, AND AGGREGATE STORAGE DEPTH MUST BE SIZED TO MEET MRP PROVISION C.3.d SIZING REQUIREMENTS.
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., ORIFICE CONTROLLED SYSTEM OR EXTENDED STORAGE DEPTH WITHIN INFILTRATION SYSTEM)
5. AN AGGREGATE COURSE UNDER THE BIORETENTION SOIL IS REQUIRED. AGGREGATE SHALL BE CALTRANS CLASS 2 PERMEABLE MATERIAL.
6. CHECK DAMS OR WEIRS MAY BE USED TO TERRACE FACILITIES TO PROVIDE SUFFICIENT PONDING FOR HIGHER-SLOPED INSTALLATIONS. DESIGNER MUST SPECIFY CHECK DAM HEIGHT AND SPACING. REFER TO DWG NO. 820 & 821 FOR GUIDANCE ON CHECK DAM DESIGN.
7. PLANTER OVERFLOW STRUCTURES SHALL BE DESIGNED TO CONVEY THE ANTICIPATED PEAK DESIGN FLOWS. PLANTERS SHALL BE DESIGNED TO OVERFLOW TO THE STREET OR DRAIN AWAY FROM BUILDINGS (IF NOT ADJACENT TO THE STREET). DESIGNER TO CONSIDER ADDING OVERFLOW NOTCH TO DIRECT EMERGENCY OVERFLOW TO DRAIN.
8. FOR BMPS ON BUILDING STRUCTURE, PASSIVE GRAVITY OVERFLOW FROM BMP IS REQUIRED EITHER BY OVERFLOW PIPING FROM BMP OR BY "FAILSAFE" BYPASS DIVERTER VALVE.
9. MATERIALS FOR PLANTERS MUST BE WATER-TIGHT AND MAY VARY TO WORK WITH SITE AND ARCHITECTURAL PALETTE.
10. FACILITIES MAY BE EXTENDED ABOVE GRADE FOR SEATWALL OR RAISED PLANTER CONFIGURATIONS, IF APPROPRIATE CONVEYANCE MEASURES ARE PROVIDED TO MEET DESIGN REQUIREMENTS.
11. CONVEYANCE CONNECTIONS MAY BE CONFIGURED TO ACCEPT RUNOFF VIA OVERHEAD CONVEYANCE (DOWNSPOUTS, OVERHEAD RUNNELS), SURFACE FLOW (CHANNELS), OR SUBSURFACE CONVEYANCE (PIPES, TRENCH DRAINS).
12. CONVEYANCE CONNECTIONS (E.G. SCUPPER, CHANNEL, PIPE) SHALL BE SIZED TO ACCOMMODATE DRAINAGE FROM ROOF AREA WITH ADEQUATE FREEBOARD TO AVOID OVERFLOWING DURING PEAK FLOWS.
13. UNDERDRAINS REQUIRED WHEN PLANTER IS LOCATED ON STRUCTURE TO DRAIN PLANTER AND AVOID ACCUMULATION OF WATER ON STRUCTURE WATERPROOFING SYSTEM.
14. THE DESIGNER MUST EVALUATE UTILITY SURVEYS FOR POTENTIAL UTILITY CROSSINGS OR CONFLICTS. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY ASSET PROTECTION STANDARDS. IN THE ABSENCE OF THESE STANDARDS, THE DESIGNER SHALL REFER TO CITY'S GSI HANDBOOK FOR GUIDANCE..
15. THESE FLOW-THROUGH PLANTER DETAILS ADAPTED FROM STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES (SAN FRANCISCO PUBLIC UTILITIES COMMISSION), 2016, INCLUDING APPENDIX B GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.

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FLOW-THROUGH PLANTER DESIGNER NOTES (1 OF 2)

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **822**

LAYOUT REQUIREMENTS

1. THE DESIGNER MUST COMPLY WITH ALL CURRENT LOCAL CODES, INCLUDING BUT NOT LIMITED TO:
   - CALIFORNIA BUILDING CODE
   - PALO ALTO BUILDING CODE AMENDMENTS
   - ADA STANDARDS FOR ACCESSIBLE DESIGN
2. FLOW-THROUGH PLANTERS SHOULD NOT INTERFERE WITH OTHER LAND USE REQUIREMENTS SUCH AS BUFFERING AN SCREENING, SETBACKS, SIGHT DISTANCE, AND MINIMUM SITE COVERAGE.
3. DESIGN ALL BMPS TO BE ACCESSIBLE FOR INSPECTIONS AND MAINTENANCE WITHOUT ACCESS THROUGH A TENANT RESIDENTIAL UNIT.
4. INCORPORATE 'SAFETY BY DESIGN' INTO ALL ROOFTOP VEGETATED SYSTEMS TO ENSURE EASE OF ACCESS FOR MAINTENANCE AND INSPECTION. ADHERE TO APPLICABLE CAL-OSHA AND BUILDING CODES.
5. CONSULTATION WITH A CALIFORNIA-REGISTERED STRUCTURAL ENGINEER IS RECOMMENDED TO EVALUATE LOAD-BEARING CAPACITY FOR COMPLIANCE WITH BUILDING CODE REQUIREMENTS.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE)

- ☐ PLANTER WIDTH AND LENGTH
- ☐ DEPTH OF PONDING
- ☐ DEPTH OF FREEBOARD
- ☐ DEPTH OF BIORETENTION SOIL
- ☐ DEPTH AND TYPE OF AGGREGATE STORAGE
- ☐ PLANTER SURFACE ELEVATION (TOP OF BIORETENTION SOIL) AT UPSLOPE AND DOWNSLOPE ENDS OF FACILITY (I.E., PROVIDE SPOTS AND/OR CONTOURS AS NEEDED)
- ☐ CONTROL POINTS AT EVERY PLANTER WALL CORNER OR POINT OF TANGENCY
- ☐ DIMENSIONS AND DISTANCE TO EVERY INLET, OUTLET, CHECK DAM, WEIR, SIDEWALK NOTCH, ETC.
- ☐ ELEVATIONS OF EVERY INLET, OUTLET, STRUCTURE RIM AND INVERT, CLEAN OUT, PLANTER WALL CORNER, AND SIDEWALK NOTCH
- ☐ TYPE AND DESIGN OF PLANTER COMPONENTS (E.G., EDGE TREATMENTS, INLETS/GUTTER MODIFICATIONS, UTILITY CROSSINGS, LINER SPECIFICATION/DETAIL, AND PLANTING DETAILS)
- ☐ OVERFLOW STRUCTURE SIZE/DIAMETER (NOTE: OVERFLOW STRUCTURES SHALL BE SIZED TO CONVEY CONTRIBUTING AREA PEAK FLOW PER APPLICABLE BUILDING CODE, AND ALSO CONSIDER MAINTENANCE ACCESS, COMPATIBLE GRATE SIZES, AND GENERAL AESTHETICS)
- ☐ OVERFLOW STRUCTURE GRATE SIZE, MODEL NUMBER, AND FLOW CAPACITY PER MANUFACTURER PRODUCT SHEET (NOTE: GRATE SHALL BE SIZED TO CONVEY CONTRIBUTING AREA PEAK FLOW PER APPLICABLE BUILDING CODE, WITH 4-INCH MIN.)
- ☐ OVERFLOW STRUCTURE/RISER SLAB PENETRATION DETAIL PER PLUMBING
- ☐ INLET STRUCTURES INCLUDING FITTINGS, SCUPPERS, ETC. FLOW DISTRIBUTION REQUIRED FOR EXCESSIVELY LONG OR LINEAR PLANTERS
- ☐ MINIMUM UNDERDRAIN LENGTH TO CONVEY PEAK FLOW TO BMP

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FLOW-THROUGH PLANTER DESIGNER NOTES (2 OF 2)

City of Palo Alto Standard

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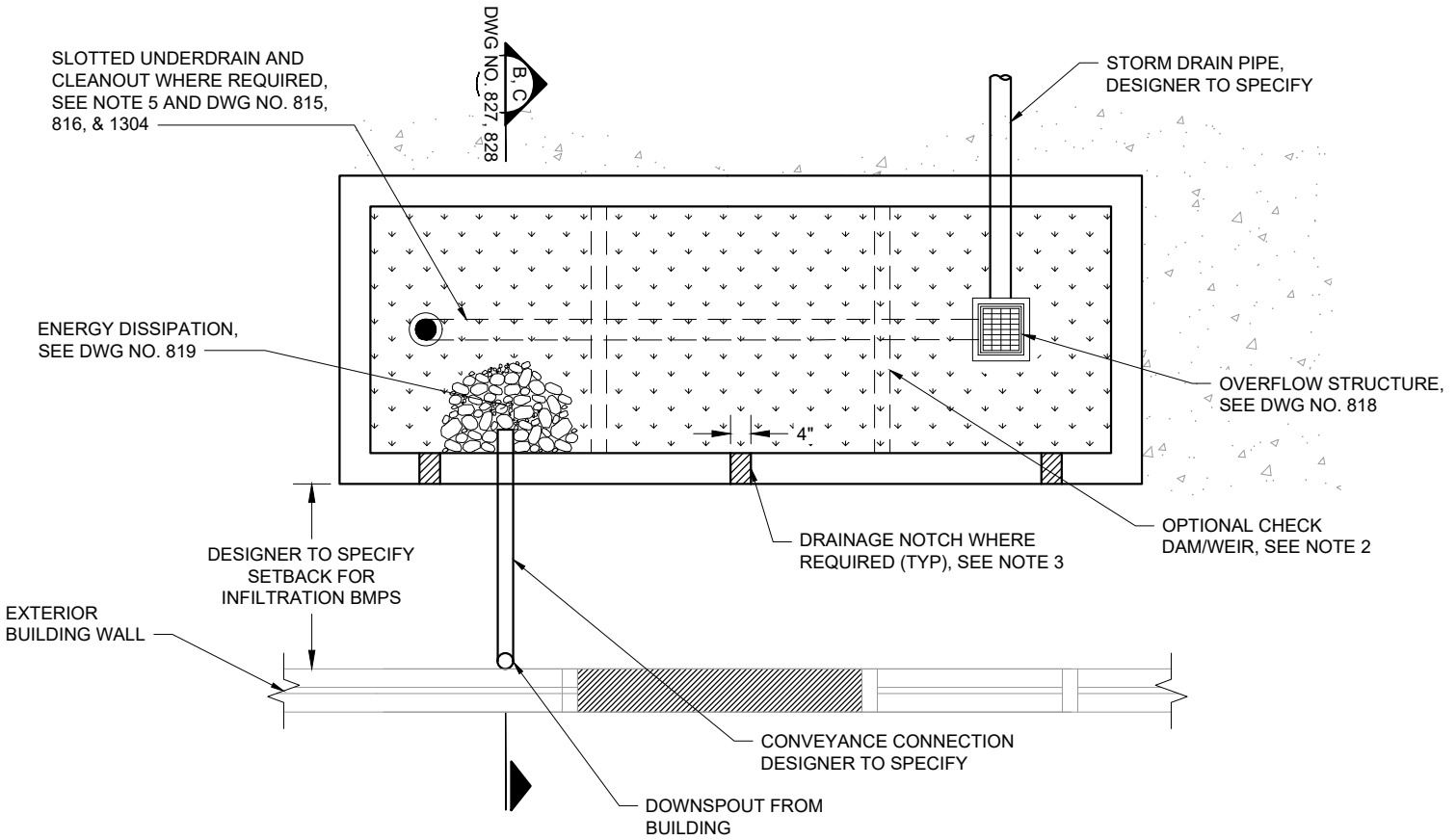
Dwg No. **823**



CONSTRUCTION NOTES:

1. REFER TO DWG NO. 822 & 823 GUIDELINES AND CHECKLIST.
2. CHECK DAMS/WEIRS (IF NEEDED) SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. WATERPROOFING AND/OR LINER SYSTEM TO BE DESIGNED AND INSTALLED BY A WATERPROOFING PROFESSIONAL.
5. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
6. MINIMUM UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK AND UTILITY CROSSINGS IN DWG NO 1303.. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

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FLOW-THROUGH PLANTER SETBACK FROM STRUCTURE

City of Palo Alto Standard

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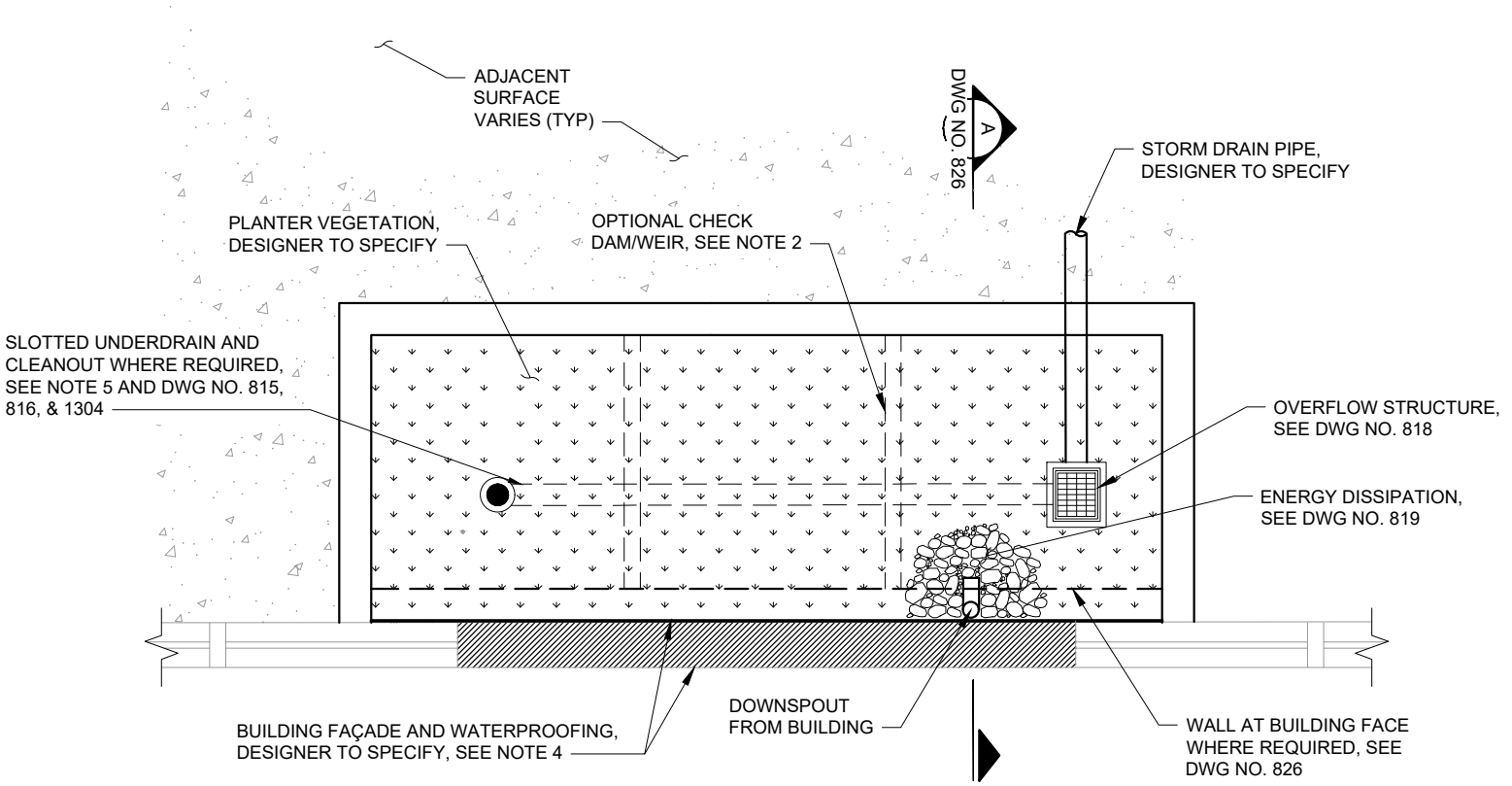
Date _____

Dwg No. **824**



CONSTRUCTION NOTES:

1. REFER TO DWG NO. 822 & 823 FOR GUIDELINES AND CHECKLIST.
2. CHECK DAMS/WEIRS (IF NEEDED) SHALL BE SPACED TO PROVIDE PONDING PER SITE SPECIFIC DESIGN.
3. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL WITH 5' MAXIMUM SPACING BETWEEN NOTCHES.
4. WATERPROOFING AND/OR LINER SYSTEM TO BE DESIGNED AND INSTALLED BY A WATERPROOFING PROFESSIONAL.
5. PROVIDE ONE CLEANOUT PER PLANTER (MIN) FOR FACILITIES WITH UNDERDRAINS.
6. MINIMUM UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK AND UTILITY CROSSINGS IN DWG NO. 1303. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

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Scale: NTS

FLOW-THROUGH PLANTER AGAINST STRUCTURE

City of Palo Alto Standard

Approved by: _____

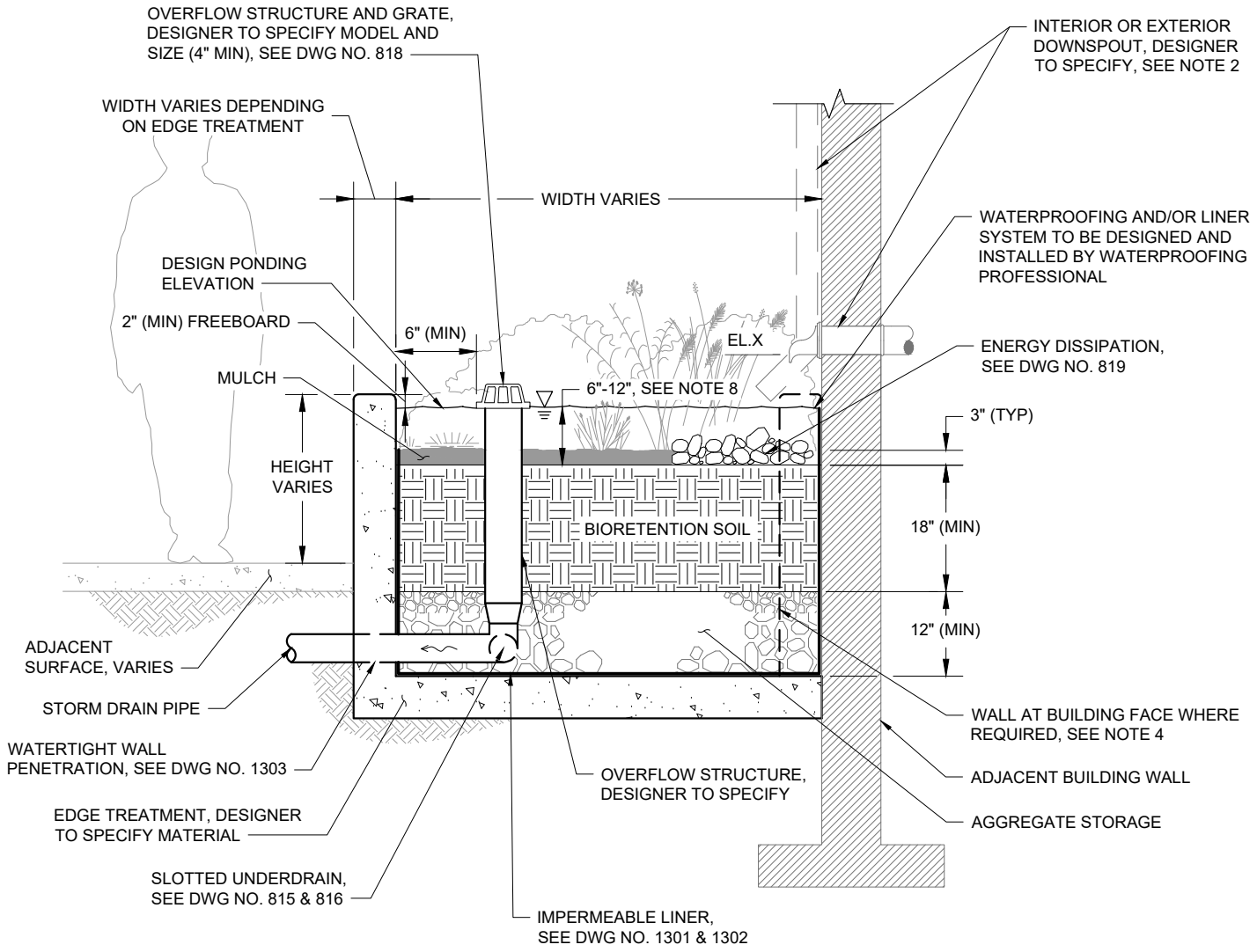
PE No. _____

Date _____

Dwg No. **825**

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 822 & 823 FOR GUIDELINES AND CHECKLIST.
2. INSTALL DOWNSPOUTS OR OTHER CONVEYANCE CONNECTIONS (E.G. SCUPPER, CHANNEL, OVERHEAD RUNNEL) FROM BUILDING TO DRAIN ABOVE DESIGN PONDING ELEVATION.
3. BUILDING WATERPROOFING BY ARCHITECT; COORDINATE PLANTER CONSTRUCTION WITH BUILDING FAÇADE / WATERPROOFING.
4. PROVIDE WALL AT BUILDING FACE IN CASES WHERE GAP IS REQUIRED BETWEEN WALL AND PLANTER OR WHERE BUILDING FAÇADE IS INCOMPATIBLE WITH PLANTER CONFIGURATION.
5. IF CONSTRUCTED OF PRECAST OR FABRICATED SECTIONS, PLANTER BOXES SHALL HAVE THEIR JOINTS SEALED WITH BUTYL RUBBER TAPE WHEN PRECAST PIECES ARE BEING SET. APPLYING ONLY MORTER AND/OR NON-SHRINK GROUT TO UNSEALED JOINTS AFTER INSTALLATION IS NOT AN ACCEPTABLE MEANS OF WATERPROOFING THE PLANTER BOX.
6. OVERFLOW RISER, FITTINGS, SLOTTED UNDERDRAIN, AND CLEANOUT PIPE SHALL BE OF SAME MATERIAL.
7. OVERFLOW GRATE MUST BE MECHANICALLY FASTENED TO RISER WITH NON-CORROSIVE MATERIAL.
8. 6" PONDING DEPTH RECOMMENDED, 12" WITH CITY APPROVAL FOR FACILITIES ON GRADE. LICENSED LANDSCAPE ARCHITECT TO APPROVE PLANTING PALETTE WHEN DESIGN PONDING DEPTH EXCEEDS 6".



SECTION - RAISED BIORETENTION PLANTER (A)

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FLOW-THROUGH PLANTER
RAISED PLANTER SECTION

City of Palo Alto Standard

Approved by: _____

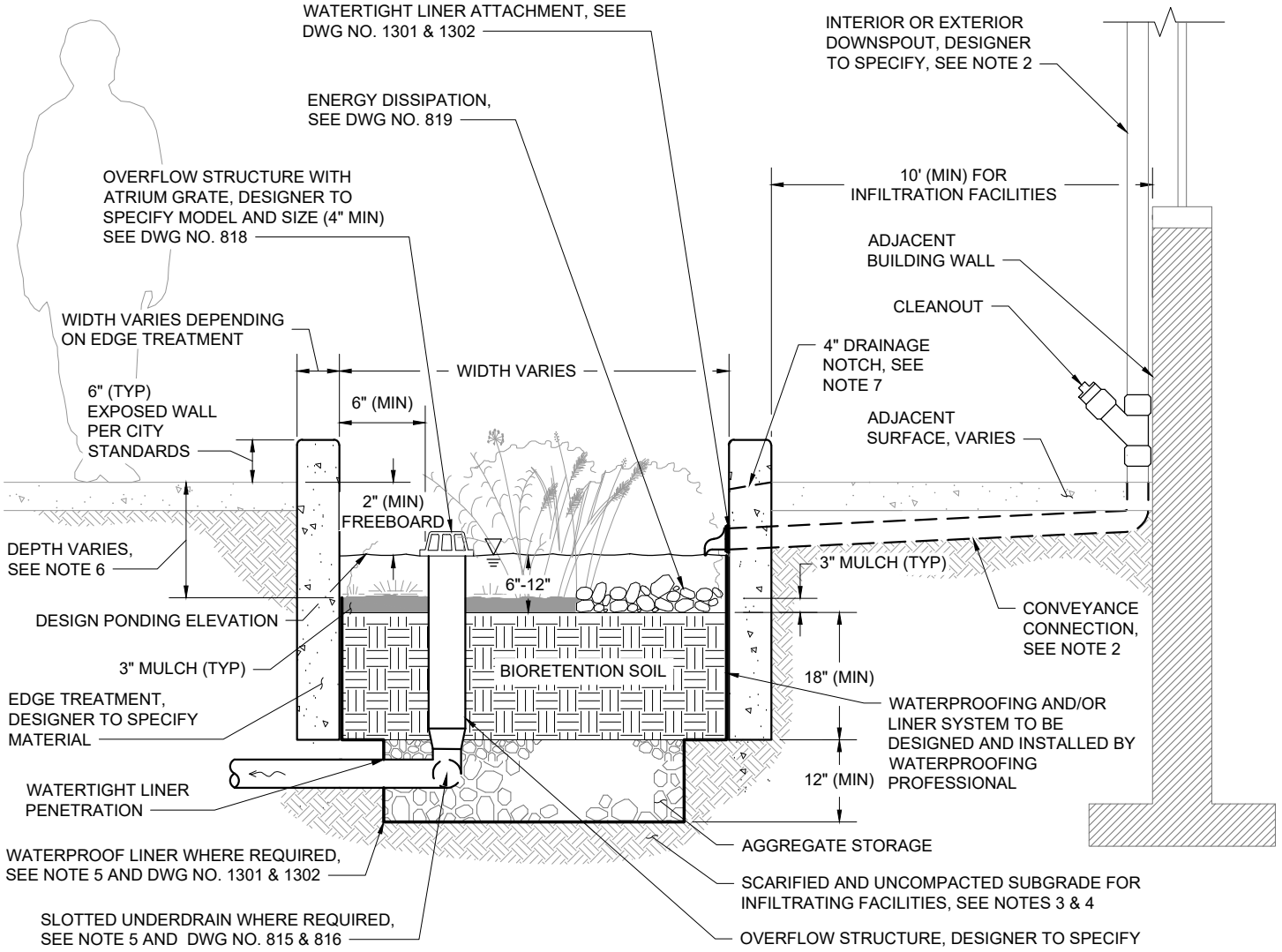
PE No. _____

Date _____

Dwg No. **826**

CONSTRUCTION NOTES:

1. REFER TO DEG NO. 822 & 823 FOR GUIDELINES AND CHECKLIST.
2. INSTALL DOWNSPOUTS AND OTHER CONVEYANCE CONNECTIONS (E.G. SCUPPER, CHANNEL, OVERHEAD RUNNEL, TRENCH DRAIN) FROM BUILDING TO DRAIN ABOVE DESIGN PONDING ELEVATION. REFER TO APPLICABLE CITY CODES FOR CONVEYANCE CONNECTION REQUIREMENTS. INCLUDE CLEANOUT AT DOWNPIPE CONNECTION FOR HORIZONTAL PIPE CONVEYANCE.
3. FOR UNLINED FACILITY, AVOID COMPACTION OF EXISTING SUBGRADE BELOW PLANTER FOR INFILTRATION FACILITIES.
4. FOR UNLINED FACILITY, SCARIFY SUBGRADE TO A DEPTH OF 3 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE AND BIORETENTION SOIL MATERIALS.
5. UNDERDRAIN AND LINER REQUIRED WITHIN 10 FEET OF BUILDING ENVELOPE UNLESS APPROVED PER DESIGNER.
6. MAXIMUM DROP FROM TOP OF WALKING SURFACE TO TOP OF MULCH SHALL INCLUDE CONSIDERATIONS FOR SOIL SETTLEMENT. SEE DWG NO. 803.
7. LAY OUT DRAINAGE NOTCHES TO PREVENT PONDING BEHIND PLANTER WALL. SLOPE NOTCHES TO DRAIN TO PLANTER.
8. IF CONSTRUCTED OF PRECAST OR FABRICATED, PLANTER BOXES SHALL HAVE THEIR JOINTS SEALED WITH BUTYL RUBBER TAPE WHEN PRECAST PIECES ARE BEING SET. APPLYING ONLY MORTAR AND/OR NON-SHRINK GROUT TO UNSEALED JOINTS AFTER INSTALLATION IS NOT AN ACCEPTABLE MEANS OF WATERPROOFING THE PLANTER BOX.
9. OVERFLOW RISER, FITTINGS, SLOTTED UNDERDRAIN, AND CLEANOUT PIPE SHALL BE OF SAME MATERIAL.
10. OVERFLOW GRATE MUST BE MECHANICALLY FASTENED TO RISER WITH NON-CORROSIVE MATERIAL..
11. 6" PONDING DEPTH RECOMMENDED, 12" WITH CITY APPROVAL FOR FACILITIES ON GRADE. LICENSED LANDSCAPE ARCHITECT TO APPROVE PLANTING PALETTE WHEN DESIGN PONDING DEPTH EXCEEDS 6".



SECTION - SURFACE BIORETENTION PLANTER B

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FLOW-THROUGH PLANTER
AT-GRADE PLANTER SECTION

City of Palo Alto Standard

Approved by: _____

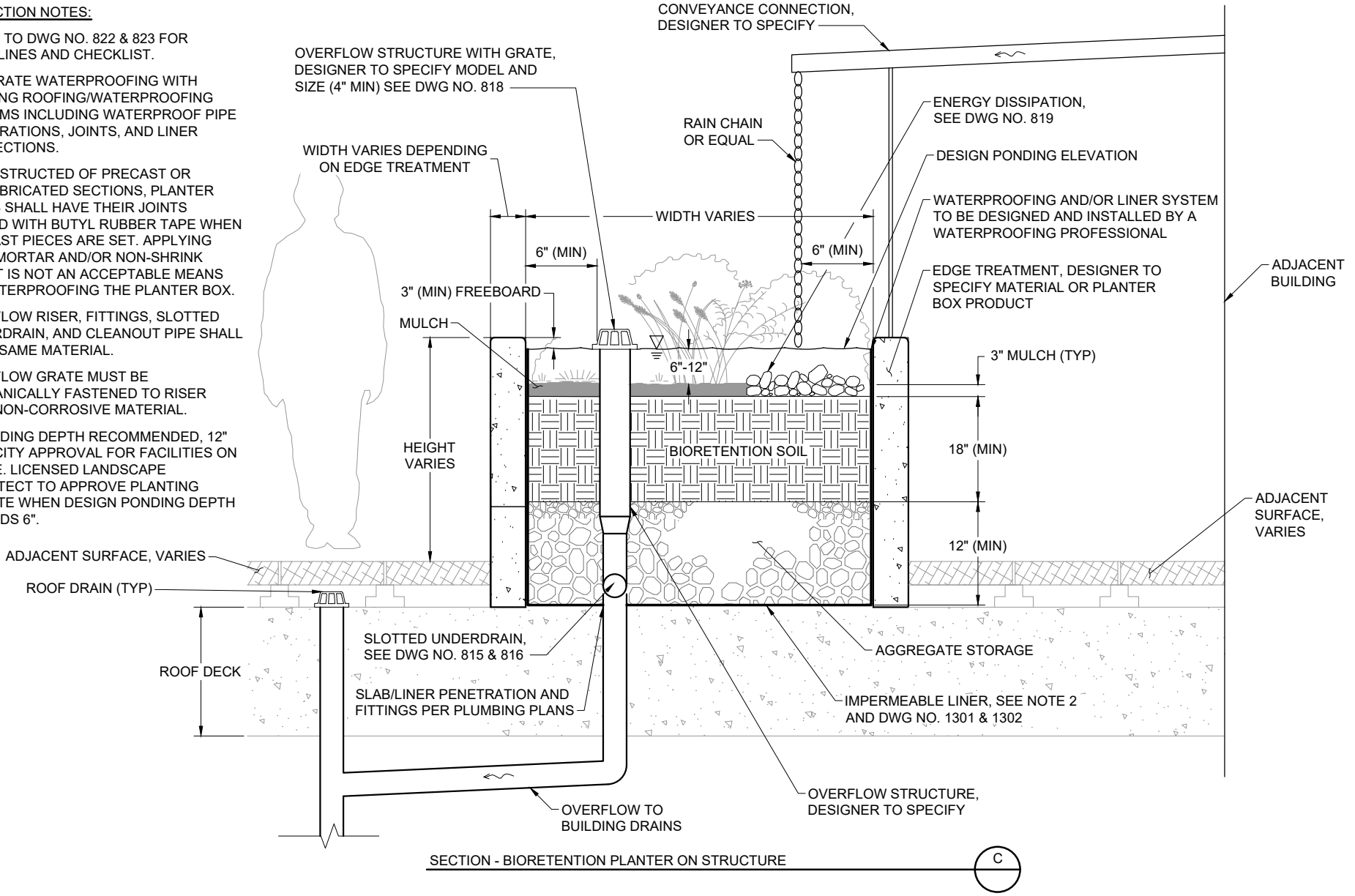
PE No. _____

Date _____

Dwg No. **827**

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 822 & 823 FOR GUIDELINES AND CHECKLIST.
2. INTEGRATE WATERPROOFING WITH BUILDING ROOFING/WATERPROOFING SYSTEMS INCLUDING WATERPROOF PIPE PENETRATIONS, JOINTS, AND LINER CONNECTIONS.
3. IF CONSTRUCTED OF PRECAST OR PREFABRICATED SECTIONS, PLANTER BOXES SHALL HAVE THEIR JOINTS SEALED WITH BUTYL RUBBER TAPE WHEN PRECAST PIECES ARE SET. APPLYING ONLY MORTAR AND/OR NON-SHRINK GROUT IS NOT AN ACCEPTABLE MEANS OF WATERPROOFING THE PLANTER BOX.
4. OVERFLOW RISER, FITTINGS, SLOTTED UNDERDRAIN, AND CLEANOUT PIPE SHALL BE OF SAME MATERIAL.
5. OVERFLOW GRATE MUST BE MECHANICALLY FASTENED TO RISER WITH NON-CORROSIVE MATERIAL.
8. 6" PONDING DEPTH RECOMMENDED, 12" WITH CITY APPROVAL FOR FACILITIES ON GRADE. LICENSED LANDSCAPE ARCHITECT TO APPROVE PLANTING PALETTE WHEN DESIGN PONDING DEPTH EXCEEDS 6".



SECTION - BIORETENTION PLANTER ON STRUCTURE C

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FLOW-THROUGH PLANTER ON STRUCTURE PLANTER SECTION

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **828**

PURPOSE:

SUBSURFACE INFILTRATION SYSTEMS, WHICH INCLUDE DRY WELLS, INFILTRATION TRENCHES, AND INFILTRATION GALLERIES, CONTROL PEAK FLOWS AND VOLUMES OF STORMWATER RUNOFF THROUGH SUBSURFACE STORAGE AND INFILTRATION INTO NATIVE SOIL. WATER IS ALSO TREATED AS IT FILTERS THROUGH THE GRAVEL, SAND (IF PROVIDED), AND NATIVE SOIL.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. SUBSURFACE INFILTRATION SYSTEMS ARE CONSIDERED CLASS V INJECTION WELLS AND SUBJECT TO THE U.S. EPA UNDERGROUND INJECTION CONTROL (UIC) PROGRAM. SUBSURFACE INFILTRATION SYSTEMS MUST BE REGISTERED WITH EPA REGION IX PRIOR TO COMING ONLINE. SEE THE SCVURPPP C.3 STORMWATER HANDBOOK APPENDIX A FOR GUIDELINES.
3. 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 STORAGE DEPTH DIVIDED BY THE NATIVE SOIL INFILTRATION RATE.
4. SUBSURFACE INFILTRATION SYSTEM SUBGRADES SHOULD BE LEVEL, REGARDLESS OF ANY LONGITUDINAL SLOPE OF THE SITE, TO PROMOTE EQUAL SUBSURFACE DISTRIBUTION OF RUNOFF.
5. DEPENDING ON THE HEIGHT AND AREA OF THE PROPOSED SUBSURFACE INFILTRATION SYSTEM, ADDITIONAL STRUCTURAL CONSIDERATIONS MAY BE REQUIRED TO ADDRESS EARTH PRESSURE AND/OR SURFACE LOADING.
6. SUBSURFACE INFILTRATION SYSTEMS ARE MOST COMMONLY USED TO MANAGE STORMWATER RUNOFF FROM ROOFS AND PARKING LOTS, BUT CAN BE USED IN OTHER APPLICATIONS. RUNOFF SHOULD PASS THROUGH STORMWATER PRE-TREATMENT MEASURES TO REMOVE COARSE SEDIMENT THAT CAN CLOG PORE SPACES. REFER TO SCVURPPP C.3 STORMWATER HANDBOOK APPENDIX A FOR ADDITIONAL GUIDELINES.
7. SUBSURFACE INFILTRATION SYSTEMS ARE NOT APPROVED AS TREATMENT MEASURES FOR RUNOFF FROM INDUSTRIAL AREAS, AREAS SUBJECT TO HIGH (GREATER THAN 15,000 VEHICLES PER DAY) TRAFFIC LOADING, AUTOMOTIVE REPAIR SHOPS, CAR WASHES, FLEET STORAGE AREAS, NURSERIES, SITES THAT STORE CHEMICALS OR HAZARDOUS MATERIALS, OR OTHER LAND USES THAT POSE A HIGH THREAT TO WATER QUALITY.
8. SUBSURFACE INFILTRATION SYSTEMS SHOULD NOT BE USED IN AREAS OF KNOWN OR PRESUMED CONTAMINATED SOIL OR GROUNDWATER, AREAS WITH CURRENT OR HISTORICAL INDUSTRIAL USE, AREAS WITHIN 100 FEET OF CURRENT OR HISTORICAL UNDERGROUND STORAGE TANKS, FILLED FORMER BAY, MARSH OR CREEK AREAS, OR AREAS WITHIN 150 FEET OF A CURRENT OR HISTORICAL HIGHWAY. SEE SITING REQUIREMENTS TABLE ON DWG NO. 902.
9. SMALL DEEP SYSTEMS (TYPICALLY A FEW FEET IN WIDTH) ARE KNOWN AS DRY WELLS AND ARE RECOMMENDED FOR SMALL DRAINAGE AREAS WITH LOW POLLUTANT LOADINGS, SUCH AS ROOFTOPS LESS THAN 0.25 ACRES IN SIZE. LARGER SYSTEMS (TYPICALLY 10 TO 100 FEET IN WIDTH) ARE KNOWN AS INFILTRATION GALLERIES AND CAN BE USED TO RECEIVE RUNOFF FROM DRAINAGE AREAS TYPICALLY UP TO 5 ACRES IN SIZE.
10. THE DRAWINGS PROVIDED DO NOT COVER DESIGNS THAT UTILIZE PROPRIETARY STORAGE, DISTRIBUTION, AND/OR STRUCTURAL SYSTEMS OTHER THAN PREFABRICATED DRY WELL STRUCTURES, WHICH HAVE BEEN SHOWN IN A GENERIC WAY. REFER TO THE MANUFACTURER'S RECOMMENDATIONS FOR ALL PROPRIETARY SYSTEMS.
11. THESE SUBSURFACE INFILTRATION SYSTEMS DETAILS ADAPTED FROM STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES (SAN FRANCISCO PUBLIC UTILITIES COMMISSION), 2016, INCLUDING APPENDIX B GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.

GENERAL UTILITY NOTES:

1. MINIMUM UTILITY SETBACKS AND PROTECTION MEASURES MUST CONFORM TO CURRENT CITY ASSET PROTECTION STANDARDS. IN THE ABSENCE OF THESE STANDARDS, THE DESIGNER SHALL REFER TO CITY'S GSI HANDBOOK FOR GUIDANCE. SEE UTILITY CROSSING DESIGNER NOTES ON DWG NO. 1303.
2. PROVIDE UTILITY TRENCH DAM, ANTI-SEEP COLLAR, OR EQUIVALENT TO PREVENT PREFERENTIAL FLOW OF WATER FROM INFILTRATIVE FACILITY INTO UTILITY TRENCH FROM CAUSING DAMAGE DOWNSTREAM. ENGINEER TO EVALUATE SITE CONDITIONS AND NEED FOR TRENCH DAM. SEE GSI SITING TABLE IN CITY GSI HANDBOOK.
3. PROPOSED UTILITY LINES TO BE LOCATED OUTSIDE OF FACILITY.

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Scale: NTS

SUBSURFACE INFILTRATION SYSTEM DESIGNER NOTES (1 OF 2)

City of Palo Alto Standard

Approved by: _____

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Dwg No. **901**

LAYOUT REQUIREMENTS:

REFER TO SCVURPPP C.3 STORMWATER HANDBOOK APPENDIX A FOR MORE DETAILED INFORMATION ON SITING AND DESIGN REQUIREMENTS FOR INFILTRATION BASED BMPS.

1. STANDARD SETBACK REQUIREMENTS PER THE STORMWATER MANAGEMENT REQUIREMENTS:

SETBACK DISTANCE (FEET)	SETBACK FROM:
5	PROPERTY LINE
10	DOWNGRADIENT FROM ADJACENT FOUNDATIONS
100	UPGRADIENT FROM ADJACENT FOUNDATIONS
100	UPGRADIENT FROM GROUND SLOPES >15%
150	DRINKING WATER WELL

2. REFER TO SCVURPPP C.3 STORMWATER HANDBOOK APPENDIX A FOR CONDITIONAL SETBACK REQUIREMENTS AND THE CITY PROTECTION STANDARDS FOR ADDITIONAL SETBACK REQUIREMENTS REGARDING WATER AND SEWER INFRASTRUCTURE.

3. MINIMUM 4-FOOT VERTICAL SEPARATION FROM BASE OF SUBSURFACE INFILTRATION SYSTEM TO BEDROCK IS REQUIRED.

4. VERTICAL SEPARATION TO GROUND WATER:
   - BAYSIDE: MINIMUM 4-FOOT VERTICAL SEPARATION FROM BASE OF SUBSURFACE INFILTRATION SYSTEM TO SEASONAL HIGH GROUNDWATER TABLE IS REQUIRED FOR ALL BAYSIDE GROUNDWATER BASINS.
   - MINIMUM 4-FOOT TO 10-FOOT VERTICAL SEPARATION FROM BASE OF SUBSURFACE INFILTRATION SYSTEM TO SEASONAL HIGH GROUNDWATER TABLE IS REQUIRED IN THE LOBOS AND WESTSIDE GROUNDWATER BASINS, DEPENDENT UPON SITE CHARACTERISTICS. REFER TO SCVURPPP C.3 STORMWATER HANDBOOK FOR GROUNDWATER SEPARATION ALLOWANCE.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ SUBSURFACE INFILTRATION SYSTEM WIDTH AND LENGTH
- ☐ DEPTH AND TYPE OF AGGREGATE STORAGE LAYER
- ☐ DEPTH AND TYPE OF FILTER SAND, IF REQUIRED
- ☐ ELEVATIONS AND CONTROL POINTS AT EVERY CORNER
- ☐ AGGREGATE STORAGE SPECIFICATIONS AND/OR DRY WELL TYPE AND DIMENSIONS
- ☐ ELEVATIONS OF EACH PIPE INLET AND OVERFLOW INVERT
- ☐ TYPE AND DESIGN OF SUBSURFACE INFILTRATION COMPONENTS (E.G. INLETS, OVERFLOWS, OBSERVATION WELLS)
- ☐ SETBACK DIMENSIONS TO BEDROCK, HIGH GROUNDWATER TABLE, PROPERTY LINES, FOUNDATIONS, WATER SUPPLY WELLS, SEWER MAINS, AND GROUND SLOPES OF 15% OR GREATER, AS APPLICABLE. SEE CITY ASSET PROTECTION STANDARDS.
- ☐ TYPE AND SIZE OF PRETREATMENT MEASURE, AS NESSESARY

SOIL TYPE GUIDANCE:

HYDROLOGIC SOIL GROUP	SOIL TYPE	CORRESPONDING UNIFIED SOIL CLASSIFICATION	DESCRIPTION
A	SAND, LOAMY SAND, OR SANDY LOAM	GW - WELL-GRADED GRAVELS, SANDY GRAVELS GP - GAP-GRADED OR UNIFORM GRAVELS, SANDY GRAVELS GM - SILTY GRAVELS, SILTY SANDY GRAVELS SW - WELL-GRADED, GRAVELLY SANDS SP - GAP-GRADED OR UNIFORM SANDS, GRAVELLY SANDS	LOW RUNOFF POTENTIAL. SOILS HAVING HIGH INFILTRATION RATES EVEN WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF DEEP, WELL TO EXCESSIVELY DRAINED SANDS OR GRAVELS.
B	SILT LOAM OR LOAM	SM - SILTY SANDS, SILTY GRAVELLY SANDS MH - MICACEOUS SILTS, DIATOMACEOUS SILTS, VOLCANIC ASH	SOILS HAVING MODERATE INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF MODERATELY DEEP TO DEEP, MODERATELY WELL TO WELL-DRAINED SOILS WITH MODERATELY FINE TO MODERATELY COARSE TEXTURES.
C	SANDY CLAY LOAM	ML - SILTS, VERY FINE SANDS, SILTY AND CLAYEY FINE SANDS	SOILS HAVING SLOW INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF SOILS WITH A LAYER THAT IMPEDES DOWNWARD MOVEMENT OF WATER, OR SOILS WITH MODERATELY FINE TO FINE TEXTURES.
D	CLAY LOAM, SANDY CLAY, SILTY CLAY, OR CLAY	GC - CLAYEY GRAVELS, CLAYEY SANDY GRAVELS SC - CLAYEY SANDS, CLAYEY GRAVELLY SANDS CL - LOW PLASTICITY CLAYS, SANDY OR SILTY CLAYS OL - ORGANIC SILTS AND CLAYS OF LOW PLASTICITY CH - HIGHLY PLASTIC LAYS AND SANDY CLAYS OH - ORGANIC SILTS AND CLAYS OF HIGH PLASTICITY	HIGH RUNOFF POTENTIAL. SOILS HAVING VERY SLOW INFILTRATION RATES WHEN THOROUGHLY WETTED AND CONSISTING CHIEFLY OF CLAY SOILS WITH A HIGH SWELLING POTENTIAL, SOILS WITH A PERMANENT HIGH WATER TABLE, AND SHALLOW SOILS OVER NEARLY IMPERVIOUS MATERIAL.

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SUBSURFACE INFILTRATION SYSTEM DESIGNER NOTES (2 OF 2)

City of Palo Alto Standard

Approved by: _____

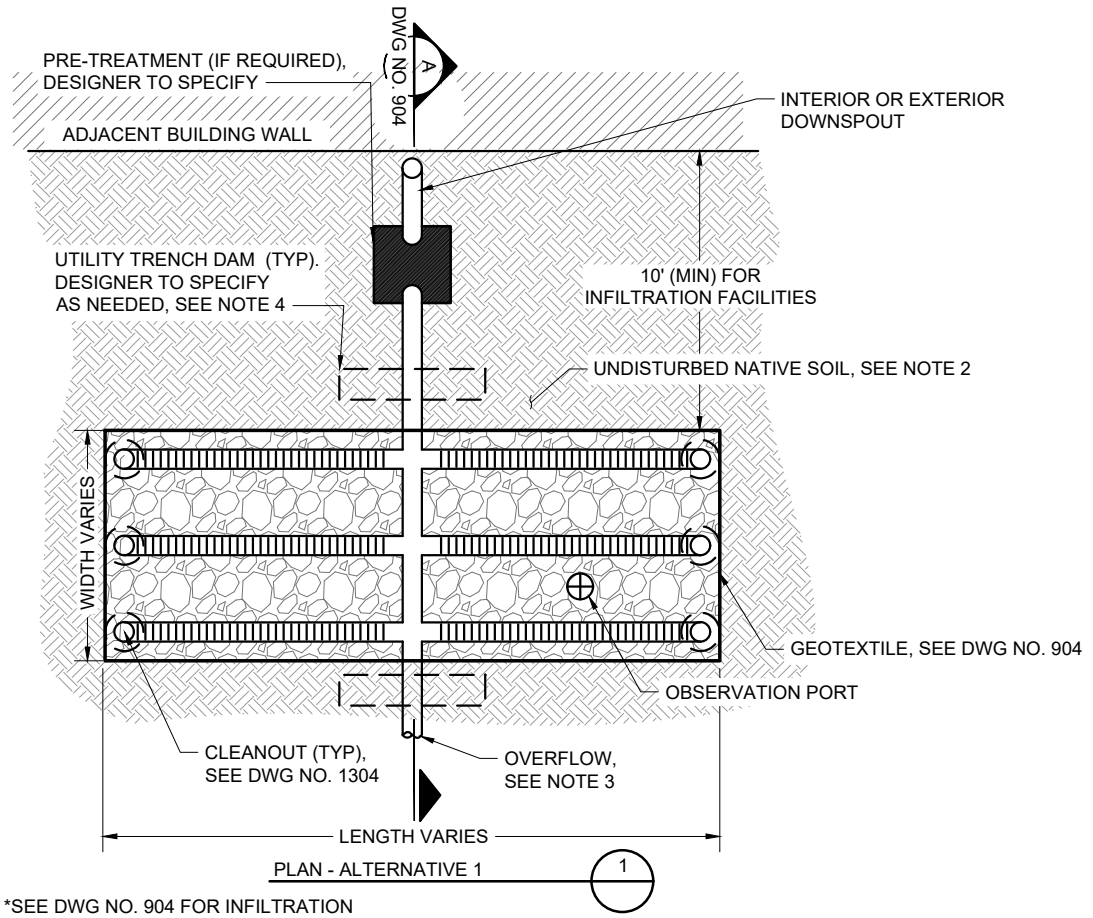
PE No. _____

Date _____

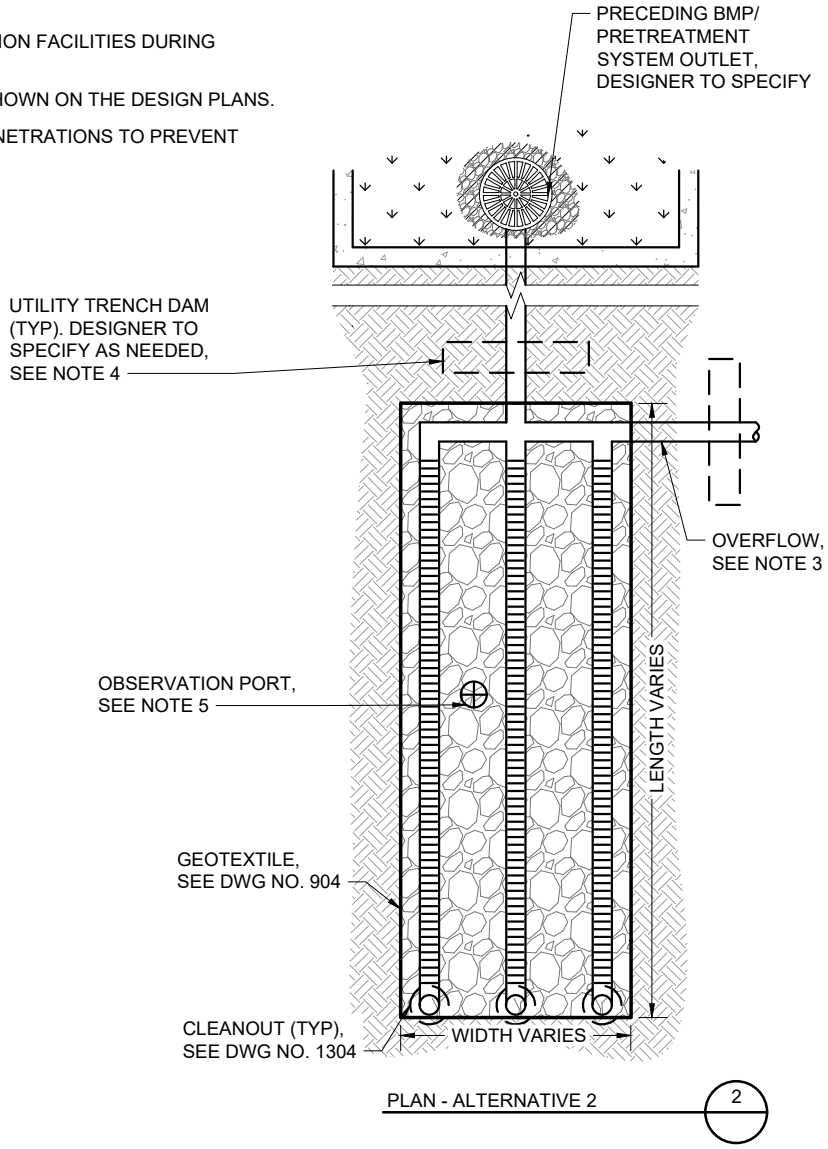
Dwg No. **902**

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 901 & 902 FOR GUIDELINES AND CHECKLIST.
2. AVOID COMPACTION AND DISTURBANCE OF EXISTING SOIL WITHIN 5 FEET ADJACENT TO AND BELOW INFILTRATION FACILITIES DURING CONSTRUCTION.
3. ROUTE OVERFLOW PIPE TO THE STORM DRAIN SYSTEM OR TO ANOTHER BMP FOR FURTHER TREATMENT AS SHOWN ON THE DESIGN PLANS.
4. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.
5. OBSERVATION PORTS TO BE INSTALLED IF REQUIRED BY PROJECT SPECIFICATIONS.



*SEE DWG NO. 904 FOR INFILTRATION GALLERY CROSS SECTION VIEW



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SUBSURFACE INFILTRATION SYSTEM
INFILTRATION GALLERY
LARGE SYSTEM PLAN

City of Palo Alto Standard

Approved by: _____

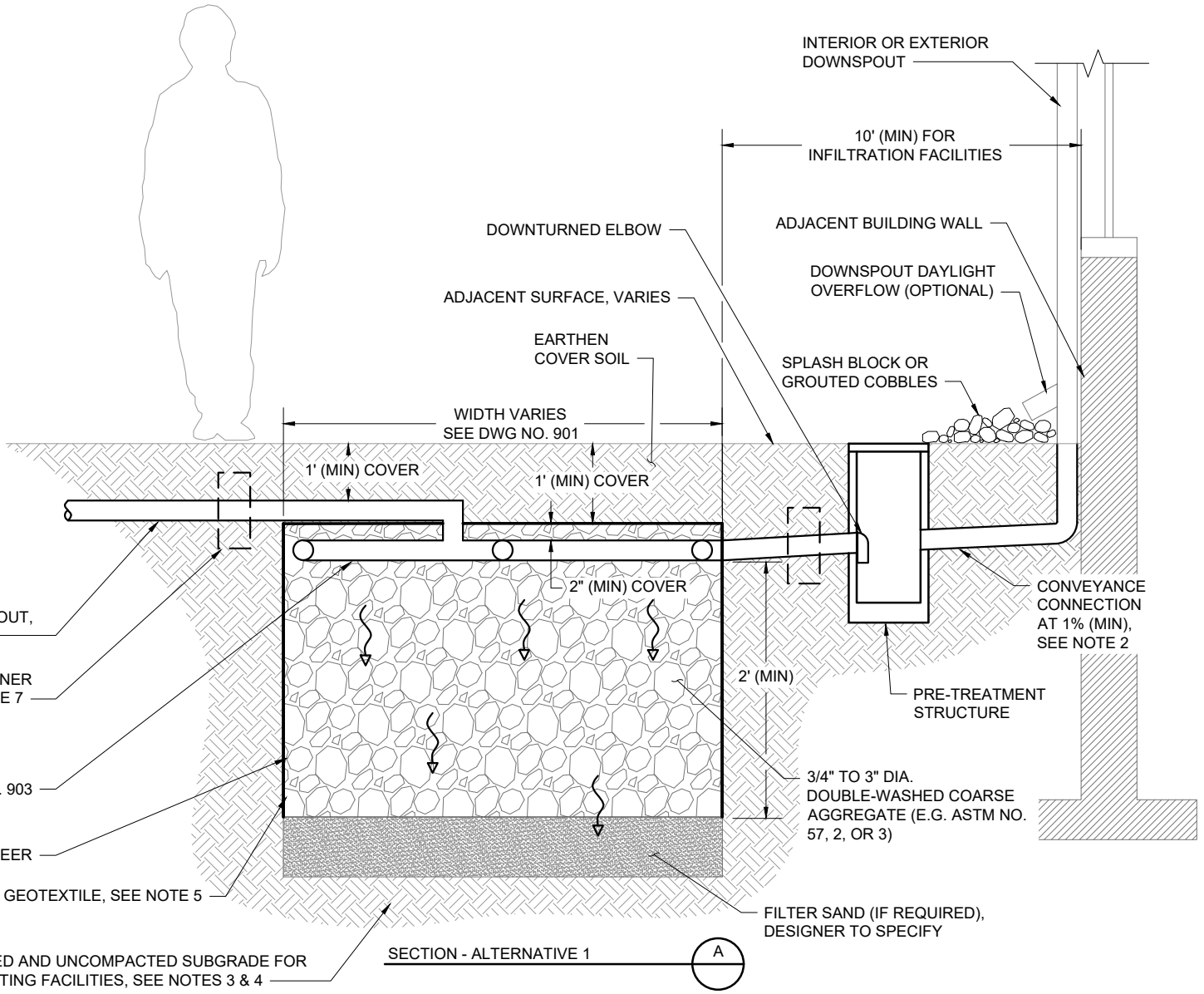
PE No. _____

Date _____

Dwg No. **903**

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 901 & 902. FOR GUIDELINES AND CHECKLIST.
2. REFER TO APPLICABLE CITY REQUIREMENTS FOR CONVEYANCE.
3. AVOID COMPACTION AND DISTURBANCE OF EXISTING SOIL ADJACENT TO AND BELOW INFILTRATION FACILITIES DURING CONSTRUCTION.
4. SCARIFY SUBGRADE TO A DEPTH OF 6 INCHES (MIN) IMMEDIATELY PRIOR TO PLACEMENT OF AGGREGATE STORAGE.
5. SIDEWALLS AND TOP OF AGGREGATE STORAGE SHALL BE LINED WITH A GEOTEXTILE TO PREVENT MIGRATION OF ADJACENT SOILS INTO SUBSURFACE INFILTRATION SYSTEM. DO NOT LINE BOTTOM TO AVOID CLOGGING OF FACILITY BASE.
6. SUBSURFACE DISTRIBUTION PIPING SHALL BE A 6 INCHES (MIN) IN DIAMETER.
7. PROVIDE UTILITY TRENCH DAM OR EQUIVALENT MEASURE OUTSIDE OF THE INFILTRATION FACILITY AT PIPE PENETRATIONS TO PREVENT PREFERENTIAL FLOW FROM INFILTRATION GALLERY INTO UTILITY TRENCHES. COORDINATE WITH ENGINEER.



SECTION - ALTERNATIVE 1 (A)

*SEE DWG NO. 903 FOR INFILTRATION GALLERY PLAN VIEW

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SUBSURFACE INFILTRATION SYSTEM
INFILTRATION GALLERY
LARGE SYSTEM SECTION

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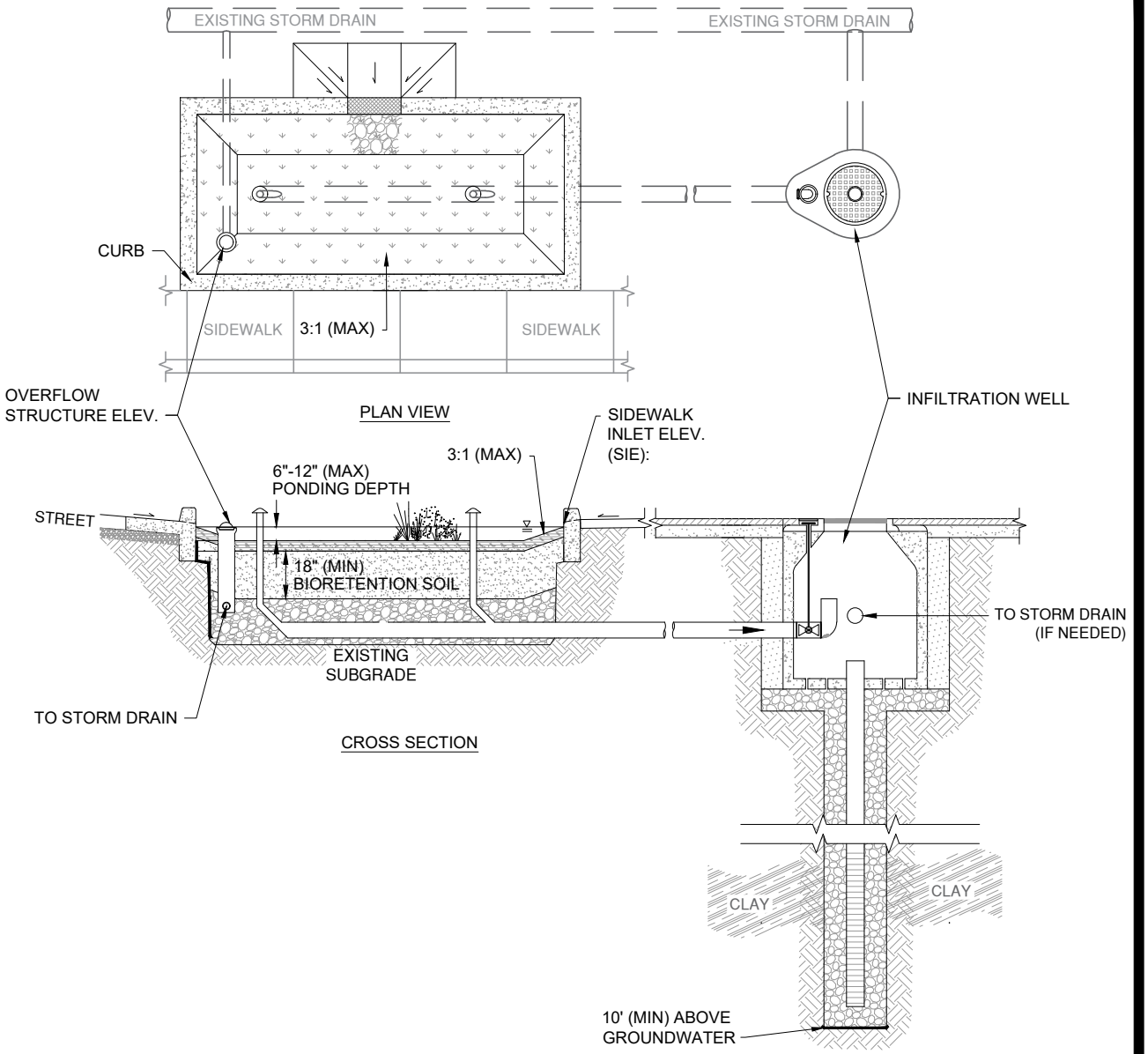
Date _____

Dwg No. **904**

DESIGNER NOTES:

1. ADDITIONAL DESIGN GUIDANCE FOR BIOFILTRATION SYSTEM PROVIDED IN LIDI BIORETENTION TECHNICAL SPECIFICATIONS (BTS) DOCUMENT.
2. BOTTOM WIDTH - PROVIDE 2 FT MINIMUM FLAT BREGENALL.
3. BOTTOM WITH A MAX 3:1 SLOPE FOR SURFACE FINISHING WITHIN BIOFILTRATION SYSTEM .
4. IF CALTRANS CLASS 2 PERMEABLE IS NOT AVAILABLE, SUBSTITUTE CLASS 3 PERMEABLE WITH AN OVERLYING 3" DEEP LAYER OF ¾" (NO. 4) OPEN-GRADED AGGREGATE, OR CALTRANS CLASS 2 AGGREGATE MATERIAL.
5. PROVIDE SPOT ELEVATIONS AT INLETS ON CIVIL PLANS (FE, OE, GIE, SIE).
6. EDGE CONDITION WILL VARY FOR NEW AND RETROFIT PROJECTS. CURB, WALL, AND SIDEWALK DETAILS MAY BE MODIFIED FOR PROJECT BY CIVIL AND GEOTECHNICAL ENGINEERS.
7. PROVIDE MONITORING WELL IN EACH FACILITY, PER TECHNICAL SPECIFICATIONS.
8. LONGITUDINAL SLOPE 6% WITH CHECK DAMS.
9. USE CHECK DAMS, IF NEEDED TO PROVIDE PRETREATMENT BASE.
10. VARIATIONS IN DRY WELL DESIGN SHOULD BE MADE TO ACCOMMODATE STORAGE VOLUME DESIGN AND TO SUIT LOCAL CONDITIONS AND CONSTRAINTS.
11. IN AREAS WITHOUT A STORMDRAIN, THE SYSTEM SHOULD ONLY BE CONSTRUCTED WHERE THE MAINTENANCE HOLE SURFACE INVERT IS ABOVE THE PRETREATMENT OVERFLOW ELEVATION.
12. ALTERNATIVE VAULT LOCATIONS POSSIBLE INCLUDING WITHIN THE BIOFILTER FOOTPRINT.
13. VALVE CAN BE MOVED TO THE PRETREATMENT FACILITY IF DESIRED. REQUIRES STRUCTURAL SUPPORT.
14. ALTERNATIVE PRODUCTS SUCH AS VENDOR-SUPPLIED DRY WELL PRODUCTS MAY BE USED AS A SUBSTITUTE PROVIDED THAT THE ALTERNATIVE PRODUCT IS EQUAL.
15. THIS DESIGN IS LIKELY TO QUALIFY AS A CLASS V WELL SUBJECT TO REGISTRATION WITH THE USEPA.
16. THESE DRYWELL DETAILS ARE ADAPTED FROM THE BIORETENTION ENGINEERING STANDARDS: DETAILS AND TECHNICAL SPECIFICATIONS (CENTRAL COAST LOW IMPACT DEVELOPMENT INITIATIVE), 2017, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.

SEE DWG NO. 906 FOR SPECIFICATIONS.



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DRYWELL AND DESIGNER NOTES

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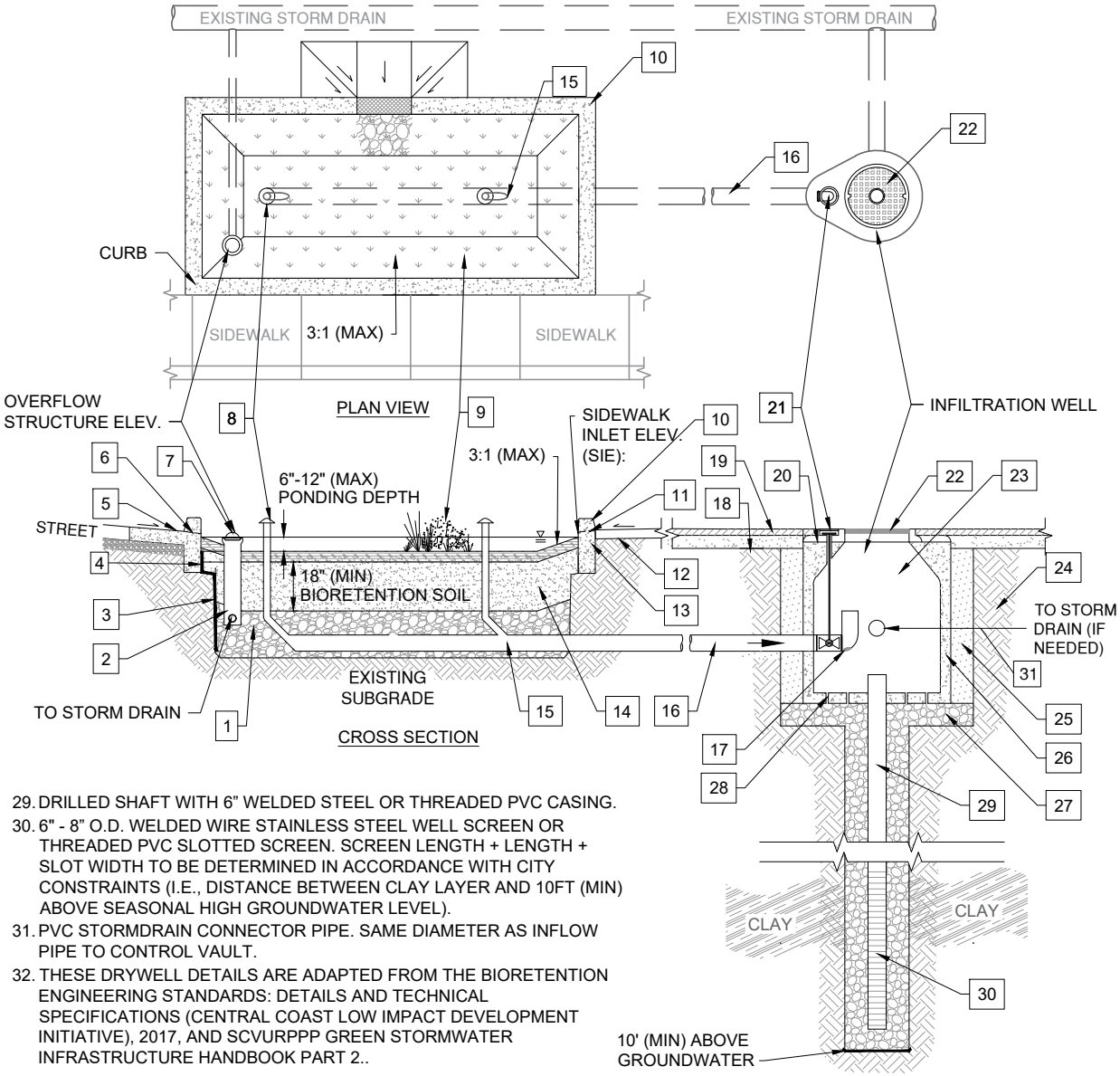
Dwg No. **905**

CONSTRUCTION NOTES:

1. 12” DEEP OPEN GRADED WASHED STONE (TYPICALLY 3/4” TO 1-1/2” (ASTM #4 STONE) OR 1” TO 2” (ASTM #3 STONE).
2. DO NOT USE FILTER FABRIC BETWEEN BIOFILTER SOIL MATERIAL (BSM) AND AGGREGATE.
3. 30 ML LINER MAY BE REQUIRED TO AVOID LATERAL INFILTRATION BELOW STREET; SUBJECT TO GEOTECHNICAL RECOMMENDATIONS.
4. MAINTAIN 6” MINIMUM BENCH OF NATIVE SOIL FOR SUPPORT OF ADJACENT SIDEWALK/ROAD (TYPICAL).
5. CURB AND GUTTER DETAIL DWG NO. 809 - 814.
6. GUTTER INLET ELEV (GIE). LOCATE ENERGY DISSIPATION COBBLE. PADS AS SPECIFIED IN INLET DETAILS.
7. OVERFLOW STRUCTURE REQUIRED FOR IN-LINE SYSTEMS WITHOUT OVERFLOW BYPASS, DETAIL DWG NO. 818.
8. MAINTENANCE PIPES - 4” MIN. DIAMETER VERTICAL PVC PIPES CONNECTED TO UNDERDRAIN. PLACED AT START AND 3 FEET BEFORE END OF UNDERDRAIN. REQUIRES DIRECTIONAL SWEEP BEND. THREADED AND CAPPED.
9. PLANT SELECTION AND MULCH PER DWG NO. 801 NOTE 9.
10. 4” MINIMUM EXPOSED WALL HEIGHT.
11. SIDEWALK DRAINAGE NOTCH 1” LOWER THAN SIDEWALK, SLOPED TO FACILITY.
12. SEE CITY STD DETAILS FOR SIDEWALK RESTORATION.
13. DEEP CURB.
14. BIORETENTION SOIL MEDIA PER BIORETENTION TECHNICAL SPECIFICATIONS. SPECIFICATION SHOULD AVOID COMPOST OR OTHER MATERIAL KNOWN TO LEACH NUTRIENTS.
15. UNDERDRAIN, MIN. 4” DIA. PVC SDR 35 PERFORATED PIPE OR LARGER AS NEEDED TO CONVEY PEAK TREATED FLOW RATE WITH MINIMAL HEAD LOSS, SEE CONSTRUCTION NOTES.
16. 8” INLET PIPE OR OTHER.
17. LOW FLOW ORIFICE. (SEE DWG NO. 905 DESIGN NOTE 11).
18. STABILIZED BACKFILL - TWO-SACK SLURRY MIX.
19. SIDEWALK PER CITY STD DETAILS.
20. COMPACTED BASE MATERIAL.
21. ACCESS HATCH WITH SHUT OF VALVE SWITCH. CONNECTED TO SHUT OF VALVE IN INLET PIPE.
22. MAINTENANCE HOLE COS TYPE 204-204 MH A OR B. 3/4” I.D. MIN OBSERVATION PORT, SEE DWG NO. 817 .
23. MANHOLE CONE - MODIFIED FLAT BOTTOM.
24. EXISTING SOILS.
25. COMPACTED BACKFILL.
26. PRE-CAST OR INSITU CAST CONTROL VAULT (SEE DWG NO. 905 DESIGN NOTE 12).
27. ROCK - WASHED, SIZED BETWEEN 3/8” AND 1-1/2".
28. PERFORATED BASE OF CONTROL VAULT.

*SEE DWG NO. 905 FOR DESIGNER NOTES.



29. DRILLED SHAFT WITH 6” WELDED STEEL OR THREADED PVC CASING.
30. 6" - 8” O.D. WELDED WIRE STAINLESS STEEL WELL SCREEN OR THREADED PVC SLOTTED SCREEN. SCREEN LENGTH + LENGTH + SLOT WIDTH TO BE DETERMINED IN ACCORDANCE WITH CITY CONSTRAINTS (I.E., DISTANCE BETWEEN CLAY LAYER AND 10FT (MIN) ABOVE SEASONAL HIGH GROUNDWATER LEVEL).
31. PVC STORMDRAIN CONNECTOR PIPE. SAME DIAMETER AS INFLOW PIPE TO CONTROL VAULT.
32. THESE DRYWELL DETAILS ARE ADAPTED FROM THE BIORETENTION ENGINEERING STANDARDS: DETAILS AND TECHNICAL SPECIFICATIONS (CENTRAL COAST LOW IMPACT DEVELOPMENT INITIATIVE), 2017, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2..

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DRYWELL SPECIFICATIONS

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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 SUBSURFACE OUTLETS (WHERE REQUIRED). RUNOFF IS TREATED AS IT 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. PERVIOUS PAVEMENT CAN BE USED AS A SELF-TREATING OR SELF RETAINING AREA, BUT CANNOT BE USED TO MEET MRP C.3 SIZING REQUIREMENTS.
3. ALL PAVEMENT SYSTEMS MUST BE DESIGNED BY A LICENSED ENGINEER IN ACCORDANCE WITH AASHTO OR CALTRANS DESIGN MANUAL 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.
4. 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 (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		

5. GEOTECHNICAL EVALUATION OF SUBGRADE SOILS TO VERIFY THEIR STRUCTURAL SUITABILITY FOR PERVIOUS PAVEMENT INSTALLATIONS IS REQUIRED.
6. GEOTECHNICAL EVALUATION OF SEASONAL HIGH GROUND. WATER LEVEL IS REQUIRED TO VERIFY MINIMUM 5 FT. SEPARATION BETWEEN BASE OR RESERVOIR COURSE AND GROUNDWATER.
7. THE PERVIOUS 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), SUBGRADE SLOPE, AND THE HEIGHT AND SPACING OF SUBSURFACE CHECK DAMS.
8. ENTIRE PAVEMENT BASE SECTION MAY BE USED TO MEET SUBSURFACE STORAGE REQUIREMENTS.
9. 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.
10. 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. SEE EDGE TREATMENTS (DWG NO. 1007 - 1009) FOR GUIDANCE ON DESIGN OF THESE COMPONENTS.
11. THE DESIGNER MUST EVALUATE UTILITY SURVEYS FOR POTENTIAL UTILITY CROSSINGS OR CONFLICTS. REFER TO DWG NO. 1303 FOR UTILITY CROSSING DETAILS.
12. ALL PERVIOUS PAVEMENT DESIGN MUST COMPLY WITH CITY STANDARDS ACCESSIBILITY/ADA REQUIREMENTS.

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PERVIOUS PAVEMENT DESIGNER NOTES (1 OF 2)

City of Palo Alto Standard

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Dwg No. **1001**

LAYOUT REQUIREMENTS:

1. ALL PERVIOUS PAVEMENT DESIGN MUST COMPLY WITH CITY STANDARD ACCESSIBILITY/ADA REQUIREMENTS.
2. THE ALLOWABLE CATCHMENT AREA CONTRIBUTING RUN-ON TO A PERVIOUS PAVEMENT FACILITY IS A MAXIMUM OF 2:1 RATIO. THE DESIGNER 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, PERVIOUS 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 UNSTABILIZED LANDSCAPE AREAS OR OTHER HIGH POLLUTANT AREAS (I.E. MORE POLLUTANT DISCHARGE THAN PARKING LOTS AND ROADWAYS) IS PROHIBITED. ANY LANDSCAPED AREAS WHICH DRAIN TO A PERVIOUS PAVEMENT SURFACE MUST BE FULLY MULCHED AND GRADED TO PREVENT SEDIMENT LADEN RUN-OFF FROM DEVELOPING. ANY TURF AREAS MUST BE ESTABLISHED FROM SOD.
   - CONCENTRATED RUN-ON (E.G., DIRECT DISCHARGE FROM A DOWNSPOUT) SHOULD BE DISPERSED PRIOR TO DISCHARGE TO A PERVIOUS PAVEMENT FACILITY. ACCEPTABLE METHODS INCLUDE SHEET FLOW OR SUBSURFACE DELIVERY TO THE STORAGE RESERVOIR. IF SUBSURFACE DELIVERY IS USED, PRETREATMENT AND FLOW DISTRIBUTION ARE REQUIRED.
4. WEARING COURSE FOR PAVERS SHALL BE SET ¼ INCH HIGHER THAN FINAL ELEVATION TO ALLOW FOR SETTLING AFTER CONSTRUCTION.
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% SLOPE
   b. PERVIOUS CONCRETE SURFACE: = 10% SLOPE
   c. PERMEABLE PAVERS OR PERMEABLE INTERLOCKING PAVERS: = 10% SLOPE (OR PER MANUFACTURER'S RECOMMENDATION)
   d. SLOPES EXCEEDING 2% TYPICALLY REQUIRE SUBSURFACE CHECK DAMS.
6. WHILE THERE IS NO MAXIMUM SLOPE FOR THE SUBGRADE UNDER THE PERVIOUS PAVEMENT COURSES, THERE MAY BE ENGINEERING CHALLENGES ASSOCIATED WITH SUBSURFACE CHECK DAM REQUIREMENTS ON SUBGRADE SLOPES EXCEEDING 5%.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ PERVIOUS PAVEMENT SPECIFICATIONS AND/OR PAVER TYPE AND GAP WIDTH
- ☐ PERVIOUS 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
- ☐ SUBSURFACE CHECK DAM SPACING, HEIGHT, AND TYPE
- ☐ ELEVATIONS OF EACH PIPE INLET AND OUTLET INVERT
- ☐ TYPE AND DESIGN OF PERVIOUS PAVEMENT COMPONENTS (E.G., EDGE TREATMENTS, OUTLETS, UNDERDRAINS)
- ☐ STRUCTURAL PAVER SPACER MODEL, HEIGHT, AND WIDTH (PEDESTRIAN ONLY)
- ☐ SUBSURFACE OVERFLOW STRUCTURE
- ☐ DETAIL OF PAVEMENT EDGE SHOWING STRUCTURAL SUPPORT AND TRANSITION TO ADJACENT SURFACE

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PERVIOUS PAVEMENT DESIGNER NOTES (2 OF 2)

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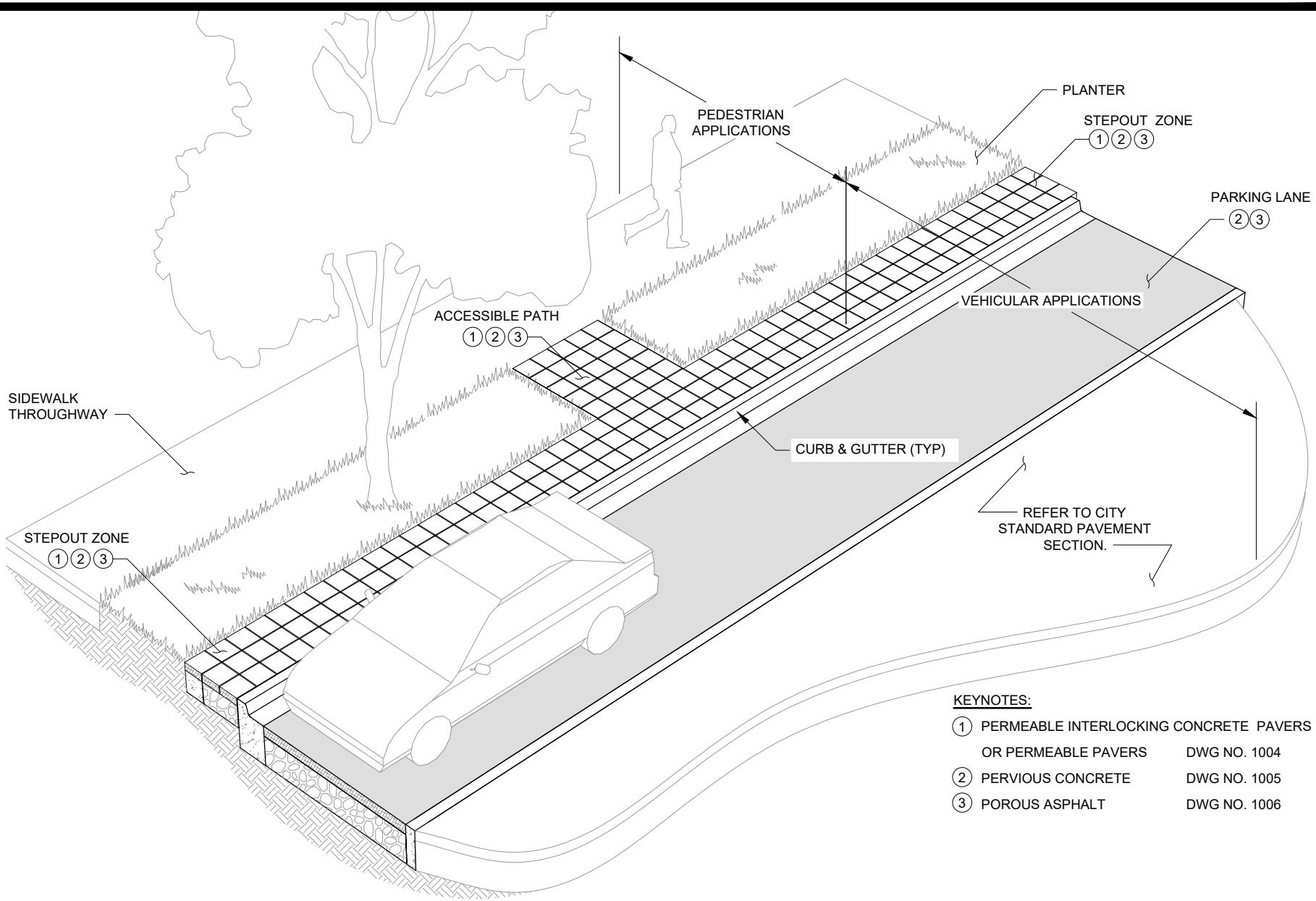
Dwg No. **1002**



KEYNOTES:

1	PERMEABLE INTERLOCKING CONCRETE PAVERS OR PERMEABLE PAVERS	DWG NO. 1004
2	PERVIOUS CONCRETE	DWG NO. 1005
3	POROUS ASPHALT	DWG NO. 1006

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PERVIOUS PAVEMENT KEY MAP

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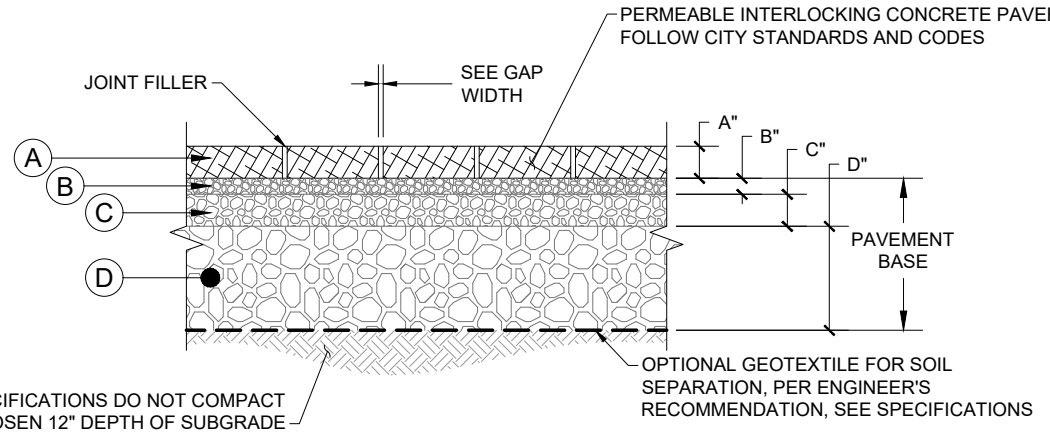
Date _____

Dwg No. **1003**

CONSTRUCTION NOTES:

1. SEE PERMEABLE INTERLOCKING CONCRETE PAVER SPECIFICATIONS FOR WEARING COURSE, PAVEMENT BASE, SUBGRADE, AND OTHER REQUIREMENTS FOR PERMEABLE INTERLOCKING CONCRETE PAVER FACILITIES.
2. MINIMUM UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK AND UTILITY CROSSINGS IN DWG NO 1303. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
3. IF UNDERDRAIN IS REQUIRED, DESIGN AND PLACEMENT IS PER ENGINEER'S RECOMMENDATION. SEE DWG NO. 1010, 1011 & 1307.
4. SEE DWG NO. 1007 - 1009 FOR EDGE TREATMENT.



PERMEABLE INTERLOCKING CONCRETE PAVERS 1

MINIMUM MATERIAL THICKNESS (IN) GUIDANCE:

LAYER	MATERIAL TYPE*	MODERATE VEHICULAR		LIGHT VEHICULAR		PEDESTRIAN	
		GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**	GOOD SOILS**	POOR SOILS**
A	PERMEABLE INTERLOCKING CONCRETE 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% 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).

*** FOR HEAVY VEHICLE TRAFFIC, LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON EXPECTED LOADS AND SITE CONDITIONS.

TYPICAL JOINT FILLER AGGREGATE SIZE:

GAP WIDTH (IN)	JOINT FILLER AGGREGATE*
3/8 OR 1/2	ASTM NO. 8 OR 89
1/4	ASTM NO. 9

* PROVIDED FOR REFERENCE ONLY, FOLLOW MANUFACTURER'S RECOMMENDATIONS

FOR PERMEABLE PAVERS ONLY, ASTM NO. 20 SAND NOT ALLOWED PER MANUFACTURER'S RECOMMENDATIONS. PERMEABLE PAVERS REFER TO PAVERS THAT ALLOW WATER TO FLOW THROUGH ACTUAL UNIT PAVER WHILE PERMEABLE INTERLOCKING CONCRETE PAVERS REFER TO PAVER SYSTEMS THAT ONLY ALLOW WATER TO PASS THROUGH JOINTS.

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PERVIOUS PAVEMENT PERMEABLE INTERLOCKING CONCRETE PAVERS

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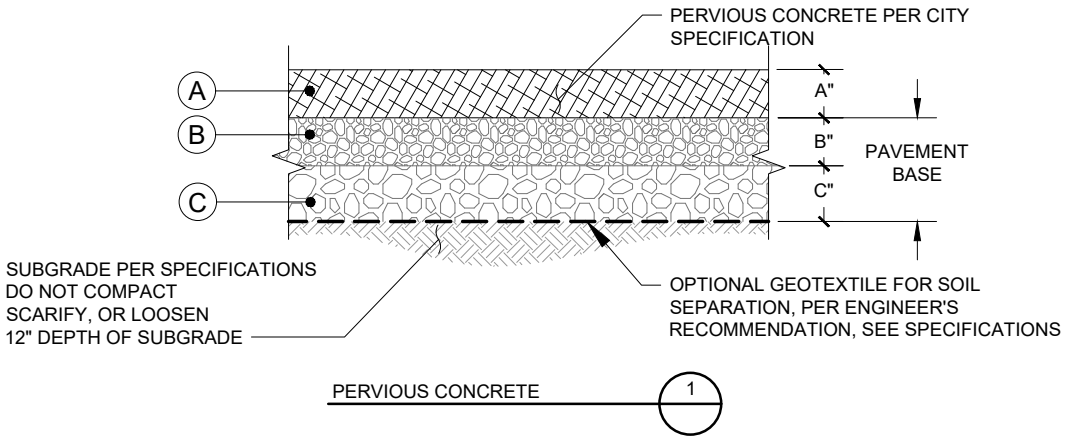
Dwg No. **1004**



MINIMUM MATERIAL THICKNESS (IN) GUIDANCE:

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% 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).

***FOR HEAVY VEHICLE TRAFFIC LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASED ON EXPECTED LOAD AND 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 IN PALO ALTO GSI HANDBOOK AND UTILITY CROSSINGS IN DWG NO 1303. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
3. IF UNDERDRAIN IS REQUIRED, DESIGN AND PLACEMENT IS PER ENGINEER'S RECOMMENDATION. SEE DWG NO. 1010, 1011, & 1307.
4. SEE DWG NO. 1007 - 1009 FOR EDGE TREATMENT.

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PERVIOUS PAVEMENT
PERVIOUS CONCRETE

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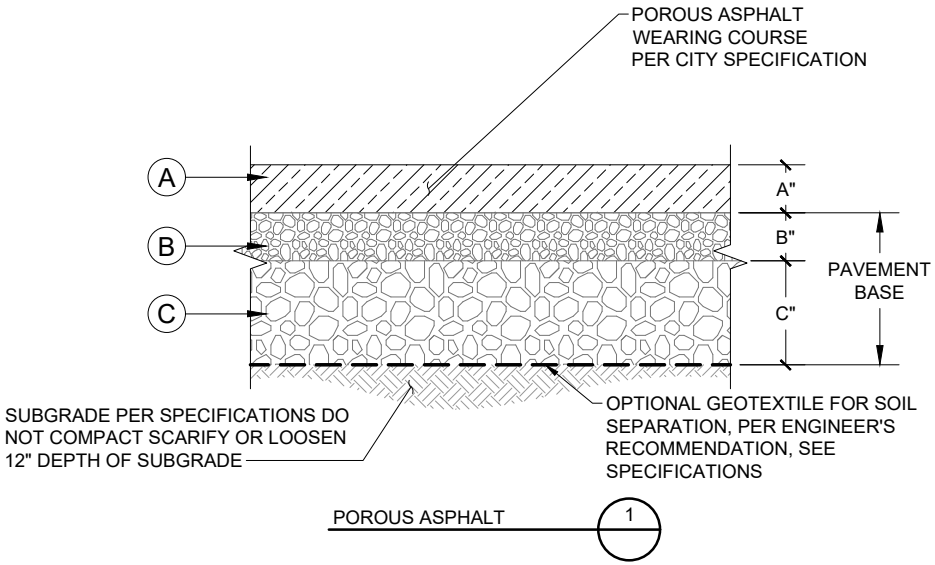
Date _____

Dwg No. **1005**



POROUS ASPHALT 1

MINIMUM MATERIAL THICKNESS (IN) GUIDANCE:

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% 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).

***FOR HEAVY VEHICLE TRAFFIC LICENSED PROFESSIONAL MUST CALCULATE REQUIRED DEPTH BASE ON EXPECTED LOAD AND 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 IN PALO ALTO GSI HANDBOOK AND UTILITY CROSSINGS IN DWG NO 1303. COORDINATE WITH ENGINEER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.
3. IF UNDERDRAIN IS REQUIRED, DESIGN AND PLACEMENT IS PER ENGINEER'S RECOMMENDATION, SEE DWG NO. 1010, 1011, & 1307.
4. SEE DWG NO. 1007 - 1009 FOR EDGE TREATMENT.

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PERVIOUS PAVEMENT
POROUS ASPHALT

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **1006**

PURPOSE:

EDGE TREATMENTS ARE USED TO STABILIZE THE EDGE OF THE PERVIOUS PAVEMENT AND CONTAIN WATER WITHIN THE PERVIOUS PAVEMENT SECTION.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT PLAN AND SECTION DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. ALL EDGE TREATMENT SYSTEMS MUST BE DESIGNED BY A LICENSED ENGINEER BASED ON SITE SPECIFIC CONDITIONS.
3. MINIMUM EDGE TREATMENT EMBEDMENT KEY DEPTHS ARE SPECIFIED TO PREVENT LATERAL SEEPAGE UNDER THE EDGE TREATMENT AND INTO ADJACENT PAVEMENT SECTIONS. DEEPER EMBEDMENT MAY BE REQUIRED UNDER SOME CONDITIONS.
4. FOR DEEP PAVEMENT SECTIONS, EDGE TREATMENT NOT REQUIRED TO EXTEND MORE THAN 12 INCHES BELOW WEARING COURSE PROVIDED REQUIREMENTS AT INTERFACE WITH IMPERMEABLE PAVEMENTS ARE SATISFIED.
5. USE THE EDGE TREATMENT KEY MAP ON DWG NO. 1008 TO IDENTIFY WHERE EACH TYPE OF EDGE TREATMENT IS REQUIRED OR ALLOWED.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ EDGE TREATMENT TYPE AND MATERIAL
- ☐ EDGE TREATMENT WIDTH AND HEIGHT
- ☐ EMBEDMENT KEY DEPTH IF DIFFERENT THAN THE PROVIDED MINIMUMS
- ☐ MINIMUM UNDERDRAIN LENGTH TO CONVEY PEAK FLOW TO BMP

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PAVEMENT COMPONENTS
EDGE TREATMENT
DESIGNER NOTES

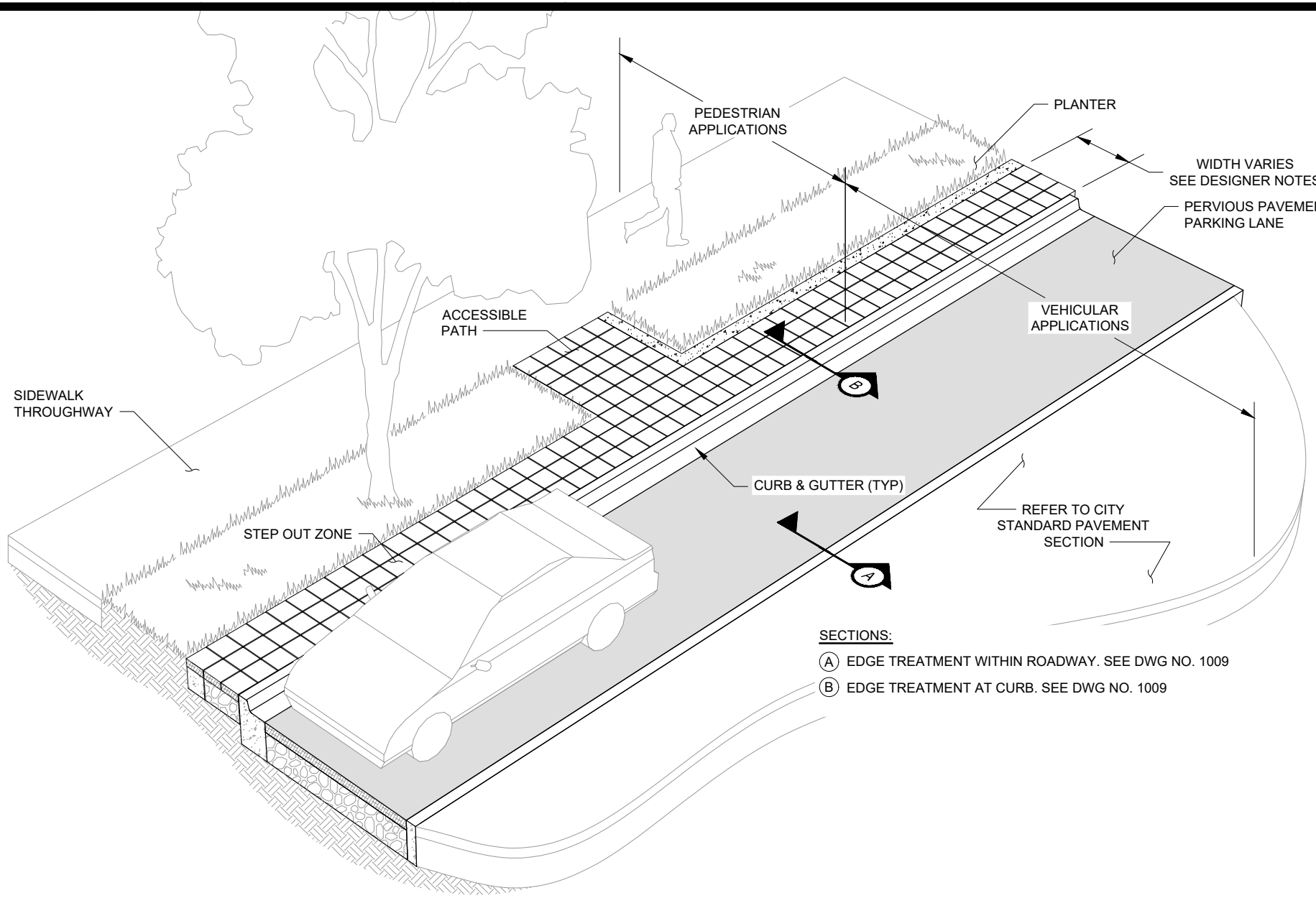
City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **1007**



SECTIONS:

(A) EDGE TREATMENT WITHIN ROADWAY. SEE DWG NO. 1009

(B) EDGE TREATMENT AT CURB. SEE DWG NO. 1009

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PAVEMENT COMPONENTS
EDGE TREATMENT
KEY MAP

City of Palo Alto Standard

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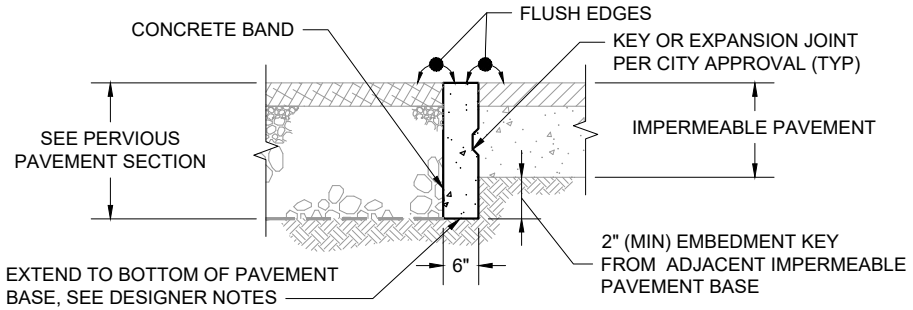
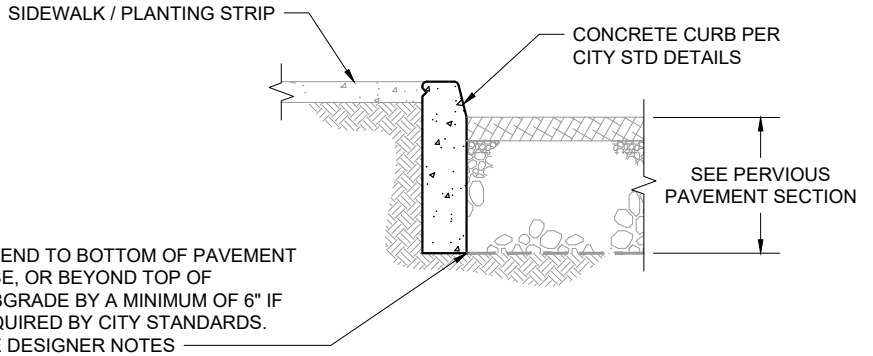
Date _____

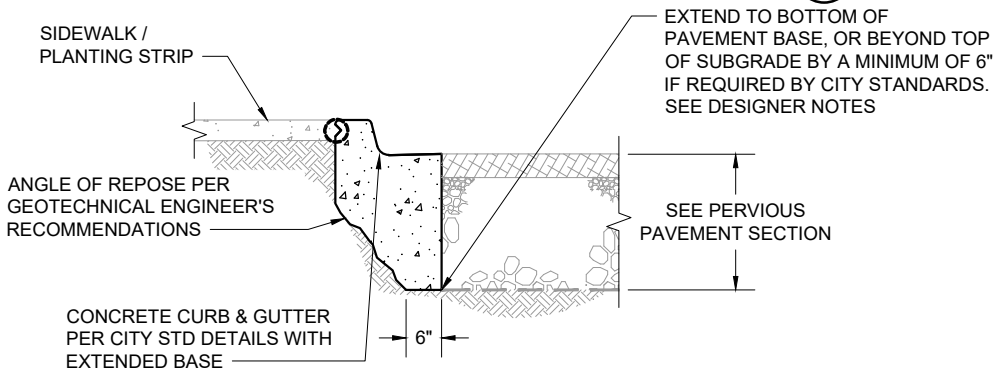
Dwg No. **1008**



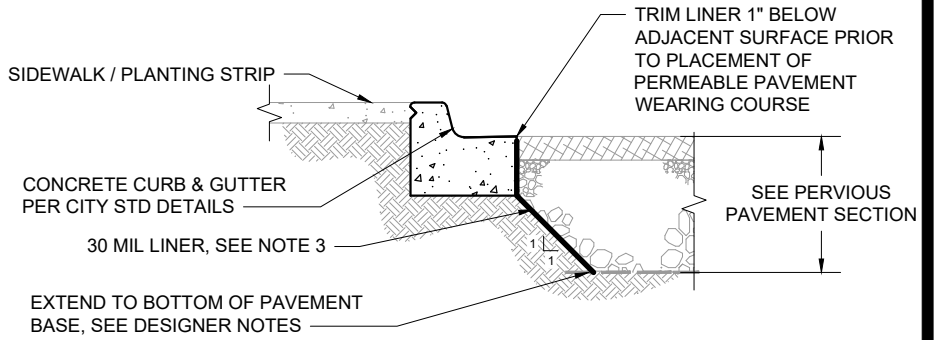
CONCRETE BAND WITHIN PAVED AREA — 1



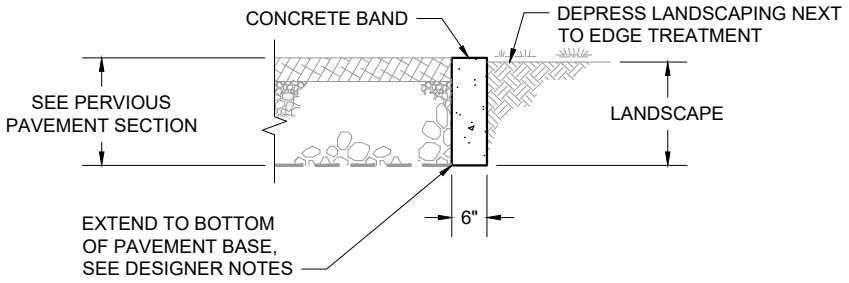
DEEPENED STANDARD CURB — 2



DEEPENED STANDARD CURB AND GUTTER — 3



IMPERMEABLE LINER AT STANDARD CURB AND GUTTER — 4



CONCRETE BAND AT LANDSCAPE — 5

CONSTRUCTION NOTES:

1. REFER DWG NO. 1007 FOR GUIDELINES AND CHECKLIST.
2. ALL MATERIAL REINFORCEMENT, AND WORKMANSHIP FOR EDGE TREATMENTS, SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
3. LINER SHALL BE HDPE CONFORMING TO GEOSYNTHETIC RESEARCH INSTITUTE (GRI) GM13 OR LLDPE CONFORMING TO GRI GM 17.

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PAVEMENT COMPONENTS
EDGE TREATMENT
VEHICULAR APPLICATIONS

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **1009**

PURPOSE:

PERVIOUS PAVEMENT UNDERDRAINS ARE DESIGNED TO CONVEY EXCESS FLOW TO AN APPROVED DISCHARGE POINT. FOR SUBSURFACE UNDERDRAIN CONFIGURATIONS, THE UNDERDRAIN OUTLET ELEVATION IS SET AT THE MAXIMUM DESIGN PONDING DEPTH. WHEN CHECK DAMS ARE REQUIRED, THE CHECK DAM IS SET AT THE MAXIMUM DESIGN PONDING DEPTH IN THE PAVEMENT BASE. IN BOTH CASES, THE UNDERDRAIN IS LOCATED IN AN UNDERDRAIN TRENCH. WATER BELOW THE OVERFLOW RISER, UNDERDRAIN OUTLET ELEVATION, OR CHECK DAM ELEVATION IS TEMPORARILY STORED AND INFILTRATED INTO THE UNDERLYING SUBGRADE. UNDERDRAINS ARE ONLY RECOMMENDED WHEN AN AVAILABLE DAYLIGHT CONDITION EXISTS.

DESIGNER NOTES & GUIDELINES:

1. DESIGNERS MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. CONVEYANCE IS TYPICALLY PROVIDED BY PERFORATED PIPE(S) WITH DOWNSTREAM OUTLET CONTROL OR UPSTREAM CHECK DAMS SET AT THE DESIGN PONDING ELEVATION.
3. LARGE STORM EVENTS CAN BE CONVEYED BY SURFACE SHEET FLOW UPON INUNDATION OF THE PAVEMENT SECTION (REQUIRES SURFACE CONVEYANCE SYSTEM OR OTHER RUNOFF COLLECTION METHOD).
4. THE DESIGNER MUST CONSIDER THE FLOW PATH OF WATER WHEN THE PERMEABLE PAVEMENT SECTION IS FULLY SATURATED TO THE MAXIMUM DESIGN DEPTH TO CONFIRM THERE ARE NO UNANTICIPATED DISCHARGE LOCATIONS (E.G., INTERSECTING UTILITY TRENCHES) AND TO ENSURE THE DESIGN PROVIDES EMERGENCY OVERFLOW CONVEYANCE TO AN APPROVED DISCHARGE POINT.
5. CONVEYANCE CALCULATIONS ARE REQUIRED TO DESIGN THE UNDERDRAIN PIPE DIAMETER AND PIPE SPACING TO SATISFY CITY HYDRAULIC REQUIREMENTS.
6. WEARING COURSE MAY BE USED TO FULFILL MINIMUM COVER REQUIREMENTS PROVIDED WEARING COURSE IS RIGID PAVEMENT.
7. OBSERVATION PORTS ARE REQUIRED FOR LARGE SYSTEM COLLECTING RUNOFF FROM ADJACENT AREAS. OBSERVATION PORTS CAN BE USED TO DETERMINE WHETHER AN UNDERDRAIN IS DEWATERING PROPERLY. REFER TO DWG NO. 1305 & 1307.
8. UNDERDRAIN PIPES MUST BE EQUIPPED WITH CLEANOUTS. REFER TO DWG NO. 1304.
9. PIPE MATERIAL SHALL BE DESIGNED PER CITY OF PALO ALTO REQUIREMENTS.
10. AN OUTLET ORIFICE CONTROL DEVISE MAY BE INSTALLED TO FURTHER DETAIN OUTFLOW AND MAXIMIZE INFILTRATION. ENGINEER SHALL DESIGN, DETAIL, SPECIFY, AND CONDUCT SUPPLEMENTAL PERFORMANCE CALCULATIONS AS NEEDED.
11. UNDERDRAIN PIPES MUST BE LOCATED AT AN ELEVATION HIGHER THAN THE STORM DRAIN HYDRAULIC GRADE LINE TO PREVENT BACK FLOW INTO THE PAVEMENT SECTION.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ UNDERDRAIN PIPE MATERIAL, DIAMETER, AND COVER DEPTH
- ☐ UNDERDRAIN PIPE INVERT ELEVATION AND SLOPE
- ☐ UNDERDRAIN PIPE ALIGNMENT AND DISCHARGE LOCATION

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PAVEMENT COMPONENTS
SUBSURFACE UNDERDRAIN
DESIGNER NOTES

City of Palo Alto Standard

Approved by: _____

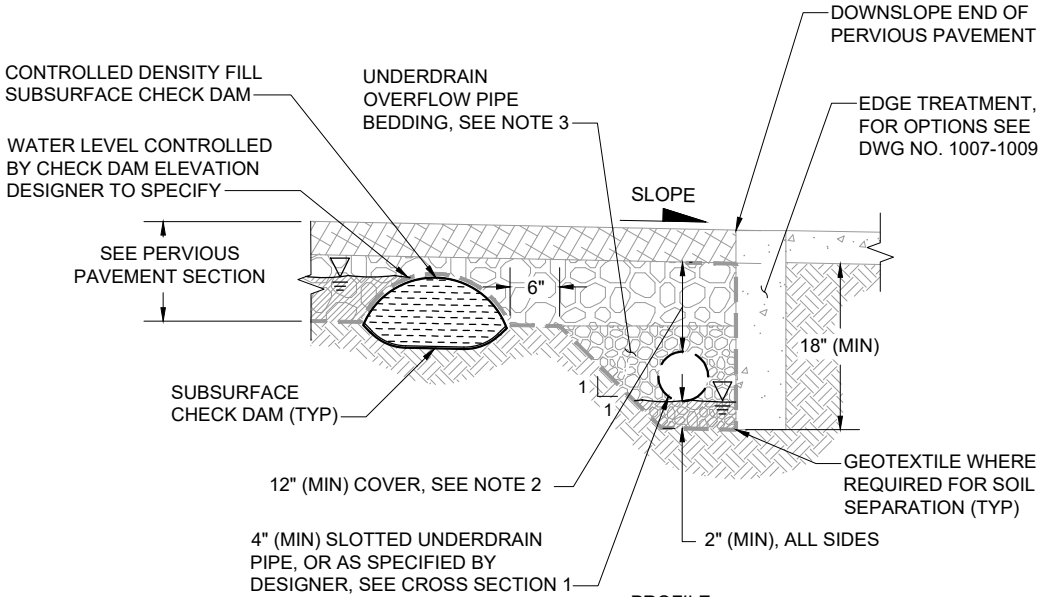
PE No. _____

Date _____

Dwg No. **1010**

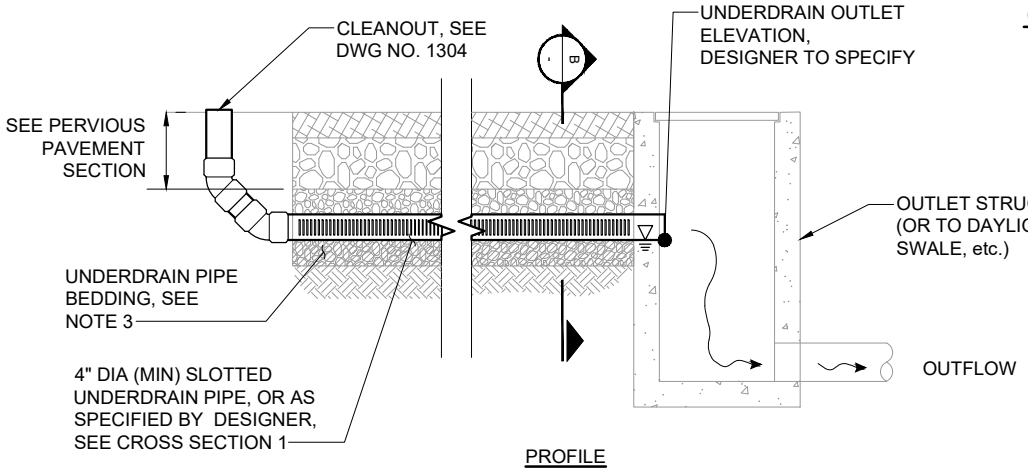
CONSTRUCTION NOTES:

1. ALL MATERIAL AND WORKMANSHIP FOR OVERFLOW STRUCTURES SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
2. LOCATE UNDERDRAIN PIPE BELOW STRUCTURAL PAVEMENT BASE DEPTH.
3. UNDERDRAIN PIPE BEDDING SHALL BE ASTM NO. 57 CONFORMING TO THE REQUIREMENTS OF GRAVEL BASE MATERIAL FOR PAVEMENTS, UNLESS OTHERWISE SPECIFIED.
4. SLOTTED UNDERDRAIN PIPE IS PREFERRED BUT DESIGNER MAY SPECIFY PERFORATED PIPE.
5. UNDERDRAIN PIPE SHALL BE SLOTTED HDPE SDR 17 OR ACCEPTABLE SUBSTITUTE MATERIAL (SUCH AS PERFORATED PIPE) PER ENGINEERS SPECIFICATION. SINGLE WALL AND DUAL WALL CORRUGATED HDPE PIPE (AASHTO M252 AND M294 TYPES C, S, AND D) ARE NOT ACCEPTABLE.
5. UNDERDRAIN PIPE SHALL BE SLOTTED TYPE, MEASURING 0.064 INCH WIDE (MAX), SPACED AT 0.30 INCH ON CENTER, AND PROVIDING A MINIMUM INLET AREA OF 10.0 SQUARE INCHES PER LINEAR FOOT OF PIPE. OTHER SLOT CONFIGURATIONS PROVIDING A MINIMUM INLET OF 10.0 SQUARE INCHES PER LINEAR FOOT OF PIPE MAY BE SUBMITTED FOR CITY APPROVAL.
6. SLOTS SHALL BE ORIENTED PERPENDICULAR TO LONG AXIS OF PIPE, AND EVENLY SPACED AROUND CIRCUMFERENCE AND LENGTH OF PIPE.



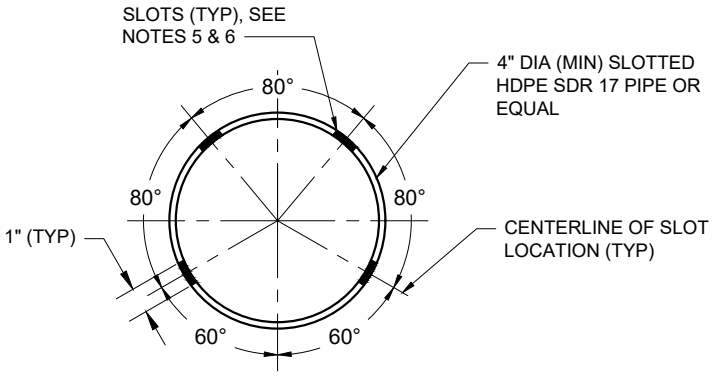
PROFILE

CHECK DAM-CONTROLLED WITH UNDERDRAIN — B



PROFILE

UNDERDRAIN TO DAYLIGHT — A



SLOTTED UNDERDRAIN PIPE — 1

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PAVEMENT COMPONENTS SUBSURFACE UNDERDRAIN PROFILE AND NOTES

City of Palo Alto Standard

Approved by: _____

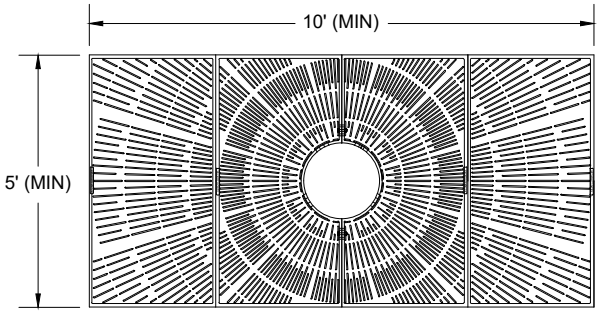
PE No. _____

Date _____

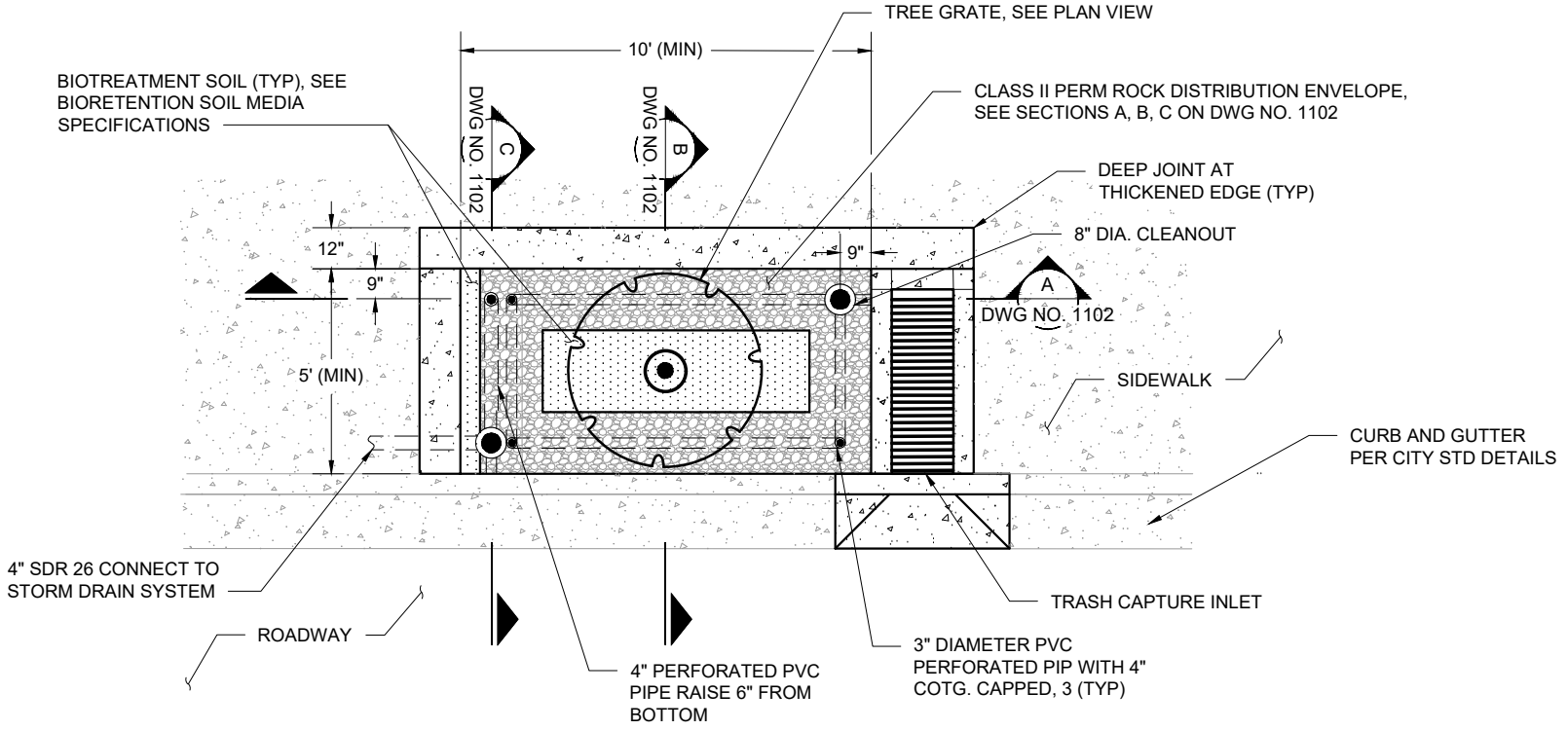
Dwg No. **1011**

CONSTRUCTION NOTES:

1. TREE GRATE (WITH EXTENSIONS) PER CITY STANDARDS. SEE DWG NO. 1102 FOR SECTION VIEW A, B, C.
2. TREATMENT SOIL SPECIFICATION SHALL BE COMPOSED OF:
   60% ASTM C-33 SAND
   30% USCC STA CERTIFIED COMPOST
   10% SMALL WOOD CHIPS



PLAN VIEW - TREE GRATE



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TREE WELL FILTER PLAN AND NOTES

City of Palo Alto Standard

Approved by: _____

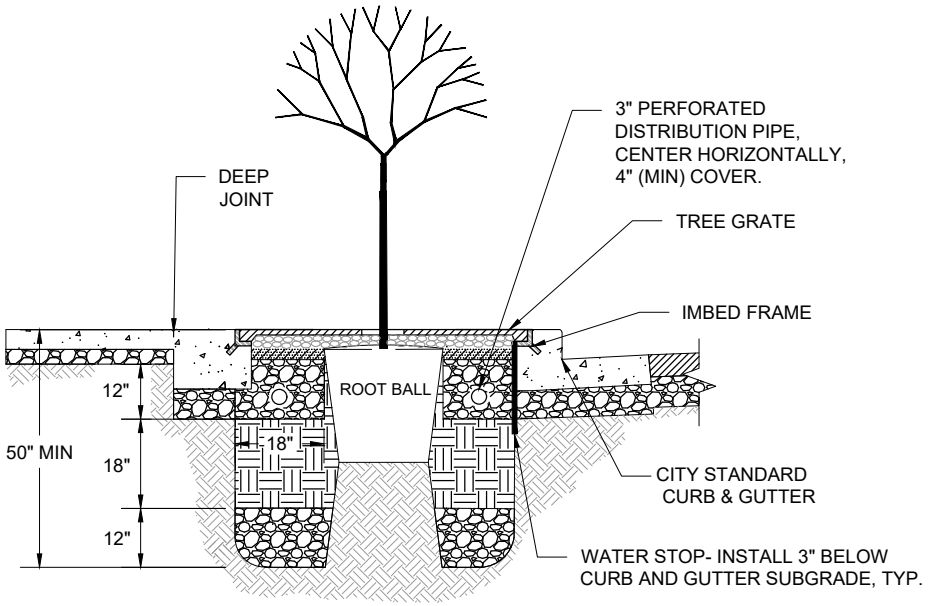
PE No. _____

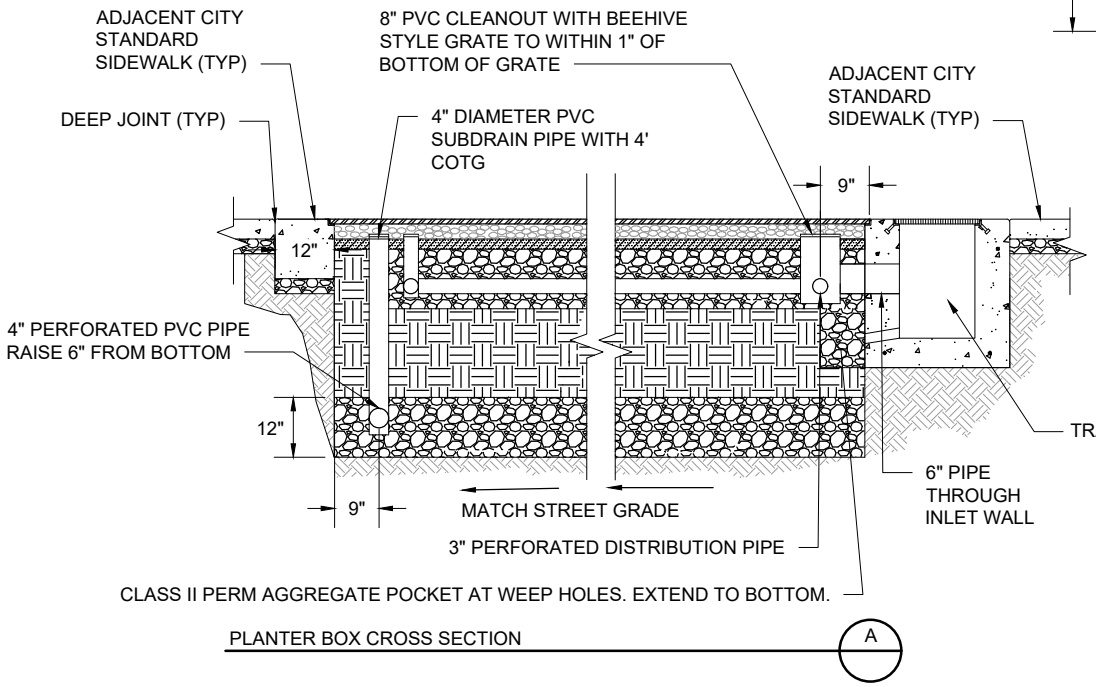
Date _____

Dwg No. **1101**

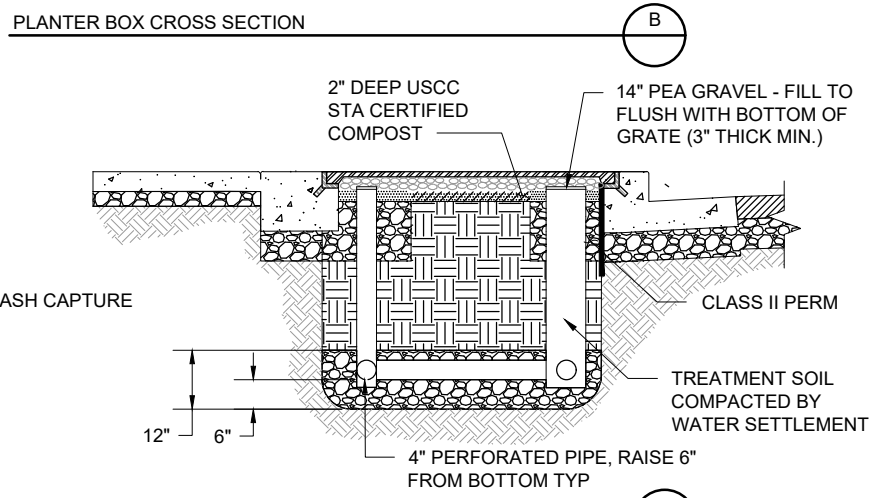
CONSTRUCTION NOTES:

1. THE MAXIMUM ALLOWABLE DRAINAGE AREA FOR THIS TREEWELL AS SHOWN (10' x 5') SHALL BE 1,250 SQ. FT. TREEWELL HAS BEEN SIZED USING THE COMBINED FLOW AND VOLUME METHODOLOGY AS DETAILED IN THE C.3 STORMWATER TECHNICAL MANUAL. ANY DEVIATION FROM THIS SIZE (10' x 5') WOULD REQUIRE FLOW-VOLUME CALCULATIONS. SUBSURFACE TREEWELL TREATMENT DEVICES WILL NOT BE ACCEPTED USING SIMPLIFIED SIZING CRITERIA OF 4%.
2. THE CURB INLET OPENING OF 15" AS SHOWN IS SUFFICIENT TO CAPTURE 100% OF THE TREATMENT RUNOFF FROM THE MAXIMUM DRAINAGE AREA (1,250 SQ.FT. OF IMPERVIOUS AREA) PERTINENT TO THIS TREEWELL SIZE. THE LENGTH OF CURB OPENING REQUIRED FOR 100% CAPTURE IS DEPENDENT ON THE GUTTER SLOPE (FOR TREEWELLS INSTALLED AT GRADE). STREETS GREATER THAN 3.4% SHALL REQUIRE LONGER OR MULTIPLE CURB OPENINGS BASED ON INLET CAPTURE CALCULATIONS.
3. FOR ADDITIONAL PLANTING AND IRRIGATION REFER TO PUBLIC WORKS REQUIREMENTS. TREES MUST BE IRRIGATED.





PLANTER BOX CROSS SECTION A



PLANTER BOX CROSS SECTION C

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TREE WELL FILTER SECTIONS AND NOTES

City of Palo Alto Standard

Approved by: _____

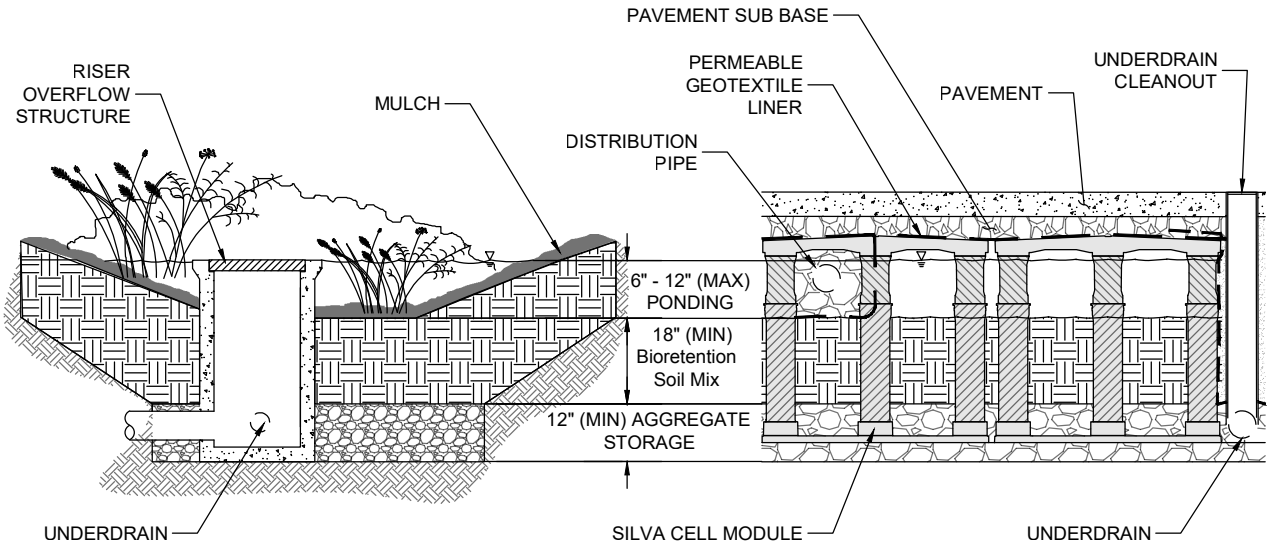
PE No. _____

Date _____

Dwg No. **1102**

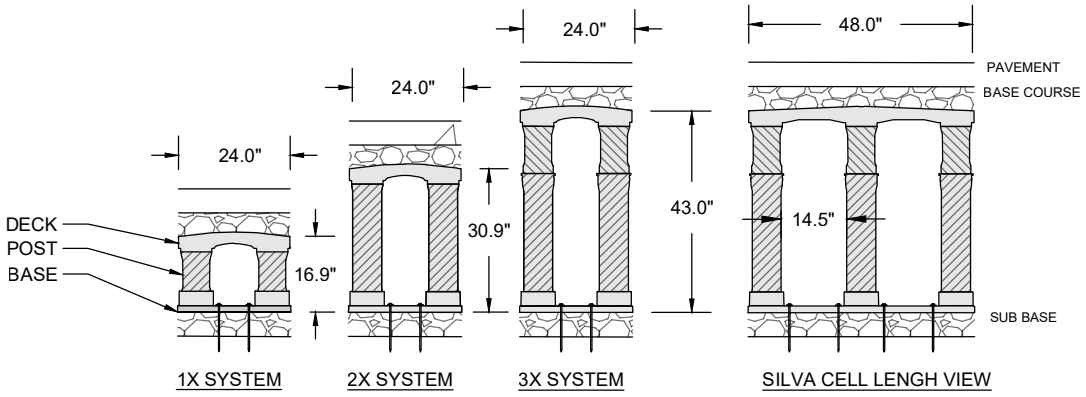
CONSTRUCTION NOTES:

1. 3X SILVA CELL LENGTH SHOWN.
2. 1X, 2X, AND 3X HAVE SAME LENGTH DIMENSIONS.
3. 3X SILVA CELL SYSTEM SHOWN.
4. OVERFLOW OUTLET NOT SHOWN, TYPICALLY INTEGRATED INTO INLET STRUCTURE.
5. TYPICAL BIORETENTION CROSS SECTION ADAPTED FROM SAN FRANCISCO PUBLIC UTILITIES COMMISSION (SFPUC) TYPICAL DETAILS (2023)
6. CITY OF PALO ALTO IS NOT ENDORSING DEEPROOT AND RECOMMENDS CONSIDERATION OF SIMILAR PRODUCTS FOR THIS TYPE OF GSI MEASURE.



TYPICAL BIORETENTION CROSS SECTION A

SILVA CELL BIORETENTION CROSS SECTION B



SILVA CELL SYSTEM SIZES 1

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Scale: NTS

SUSPENDED PAVEMENT SYSTEM
SILVA CELL COMPONENTS
BIORETENTION APPLICATION

City of Palo Alto Standard

Approved by: _____

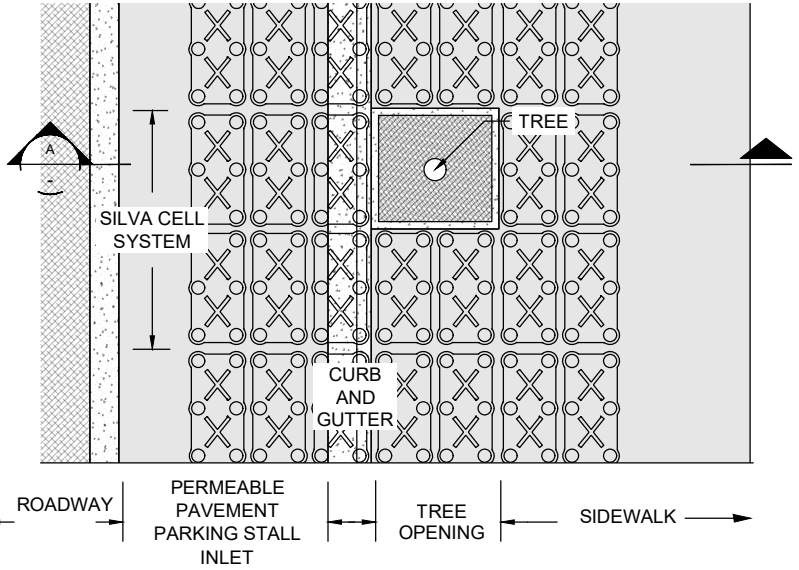
PE No. _____

Date _____

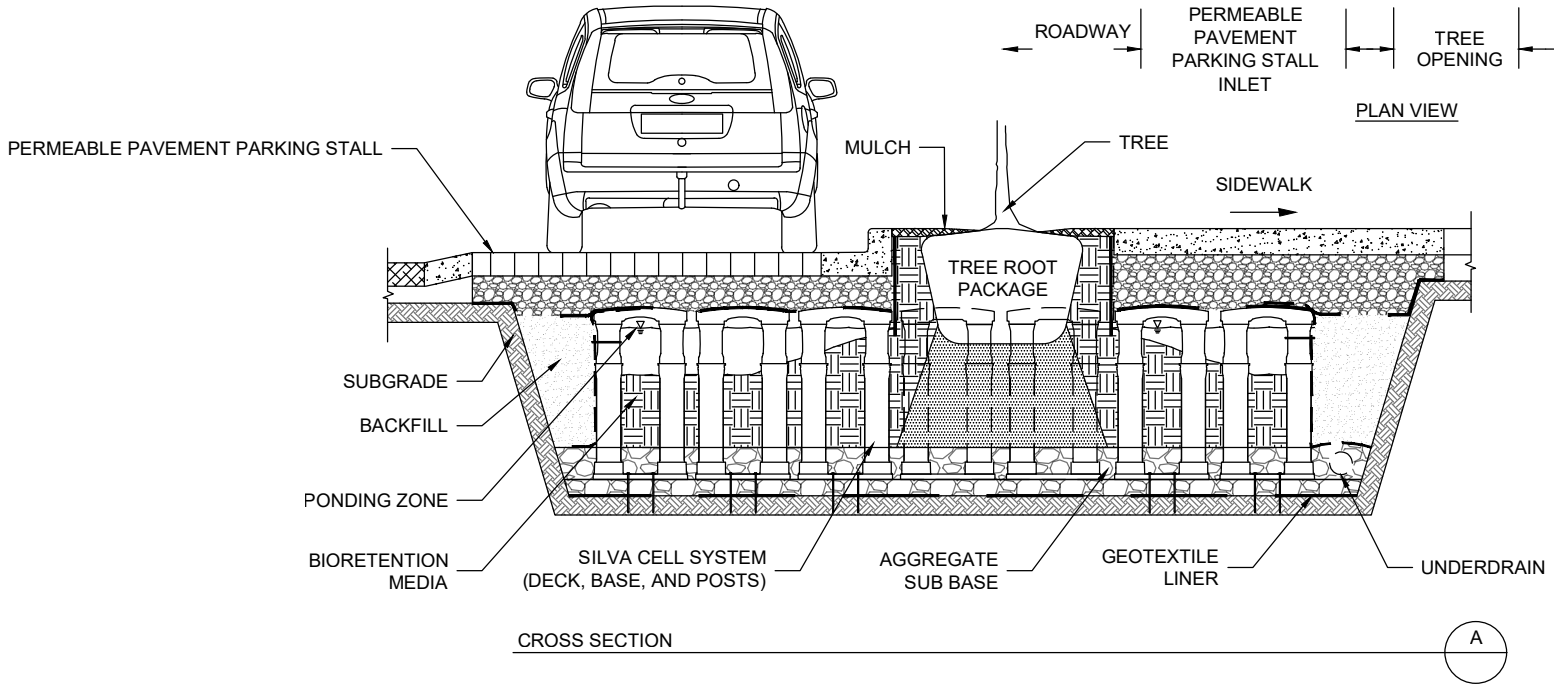
Dwg No. **1201**

CONSTRUCTION NOTES:

1. MEETS AASHTO HS-20 (USA) CSA-S6, 87.5 AND OBC 54KN (CANADA), AND BS EN 1991-1-1:2002 BS EN 1991-1-2:2003 (UK) LOADING STANDARDS WHEN USED WITH STANDARD PAVING PROFILES. INCREASED LOADING CAPACITY CAN BE ACHIEVED BY ADJUSTING THE STANDARD PROFILES.
2. CITY OF PALO ALTO IS NOT ENDORSING DEEPROOT AND RECOMMENDS CONSIDERATION OF SIMILAR PRODUCTS FOR THIS TYPE OF GSI MEASURE.



PLAN VIEW



CROSS SECTION A

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SUSPENDED PAVEMENT SYSTEM SILVA CELL COMPONENTS PLAN AND SECTION

City of Palo Alto Standard

Approved by: _____

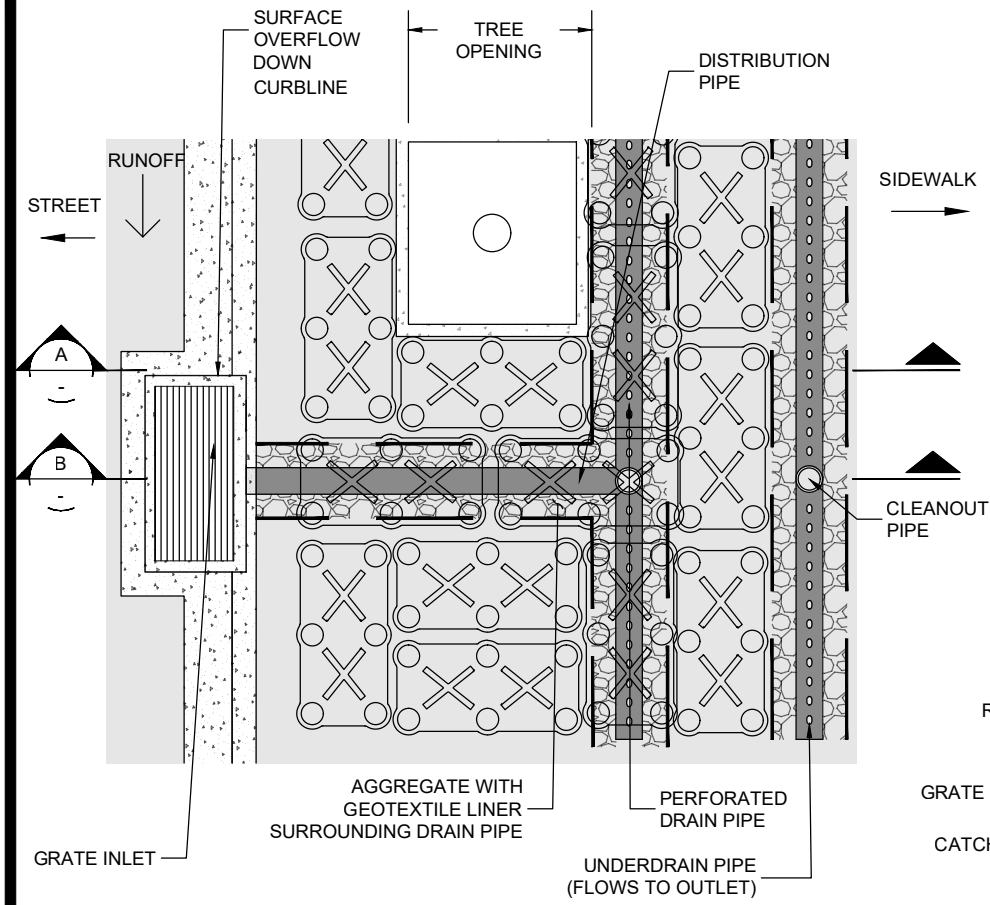
PE No. _____

Date _____

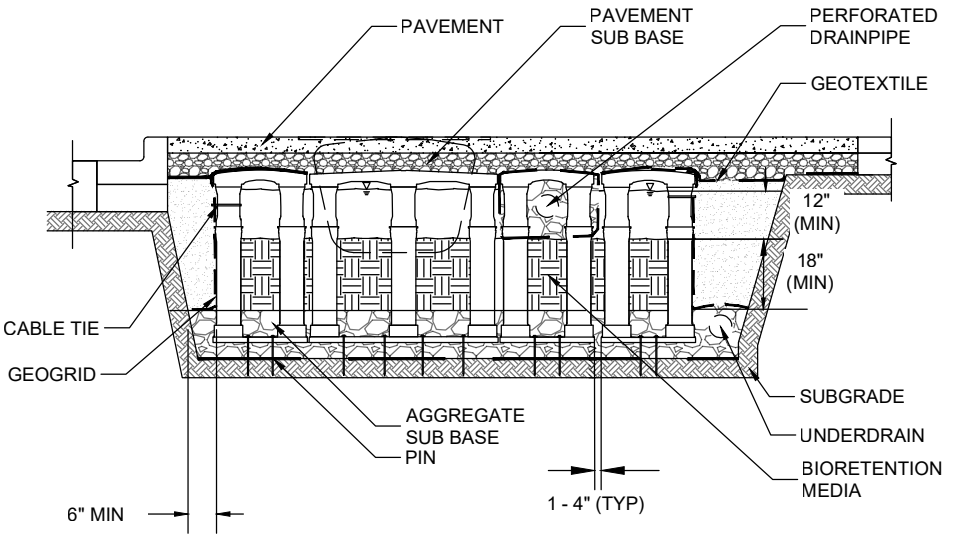
Dwg No. **1202**

CONSTRUCTION NOTES:

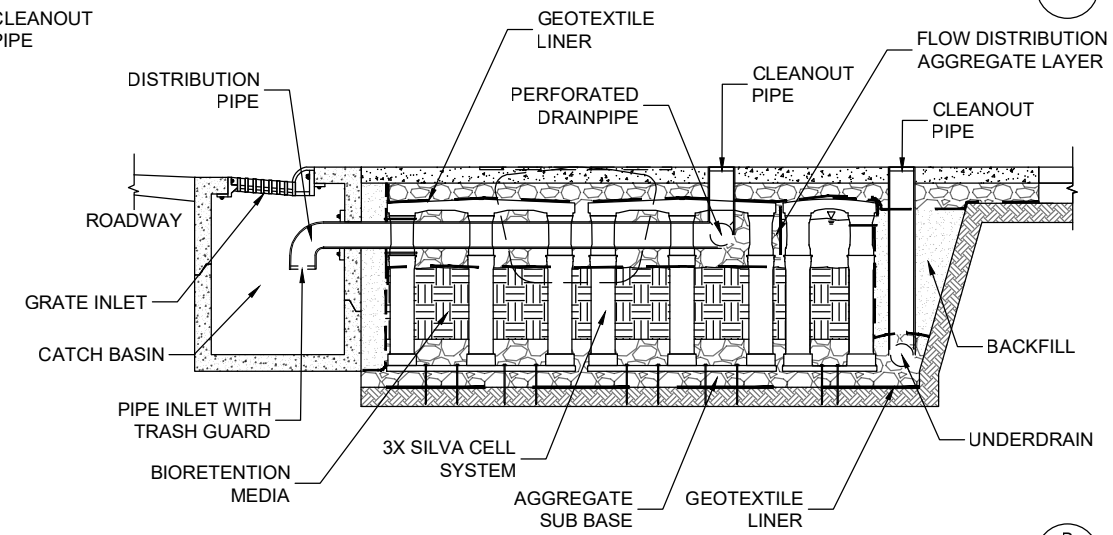
1. SEE DWG NO. 1204 FOR ALTERNATE INLET CONFUGURATIONS.
2. CITY OF PALO ALTO IS NOT ENDORSING DEEPROOT AND RECOMMENDS CONSIDERATION OF SIMILAR PRODUCTS FOR THIS TYPE OF GSI MEASURE.



PLAN VIEW



SILVA CELL CROSS SECTION A



SILVA CELL CROSS SECTION B

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Scale: NTS

SUSPENDED PAVEMENT SYSTEM
SILVA CELL HYDRAULIC COMPONENTS
PLAN AND SECTIONS

City of Palo Alto Standard

Approved by: _____

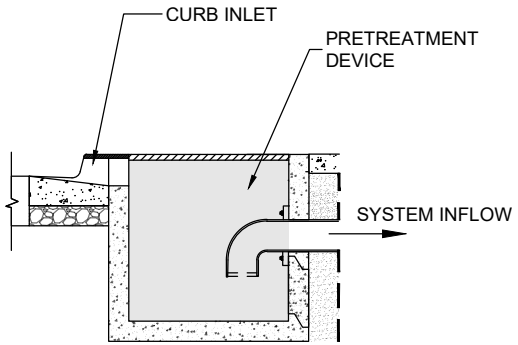
PE No. _____

Date _____

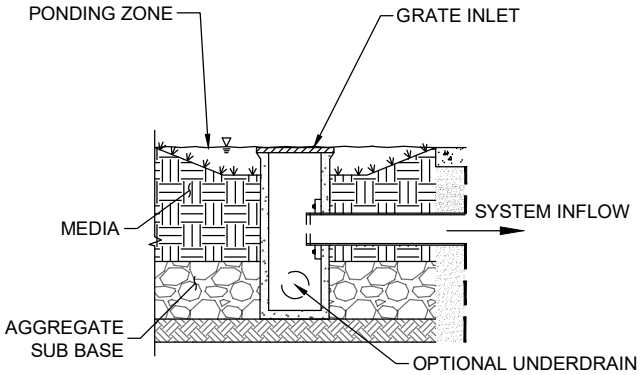
Dwg No. **1203**

CONSTRUCTION NOTES:

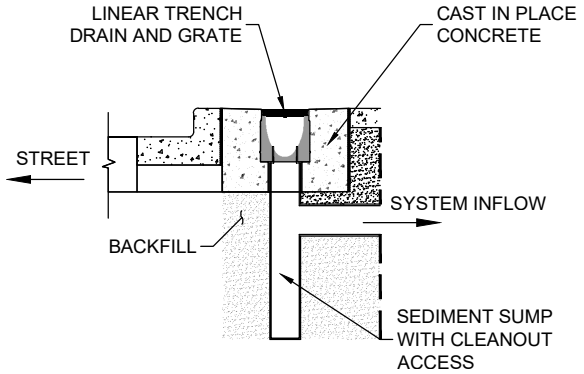
1. PRETREATMENT DEVICE INSTALLED PER MANUFACTURER RECOMMENDATIONS. OPTIONS INCLUDE HYDRODYNAMIC SEPARATORS, FILTRATION DEVICES, AND FLOW REGULATORS.
2. SEE DWG NO. 1202 FOR PERMEABLE PAVEMENT INLET AND DWG NO. 1203 FOR CATCH BASIN INLET. SEE DWG NO. 1203 FOR INLET CONNECTION TO SILVA CELL.
3. SWALE AND BIORETENTION ROAD VERGE CONFIGURATIONS POSSIBLE.
4. CITY OF PALO ALTO IS NOT ENDORSING DEEPROOT AND RECOMMENDS CONSIDERATION OF SIMILAR PRODUCTS FOR THIS TYPE OF GSI MEASURE.



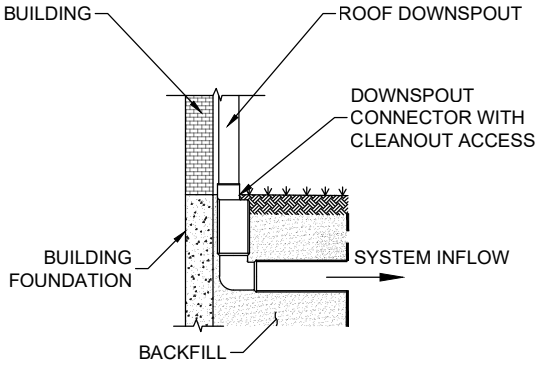
PRETREATMENT CROSS SECTION 1



ROAD VERGE CROSS SECTION 2



TRENCH DRAIN CROSS SECTION 3



ROOF LEADER CROSS SECTION 4

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Scale: NTS

SUSPENDED PAVEMENT SYSTEM
SILVA CELL INLET DETAILS
SECTIONS

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **1204**

PURPOSE:

IMPERMEABLE LINERS IN GREEN STORMWATER INFRASTRUCTURE CAN BE USED TO RESTRICT MOVEMENT OF WATER INTO UNDERLYING AND/OR ADJACENT SOILS AND/OR AGGREGATES TO PROTECT SENSITIVE INFRASTRUCTURE (E.G., IMPERMEABLE ROADWAY BASE, FOUNDATIONS, UTILITIES), MITIGATE RISK OF GEOLOGIC HAZARDS (E.G., STEEP SLOPES, CONTAMINATED SOILS), OR OTHER SITE-SPECIFIC CONDITIONS.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. THE DESIGNER AND/OR GEOTECHNICAL ENGINEER SHOULD ASSESS THE RISK OF WATER LEAKAGE FROM THE GREEN STORMWATER INFRASTRUCTURE FACILITY AND DETERMINE THE LINER EXTENTS AND LINER CONNECTION REQUIREMENTS (E.G., WATER TIGHT, SOIL TIGHT), DEPENDING ON DEGREE OF PROTECTION NECESSARY TO PROTECT ADJACENT INFRASTRUCTURE.
3. CONSIDER PLACING GEOTEXTILE ON PREPARED SUBGRADE PRIOR TO PLACEMENT OF LINER TO PROTECT LINER FROM DAMAGE DURING INSTALLATION.
4. DEPENDING ON ANTICIPATED FACILITY MAINTENANCE, IT MAY BE PRUDENT TO INCLUDE A GEOTEXTILE OVER THE LINER TO PROVIDE AN ADDITIONAL BARRIER BETWEEN LINER AND MAINTENANCE EQUIPMENT OR TO PROTECT AGAINST AGGRESSIVE PUNCTURES DURING PLACEMENT AND COMPACTION.
5. THESE GENERAL COMPONENTS LINER DETAILS ADAPTED FROM STORMWATER MANAGEMENT REQUIREMENTS AND DESIGN GUIDELINES (SAN FRANCISCO PUBLIC UTILITIES COMMISSION), 2016, INCLUDING APPENDIX B GREEN STORMWATER INFRASTRUCTURE TYPICAL DETAILS AND SPECIFICATIONS, AND SCVURPPP GREEN STORMWATER INFRASTRUCTURE HANDBOOK PART 2.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ LINER TYPE AND EXTENTS (E.G., FULL LINER, PARTIAL LINER)
- ☐ LINER ANCHOR TYPE (E.G., WATER TIGHT, SOIL TIGHT)
- ☐ LINER JOINT WELDING/SEALING REQUIREMENTS
- ☐ OTHER CRITICAL PROJECT-SPECIFIC PLACEMENT REQUIREMENTS

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GENERAL COMPONENTS
LINER DESIGNER NOTES

City of Palo Alto Standard

Approved by: _____

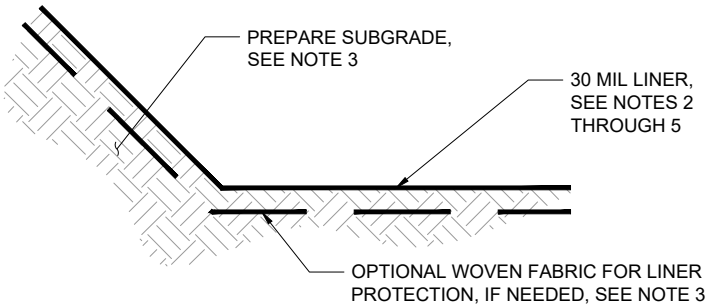
PE No. _____

Date _____

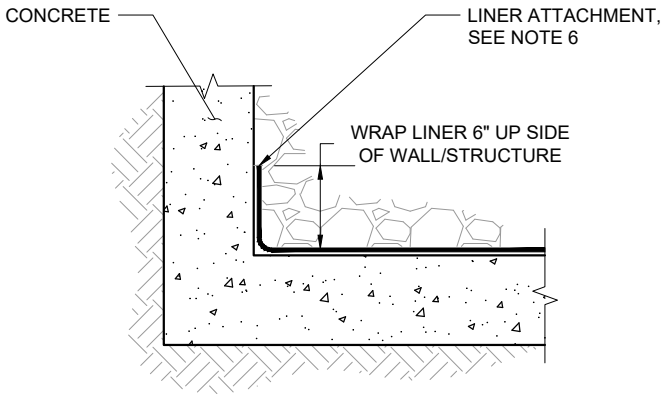
Dwg No. **1301**

CONSTRUCTION NOTES:

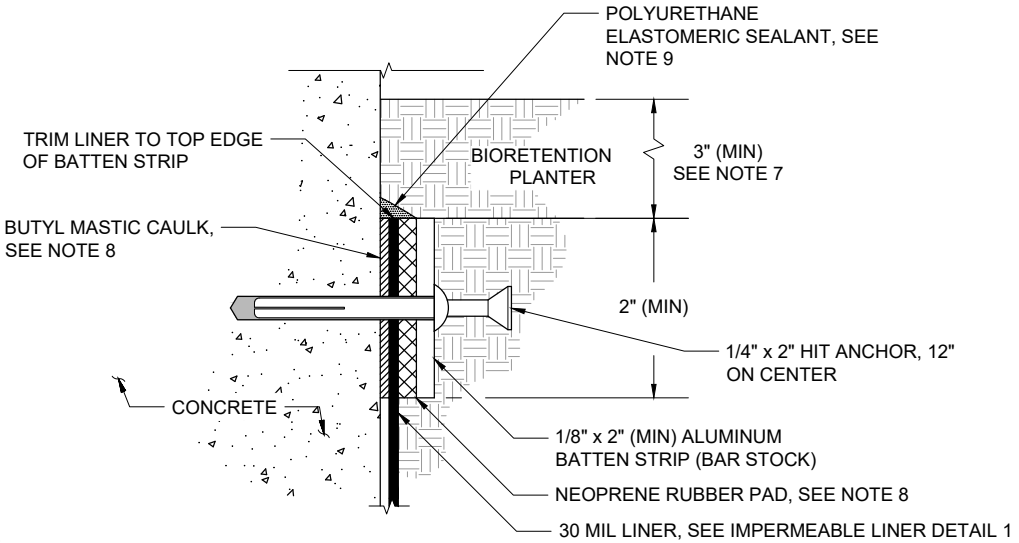
1. REFER TO DWG NO. 1301 FOR LINER GUIDELINES AND CHECKLIST.
2. LINER SHALL BE HDPE CONFORMING TO GEOSYNTHETIC RESEARCH INSTITUTE (GRI) GM13 OR LLDPE CONFORMING TO GRI GM17.
3. LINER SHALL LAY FLUSH WITH GROUND WITH NO AIR VOIDS BELOW THE LINER PRIOR TO BACKFILLING MATERIAL ABOVE THE LINER AND REMOVE ALL SHARP ROCKS AND DEBRIS. IF SUBGRADE SOIL CONTAINS ANGULAR ROCKS/DEBIRS, INSTALL WOVEN GEOTEXTILE FABRIC OVER SUBGRADE TO PROTECT LINER FROM PUNCTURE. CONTOUR THE SUBGRADE AS NEEDED TO ENSURE LINER LAYS FLUSH WITH GROUND.
4. OVERLAP LINER PER MANUFACTURER'S RECOMMENDATIONS.
5. ALL SEAMS SHALL BE WELDED PER MANUFACTURER'S RECOMMENDATIONS UNLESS OTHERWISE SPECIFIED.
6. SECURE LINER CONTINUOUSLY WITH DOUBLE-SIDED TAPE ALONG LINER EDGE AND SINGLE SIDED TAPE ALONG THE TOP EDGE OF LINER TO HOLD LINER IN PLACE DURING BACKFILLING.
7. TOP OF LINER TO BE AT LEAST 3" BELOW FINISH GRADE OF BIORETENTION SOIL EXCEPT WHEN ADJACENT TO BUILDING WALL. WHEN ADJACENT TO BUILDING WALL, LINER OR EQUAL WATERPROOFING SHALL EXTEND TO TOP OF FREEBOARD ELEVATION.
8. APPLY BUTYL MASTIC CAULK, BATTEN STRIP, AND NEOPRENE RUBBER PAD CONTINUOUSLY ALONG TOP EDGE OF LINER.
9. APPLY BEAD OF POLYURETHANE ELASTOMERIC SEALANT CONTINUOUSLY ALONG TOP EDGE OF BATTEN STRIP ASSEMBLY.



IMPERMEABLE LINER 1



SOIL TIGHT LINER ATTACHMENT AT WALL/STRUCTURE 2



WATER TIGHT LINER ATTACHMENT AT WALL/STRUCTURE 3

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GENERAL COMPONENTS
LINER AND LINER ATTACHMENTS

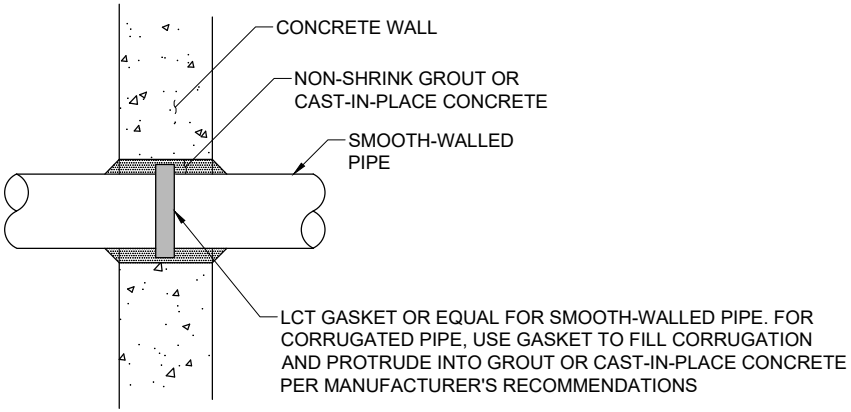
City of Palo Alto Standard

Approved by: _____

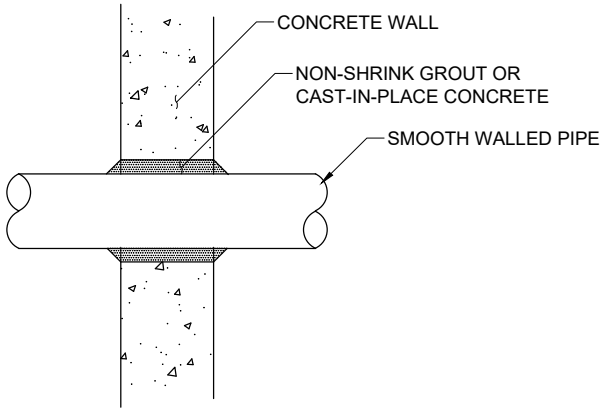
PE No. _____

Date _____

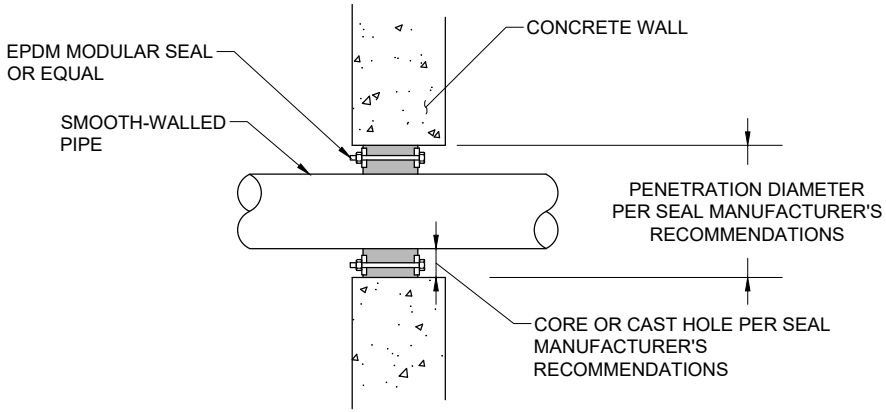
Dwg No. **1302**



TYPICAL WATERTIGHT WALL PENETRATION - ALTERNATE 1 — 1



TYPICAL SOIL TIGHT WALL PENETRATION — 3



TYPICAL WATERTIGHT WALL PENETRATION - ALTERNATE 2 — 2

CONSTRUCTION NOTES:

1. REFER TO SITING REQUIREMENTS FOR UTILITY SETBACKS AND PROTECTION IN PALO ALTO GSI HANDBOOK TABLE 6. COORDINATE WITH PROJECT MANAGER IN THE EVENT OF UTILITY CROSSING AND UTILITY CONFLICTS.

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Scale: NTS

GENERAL COMPONENTS
UTILITY CROSSINGS
WALL PENETRATIONS

City of Palo Alto Standard

Approved by: _____

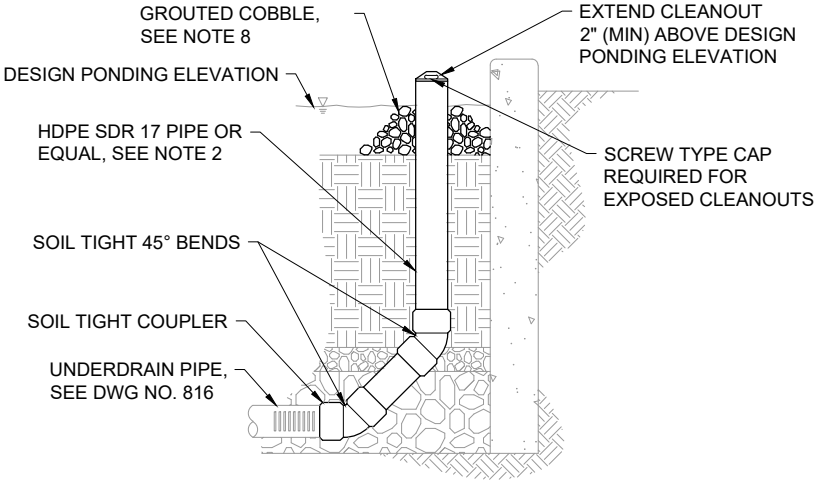
PE No. _____

Date _____

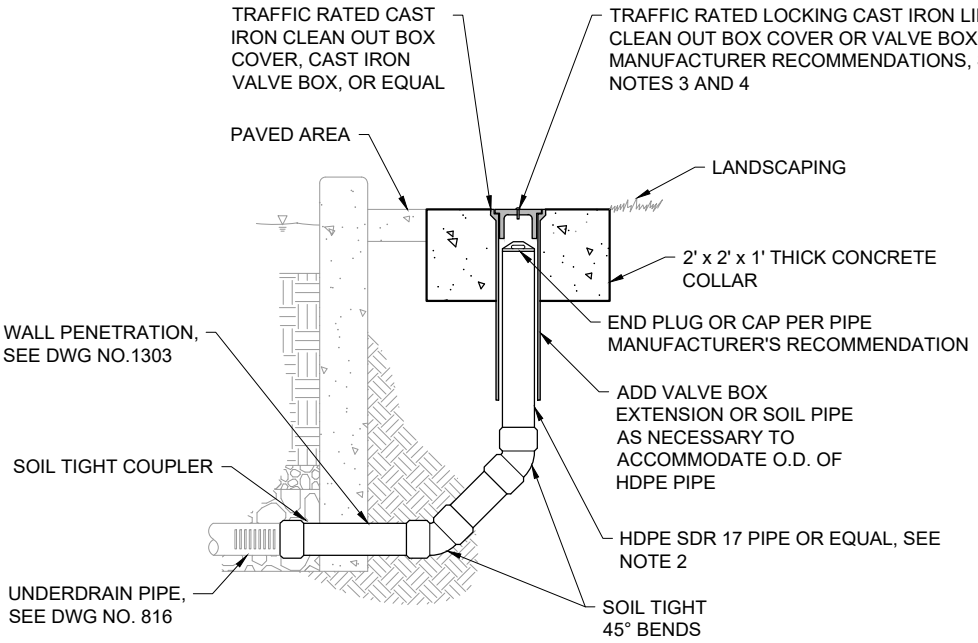
Dwg No. **1303**

CONSTRUCTION NOTES:

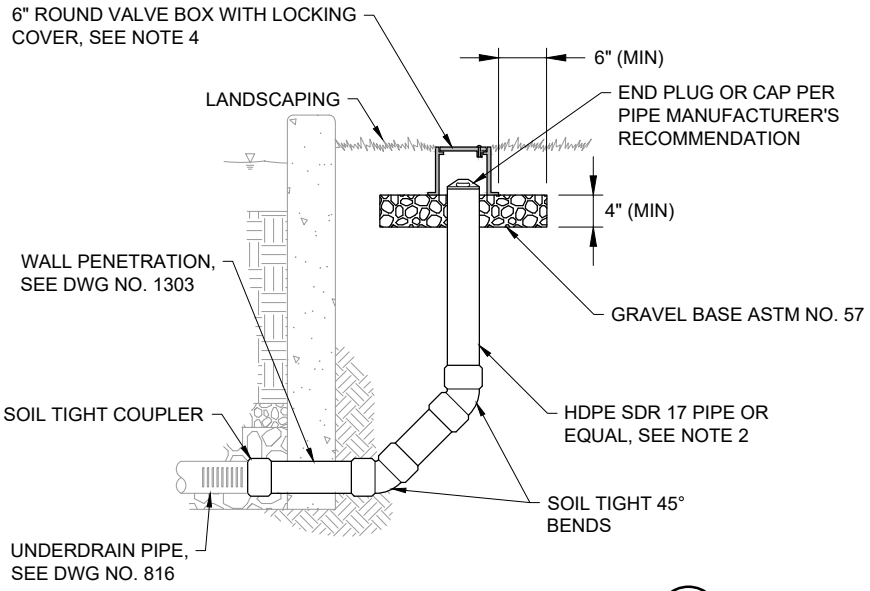
1. ALL MATERIAL AND WORKMANSHIP FOR CLEANOUTS SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND CODES.
2. CLEANOUT PIPE, FITTINGS, AND SLOTTED UNDERDRAIN SHALL BE SAME SIZE AND MATERIAL.
3. COVER SHALL BE TRAFFIC RATED WITH TAMPER RESISTANT LOCKING MECHANISM. COVER SHALL INCLUDE CASTING OF "CO" OR EQUAL.
4. CLEANOUT COVERS AND LIDS MUST COMPLY WITH CITY STANDARD ACCESSIBILITY REQUIREMENTS.
5. CLEANOUT SHALL BE INSTALLED TO ALLOW FOR MAINTENANCE ACCESS TO ALL PIPES.
6. ALL FITTINGS SHALL BE SOIL TIGHT.
7. ALTERNATIVE 3 CAN ONLY BE INSTALLED ON PARCEL, NOT ON RIGHT-OF-WAY.
8. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AROUND CLEANOUT.



CLEANOUT - ALTERNATIVE 2 — 2



CLEANOUT - ALTERNATIVE 1 — 1



CLEANOUT - ALTERNATIVE 3 (PARCEL ONLY) — 3

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GENERAL COMPONENTS
CLEANOUTS

City of Palo Alto Standard

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Date _____

Dwg No. **1304**

PURPOSE:

OBSERVATION PORTS ALLOW FOR MEASUREMENT OF DRAWDOWN THROUGH A FACILITY (WHEN WATER LEVEL MEASUREMENTS ARE NOT OBSERVABLE AT THE SURFACE). THESE PORTS CAN ALSO BE USED FOR LONG-TERM MONITORING WITH A PRESSURE TRANSDUCER. FOR SYSTEMS INCLUDING UNDERDRAINS, CLEANOUTS MAY SERVE AS THE FACILITY OBSERVATION PORT PROVIDED LONG-TERM MONITORING IS NOT REQUIRED FOR THE FACILITY.

DESIGNER NOTES & GUIDELINES:

1. THE DESIGNER MUST ADAPT DRAWINGS TO ADDRESS SITE-SPECIFIC CONDITIONS.
2. OBSERVATION PORTS WITHIN A BIORETENTION FACILITY ARE NOT REQUIRED TO INCLUDE A SEPARATE LOCKING COVER ASSEMBLY. HOWEVER, DESIGNERS SHOULD CONSIDER REQUIRING A LOCKING OBSERVATION PORT CAP OR PLUG IF THE RISK OF TAMPERING IS CONSIDERED TO BE HIGH.
3. WHENEVER FEASIBLE, OBSERVATION PORTS SHOULD BE LOCATED OUTSIDE OF THE TRAVELED WAY. IF SITE CONSTRAINTS NECESSITATE INSTALLATION OF OBSERVATION PORTS IN AN AREA SUBJECT TO VEHICULAR TRAFFIC OR OTHER LOADING, OBSERVATION PORT COVER ASSEMBLIES AND MANHOLES MUST BE DESIGNED TO WITHSTAND ANTICIPATED LOADING (E.G., H-20).
4. OBSERVATION PORTS SHOULD INCLUDE A 12 INCH WATERTIGHT SUMP TO ACCOMMODATE CONTINUOUS WATER LEVEL MEASUREMENT WITH A PRESSURE TRANSDUCER.

DESIGNER CHECKLIST (MUST SPECIFY, AS APPLICABLE):

- ☐ OBSERVATION PORT MATERIAL, DIAMETER, AND DEPTH
- ☐ OBSERVATION PORT COVER ASSEMBLY/MANHOLE TYPE AND SIZE (IF APPLICABLE)
- ☐ CONTROL ELEVATIONS FOR OBSERVATION PORT RIMS
- ☐ TYPE OF MONITORING EQUIPMENT TO BE INSTALLED (IF APPLICABLE)

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Scale: NTS

GENERAL COMPONENTS
OBSERVATION PORT
DESIGNER NOTES

City of Palo Alto Standard

Approved by: _____

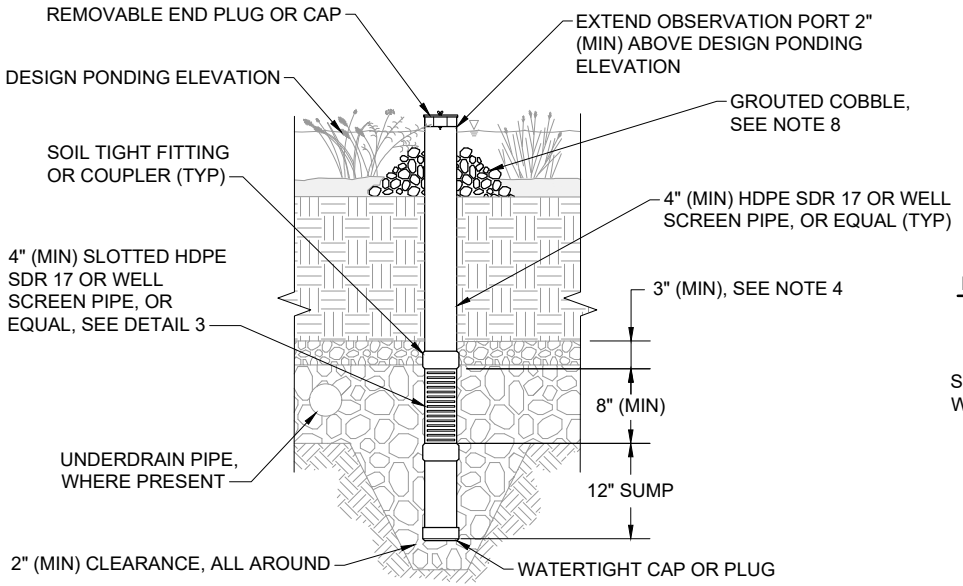
PE No. _____

Date _____

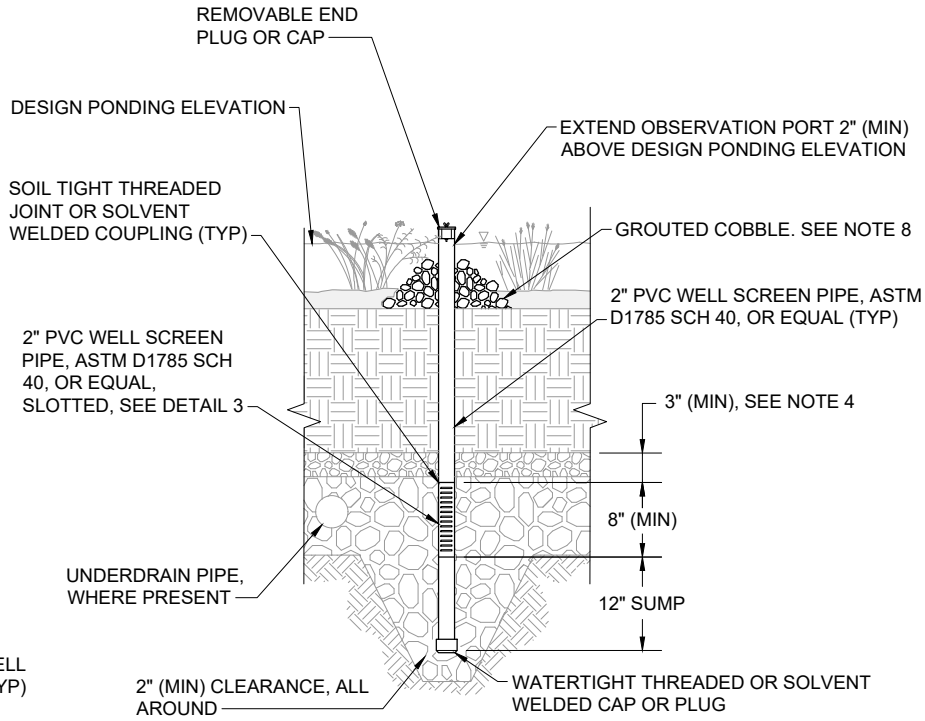
Dwg No. **1305**

CONSTRUCTION NOTES:

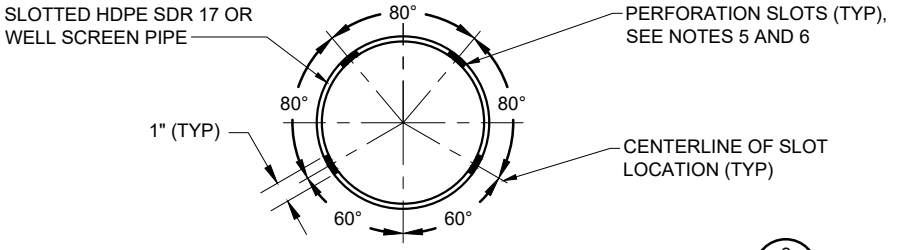
1. REFER TO DWG NO. 1305 FOR GUIDELINES AND CHECKLIST.
2. OBSERVATION PORTS ARE OPTIONAL AND MAY BE INSTALLED AS SPECIFIED BY DESIGNER. THESE ARE DIFFERENT FROM REQUIRED CLEAN OUTS.
3. ALL MATERIAL AND WORKMANSHIP FOR OBSERVATION PORTS SHALL CONFORM TO STANDARD SPECIFICATIONS AND APPLICABLE CODES PER PUBLIC WORKS.
4. PROVIDE 3" MINIMUM COVER FROM BOTTOM OF BIORETENTION SOIL TO BEGINNING OF OBSERVATION PORT PERFORATIONS.
5. UNDERDRAIN PIPE SHALL BE SLOTTED TYPE, MEASURING 0.064 INCH WIDE (MAX), SPACED AT 0.30 INCH ON CENTER, AND PROVIDING A MINIMUM INLET AREA OF 10.0 SQUARE INCHES PER LINEAR FOOT OF PIPE. OTHER SLOT CONFIGURATIONS PROVIDING A MINIMUM INLET OF 10.0 SQUARE INCHES PER LINEAR FOOT OF PIPE MAY BE SUBMITTED FOR CITY APPROVAL.
6. SLOTS SHALL BE ORIENTED PERPENDICULAR TO LONG AXIS OF PIPE, AND EVENLY SPACED AROUND CIRCUMFERENCE AND LENGTH OF PIPE.
7. ALL FITTINGS SHALL BE SOIL TIGHT, UNLESS NOTED OTHERWISE.
8. PLACE 6" DEEP 3"- 6" ROUNDED, WASHED, COBBLE AROUND CLEANOUT.



HDPE OBSERVATION PORT 1



PVC WELL CASING/SCREEN OBSERVATION PORT 2



PIPE SLOT DETAIL 3

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Scale: NTS

GENERAL COMPONENTS
OBSERVATION PORT
BIORETENTION

City of Palo Alto Standard

Approved by: _____

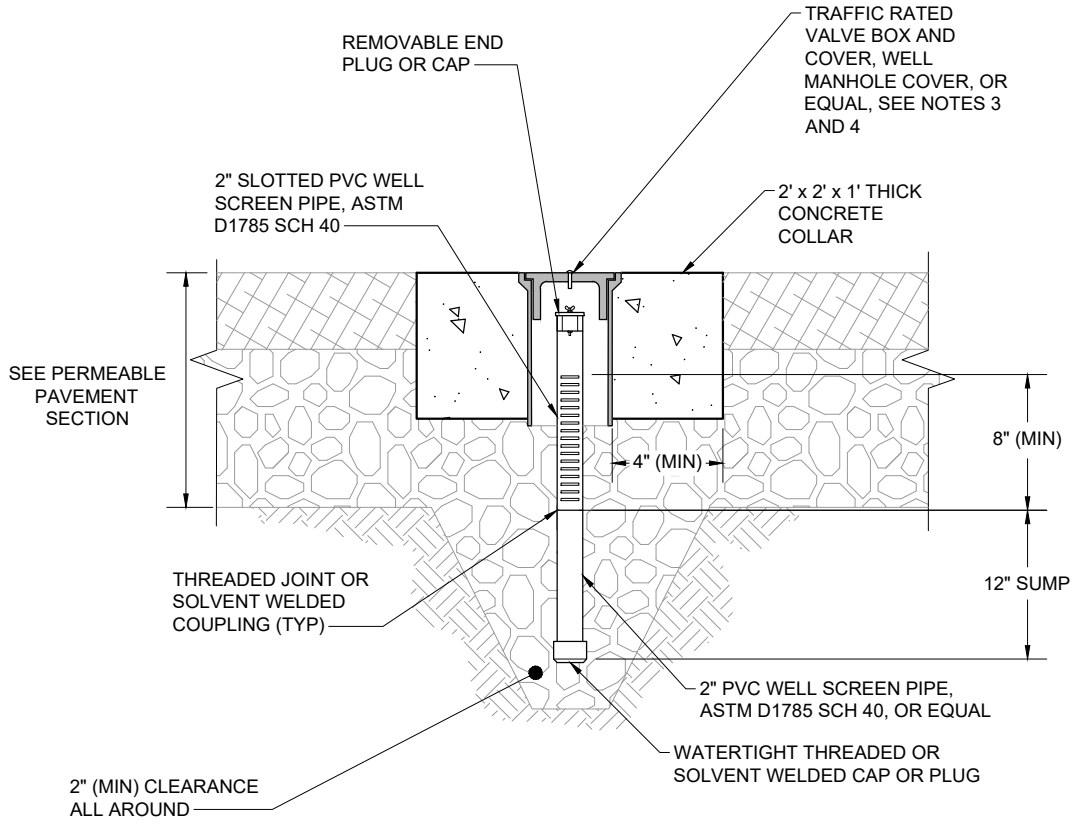
PE No. _____

Date _____

Dwg No. **1306**

CONSTRUCTION NOTES:

1. REFER TO DWG NO. 1305 FOR GUIDELINES AND CHECKLIST.
2. ALL MATERIAL AND WORKMANSHIP FOR OBSERVATION PORTS SHALL CONFORM TO CITY STANDARD SPECIFICATIONS AND APPLICABLE CODES.
3. COVER SHALL BE TRAFFIC RATED WITH TAMPER RESISTANT LOCKING MECHANISM. COVER SHALL INCLUDE CASTING OF STANDARD TRIANGLE SYMBOL, "TEST WELL", "MONITORING WELL", OR EQUAL.
4. OBSERVATION PORT COVERS AND LIDS MUST COMPLY WITH CITY STANDARD ACCESSIBILITY REQUIREMENTS.
5. WELL SCREEN SLOTS SHALL BE 0.032 INCHES WIDE (MAX), SPACED AT 0.25 INCH (MIN), AND PROVIDE A MINIMUM INLET AREA OF 2.0 SQUARE INCH PER LINEAR FOOT OF PIPE.
6. ALL FITTINGS SHALL BE SOIL TIGHT, UNLESS NOTED OTHERWISE.



PVC WELL SCREEN OBSERVATION PORT 1

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Scale: NTS

GENERAL COMPONENTS
OBSERVATION PORT
PERMEABLE PAVEMENT

City of Palo Alto Standard

Approved by: _____

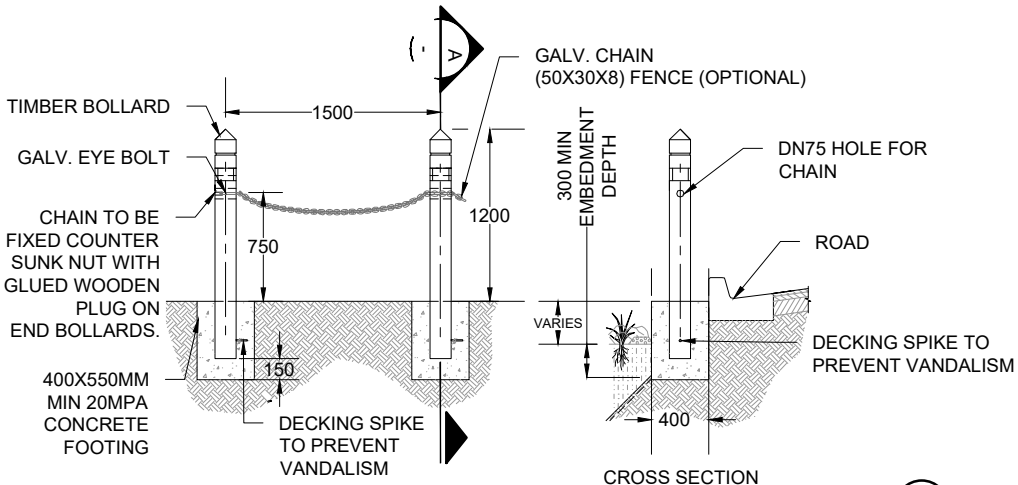
PE No. _____

Date _____

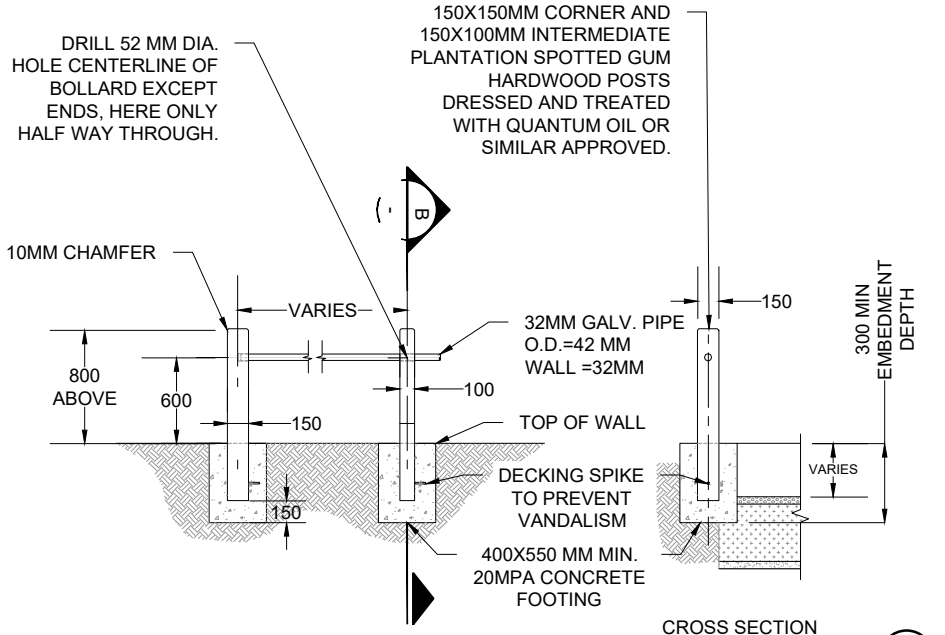
Dwg No. **1307**

CONSTRUCTION NOTES:

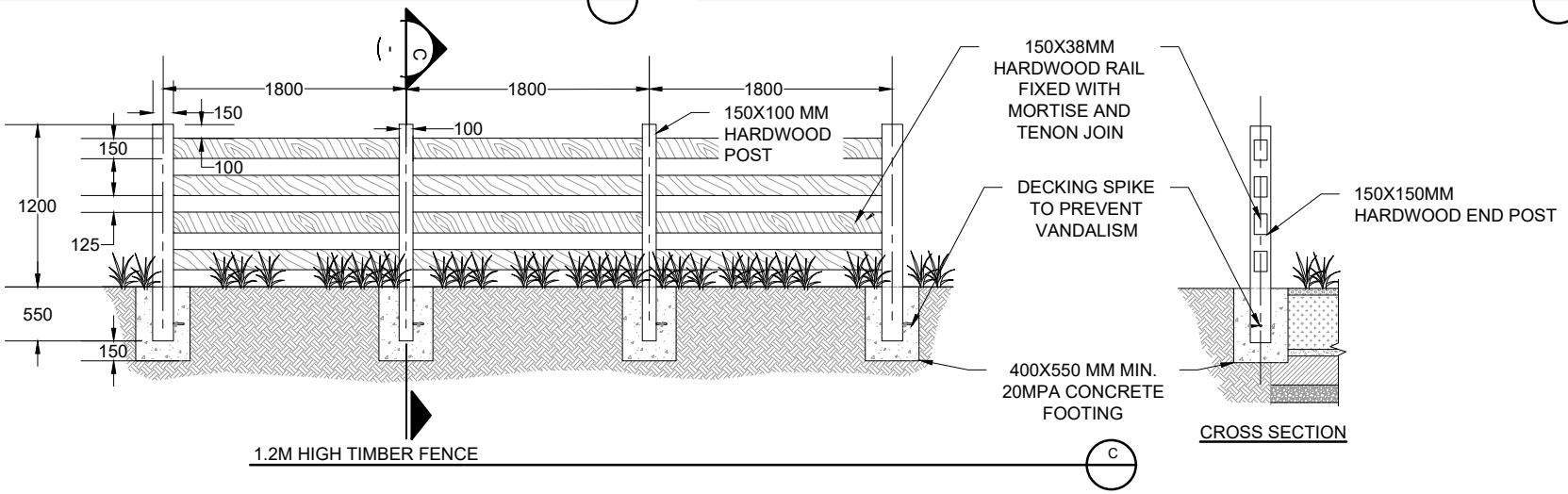
1. THE STANDARD DETAIL SHOWS ON THIS DRAWING ARE ARE TYPICAL ONLY. THESE DETAILS MAY NEED TO BE RECONFIGURED TO SUIT SITE SPECIFIC CONDITIONS.
2. DETAIL ADAPTED FROM GDH. 2013. RAIN GARDEN - MORELAND CITY COUNCIL WSUD MELBOURNE STANDARDS. DWG NO. SK007. UPDATED JULY 2013.
3. ALL UNITES IN MM UNLESS OTHERWISE SPECIFIED.



BOLLARDS FENCE A



GALVINIZED FENCE B



1.2M HIGH TIMBER FENCE C

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Scale: NTS

GENERAL COMPONENTS FENCING

City of Palo Alto Standard

Approved by: _____

PE No. _____

Date _____

Dwg No. **1308**

ATTACHMENT G:

Sizing Criteria Worksheets from SCVURPPP C.3 Handbook (2024)

ATTENTION: For consistency in the City of Palo Alto, use the term Stormwater Treatment Measure (STM) instead of the Treatment Control Measure (TCM).

B.1 SCVURPPP Sizing Criteria Worksheets

These worksheets are designed to assist municipal staff and development project proponents in sizing stormwater treatment measures. Figures referenced in the computations can be found at the end of this Appendix B. **Excel-based versions of the sizing worksheets are available on the SCVURPPP website at** https://scvurppp.org/newdev/ .

Section I. Selecting Sizing Approach Based on Type of Treatment Measure

1. Does the treatment measure operate by detaining a volume of runoff for a certain amount of time for pollutant removal (i.e., is it a volume-based treatment measure)? See Table B-1 for examples.

___ Yes ____ No

If Yes, continue to Section II. Sizing for Volume-Based Treatment Measures.
If No, continue to next question.

2. Does the treatment measure operate based on the flow of runoff through the device (i.e, is it a flow-based treatment measure)? See Table B-1 for examples.

___ Yes ____ No

If Yes, continue to Section III. Sizing for Flow-Based Treatment Measures.

Table B-1. Flow and Volume Based Treatment Measure Sizing Criteria

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

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

Section II. Sizing for Volume-Based Treatment Measures

The MRP Provision C.3.d allows two methods for sizing volume-based controls: 1) the WEF Urban Runoff Quality Management Method (URQM Method); or 2) the CASQA Stormwater Best Management Practice[2] (BMP) Handbook Volume Method adapted for Santa Clara Valley. The adapted CASQA Stormwater BMP Handbook Method is recommended because it is based on local rainfall data. Steps for applying these methods are presented in Sections II.A. and II.B. below.

Section II.A.— Sizing Volume-Based Treatment Measures based on the Urban Runoff Quality Management Approach (URQM Approach)

The equations used in this method are:

$$P_o = (a \times C_w) \times P_6$$

$$C_w = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$$

Where:

P_o = maximized detention storage volume (inches over the drainage area to the BMP)
a = regression constant (unitless)
C_w = watershed runoff coefficient (unitless)[3]
P_6 = mean storm event precipitation depth (inches);
i = watershed impervious ratio (range: 0-1)

Step 1. Determine the drainage area for the BMP, A = _____ acres

Step 2. Determine the watershed impervious ratio, "*i*", which is the amount of impervious area in the drainage area to the BMP divided by the drainage area, or the percent of impervious area in the drainage area divided by 100.

a. Estimate the amount of impervious surface (rooftops, hardscape, streets, and sidewalks, etc.) in the area draining to the BMP = _____ acres

b. Calculate the watershed impervious ratio, *i*:

i = amount of impervious area /drainage area for the BMP

i = (**Step 2.a**)/(**Step 1**) = _____ (range: 0-1)

[2] For the purpose of this worksheet, a stormwater best management practice, or BMP, is the same as a stormwater treatment measure.

[3] For the purpose of this worksheet, the watershed runoff coefficient is notated as "C_w" to avoid confusion with the runoff coefficient "C" used in the Rational Method.

Section II. Sizing for Volume-Based Treatment Measures (continued)

Section II.A.— URQM Approach (continued)

Step 3. Determine the watershed runoff coefficient, "C_w", using the following equation:

$C_w = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$, using "i" from **Step 2.b.**

C_w = _____

Step 4. Find the mean annual precipitation at the site (MAP_{site}). To do so, estimate where the site is on Figure B-1 and estimate the mean annual precipitation in inches from the rain line (isopleth) nearest to the project site.[4]

Mean annual precipitation at the site, MAP_{site} = _____

(Each line on the figure, called a rainfall isopleth, indicates locations where the same amount of rainfall falls on average each year; e.g., the isopleth marked 14 indicates that areas crossed by this line average 14 inches of rainfall per year. If the project location is between two lines, estimate the mean annual rainfall by interpolation, based on the location of the site.)

Step 5. Identify the reference rain gage closest to the project site from Table B-2a.

Table B-2a: Precipitation Data for Three Reference Gages

Gages	Mean Annual Precipitation (MAP_{gage}) (in)	Mean Storm Event Precipitation $(P_6)_{gage}$ (in)
San Jose Airport	13.9	0.512
Palo Alto	13.7	0.522
Morgan Hill	19.5	0.760

Select the MAP_{gage} and the mean storm precipitation $(P_6)_{gage}$ for the reference gage, and use them to determine $(P_6)_{site}$ for the project site in Step 6.

MAP_{gage} = _____

$(P_6)_{gage}$ = _____

[4] Check with the local municipality to determine if more detailed maps are available for locating the site and estimating MAP.

Section II. Sizing for Volume-Based Treatment Measures, continued

Section II.A.— URQM Approach (continued)

Step 6. Calculate the mean storm event precipitation depth at the project site, called $(P_6)_{site}$. Multiply the mean storm event precipitation depth for the rain gage chosen by a correction factor, which is the ratio of the mean annual precipitation at the site (MAP_{site}) to the mean annual precipitation at the rain gage (MAP_{gage}).

$$(P_6)_{site} = (P_6)_{gage} \times (MAP_{site}) / (MAP_{gage}).$$

$(P_6)_{site}$ = Mean Event Precipitation $(P_6)_{gage}$ (Step5) × (MAP_{site}) (Step4) / (MAP_{gage}) (Step5).

$P_{6\ site}$ = _____ inches

Step 7 Find "*a*", the regression constant (unitless)[5]:

a = 1.963 for a 48-hour drain time
a = 1.582 for a 24-hour drain time
a = 1.312 for a 12-hour drain time

a = _____

Recommendation: Use a 48-hour drain time.

Step 8 Determine the maximized detention storage volume P_o:

$$P_o = (a \times C_w) \times P_6$$

$$P_o = (\textbf{Step 7}) \times (\textbf{Step 3}) \times (\textbf{Step 6})$$

P_o = _____ inches

Step 9 Determine the volume of the runoff to be treated from the drainage area to the BMP (i.e., the BMP design volume):

Design volume = Po × A = (**Step 8**) × (**Step 1**) × 1 foot/12 inches

Design Volume = _____ acre-feet × 43,560 square feet/acre = _____ cubic feet

[5] *WEF Manual of Practice No. 23 and the ASCE Manual of Practice No. 87 (1998), pages 175-178.*

Section II. Sizing for Volume-Based Treatment Measures, continued

Section II.B. — Sizing Volume-Based Treatment Measures based on the Adapted CASQA Stormwater BMP Handbook Approach

The equation that will be used to size the BMP is:

Design Volume = (Rain Gage Correction Factor) × (Unit Basin Storage Volume) × (Drainage Area)

Step 1. Determine the drainage area for the BMP, A = _____acres

Step 2. Determine percent imperviousness of the drainage area:

a. Estimate the amount of impervious surface (rooftops, hardscape, streets, and sidewalks, etc.) in the area draining to the BMP: _____acres

b. % impervious area = (amount of impervious area/drainage area for the BMP) × 100
% impervious area = **(Step 2.a/Step 1)** × 100
% impervious area = _____%

Step 3. Find the mean annual precipitation at the site (MAP_{site}). To do so, estimate where the site is on Figure B-1 and estimate the mean annual precipitation in inches from the rain line (isopleth) nearest to the project site.[6] Interpolate between isopleths if necessary.

MAP_{site} = _____inches

Step 4. Identify the reference rain gage closest to the project site from Table B-2b and record the MAP_{gage}:

MAP_{gage} = _____inches

Table B-2b: Precipitation Data for Three Reference Gages

Reference Rain Gages	Mean Annual Precipitation (MAP_{gage}) (in)
San Jose Airport	13.9
Palo Alto	13.7
Morgan Hill	19.5

[6] Check with the local municipality to determine if more detailed maps are available for locating the site and estimating MAP.

Section II. Sizing for Volume-Based Treatment Measures, continued

Section II.B. —Adapted CASQA Stormwater BMP Handbook Approach (continued)

Step 5 Determine the rain gage correction factor for the precipitation at the site using the information from **Step 3** and **Step 4**.

Correction Factor = MAP_{site} (**Step 3**)/MAP_{gage} (**Step 4**)

Correction Factor = _____

Step 6. Identify the representative soil type for the BMP drainage area.

a) Identify from Figure B-1 or from site soils data, the soil type that is representative of the pervious portion of the project shown here in order of increasing infiltration capability:

____ Clay (D) ____ Sandy Clay (D) ____ Clay Loam (D)

____ Silt Loam/Loam (B) ____ Not Applicable (100% Impervious)

b) Does the site planning allow for protection of natural areas and associated vegetation and soils so that the soils outside the building footprint are not graded/compacted? ___ (Y/N)

If your answer is no, and the soil will be compacted during site preparation and grading, the soil's infiltration ability will be decreased. Modify your answer to a soil with a lower infiltration rate (e.g., Silt Loam to Clay Loam or Clay).

Modified soil type: _____

Step 7. Determine the average slope for the drainage area for the BMP: _____%

Step 8. Determine the unit basin storage volume from sizing curves.

a) Slope ≤ 1%

Use the figure at the end of this Appendix entitled "Unit Basin Volume for 80% Capture, 1% Slope" corresponding to the nearest rain gage: Figure B-2, B-3, or B-4 for San Jose, Palo Alto, or Morgan Hill, respectively. Find the percent imperviousness of the drainage area (from **Step 2**) on the x-axis. From there, find the line corresponding to the soil type (from **Step 6**), and obtain the unit basin storage volume on the y-axis.

Unit Basin Storage for 1% slope ($UBS_{1\%}$) = _____(inches)

b) Slope ≥ 15%

Use the figure at the end of this Appendix entitled "Unit Basin Volume for 80% Capture, 15% Slope" corresponding to the nearest rain gage: Figure B-5, B-6, or B-7 for San Jose, Palo Alto, or Morgan Hill, respectively. Find the percent imperviousness of the drainage area (from **Step 2**) on the x-axis. From there, find the line corresponding to the soil type (from **Step 6**), and obtain the unit basin storage volume on the y-axis.

Unit Basin Storage for 15% slope ($UBS_{15\%}$) = _____(inches)

Section II. Sizing for Volume-Based Treatment Measures, continued

Section II.B. —Adapted CASQA Stormwater BMP Handbook Approach (continued)

c) Slope > 1% and < 15%

Find the unit basin volumes for 1% and 15% using the techniques in **Steps 8.a** and **8.b** and interpolate by applying a slope correction factor per the following formula:

$UBS_x = UBS_{1\%} + (UBS_{15\%} - UBS_{1\%}) \times (X\%-1\%) / (15\% -1\%)$
$= (\textbf{Step 8a}) + (\textbf{Step 8b- Step 8a}) \times (X\%-1\%)/(15\%-1\%)$

Where UBS_x = Unit Basin Storage volume for drainage area of intermediate slope, X %

Unit Basin Storage volume (UBS_x) = _____(inches)
(corrected for slope of site)

Step 9. Determine the Adjusted Unit Basin Storage Volume for the site, using the following equation:

Adjusted UBS = Rain Gage Correction Factor × Unit Basin Storage Volume

Adjusted UBS = (**Step 5**) × (**Step 8**)

Adjusted UBS = _____inches

Step 10. Determine the BMP Design Volume, using the following equation:

Design Volume = Adjusted Unit Basin Storage Volume × Drainage Area

Design Volume = (**Step 9**) × (**Step 1**) × 1 foot/12 inch

Design Volume = _____ acre-feet × 43,560 square feet/acre = _____ cubic feet

III. Sizing for Flow-based Treatment Measures

The MRP Provision C.3.d allows three methods for sizing flow-based treatment measures: 1) the Factored Flood Flow Method (10% of the 50-year peak flow rate); 2) the CASQA Stormwater BMP Handbook Method (the flow produced by a rain event equal to at least 2 times the 85th percentile hourly rainfall intensity); or 3) the Uniform Intensity Method (the flow produced by a rain event equal to at least 0.2 inches/hour intensity). Use of Method 2 or 3 is recommended. Steps for applying these methods are presented in Sections III.A, III.B, and III.C below.

Each of the three methods will require estimating a runoff coefficient for the area draining to the BMP. Recommended coefficients are provided in Table B-3.

Table B-3 – Estimated Runoff Coefficients for Various Surfaces During Small Storms

Type of Surface	Runoff Coefficient ("C" Factor)
Roofs	0.90
Concrete	0.90
Asphalt	0.90
Gravel, crushed aggregate, or decomposed granite	0.90
Stone, brick, or concrete pavers with mortared joints and bedding	0.90
Stone, brick, or concrete pavers with sand joints and bedding	0.10
Pervious concrete	0.10
Porous asphalt	0.10
Permeable interlocking concrete pavement	0.10
Grid pavements with grass or aggregate surface	0.10
Grass	0.10

Notes:

1. If the area draining to the BMP contains multiple types of surfaces, a weighted "C" factor should be computed for use in the equations.
2. These "C" factors are only appropriate for small storm treatment BMP design and should not be used for flood control sizing. Where available, locally developed small storm "C" factors for various surfaces should be used. Sources: BASMAA, 2003; Lindeburg, 2003; Hade and Smith, 1988; Smith, 2012.

III. Sizing for Flow-based Treatment Measures, continued

Section III.A. - Sizing Flow-Based Treatment Measures based on the Factored Flood Flow Approach

This method uses the Rational Method equation to determine the design flow, using a design intensity that is 10 % of the intensity for the 50-year return period found on the local intensity-duration-frequency (IDF) curve:

$$Q=CIA$$

Where:

Q = the design flow in cubic feet per second (cfs),
C = the drainage area runoff coefficient,
I = the design intensity (in/hr), and
A = the drainage area for the BMP (acres)

Step 1. Determine the drainage area for the BMP, A = _____ acres

Step 2. Determine the runoff coefficient, C = _____ from Table B-3.

Step 3. Find the time of concentration (t_c) for the site (i.e. the travel time from the most remote portion of the BMP drainage area to the BMP). (Check with local agency's Engineering Department for standard or accepted methods of computing t_c).

t_c = Time of overland flow + time in drainage pipe: _____ hrs

Step 4. Using the time of concentration as the duration, use Figure B-8 to determine the intensity for the 50-year storm (IDF curve) (in/hr). _____

Intensity for the 50-year storm = _____ in/hr

Step 5. The design intensity (I) will be 10% of the intensity obtained from the IDF curve (intensity for the 50-year storm).

I = (**Step 4** × 0.10) = _____ in/hr

Step 6. Determine the design flow (Q) using the Rational Method equation:

$Q = C \times I \times A$
$Q =$ (**Step 2**) × (**Step 5**) × (**Step 1**)
Q = _____ acres-in/hr

Design Flow, Q = _____ *cfs*[7]

[7] No conversion factor for correct units is needed for the rational formula because (1 acre-in/hr) X (43,560 sq. ft./acre) X (1ft/12 in) X (1hr/3600 sec) ≈ 1 ft^3/sec or cfs.

III. Sizing for Flow-based Treatment Measures, continued

Section III.B.—Sizing Flow-Based Treatment Measures based on the CASQA Stormwater BMP Handbook Flow Approach

This method uses the Rational Method equation to determine the design flow:

$$Q=CIA$$

Where:
Q = the design flow in cubic feet per second (cfs),
C = the drainage area runoff coefficient,
I = the design intensity (in/hr), and
A = the drainage area for the BMP (acres)

Step 1. Determine the drainage area for the BMP, A = _____ acres

Step 2. Determine the runoff coefficient, C = _____ from Table B-3.

Step 3. Find the mean annual precipitation at the site (MAP_{site}). To do so, estimate where the site is on Figure B-1 and estimate the mean annual precipitation in inches from the rain line (isopleth) nearest to the project site.[8] Interpolate between isopleths if necessary.

MAP_{site} = _____inches

Step 4. Identify the reference rain gage closest to the project site from Table B-2b and record the MAP_{gage}:

MAP_{gage} = _____inches

Table B-2b: Precipitation Data for Three Reference Gages

Reference Rain Gages	Mean Annual Precipitation (MAP_{gage}) (in)
San Jose Airport	13.9
Palo Alto	13.7
Morgan Hill	19.5

[8] Check with the local municipality to determine if more detailed maps are available for locating the site and estimating MAP.

Section III. Sizing for Flow-Based Treatment Measures, continued

Section III.B.— CASQA Stormwater BMP Handbook Flow Approach (continued)

Step 5. Determine the rain gage correction factor for the precipitation at the site using the information from **Step 3** and **Step 4**.

Correction Factor = MAP_{site} /MAP_{gage} = (**Step 3**)/(**Step 4**)

Correction Factor = _____

Step 6. Select the design rainfall intensity, I, for the rain gage closest to the site from Table B-2c:

Table B-2c: Precipitation Data for Three Reference Gages

Reference Rain Gages	85th Percentile Hourly Rainfall Intensity (in/hr)	Design Rainfall Intensity (I) (in/hr)*
San Jose Airport	0.087	0.17
Palo Alto	0.096	0.19
Morgan Hill	0.12	0.24

*The design intensity is two times the 85th Percentile Hourly Rainfall Intensity.

Design Rainfall Intensity: I = _____ in/hr

Step 7. Determine the corrected design rainfall intensity (I) for the site:

Design intensity (site) = Correction factor × Design rainfall intensity for closest rain gage

Design intensity (site) = (**Step 5**) × (**Step 6**) = _____ in/hr

Step 8. Determine the design flow (Q) using the Rational Method equation:

$$Q = C \times I \times A$$

Q = (**Step 2**) × (**Step 7**) × (**Step 1**)

Q = _____ acres-in/hr

Design Flow, Q = _____ cfs[9]

[9] No conversion factor for correct units is needed for the rational formula because (1 acre-in/hr) X (43,560 sq. ft./acre) X (1ft/12 in) X (1hr/3600 sec) ≈ 1 ft^3/sec or cfs.

Section III. Sizing for Flow-Based Treatment Measures, continued

Section III.C.—Sizing Flow-Based Treatment Measures based on the Uniform Intensity Approach

This method uses the Rational Method equation:

$$Q=CIA$$

Where:

Q = the design flow in cubic feet per second (cfs),
C = the drainage area runoff coefficient,
I = the design intensity (in/hr), and
A = the drainage area for the BMP (acres)

Step 1. Determine the drainage area for the BMP, A = _____ acres

Step 2. Determine the runoff coefficient, C = _____ from Table B-3.

Step 3. Use a design intensity of **0.2 in/hr** for "I" in the Q=CIA equation.

I = 0.2 in/hr

Step 4. Determine the design flow (Q) using Q = CIA

$Q = C \times I \times A$

Q = (**Step 2**) × (0.2 in/hr) × (**Step 1**)

Q = _____ acres-in/hr

Design Flow, Q = _____ cfs[10]

[10] No conversion factor for correct units is needed for the rational formula because (1 acre-in/hr) X (43,560 sq. ft./acre) X (1ft/12 in) X (1hr/3600 sec) ≈ 1 ft^3/sec or cfs.

Section IV. Sizing for Flow- and Volume- Based Treatment Measures (Combination Flow and Volume Approach)

For bioretention areas and flow-through planters, the following approach may be used to take into consideration both the flow of stormwater through the planting media and the volume of stormwater in the surface ponding area. Note that the approach assumes that all of the design rainfall becomes runoff, and thus it is appropriate for use where the drainage area to the treatment measure is mostly impervious.

Step 1. **Contributing drainage area to the treatment measure:** _____ **sq. ft.**

Step 2/3. **Determine the required treatment volume using Adapted CASQA Stormwater BMP Handbook Approach** (Worksheet Section II.B). Copy the results from Steps 9 and 10 here:

Adjusted Unit Basin Storage (UBS) Volume: _____ **in.**

BMP Water Quality Design (WQD) Volume: _____ **cu. ft.**

Step 4. Determine the design rainfall intensity (Uniform Intensity Approach, Section III.C, Step 3):

Design Rainfall Intensity: __0.2__ **in/hr**

Step 5. Assume that the rain event that generates the Unit Basin Storage Volume of runoff occurs at the Design Rainfall Intensity for the entire length of the storm. Calculate the duration of the storm by dividing the Adjusted Unit Basin Storage Volume by the Design Rainfall Intensity. In other words, determine the amount of time required for the Adjusted Unit Basin Storage Volume to be achieved at the design intensity rate.

Duration = UBS Volume (inches) ÷ Design Rainfall Intensity (inches/hour)

Duration = (**Step 2**) ÷ 0.2 in/hr = _____ **hrs.**

IV. Sizing for Flow- and Volume-Based Treatment Measures, continued

Step 6. Make a preliminary estimate of the surface area of the bioretention facility by multiplying the drainage area to be treated by a sizing factor of **0.03.**

Estimated Surface Area = Contributing Drainage Area × 0.03

Estimated Surface Area = _____ sq. ft. × 0.03 = _____ **sq. ft.**
(**Step 1**)

Step 7. Calculate the volume of runoff that filters through the biotreatment soil at a rate of 5 inches per hour (the design surface loading rate for bioretention facilities), for the duration of the storm calculated in Step 5.

Volume of Treated Runoff = Estimated Surface Area × 5 in/hr × (1 ft/12 in) × Duration

Volume of Treated Runoff = _____ sq. ft. × 5/12 × _____ hrs. = _____ **cu. ft.**
(**Step 6**) (**Step 5**)

Step 8. Calculate the portion of the water quality design (WQD) volume remaining after treatment is accomplished by filtering through the biotreatment soil. The result is the amount that must be stored in the ponding area above the bioretention surface area estimated in Step 6.

Volume in ponding area = WQD Volume – Volume of Treated Runoff

Volume in ponding area = _____ cu. ft. – _____ cu. ft. = _____ **cu. ft.**
(**Step 3**) (**Step 7**)

Step 9. Calculate the depth of the volume in the ponding area by dividing this volume by the estimated surface area in Step 6.

Depth of ponding = Volume in Ponding Area ÷ Estimated Surface Area

Depth of ponding = _____ cu. ft. ÷ _____ sq. ft. = _____ **ft.**
(**Step 8**) (**Step 6**)

Check to see if the average ponding depth is between 0.5 and 1.0 feet (6 and 12 inches), which is the range of allowable ponding depths in a bioretention facility or flow-through planter (**0.5 feet is recommended**). If the ponding depth is less than 0.5 feet, the bioretention design can be optimized with a smaller surface area (i.e., repeat Steps 6 through 9 with a smaller surface area). If the ponding depth is greater than 1 foot, a larger surface area will be required (i.e., repeat Steps 6 through 9 with a larger surface area).

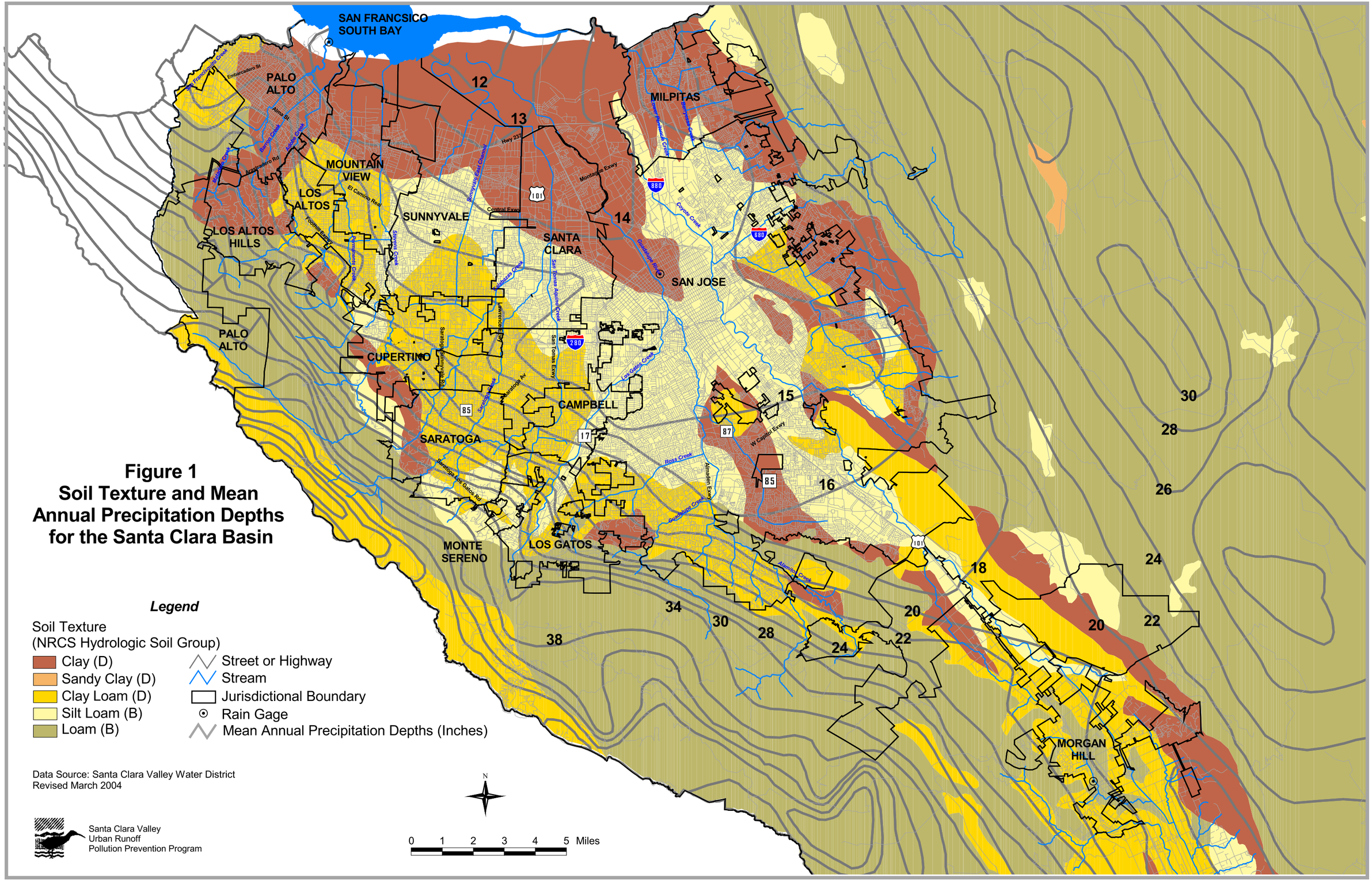

Figure 1
Soil Texture and Mean Annual Precipitation Depths for the Santa Clara Basin

Legend

Soil Texture
(NRCS Hydrologic Soil Group)

- Clay (D)
- Sandy Clay (D)
- Clay Loam (D)
- Silt Loam (B)
- Loam (B)

- Street or Highway
- Stream
- Jurisdictional Boundary
- Rain Gage
- Mean Annual Precipitation Depths (Inches)

Data Source: Santa Clara Valley Water District
Revised March 2004

N

0 1 2 3 4 5 Miles

Santa Clara Valley
Urban Runoff
Pollution Prevention Program

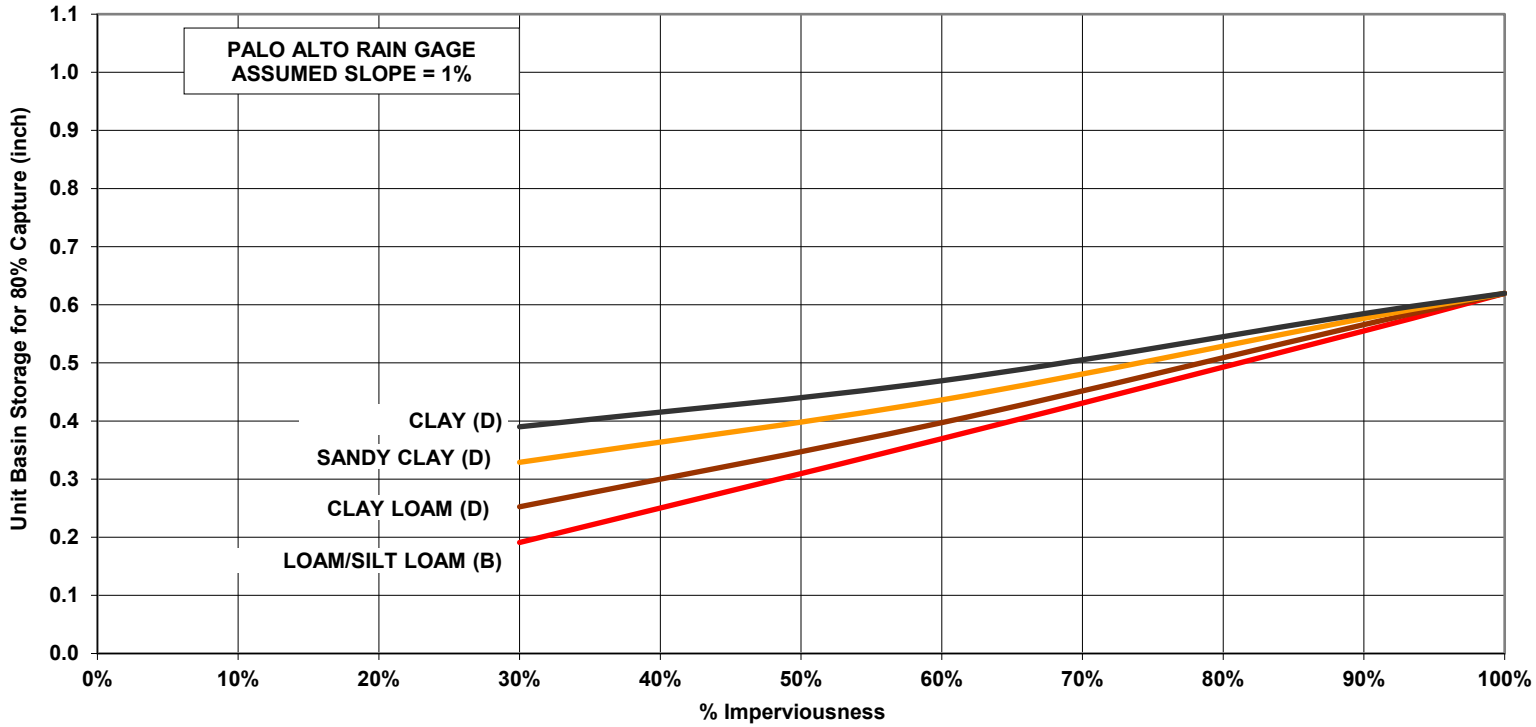

Figure B-3 Unit Basin Volume for 80% Capture - Palo Alto Rain Gage

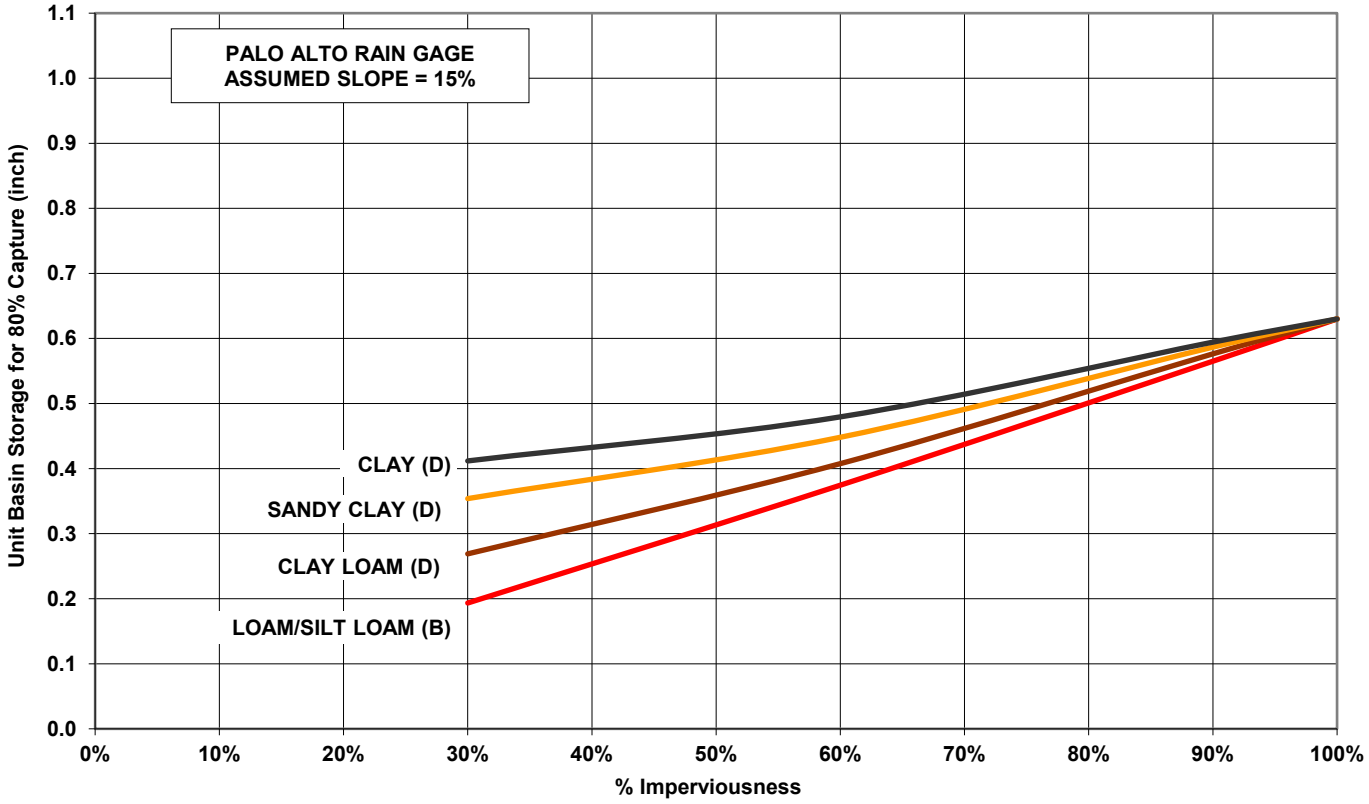

Figure B-6 Unit Basin Volume for 80% Capture - Palo Alto Rain Gage

Appendix

Guidance on Determining Feasibility and Sizing of Rainwater Harvesting Systems

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I.1 Introduction
I.2 Rainwater Harvesting/Use Feasibility Guidance
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2. Attachment 2: Excerpts from the Feasibility Report (Map of Soil Hydraulic Conductivity and Rain Gauge Areas, Tables 8 through 11 and curves from the report's Appendix F)

I.1 Introduction

The MRP allows development projects to use infiltration, evapotranspiration, harvesting and use, or biotreatment to treat the full water quality design flow or volume of stormwater runoff, as specified in MRP Provision C.3.d. Project applicants are no longer required to evaluate the feasibility of infiltration of rainwater harvesting and use before proceeding to biotreatment.

If a project applicant desires to use rainwater harvesting systems to meet LID treatment requirements, there must be sufficient demand on the project site to use the water quality design volume, i.e., 80 percent of the average annual rainfall runoff, from the collection area. Appendix I provides guidance on how to estimate the required landscaping or toilet flushing demand to meet C.3.d requirements. If the project appears to have sufficient demand for captured rainwater, Appendix I provides guidance on sizing the cistern (or other storage facility) to achieve the appropriate combination of drawdown time and cistern volume.

The information presented in this guidance is based on the "Harvest and Use, Infiltration and Evapotranspiration Feasibility/Infeasibility Criteria Report" (referred to as the "Feasibility

Report") prepared by the Bay Area Stormwater Management Agencies Association (BASMAA) and submitted to the Regional Water Board in 2011[1].

I.2 Rainwater Harvesting/Use Feasibility Guidance

Rooftop runoff is the source of stormwater most often collected in a harvesting/use system, because it often contains lower pollutant loads than at-grade surface runoff, and it provides accessible locations for collection in storage facilities via gravity flow.

The 2022 California Plumbing Code effective January 1, 2023 includes rainwater harvesting and graywater requirements, codes, and treatment standards. Chapter 16 of the Plumbing Code, which contains the rainwater harvesting requirements, allows rainwater to be harvested from rooftops for use in outdoor irrigation and some non-potable indoor uses. Rainwater collected from parking lots or other impervious surfaces at or below grade is considered graywater and subject to the water quality requirements for graywater in Chapter 15 of the Code. Some small catchment systems (5,000 gallons or less) being used for non-spray irrigation do not require permits – see Chapter 16 for more details[2].

The Plumbing Code defines rainwater as "precipitation on any public or private parcel that has not entered an offsite storm drain system or channel, a flood control channel, or any other stream channel, and has not previously been put to beneficial use."[3] The Rainwater Capture Act of 2012, which took effect January 1, 2013, specifically states that the use of rainwater collected from rooftops does not require a water right permit from the State Water Resources Control Board.

I.3 Determining Feasibility of Rainwater Harvesting and Sizing of Cisterns

A key parameter needed to evaluate the feasibility of using harvested rainwater for irrigation or indoor toilet flushing use is the **Potential Rainwater Capture Area**. This is the impervious area from which rainwater may potentially be captured, if rainwater harvesting and use were implemented for a project. This is typically the roof area of the building(s) draining to the capture facilities.

The text below describes how to determine if you can use rainwater harvesting to treat the C.3.d amount of runoff on your project site.

Feasibility of Using Harvested Rainwater for Irrigation. Harvested rainwater can be used for irrigation in projects that include a considerable amount of landscaping. Follow the steps below to determine if adequate landscaping is available on the project site:

- Calculate the landscaping available on the project site. Note that the landscape area(s) would have to be contiguous and within the same Drainage Management Area to use harvested rainwater for irrigation via gravity flow.
- Refer to Table 11 in Attachment 2 of this guidance, which present ratios of "Effective Irrigated Area to Impervious Area" (EIATIA) for rain gauge areas.

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[1] This report is available on the Urban Runoff Program's website. Go to www.scvurppp.org and click on "Low Impact Development" under Quick Links.

[2] https://epubs.iapmo.org/2022/CPC/ See Chapter 16.

[3] https://epubs.iapmo.org/2022/CPC/ See Chapter 2.

- Determine if your project has sufficient demand for rainwater for use in landscaping, and size the cistern (or other storage facility) to achieve the appropriate combination of drawdown time and cistern volume indicated in the sizing curves included in Attachment 2. Find the page that shows curves corresponding to the closest rain gauge to your project. You can select any combination of drawdown time and cistern size that achieves at least 80 percent capture of runoff on the Y-axis of the graphs. Note that the sizing curves are for **1 acre of tributary impervious area**, (i.e., potential rainwater capture area). The resulting cistern volume must be scaled down to the exact size of your project's rainwater capture area.
- Determine the required demand in gallons per day by dividing the cistern volume by the drawdown time (converted to days).

Feasibility of Using Harvested Rainwater for Residential Toilet Flushing. If your project consists entirely of residential use, or you are considering rainwater harvesting for the residential portion of mixed use projects that include some residential use, follow the following steps:

- Calculate the dwelling units per impervious acre by dividing the number of dwelling units by the acres of the Potential Rainwater Capture Area.
- Refer to applicable Countywide table in Attachment *2.*
- Identify the number of dwelling units per impervious acre needed in your Rain Gauge Area to provide the toilet flushing demand required for rainwater harvesting.
- If the project appears to have sufficient demand for rainwater, size the cistern (or other storage facility) to achieve the appropriate combination of drawdown time and cistern volume indicated in the sizing curves included in Attachment 2. Find the page that shows curves corresponding to the closest rain gauge to your project. The applicant can select any combination of drawdown time and cistern size that achieves at least 80 percent capture of runoff on the Y-axis of the graphs. Note that the sizing curves are for **1 acre of tributary impervious area**, (i.e., potential rainwater capture area). The resulting cistern volume must be scaled down to the exact size of your project's rainwater capture area.
- Determine the required demand in gallons per day by dividing the cistern volume by the drawdown time (converted to days).

Commercial/Institutional/Industrial Toilet Flushing. For projects that consist entirely of commercial, institutional, and/or industrial use, and for the commercial portion of mixed use projects, follow the following steps:

- Calculate the proposed interior floor area (sq.ft.) per acre of impervious surface by diving the interior floor area (sq.ft.) by the acres of the Potential Rainwater Capture Area.
- Refer to Table 10 in Attachment 2. This table identifies the required toilet flushing demand based on employees per impervious acre. Identify the square feet of non-residential interior floor area per impervious acre needed in your Rain Gauge Area to provide the toilet flushing demand required for rainwater harvest feasibility.
- If the project appears to have sufficient demand for rainwater, size the cistern (or other storage facility) to achieve the appropriate combination of drawdown time and cistern

volume indicated in the sizing curves included in Attachment 2. Find the page that shows curves corresponding to the closest rain gauge to your project. You can select any combination of drawdown time and cistern size that achieves at least 80 percent capture of runoff on the Y-axis of the graphs. Note that the sizing curves are for **1 acre of tributary impervious area**, (i.e., potential rainwater capture area). The resulting cistern volume must be scaled down to the exact size of your project's rainwater capture area.

- Determine the required demand in gallons per day by dividing the cistern volume by the drawdown time (converted to days).

School Toilet Flushing. For school projects, follow the following steps:

- Calculate the proposed interior floor area (sq.ft.) per acre of impervious surface by diving the interior floor area (sq.ft.) by the acres of the Potential Rainwater Capture Area.
- Refer to Table 10 in the Feasibility Report (see Attachment 2), which identifies the required toilet flushing demand based on employees per impervious acre.
- If the project appears to have sufficient demand for rainwater, size the cistern (or other storage facility) to achieve the appropriate combination of drawdown time and cistern volume indicated in the sizing curves included in Attachment 2. Find the page that shows curves corresponding to the closest rain gauge to your project. You can select any combination of drawdown time and cistern size that achieves at least 80 percent capture of runoff on the Y-axis of the graphs. Note that the sizing curves are for **1 acre of tributary impervious area**, (i.e., potential rainwater capture area). The resulting cistern volume must be scaled down to the exact size of your project's rainwater capture area.
- Determine the required demand in gallons per day by dividing the cistern volume by the drawdown time (converted to days).

Mixed Commercial and Residential Use Projects. Follow the following steps for mixed use projects:

- Evaluate the residential toilet flushing demand based on the dwelling units per impervious acre for the residential portion of the project, following the instructions above, except you will use a prorated acreage of impervious surface, based on the percentage of the project dedicated to residential use.
- Evaluate the commercial toilet flushing demand per impervious acre for the commercial portion of the project, following the instructions above, except you will use a prorated acreage of impervious surface, based on the percentage of the project dedicated to commercial use.
- If the project appears to have sufficient demand for rainwater, size the cistern (or other storage facility) to achieve the appropriate combination of drawdown time and cistern volume indicated in the sizing curves included in Attachment 2. Find the page that shows curves corresponding to the closest rain gauge to your project. You can select any combination of drawdown time and cistern size that achieves at least 80 percent capture of runoff on the Y-axis of the graphs. Note that the sizing curves are for **1 acre of tributary impervious area**, (i.e., potential rainwater capture area). The resulting cistern volume must be scaled down to the exact size of your project's rainwater capture area.

- Determine the required demand in gallons per day by dividing the cistern volume by the drawdown time (converted to days).

Industrial Projects. Follow the steps below for industrial projects:

- If the project will include an industrial processing use for non-potable water, identify the demand for this use.
- Refer to Table 9 in Attachment 2. This Table identifies demand based on the required cistern volume and demand, for the maximum allowable drawdown time, to capture the C.3.d amount of runoff.
- If the project appears to have sufficient demand for rainwater, size the cistern (or other storage facility) to achieve the appropriate combination of drawdown time and cistern volume indicated in the sizing curves included in Attachment 3. Find the page that shows curves corresponding to the closest rain gauge to your project. You can select any combination of drawdown time and cistern size that achieves at least 80 percent capture of runoff on the Y-axis of the graphs. Note that the sizing curves are for **1 acre of tributary impervious area**, (i.e., potential rainwater capture area). The resulting cistern volume must be scaled down to the exact size of your project's rainwater capture area.
- Determine the required demand in gallons per day by dividing the cistern volume by the drawdown time (converted to days).

I.4 Attachments

The following pages include the attachments listed below.

- Attachment 1: Toilet-Flushing Demand for Harvested Rainwater
- Attachment 2: Excerpts from the Feasibility Report (Map of Soil Hydraulic Conductivity and Rain Gauge Areas, Tables 8 through 11 and curves from the report's Appendix F)

Appendix I

Attachment 1: Toilet-Flushing Demand Required for Rainwater Harvesting Feasibility per Impervious Acre (IA) [1,2]

Table 1 - Alameda County:

Rain Gauge[3]	Required Demand (gal/day/IA)[4]	Residential		Office/Retail[5]		Schools[6]	
		No. of residents per IA[7]	Dwelling Units per IA[8]	Employees per IA[9]	Interior Floor Area (sq.ft./IA)[10]	Employees[11] per IA	Interior Floor Area (sq.ft./IA)[12]
Berkeley	5,900	690	255	860	172,000	170	51,000
Dublin	4,100	480	177	590	118,000	120	36,000
Hayward	4,800	560	207	700	140,000	140	42,000
Palo Alto	2,900	340	125	420	84,000	90	27,000
San Jose	2,400	280	103	350	70,000	70	21,000

Table 2 - Santa Clara County:

Rain Gauge[3]	Required Demand (gal/day/IA)[4]	Residential		Office/Retail[5]		Schools[6]	
		No. of residents per IA[7]	Dwelling Units per IA[8]	Employees per IA[9]	Interior Floor Area (sq.ft./IA)[10]	Employees[11] per IA	Interior Floor Area (sq.ft./IA)[12]
Morgan Hill	6,500	760	260	940	188,000	190	57,000
Palo Alto	2,900	340	116	420	84,000	90	27,000
San Jose	2,400	280	96	350	70,000	70	21,000

Table 3 – San Mateo County:

Rain Gauge[3]	Required Demand (gal/day/IA)[4]	Residential		Office/Retail[5]		Schools[6]	
		No. of residents per IA[7]	Dwelling Units per IA[8]	Employees per IA[9]	Interior Floor Area (sq.ft./IA)[10]	Employees[11] per IA	Interior Floor Area (sq.ft./IA)[12]
Palo Alto	2,900	340	124	420	84,000	90	27,000
San Francisco	4,600	530	193	670	134,000	140	42,000
SF Oceanside	4,300	500	182	620	124,000	130	39,000

Appendix I

Table 4 – Contra Costa County:

Rain Gauge[3]	Required Demand (gal/day/IA)[4]	Residential		Office/Retail[5]		Schools[6]	
		No. of residents per IA[7]	Dwelling Units per IA[8]	Employees per IA[9]	Interior Floor Area (sq.ft./IA)[10]	Employees[11] per IA	Interior Floor Area (sq.ft./IA)[12]
Berkeley	5,900	690	254	860	172,000	170	51,000
Brentwood	4,200	490	180	610	122,000	120	36,000
Dublin	4,100	480	176	590	118,000	120	36,000
Martinez	5,900	690	254	860	172,000	170	51,000

Table 5 – Solano County:

Rain Gauge[3]	Required Demand (gal/day/IA)[4]	Residential		Office/Retail[5]		Schools[6]	
		No. of residents per IA[7]	Dwelling Units per IA[8]	Employees per IA[9]	Interior Floor Area (sq.ft./IA)[10]	Employees[11] per IA	Interior Floor Area (sq.ft./IA)[12]
Lake Solano	9,000	1,050	362	1,300	260,000	270	81,000
Martinez	5,900	690	238	860	172,000	170	51,000

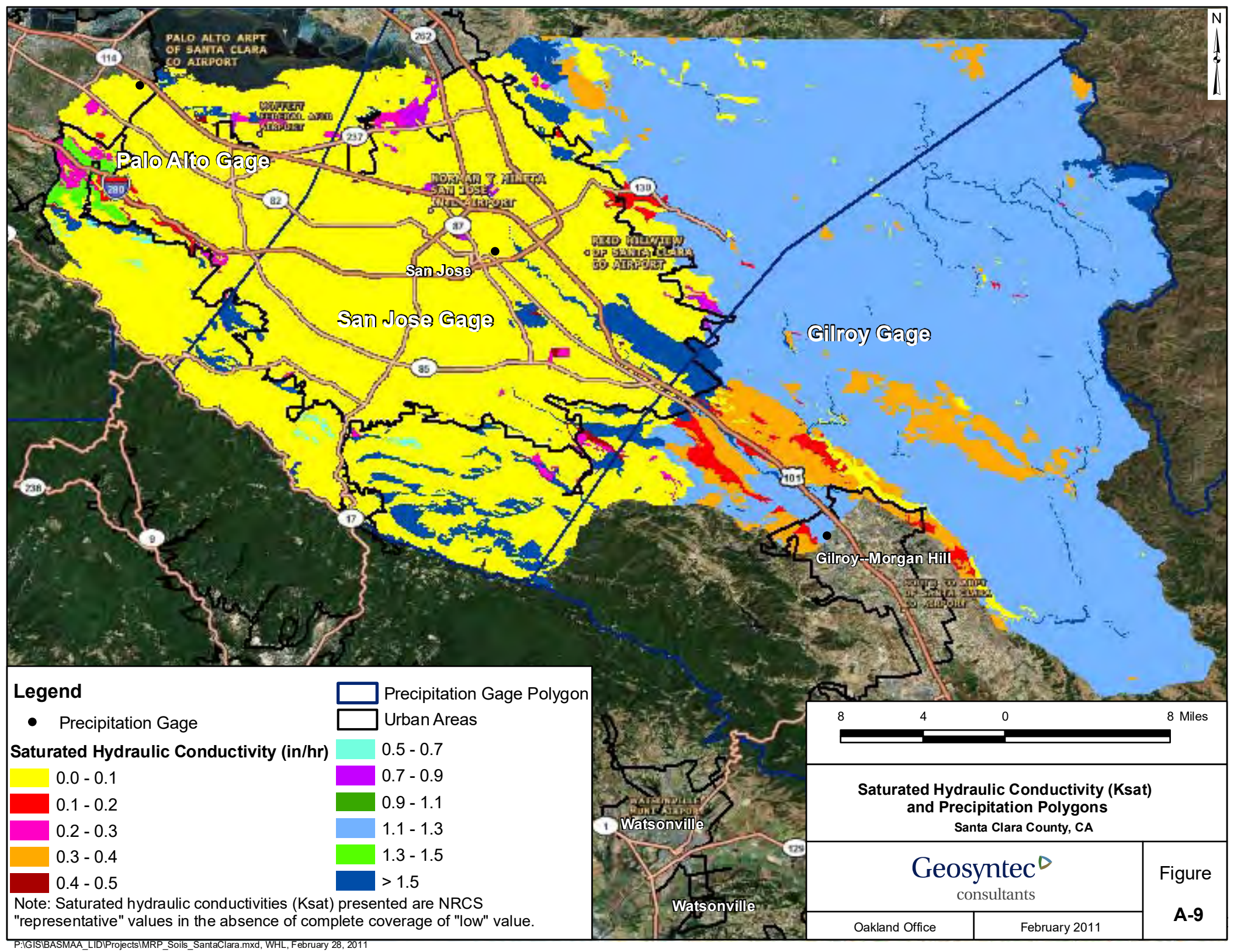
Notes:

1. Demand thresholds obtained from the "Harvest and Use, Infiltration and Evapotranspiration Feasibility/Infeasibility Criteria Report" (LID Feasibility Report) submitted to the Regional Water Board on May 1, 2011.
2. Toilet flushing demands assume use of low flow toilets per the California Green Building Code.
3. See Attachment 3 to identify the rain gauge that corresponds to the project site.
4. Required demand per acre of impervious area to achieve 80% capture of the C.3.d runoff volume with the maximum allowable drawdown time for cistern of 50,000 gallons or less, from Table 9 of the LID Feasibility Report.
5. "Office/Retail" includes the following land uses: office or public buildings, hospitals, health care facilities, retail or wholesale stores, and congregate residences.
6. "Schools" includes day care, elementary and secondary schools, colleges, universities, and adult centers.
7. Residential toilet flushing demand identified in Table 10 of the LID Feasibility Report.
8. Residential toilet flushing demand divided by the countywide average number of persons per household (US Census data reported on www.abag.org), as follows: Alameda County: 2.71 persons per household; Santa Clara County: 2.92; San Mateo County: 2.74; Contra Costa County: 2.72; Solano County: 2.90.
9. Office/retail employee toilet flushing demand identified in Table 10 of the LID Feasibility Report.
10. Interior floor area required for rainwater harvest and use feasibility per acre of impervious area is based on the number of employees in Column 5 multiplied by an occupant load factor of 200 square feet per employee (reference: 2010 California Plumbing Code, Chapter 4, Plumbing Fixtures and Fitting Fixtures, Table A, page 62.)
11. School employee toilet flushing demand identified in Table 10 of the LID Feasibility Report. Each school employee represents 1 employee and 5 "visitors" (students and others).
12. Interior floor area required for rainwater harvest and use feasibility per acre of impervious area is based on the number of employees in Column 7 multiplied by 6 to account for visitors, then multiplied by an occupant load factor of 50 square feet per employee (reference: 2010 California Plumbing Code).

Appendix I

Attachment 2:
Excerpts from BASMAA's
Feasibility/Infeasibility Report

- Figure A-9: Saturated Hydraulic Conductivity (Ksat) and Precipitation Polygons, Santa Clara County, CA
- Table 8: Required Cistern Volume and Demand per Acre of Impervious Area to Achieve 80% Capture with a 48-hour Drawdown Time
- Table 9: Required Cistern Volume and Demand per Acre of Impervious Area to Achieve 80% Capture with the Longer Drawdown Time Allowable (Minimum Demand) for Cistern of 50,000 Gallons or Less
- Table 10: TUTIA Ratios for Typical Land Uses for Rain Gauges Analyzed
- Table 11: EIATIA Ratios for Rain Gauges Analyzed
- Figure F-7: Percent Capture Achieved by BMP Storage Volume with Various Drawdown Times for 1-Acre, 100% Impervious Tributary Area: Morgan Hill
- Figure F-8: Percent Capture Achieved by BMP Storage Volume with Various Drawdown Times for 1-Acre, 100% Impervious Tributary Area: Palo Alto
- Figure F-11: Percent Capture Achieved by BMP Storage Volume with Various Drawdown Times for 1-Acre, 100% Impervious Tributary Area: San Jose



Saturated Hydraulic Conductivity (Ksat) and Precipitation Polygons

Santa Clara County, CA

Geosyntec consultants

Oakland Office | February 2011

Figure **A-9**

P:\GIS\BASMAA_LID\Projects\MRP_Soils_SantaClara.mxd, WHL, February 28, 2011

Table 8: Required Cistern Volume and Demand per Acre of Impervious Area to Achieve 80% Capture with a 48-hour Drawdown Time

Rain Gauge	Drawdown Time (hr.)	Required Cistern Size (gallons)	Required Demand (gal/day)
Berkeley	48	23,000	11,500
Brentwood	48	19,000	9,500
Dublin	48	21,000	10,500
Hayward	48	23,500	11,750
Lake Solano	48	29,000	14,500
Martinez	48	23,000	11,500
Morgan Hill	48	25,500	12,750
Palo Alto	48	16,500	8,250
San Francisco	48	20,000	10,000
San Francisco Oceanside	48	19,000	9,500
San Jose	48	15,000	7,500

If a longer drawdown time (and lower minimum demand) is desired, Table 9 includes the maximum drawdown time allowable to achieve 80 percent capture for a cistern sized at 50,000 gallons or less per acre of impervious area, along with the required cistern sizes and daily demands.

Table 9: Required Cistern Volume and Demand per Acre of Impervious Area to Achieve 80% Capture with the Longer Drawdown Time Allowable (Minimum Demand) for Cistern of 50,000 Gallons or Less

Rain Gauge	Drawdown Time (hr.)	Required Cistern Size (gallons)	Required Demand (gal/day)
Berkeley	180	44,000	5,900
Brentwood	240	42,000	4,200
Dublin	240	41,000	4,100
Hayward	240	47,500	4,800
Lake Solano	120	45,000	9,000
Martinez	180	44,000	5,900
Morgan Hill	180	49,000	6,500
Palo Alto	360	44,000	2,900
San Francisco	240	45,500	4,600
San Francisco Oceanside	240	43,000	4,300
San Jose	480	48,000	2,400

Table 10: TUTIA Ratios for Typical Land Uses for Rain Gauges Analyzed

Rain Gauge	Required Demand[1] (gal/day)	Toilet Users per Impervious Acre (TUTIA)[2]							
		Residential		Office/Retail		Schools		Industrial	
		Current	CGBC[3]	Current	CGBC	Current	CGBC	Current	CGBC
Assumed Per Capita Use per Day (gal/day)[4]		18	8.6	14	6.9	66	34	11	5.4
Berkeley	5,900	320	690	420	860	90	170	540	1,090
Brentwood	4,200	230	490	300	610	60	120	380	780
Dublin	4,100	220	480	290	590	60	120	370	760
Hayward	4,800	260	560	340	700	70	140	440	890
Lake Solano	9,000	490	1050	640	1,300	140	270	820	1,670
Martinez	5,900	320	690	420	860	90	170	540	1090
Morgan Hill	6,500	350	760	460	940	100	190	590	1,200
Palo Alto	2,900	160	340	210	420	40	90	260	540
San Francisco	4,600	250	530	330	670	70	140	420	850
San Francisco Oceanside	4,300	230	500	310	620	70	130	390	800
San Jose	2,400	130	280	170	350	40	70	220	440

Footnotes:
[1] For a 50,000 or less gallon tank to achieve 80 percent capture within maximum allowable drawdown time (Table 9).
[2] The TUTIA ratios are based on employee toilet users per impervious acre. These ratios were calculated using the daily toilet and urinal water usage from Table 5, which are per employee and encompass usage by visitors and students within the daily demand (assumes about 5 students per school employee).
[3] CGBC = California Green Building Code Requirements water usage accounting for water conservation.
[4] From Table 5, Toilet and Urinal Water Usage per Resident or Employee.

EIATA Ratios

Comparing the required daily demands for rainwater harvesting systems for both 48-hour drawdown times and maximum drawdown times to daily demands per irrigated acre, it becomes evident that the required demands are many times larger than irrigation demands. This can be translated into an 'Effective Irrigated Area to Impervious Area' (EIATIA) ratio by dividing the required rainwater harvesting system demand by the daily irrigation demand (shown in Table 7). Since both demands are calculated on a per acre basis, the EIATIA ratio represents the number of acres of irrigated area needed per acre of impervious surface to meet the demand needed for 80 percent capture. EIATIA ratios were analyzed for the rain gauges used for analysis and the evapotranspiration data listed in Table F-1. These ratios, as well as the required total imperviousness (assuming a project includes the impervious tributary area and the irrigated area only) are included in Table 11.

Table 11: EIATIA Ratios for Rain Gauges Analyzed

Rain Gauge	Required Daily Demand[1] (gal/day)	ET Data Location[2]	Conservation Landscaping			Turf Areas		
			Demand per Irrigated Acre[3]	EIATIA	Resultant Imper-viousness (%)	Demand per Irrigated Acre[3]	EIATIA	Resultant Imper-viousness (%)
Berkeley	5,900	Oakland	420	14.0	7%	850	6.9	13%
Brentwood	4,200	Brentwood	420	10.0	9%	850	4.9	17%
Dublin	4,100	Pleasanton	430	9.5	9%	850	4.8	17%
Hayward	4,800	Fremont	520	9.2	10%	1,040	4.6	18%
Lake Solano	9,000	Fairfield	420	21.4	4%	840	10.7	9%
Martinez	5,900	Martinez	380	15.5	6%	760	7.8	11%
Morgan Hill	6,500	Morgan Hill	500	13.0	7%	1,000	6.5	13%
Palo Alto	2,900	Redwood City	450	6.4	13%	900	3.2	24%
San Francisco	4,600	San Francisco	360	12.8	7%	720	6.4	14%
San Francisco Oceanside	4,300	San Francisco	360	11.9	8%	720	6.0	14%
San Jose	2,400	San Jose	470	5.1	16%	940	2.6	28%

Footnotes:
[1] To achieve 80 percent capture within maximum allowable drawdown time (Table 9).
[2] Closest location selected, from Table F-1.
[3] From Table 7.

3.3.3 Summary

In summary, TUTIA ratios indicate that dense land uses would be required to provide the needed demand to make rainwater harvesting feasible in the MRP area. A project must have sufficiently high toilet flushing uses to achieve 80 percent capture within the maximum allowable drawdown time (see Table 9 for maximum allowable drawdown time for a 50,000 gallon tank or less). For instance, approximately 280 to 1,050 residential toilet users (roughly 90 – 130 dwelling units per acre[5]) are required, depending on location, per impervious acre to meet the demand needed for 80 percent capture with the maximum allowable drawdown time and CA Green Building Code flush requirements. Meeting the demand requirements would entail a very dense housing

[5] Assuming three residents per dwelling unit.

Figure F-7: Percent Capture Achieved by BMP Storage Volume with Various Drawdown Times for 1-Acre, 100% Impervious Tributary Area - Morgan Hill

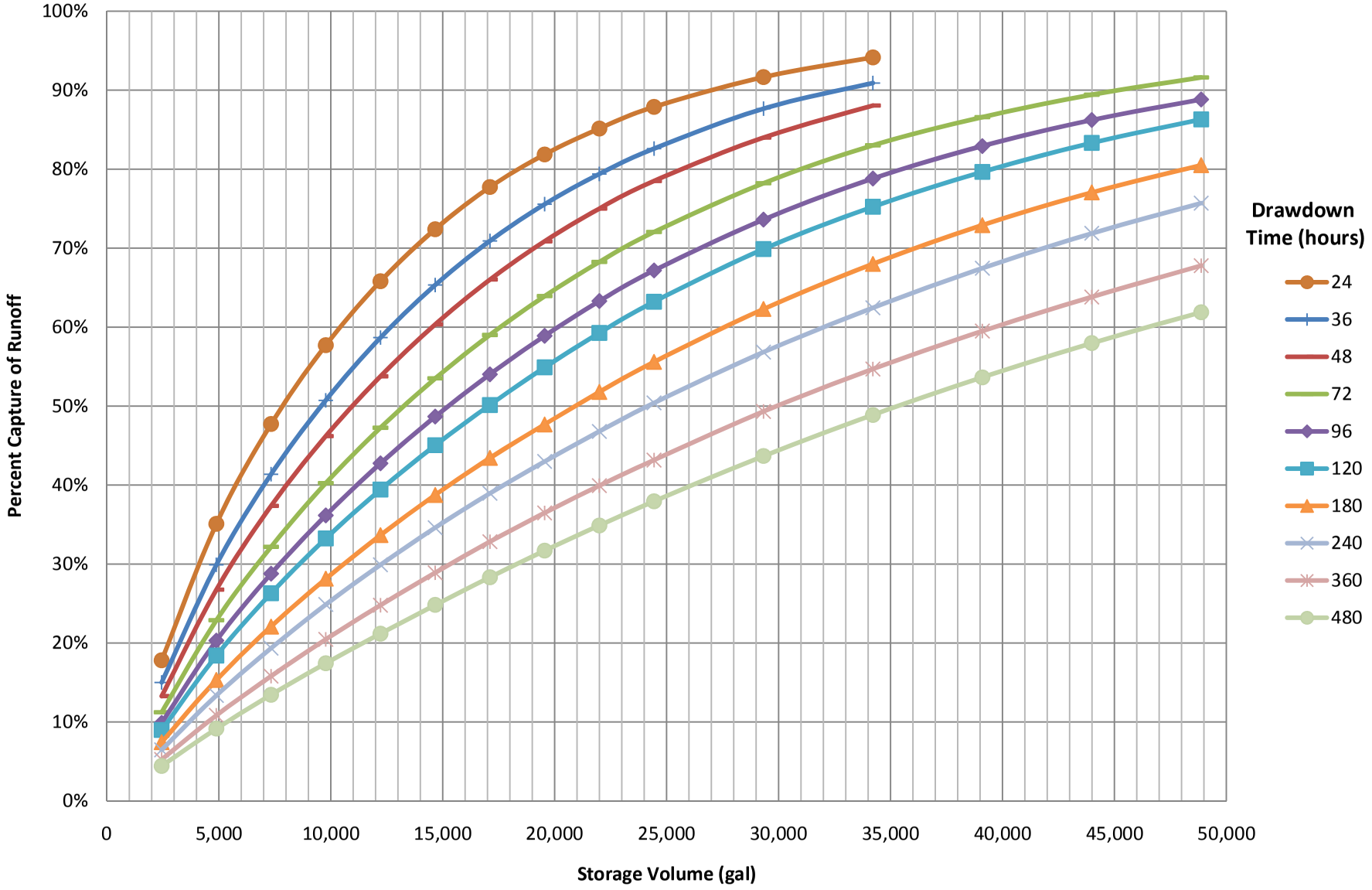


Figure F-8: Percent Capture Achieved by BMP Storage Volume with Various Drawdown Times for 1-Acre, 100% Impervious Tributary Area - Palo Alto

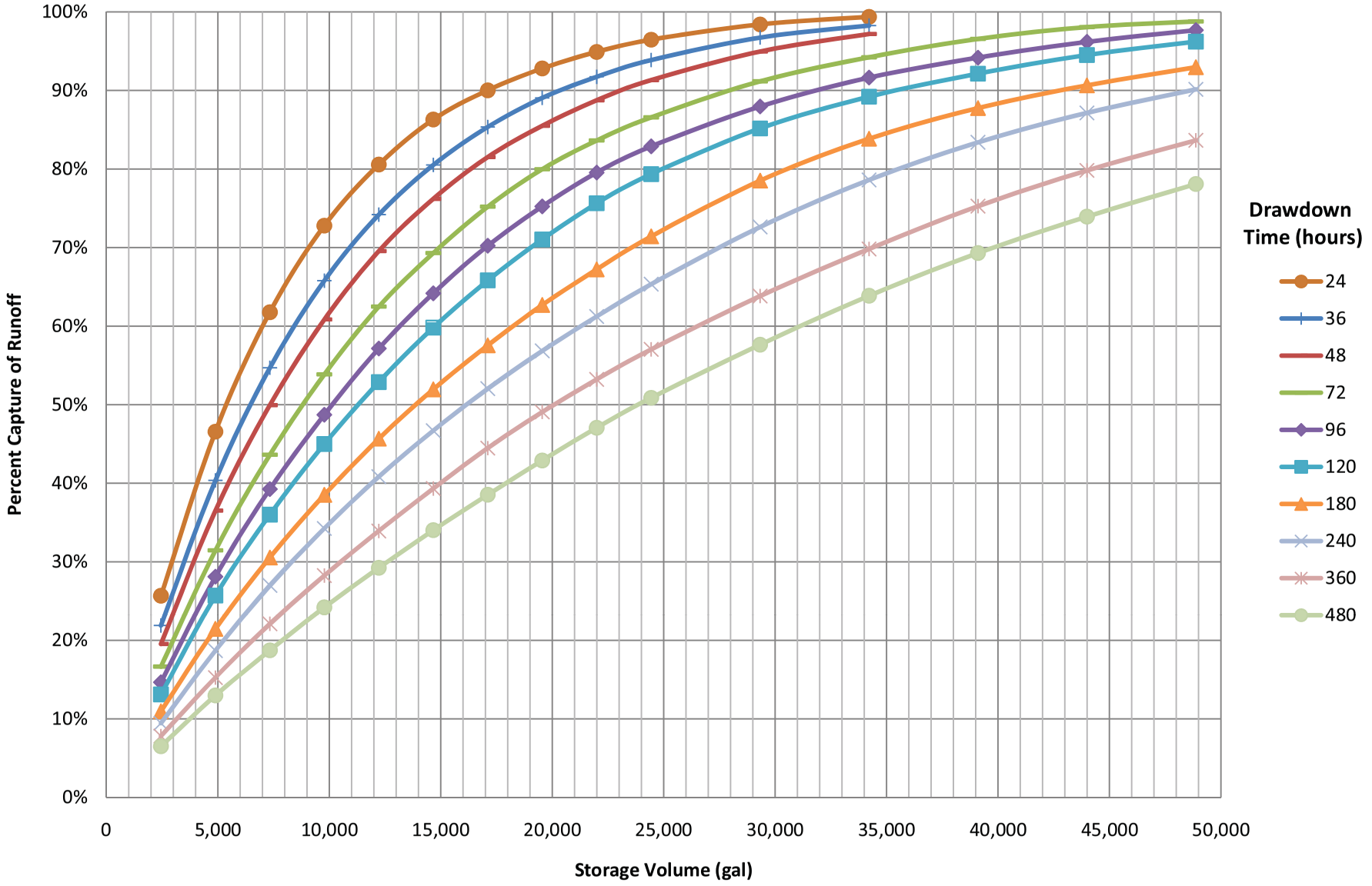
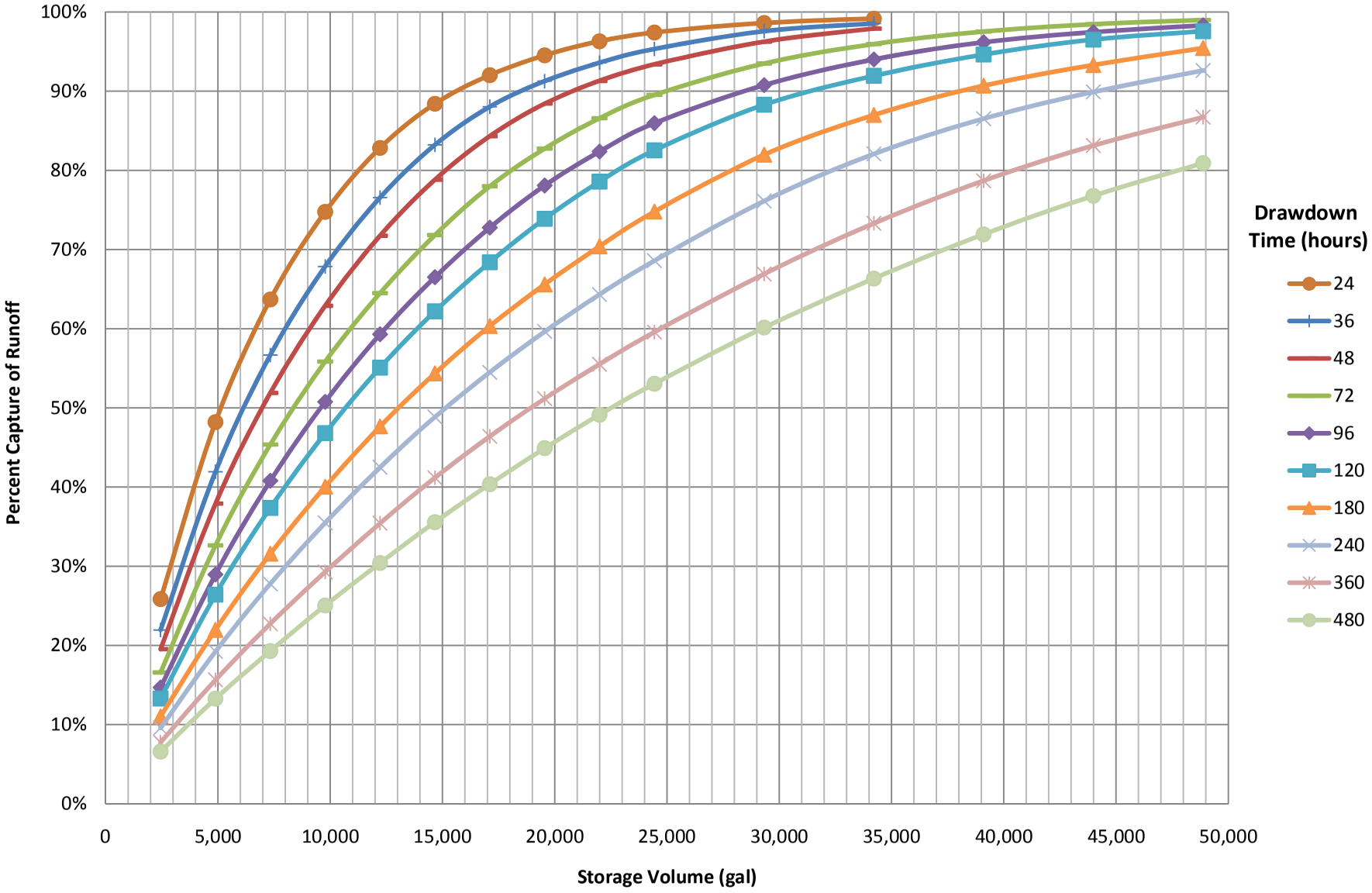


Figure F-11: Percent Capture Achieved by BMP Storage Volume with Various Drawdown Times for 1-Acre, 100% Impervious Tributary Area - San Jose



ATTACHMENT H:

Typical GSI Measure Specifications

This attachment includes the following typical specifications:

Section 33 47 27 – Bioretention (San Francisco Public Utilities Commission, 2016), includes Santa Clara Valley Urban Runoff Pollution Prevention Program Biotreatment Soil Verification Checklists and Documentation and Mulch Specifications

Section 32 12 43 – Porous Asphalt Concrete (San Francisco Public Utilities Commission, 2016)

Section 32 13 43 – Pervious Concrete (San Francisco Public Utilities Commission, 2016)

Section 32 14 43 – Permeable/Porous Unit Pavers (San Francisco Public Utilities Commission, 2016)

DESIGNER NOTE: Green text corresponds to notes to the designer. Remove prior to use.

DESIGNER NOTE: Replace "Engineer/Landscape Architect" with person in responsible charge for the project (e.g., Owner, Engineer, Landscape Architect).

PART 1 GENERAL

1.01 SUMMARY

A. This section includes:

1. Bioretention Soil Mix
2. Aggregate Storage
3. Composted Mulch [Refer to Exhibit C: Composted Wood Mulch Specification]
4. Streambed Gravel [To be completed by designer.]

B. Related Sections:

1. Section 01 57 29 – Temporary Protection of Green Infrastructure Facilities

DESIGNER NOTE: The designer should list any additional specification sections which relate to the bioretention work (i.e., clean outs and underdrains, overflow structures, planting, temporary erosion control, utilities, irrigation, earthwork, other appurtenances, etc.).

1.02 STANDARDS AND CODES

A. Reference Standards: This section incorporates by reference the latest versions of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications
San Francisco DPW	Engineering Standard Specifications
ASTM	Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition.

1.03 DEFINITIONS

A. Bioretention Soil Mix (BSM): A soil mix that has been specially blended and tested for use in bioretention facilities with the intent to meet the following objectives:

1. Infiltrate runoff at a minimum rate of 5 inches per hour throughout the life of the facility, and
2. By nature of its components be capable of the removal of certain suspended and dissolved stormwater pollutants, and
3. Have sufficient moisture retention and other agronomic properties to support healthy vegetation.

1.04 REFERENCES

DESIGNER NOTE: Designer to provide references to all project specific documents (e.g., geotechnical report).

1.05 SUBMITTALS

A. Pre-Installation Submittals: The Contractor shall submit to the Engineer/Landscape Architect the following a minimum of 20 calendar days (or as directed by the Engineer/Landscape Architect) prior to the construction of bioretention facilities. Complete and submit the Biotreatment Soil Media Specification Verification Checklist (See Exhibit A at the End of this Section).

1. BSM Submittals

a. Two one (1) gallon samples of the BSM.

b. Source certificates for all BSM materials.

c. Sieve analysis of BSM per ASTM D422 performed within two (2) months of product delivery to site

d. Certification from the soil supplier or an accredited testing agency that the BSM, including sand and compost components, conforms to all industry or technical society reference standards specified in Sections 2.01.A, 2.01.B, and 2.01C.

e. A description of the equipment and methods used to mix the sand and compost to produce BSM.

f. Organic content test results of the BSM, performed in accordance with Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, "Loss-On-Ignition Organic Matter Method."

g. Permeability test results for BSM per ASTM D2434 (Modified). See SFPUC Modified ASTM D2434 Procedures for required modifications to test.

DESIGNER NOTE: On larger projects, it may be appropriate to require that the above testing be performed on samples taken at the supplier's yard from the stockpile to be used for the project; see designer note in Section 1.06.C.2.

2. Sand Submittals

a. Sieve analysis of sand per ASTM D422 performed within two (2) months of product delivery to site.

DESIGNER NOTE: Consider revising acceptable age of sieve tests depending on scale of project. On a larger project it may be appropriate to require testing on samples taken at the supplier's yard from the stockpile to be used for the project.

3. Compost Submittals

a. Quality analysis results for compost performed in accordance with Seal of Testing Assurance (STA) standards, as specified in Section 2.01.C, and performed within two (2) months of product delivery to site.

b. Sieve analysis of compost per TMECC 02.02-B performed within two (2) months of product delivery to site.

4. Other Submittals

a. Cut sheets of any media or soil admixes to enhance moisture retention properties, if used.

b. Testing agency qualifications as specified in Section 1.06.B.

DESIGNER NOTE: Designer should include relevant submittal requirements for mulch and streambed gravel (e.g., sieve analysis), to ensure quality of delivered products.

1.06 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect bioretention materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered after installation, nor shall it constitute final acceptance.

B. Testing Agency Qualification:

1. General: Agencies that perform testing on bioretention materials, including permeability testing, shall be accredited by STA, ASTM, AASHTO, or other designated recognized standards organization. All certifications shall be current. Testing agency shall be capable of performing all tests to the designated and recognized standards specified and shall provide test results with an accompanying Manufacturer's Certificate of Compliance. The following information shall be provided for all testing laboratories used:

a. Name of lab(s) and contact person(s)

b. Address(es) and phone number(s)

c. Email address(es)

d. Qualifications of laboratory and personnel including the date of current certification by STA, ASTM, AASHTO, or approved equal.

2. Compost: Laboratory that performs testing shall be independent, enrolled in the US Composting Council's (USCC) Compost Analysis Proficiency (CAP) program, and perform testing in accordance with USCC Test Method for The Examination of Composting and Compost (TMECC). The sample collection protocol can be obtained from the U.S. Composting Council, 4250 Veterans Memorial Highway, Suite 275, Holbrook, NY 11741, 631-737-4931, www.compostingcouncil.org.

C. Responsibilities of Contractor

1. Submittals: Some of the tests required for this specification are unique, and BSM shall be considered a long-lead-time item. Under no circumstance shall failure to comply with all specification requirements be an excuse for a delay or for expedient substitution of unacceptable material(s). The requirements of Division 0 apply in their entirety. Pre-Placement Conference: A mandatory pre-placement conference will take place, including at a minimum the Engineer/Landscape Architect, the Resident Engineer, the Owner/Client Representative, Installer, and general Contractor, to review schedule, products, soil testing, permeability testing, and installation. The Contractor shall notify the Engineer/Landscape Architect a minimum of 2 working days prior to conference.

DESIGNER NOTE: Pre-placement conference is mandatory for all projects within the public right-of-way, or on other public property, and is strongly recommended for privately-owned parcel projects.

2. Testing: All testing specified herein is the responsibility of the Contractor and shall be conducted by an independent testing agency, retained by the Contractor. The Owner reserves the right to conduct additional testing on all materials submitted, delivered, or in-place to ensure compliance with Specifications. Test must be conducted within 120 days prior to the delivery date of the bioretention soil to the project site. Batch-specific test results and certifications shall be required for projects installing more than 100 cubic yards of BSM.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Protect the BSM and mulch from contamination and all sources of additional moisture at supplier site, during transport, and at the project site, until incorporated into the Work.

B. The Contractor is required to coordinate delivery of BSM and aggregates with bioretention facility excavation and soil installation. A written schedule shall be submitted for review as part of the submittal package. BSM should not be stockpiled onsite for any length of time. In no case shall BSM be stockpiled onsite for more than 24 hours without prior written approval by the Engineer/Landscape Architect. If stockpiling onsite for any length of time, BSM stockpiles shall meet the following requirements:

1. Locate stockpiles away from drainage courses, inlets, sewer cleanout vents, and concentrated stormwater flows

2. Place stockpiles on geotextile fabric

3. Cover stockpiles with plastic or comparable material

4. Contain stockpiles (and prevent contamination from adjacent stockpiles) with temporary perimeter barrier (e.g., sand bags, wattles, silt fence)

PART 2 PRODUCTS

2.01 BIORETENTION SOIL MIX (BSM)

A. General: BSM shall be a well-blended mixture of sand and compost, shall have sufficient moisture retention to support healthy plant growth, and shall meet the following criteria:

1. Mixture proportions: 30 to 40 percent Compost by volume and 60 to 70 percent Sand by volume

DESIGNER NOTE: Up to 15 percent of the sand fraction may be replaced with other media or soil admixtures (e.g., scoria, coconut coir, perlite, expanded shale, gypsum, vermiculite, pumice, biochar, etc.) to enhance moisture retention capacity of soil, provided admixtures are low in fines (less than 5 percent passing the 200 sieve) and do not break down under normal handling and use. No topsoil, peat, silts, or clays are permitted to be used as admixtures. Admixtures shall be free of sediments and other materials deleterious to plant growth.

2. Organic matter content: 4 to 8 percent as determined by TMECC 05.07-A, Loss on Ignition Method.

3. Extraneous materials: BSM shall be free of all roots, plants, weeds, sod, stones, clods, pockets of coarse sand, construction debris, or other extraneous materials harmful to plant growth.

4. Permeability/Saturated Hydraulic Conductivity: 10 inches per hour (minimum) tested in accordance with ASTM D2434 (Modified). See SFPUC Modified ASTM D2434 Procedures for required modifications to test.

DESIGNER NOTE: 10-inch-per-hour minimum rate assumes a design rate of 5 inches per hour and a correction factor of 2 to account for reduction in performance from initially measured rates.

5. Acceptance of BSM quality and performance may be based on samples taken from stockpiles at supplier's yard, submitted test results, and/or onsite and laboratory testing of installed material at the discretion of the Engineer/Landscape Architect. The point of acceptance will be determined in the field by the Engineer/Landscape Architect.

DESIGNER NOTE: Designer to consider non-compost based BSM specification if facility is serviced by an underdrain and if it is draining to phosphorus sensitive water body.

B. Sand: Sand in the BSM shall conform to the requirements for Sand, Type [specify type from table below] specified herein, unless otherwise approved by the Engineer/Landscape Architect.

DESIGNER NOTE: Designer to specify sand type based on project specific requirements. If bioretention facilities will be subjected to heavy sediment loads (e.g., arterial runoff), consider specifying Sand, Type B (low fines sand)

in an effort to reduce clogging risk (pending local availability). Additionally, projects anticipating heavy sediment loads should incorporate pre-settling measures at the upstream end of the facility to allow for more efficient maintenance of facilities.

1. Sand shall be free of wood, waste, coating, or any other deleterious material.

2. Sand material shall meet the following specifications for gradation.

Sieve Size[1]	Percent Passing by Weight	
	Type A[2]	Type B (low fines)[3]
3/8 inch	100	100
No. 4	90 to 100	90 to 100
No. 8	70 to 100	70 to 100
No. 16	40 to 95	40 to 85
No. 30	15 to 70	15 to 60
No. 50	5 to 55	8 to 15
No. 100	0 to 15	0 to 4
No. 200	0 to 5	0 to 2

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Sand conforming to ASTM C33 for Fine Aggregate satisfies the requirements of this specification for Sand, Type A.

[3] Type B (low fines) sand gradation pending local availability.

3. Coefficient of Uniformity: $C_u = \frac{D_{60}}{D_{10}}$: 4 or less for Sand, Type B.

4. Effective Particle Size (D_{10}): 0.3 to 0.5 mm for Sand, Type B.

5. All aggregate passing the No. 200 sieve shall be non-plastic.

6. Acceptance of grading and quality of the sand may be based on samples taken from stockpiles at supplier's yard or a submitted gradation report at the discretion of the Engineer/Landscape Architect. The point of acceptance will be determined in the field by the Engineer/Landscape Architect.

C. Compost: Compost in the BSM shall be well decomposed, stable, weed free organic matter sourced from waste materials including yard debris, wood wastes or other organic materials, not including biosolids or manure feedstock. Compost shall conform to California Code of Regulations Title 14, Division 7, Chapter 3.1 requirements, be certified through the USCC Seal of Testing Assurance (STA) Program, and meeting the criteria specified herein.

1. Feedstock: Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues. Feedstock shall not include biosolids or manure.

2. Organic Matter Content: 35 to 75 percent by dry weight tested in accordance with TMECC 05.07-A (Loss on Ignition Organic Matter Method).

3. Carbon to Nitrogen Ratio: C:N between 15:1 and 25:1 when tested in accordance with TMECC 05.02-A.

4. Maturity/Stability: shall have a dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120°F) upon delivery or rewetting is not acceptable. In addition any one of the following is required to indicate stability:

a. Specific Oxygen Uptake Rate (SOUR): 1.5 milligrams O_2 per gram biodegradable volatile solids per hour (maximum) per TMECC 05.08-A.

b. Carbon Dioxide Evolution Rate: 8 milligrams CO_2 per gram volatile solids per day per TMECC 05.08-B.

c. Dewar Self Heating Test: 20°C temperature rise (maximum) per TMECC 05.08-D (Class IV or V).

d. Solvita®: Index value greater than 6 per TMECC 05.08-E.

5. Toxicity: Seed Germination: greater than 80 percent of control AND Vigor: greater than 80 percent of control per TMECC 05.05-A.

6. Nutrient Content: provide analysis detailing nutrient content including N-P-K, Ca, Na, Mg, S, and B.

a. Total Nitrogen: 0.9 percent (minimum).

b. Boron: Total shall be < 80 ppm

7. Salinity/Electrical Conductivity: less than 6.0 deciSiemen per meter (dS/m or mmhos/cm) per TMECC 04.10-A (1:5 Slurry Method, Mass Basis).

8. pH: 6.5 to 8 per TMECC 04.11-A (1:5 Slurry pH).

9. Gradation: Compost for BSM shall meet the following size gradation per TMECC 02.02-B (test shall be run on dry compost sample):

Sieve Size	Percent Passing by Weight	
	Min	***Max***
1 inch	99	100
1/2 inch	90	100
1/4 inch	40	90
No. 200	1	10

10. Bulk density: 500 to 1,100 dry pounds per cubic yard.

11. Moisture content: 30 to 55 percent of dry solids.

12. Inerts: compost shall be relatively free of inert ingredients, including glass, plastic and paper, less than 1 percent by weight or volume per TMECC 03.08A.

13. Weed seed/pathogen destruction: provide proof of process to further reduce pathogens (PFRP). For example, turned windrows must reach minimum 55°C for 15 days with at least 5 turnings during that period.

14. Select Pathogens

a. Salmonella: less than 3 Most Probable Number per 4 grams of total solids, dry weight per TMECC 07.02.

b. Coliform Bacteria: fecal coliform less than 1,000 Most Probable Number per gram of total solids, dry weight per TMECC 07.01.

15. Trace Contaminants Metals (lead, mercury, etc.): Product must meet US EPA, 40 CFR 503 regulations.

D. Soil Admixtures: [Specify admixtures, if used]

E. Verification of Alternative Bioretention Soil Mixes - See Exhibit B at the end of this Section.

2.02 AGGREGATE STORAGE

DESIGNER NOTE: Aggregate storage layer requirements are dependent on location of project (i.e., MS4 areas vs. combined sewer areas), site specific conditions (e.g., native soil infiltration rates, storage volume needs of project). The designer should update this specification based on the aggregate storage materials required for the project.

DESIGNER NOTE: Aggregate storage is optional in combined sewer areas for facilities without underdrains. BSM depth may also be increased for additional storage capacity (in lieu of an aggregate storage layer), provided the facility is within a combined sewer area and not serviced by an underdrain.

A. Aggregate Storage shall consist of hard, durable, and clean, sand, gravel, or mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove fines, organic matter, extraneous debris, or objectionable materials. Recycled materials are not permitted. The material shall be obtained only from a source(s) approved by the Engineer/Landscape Architect. Written requests for source approval shall be submitted to the Engineer/Landscape Architect not less than ten (10) working days prior to the intended use of the Material. Should the proposed source be one that the Engineer/Landscape Architect has no history of Material performance with, the Engineer/Landscape Architect reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract.

B. Aggregate storage shall meet the following specifications for grading and quality.

1. Aggregate gradation testing in accordance with ASTM C136 at least once per 500 cubic yards.

Sieve[1]	Percent Passing by Weight		
	Choking Course ASTM No. 9 (Modified)[3]	**Reservoir Course ASTM No. 7 (Modified)[4]**	**Caltrans Class 2 Permeable Aggregate (MS4 Areas Only)**
1 inch	–	–	100
3/4 inch	–	100	90 to 100
1/2 inch	100	90 to 100	–
3/8 inch	100	40 to 70	40 to 100
No. 4	85 to 100	0 to 15	25 to 40
No. 8	10 to 40	0 to 5	18 to 33
No. 16	0 to 10	–	–
No. 30	–	–	5 to 15
No. 50	–	–	0 to 7
No. 200[2]	0 to 2	0 to 2	0 to 3

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Gradation modified from ASTM for portion passing the No. 200 sieve.

[3] Materials likely to meet this specification are available locally as Graniterock 1/4” premium screenings (Wilson 1/4" x #10 Premium Screenings).

[4] Materials likely to meet this specification are available locally as Graniterock 1/2” premium screenings (Wilson 1/2" x #4 Roofing Aggregate).

2. Crushed Particles: 90 percent (minimum) fractured faces tested in accordance with California Test 205. Do not use rounded river gravel.

3. L.A. Abrasion: 40 percent (maximum) tested in accordance with ASTM C 131.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying coarser graded materials or reduction in permeability relative to the underlying material. Refer to the SFPUC Aggregate Filter Criteria Guidance document for information on selecting appropriate alternate materials.

DESIGNER NOTE: Designer should verify that underdrain slot dimensions for project are compatible with aggregate gradation specified. Refer to the SFPUC Aggregate Filter Criteria Guidance document for information on selecting appropriate underdrain materials.

2.03 MULCH

DESIGNER NOTE: See Exhibit C: COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREA at the end of this section.

2.04 ENERGY DISSIPATION: STREAMBED COBBLE

DESIGNER NOTE: Designer to specify cobble requirements, including gradation, for flow-through type bioretention facilities. Streambed cobble shall be sized 3" - 6" to provide energy dissipation and to minimize erosion at facility inlets and outlets.

The following text is a sample/template specification for cobbles within a bioretention facility: Streambed cobble shall be clean, 3" - 6" naturally occurring water rounded cobble material. Streambed cobble shall have a well-graded distribution of cobble sizes and conform to the following gradation [Designer to specify]:

Streambed Cobble	
Approximate Size[1]	**Percent Passing by Weight**

[1] Approximate size can be determined by taking the average dimension of the three axes of the rock, Length, Width, and Thickness, by use of the following calculation: (Length + Width + Thickness)/3 = Approximate Size Length is the longest axis, width is the second longest axis, and thickness is the shortest axis.

The grading of the cobble shall be determined by the Engineer/Landscape Architect by visual inspection of the load before it is dumped into place, or, if so ordered by the Engineer/Landscape Architect, by dumping individual loads on a flat surface and sorting and measuring the individual rocks contained in the load. Cobble must be washed before placement.

PART 3 EXECUTION

3.01 GENERAL

A. Prevent runoff from adjacent pervious and impervious surfaces from entering the bioretention facility (e.g., sand bag inlet curb cuts, stabilize adjacent areas, flow diversion) until authorization is given by the Engineer/Landscape Architect. Refer to SFPUC Specification Section 01 57 29 Temporary Protection of Green Infrastructure Facilities.

B. Exclude equipment from bioretention facilities. No equipment shall operate within the facility once bioretention facility excavation has begun, including during and after excavation, backfilling, mulching, or planting.

C. Prevent foreign materials and substances, such as silt laden run-off, construction debris, paint, paint washout, concrete slurry, concrete layers or chunks, cement, plaster, oils, gasoline, diesel fuel, paint thinner, turpentine, tar, roofing compound, or acid from entering or being stored in the facility at any point during construction.

3.02 GRADING

A. The Contractor shall not start bioretention facility grading until all areas draining to the facility are stabilized and authorization has been given by the Engineer/Landscape Architect.

B. Construct bioretention facility subgrade to +/- 3/4 inch of the grades and slopes specified on the Plans.

C. Excavation within 6 inches of final native soil grade shall not be permitted if facility soils have standing water, or have been subjected to more than 1/2 inch of precipitation within the previous 48 hours.

3.03 SUBGRADE PREPARATION AND PROTECTION

A. Protect the bioretention excavation from over compaction and/or contamination.

1. Areas which have been over compacted by equipment or vehicle traffic or by other means and which need to be ripped, over excavated, receive additional scarification, or other restorative means shall be done at the Contractor's expense and at the direction of the Engineer/Landscape Architect.

2. Excavated areas contaminated by sediment laden runoff prior to placement of BSM or Aggregate Storage material shall be remediated at the Contractor's expense by removing the contaminated soil (top 3 inches minimum) and replacing with a suitable material, as determined by the Engineer/Landscape Architect.

B. Remove all trash, debris, construction waste, cement dust and/or slurry, or any other materials that may impede infiltration into prepared subgrade.

C. The subgrade shall be inspected and accepted by the Engineer/Landscape Architect prior to placement of any materials or final subgrade scarification.

D. Scarify the surface of the subgrade to a minimum depth of 3 inches immediately prior to placement of BSM or aggregate storage material. Acceptable methods of scarification include use of excavator bucket teeth or a rototiller to loosen the surface of the subgrade.

E. Place aggregate storage material, where shown on drawings with conveyor belt or with an excavator or loader from a height no higher than 6 feet unless otherwise approved by the Engineer/Landscape Architect (i.e., do not dump material directly from truck into cell).

F. Aggregate Storage areas contaminated by sediment-laden runoff prior to placement of BSM shall be remediated at the Contractor's expense by removing the contaminated aggregate storage material (top 3 inches minimum or as directed by the Engineer/Landscape Architect) and replacing with clean aggregate storage material per Section 2.03, to the lines and grades on the Plans.

G. Aggregate Storage material shall be inspected and accepted for placement and finish grade by the Engineer/Landscape Architect prior to the installation of BSM. Any material that does not conform to this Specification shall be removed and replaced with acceptable material or remediated to the satisfaction of the Engineer/Landscape Architect, at the Contractor's expense.

3.04 BIORETENTION SOIL MIX PLACEMENT

A. The Contractor shall not place BSM until the Engineer/Landscape Architect has reviewed and confirmed the following:

1. BSM delivery ticket(s): Delivery tickets shall show that the full delivered amount of BSM matches the product type, volume and manufacturer named in the submittals. Each delivered batch of BSM shall be accompanied by a certification letter from the supplier verifying that the material meets specifications and is supplied from the approved BSM stockpile.

2. Visual match with submitted samples: Delivered product will be compared to the submitted 1-gallon sample, to verify that it matches the submitted sample. The Engineer/Landscape Architect may inspect any loads of BSM on delivery and stop placement if the soil does not appear to match the submittals; and require sampling and testing of the delivered soil to determine if the soil meets the requirements of Section 2.01 before authorizing soil placement.

3. Inspection of the aggregate storage layer, underdrain, cleanout, and overflow structure installation, where included on the plans.

DESIGNER NOTE: On larger projects, it may be appropriate to require that the testing specified in Section 2.01 be performed on samples taken at the supplier's yard from the stockpile to be used for the project; see designer note in Section 1.06.C.2.

B. BSM placement, grading and consolidation shall not occur when the BSM is excessively wet, or has been subjected to more than 1/2 inch of precipitation within 48 hours prior to placement. Excessively wet is defined as being at or above 22 percent soil moisture by a General Tools & Instruments DSMM500

Precision Digital Soil Moisture Meter with Probe (or equivalent). A minimum of three readings with the soil moisture probe will be used to determine the average percent soil moisture reading per each truck load. There should be no visible free water in the material.

C. The Contractor shall place BSM loosely with a conveyor belt or with an excavator or loader from a height no higher than 6 feet, unless otherwise approved by the Engineer/Landscape Architect (i.e., do not dump material directly from truck into cell). Soil shall be placed upon a prepared subgrade in accordance with these Specifications and in conformity with the lines, grades, depth, and typical cross-section shown in the Drawings or as established by the Engineer/Landscape Architect.

D. Excessively dry BSM may be lightly and uniformly moistened, as necessary, to facilitate placement and workability.

E. Compact BSM using non-mechanical compaction methods (e.g., boot packing, hand tamping, or water consolidation) to 83 percent (+/- 2 percent) of the maximum dry density per modified Proctor test (ASTM D1557), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6938. Moisture content determination shall be conducted on a soil sample taken at the location of the nuclear gage reading per ASTM D2216.

DESIGNER NOTE: BSM compaction target density will be updated as more data from installed projects becomes available on the optimal compaction to minimize settlement while maintaining the infiltration capacity of the media. Designers are encouraged to report field density measurements, observed infiltration rates (if available), and anecdotal field observations (e.g., soil appears well draining, settlement observed minimal).

F. Grade BSM to a smooth, uniform surface plane with loose, uniformly fine texture. Rake, remove ridges, and fill depressions to meet finish grades.

G. Final soil depth shall be measured and verified only after the soil has been compacted. If after consolidation, the soil is not within +/- 3/4 inch of the grades and slopes specified on the Plans, add material to bring it up to final grade and raked.

H. The BSM shall be inspected and accepted for placement and finish grade by the Engineer/Landscape Architect prior to the installation of planting and mulch. Any BSM that does not conform to this Specification shall be remediated to the satisfaction of the Engineer/Landscape Architect, or removed and replaced with acceptable BSM, at the Contractor's expense.

3.05 PLANTING AND MULCHING

A. Bioretention facilities shall be planted and mulched as shown on the Plans.

B. Bioretention facilities shall not be planted or mulched when soils are excessively wet as defined in Section 3.04.

C. Bioretention facility areas contaminated by sediment laden runoff prior to planting or placement of mulch shall be remediated at the Contractor's expense by removing the contaminated BSM (top 3 inches minimum) and replacing with BSM per Section 2.01, to the lines and grades on the Plans.

D. All mulch shall be inspected and accepted by the Engineer/Landscape Architect to ensure appropriate depth and material prior to facility commissioning (e.g., unblocking of inlets).

DESIGNER NOTE: Planting and mulching requirements shall be determined by the designer and included or referenced herein.

3.06 FLOOD TESTING

A. Inlets shall be constructed per the Plans and free from all obstructions prior to commencing flow testing.

B. Testing shall be conducted at the conclusion of the 90-day plant grow-in period. Protection and flow diversion measures installed to comply with Section 01 57 29 Temp Protection of GI Facilities shall be removed in their entirety prior to commencing flow testing.

C. Underdrains shall be plugged at the outlet structure to minimize water consumption during testing.

D. Prior to testing, broom sweep gutter and other impervious surfaces within the test area to remove sediments and other objectionable materials.

E. The Engineer/Landscape Architect shall be present during the demonstration. The Contractor shall notify the Engineer/Landscape Architect a minimum of 2 working days prior to testing.

F. The Contractor shall water test each facility to demonstrate that all inlet curb openings are capturing and diverting all water in the gutter to the facility, outlet structures are engaging at the elevation specified, and the designed ponding depth is achieved. Testing shall include application of water from a hydrant or water truck per Section 00 73 73, Article 3.04 (Requirements for Using Water For Construction), at a minimum rate of 10 gallons per minute, into the gutter a minimum of 15 feet upstream of the inlet curb opening being tested. Each inlet shall be tested individually. If erosion occurs during testing, restore soils, plants, and other affected materials.

DESIGNER NOTE: Designer should update test flow rate for inlets to reflect project-specific design, as needed.

G. Engineer/Landscape Architect will identify deficiencies and required corrections, including but not limited to relocating misplaced plants, adjusting streambed gravel, adjusting mulch, adjusting inlets, splash pads, and forebays, removing and replacing inlets, and removing debris.

H. Once adjustments are made, the Contractor shall re-test to confirm all test water flows into the facility from the gutter and correct any remaining deficiencies identified by Engineer/Landscape Architect.

I. Inlets, outlets, and other bioretention facility appurtenances shall not be accepted until testing and any required correction and retesting is complete and accepted by the Engineer/Landscape Architect.

DESIGNER NOTE: The Owner may, at any time, conduct additional testing on all materials submitted, delivered, or in-place, to ensure compliance with the Specifications. Testing may include permeability testing per ASTM D2434 (Modified), density testing per ASTM D6938, etc., if the Engineer/Landscape Architect suspects the facility does not conform to these specifications (e.g., as evidenced by lower than anticipated infiltration capacity).

DESIGNER NOTE: Designer should consider adding a similar requirement to the Concrete Paving and Sanitary Sewerage Utilities sections of the Specifications, as needed.

END OF SECTION

Exhibit A: Biotreatment Soil Media Specification Verification Checklist

This Biotreatment Soil Media (BSM) Verification checklist is intended to assist municipal staff, contractors, designers and others with an easy-to-read summary of the information needed to verify that the biotreatment soil media being provided by the soil media supplier meets the soil media specification in the Bay Area Stormwater Management Agencies Association (BASMAA) "Specification of Soils for Biotreatment or Bioretention Facilities" dated April 18, 2016. . The checklist was most recently updated in 2021 with the current program websites. The checklist shall be provided to the soil media supplier by the municipality or contractor before the soil media has been ordered to allow for sufficient time to compile the information and time to review the completed checklist before delivery of the soil media to the job site.

Use of this checklist is not required by the MRP and is intended only for assistance in reviewing submittals. The checklist is divided into four parts for each of the four parties involved with the testing and production of the BSM product: the BSM supplier, the sand supplier and testing laboratory, the compost supplier and the compost testing laboratory. Each party is required to fill out their section of the checklist. Additionally, the Supplier Certification Statement shall be requested from the Supplier to guarantee that the product meets the specification.

The Certification Statement, a list of soil media suppliers, the BASMAA specification and other materials are available at the following websites:

- Santa Clara Valley Urban Runoff Pollution Prevention Program: www.scvurppp.org/newdev/

Tthe following five items are required to be submitted by the soil media Supplier to the requesting municipality or contractor:

- **Sample of the Biotreatment Soil Media**
  A minimum 1-gallon bag of soil media.
- **Attachment A – Supplier Analysis of the Biotreatment Soil Media**
  To be completed by the soil media supplier staff providing the soil media.
- **Attachment B – Lab Analysis of Sand Component of the Biotreatment Soil Media**
  To be completed by the laboratory staff conducting the analysis of the sand.
- **Attachment C – Lab Analysis of Compost Component of the Biotreatment Soil Media**
  To be completed by the laboratory staff conducting the analysis of the compost. Compost analysis of a sample collected (in accordance with the Seal of Testing Assurance [STA] sample collection protocol) shall be completed within the last 120 days. Analysis must be completed by a laboratory enrolled in the US Composting Council's (USCC) Compost Analysis Proficiency (CAP) program, and shall use the Test Methods for the Examination of Composting and Compost (TMECC).
- **Attachment D – Supplier Analysis of Compost Component of the Biotreatment Soil Media**
  To be completed by the compost supplier staff providing the compost component of the soil media.

Attachment A

Supplier Analysis of Biotreatment Soil Media

The table below shall be completed by the biotreatment soil media supplier staff.

Date: **(All lab tests must be done within the last 120 days)**	**Name of Person Filling Out This Form:**
Title:	**Signature:**
Phone:	**Email:**
Company Name:	**City:**
Street Address:	**Zip:**

I certify that the provided biotreatment soil media meets the requirements of the BASMAA 2016 specification.	☐ Yes (Pass) ☐ No (Fail)

Describe the equipment and methods used to mix the compost and sand components of the biotreatment soil media.	

Material	Standard Percent (by volume)	Actual Media %	Pass	Fail
Sand	60% - 70%		☐	☐
Compost	30% - 40%		☐	☐

Does the soil media have a permeability of at least 5 inches per hour?[1]	☐ Yes (Pass) ☐ No (Fail)
Will the soil media support vigorous plant growth?	☐ Yes (Pass) ☐ No (Fail)

[1]Soil media permeability testing is only required for alternative biotreatment soil media. Soil permeability tests must be conducted on a minimum of two samples using constant head permeability in accordance with ASTM D2434 with a 6-inch mold and vacuum saturation.

Attachment B

Lab Analysis of Sand Component of Biotreatment Soil Media

The table below shall be completed by the laboratory staff conducting the sand analysis.

Name of Person Filling Out This Form:	**Signature:**
Title:	**Date:**
Phone:	**Email:**
Company:	**City:**
Street Address:	**Zip:**
Qualifications & relevant certifications (ASTM, CTM or approved equivalent certifications):	

Is sand free of wood, waste, coating (such as clay, stone dust, carbonate, etc.), or any other deleterious material?	☐ Yes (Pass) ☐ No (Fail)
Is all aggregate passing the No. 200 sieve non-plastic?	☐ Yes (Pass) ☐ No (Fail)

Particle size analysis shall be conducted in accordance with ASTM D 422 (Standard Test Method for Particle Size Analysis of Soils) or CTM 202. Other equivalent methods acceptable only if approved.

Sieve Size	Standard Percent Passing (% by weight)	Testing Results (%)	Pass	Fail
3/8 inch	100%		☐	☐
No. 4	90% - 100%		☐	☐
No. 8	70% - 100%		☐	☐
No. 16	40% - 95%		☐	☐
No. 30	15% - 70%		☐	☐
No. 40 or 50	5% - 55%		☐	☐
No. 100	0% - 15%		☐	☐
No. 200	0% - 5%		☐	☐

Attachment C

Lab Analysis of Compost Component of Biotreatment Soil Media

The table below shall be completed by the laboratory staff conducting the compost analysis.

Name of Person Filling Out This Form:	**Signature:**
Title:	**Date:**
Phone:	**Email:**
Company:	**City:**
Street Address:	**Zip:**
Qualifications & relevant certifications: **(USCC, ASTM or approved equivalent certification)**	

Specification	Standard	Testing Results		Pass	Fail
Organic Matter Content	35% - 75% (by dry weight)		%	☐	☐
Carbon-to-Nitrogen Ratio	15:1 to 25:1 (C:N)		C:N	☐	☐
Salinity	< 6.0 mm hos/cm		mm hos/cm	☐	☐
pH	6.2 - 8.2		pH	☐	☐
Bulk Density	500 – 1100 dry lbs / yd^3		dry lbs / yd^3	☐	☐
Moisture Content	30%-55% (of dry solids)		%	☐	☐
Percent inert ingredients (incl. plastic, glass, paper)	< 1% (by weight or volume)		%	☐	☐

Provide the results of <u>at least one</u> of the following analyses to indicate compost stability:

Specification	Standard	Testing Results		Pass	Fail
Oxygen Test	< 1.3 0_2 /unit TS/hr		0_2 /unit TS/hr	☐	☐
Specific Oxygen Test	< 1.5 0_2/unit BVS/hr		0_2/unit BVS/hr	☐	☐
Respiration Test	< 8mg CO_2-C/g OM/day		mgCO_2-C/g OM/day	☐	☐
Dewar test	< 20 ˚C Temp. rise e.		˚C Temp. rise e.	☐	☐
Solvita® Index value	> 5 Index value		Index value	☐	☐

Provide the results of at least one of the following analyses to indicate compost toxicity:

Specification	Standard	Testing Results		Pass	Fail
Ratio (NH_4^+-N: NO_3^--N)	< 3		NH_4^+-N: NO_3^--N	☐	☐
Ammonium	< 500 ppm, dry basis		ppm, dry basis	☐	☐
Seed Germination	> 80% of control		% of control	☐	☐
Plant Trials	> 80% of control		% of control	☐	☐
Solvita® Index value	= 5 Index value		Index value	☐	☐

Provide the analysis of the nutrient content of the compost, including the following:

Specification	Standard	Testing Results		Pass	Fail
Boron (total B)	< 80 ppm		ppm	☐	☐
Nitrogen (total N)	> 0.9% preferred		%		
Phosphorus (as P_2O_5)	*[not specified]*		%		
Potassium (as K_2O)	*[not specified]*		%		
Calcium (Ca)	*[not specified]*		%		
Sodium (Na)	*[not specified]*		%		
Magnesium (Mg)	*[not specified]*		%		
Sulfur (S)	*[not specified]*		ppm		

Provide the results of at least one of the following select pathogens:

Specification	Standard	Testing Results		Pass	Fail
Salmonella	< 3 MPN/4 grams TS		MPN/4 grams TS	☐	☐
Coliform Bacteria	< 10,000 MPN/gram		MPN/gram	☐	☐

Does the product meet US EPA, 40CFR 503 regulations regarding trace contaminants metals (Lead, Mercury, etc.)?	☐ Yes (Pass) ☐ No (Fail)

Particle size analysis shall be conducted in accordance with ASTM D 422 (Standard Test Method for Particle Size Analysis of Soils)-washing not required. Equivalent methods acceptable if approved.

Sieve Size	Standard Percent Passing (by weight)	Testing Results (%)	Pass	Fail
1 inch	**99% - 100%**		☐	☐
½ inch	**90% - 100%**		☐	☐
¼ inch	**40% - 90%**		☐	☐
No. 200	**1% - 10%**		☐	☐

Attachment D

Supplier Analysis of Compost Component of Biotreatment Soil Media

The table below shall be completed by the compost supplier providing the compost for the media.

Name of Company:	**Date of Delivery:**
Qualifications & relevant certifications: **(USCC, ASTM or approved equivalent certifications)**	**Date of the Compost Lab Analysis Report:** **(Must be dated within 120 days prior to delivery)**
Name of Person Filling Out This Form:	**Date:**
Signature:	**Street Address:**
Email address:	**City:**
Phone:	**Zip:**

Feedstock materials have been specified and include only the following: Landscape/yard trimmings, grass clippings, food scraps, or agricultural crop residues?	☐ Yes (Pass) ☐ No (Fail)
Compost has a dark brown color and a soil-like odor, does not exhibit a sour or putrid smell, does not contain recognizable grass or leaves, and is not hot (120˚F) upon delivery or rewetting?	☐ Yes (Pass) ☐ No (Fail)
The compost has gone through the process to further reduce pathogens (PFRP)? For example, turned windrows must reach a minimum temperature of 55˚C for 15 days with at least 5 turnings during that period.	☐ Yes (Pass) ☐ No (Fail)

EXHIBIT B: VERIFICATION OF ALTERNATIVE BIORETENTION SOIL MIXES

Bioretention soils not meeting the above criteria shall be evaluated on a case by case basis. Alternative bioretention soil shall meet the following specification: "Soils for bioretention facilities shall be sufficiently permeable to infiltrate runoff at a minimum rate of 5 inches per hour during the life of the facility, and provide sufficient retention of moisture and nutrients to support healthy vegetation."

The following steps shall be followed by municipalities and documented with the Biotreatment Soil Media Specification Verification Checklist to verify that alternative soil mixes meet the required specification:

1. General Requirements – Bioretention Soil shall achieve a long-term, in-place infiltration rate of at least 5 inches per hour. Bioretention Soil shall also support vigorous plant growth. The applicant refers to the entity proposing the soil mixture for approval.
   a. Submittals – The applicant must submit to the municipality for approval:
      (1) A minimum one-gallon size sample of mixed bioretention soil.
      (2) Certification from the soil supplier or an accredited laboratory that the Bioretention Soil meets the requirements of this guideline specification.
      (3) Certification from an accredited geotechnical testing laboratory that the Bioretention Soil has an infiltration rate between 5 and 12 inches per hour as tested according to Section 1.b.(2)(ii).
      (4) Organic content test results of mixed Bioretention Soil. Organic content test shall be performed in accordance with by Testing Methods for the Examination of Compost and Composting (TMECC) 05.07A, "Loss-On-Ignition Organic Matter Method".
      (5) Grain size analysis results of mixed Bioretention Soil performed in accordance with ASTM D 422, Standard Test Method for Particle Size Analysis of Soils.
      (6) A description of the equipment and methods used to mix the sand and compost to produce Bioretention Soil.
      (7) The name of the testing laboratory(s) and the following information:
         (i) Contact person(s)
         (ii) Address(s)
         (iii) Phone contact(s)
         (iv) E-mail address(s)
         (v) Qualifications of laboratory(s), and personnel including date of current certification by STA, ASTM, or approved equal
2. Bioretention Soil
   (1) Bioretention Soil Texture: Bioretention Soils shall be analyzed by an accredited lab using #200, and 1/2" inch sieves (ASTM D 422 or as approved by municipality), and meet the following gradation:

Sieve Size	Percent Passing (by weight)	
	Min	***Max***
1/2 inch	97	100
No. 200	2	5

(2) Bioretention Soil Permeability testing: Bioretention Soils shall be analyzed by an accredited geotechnical lab for the following tests:

(i) Moisture – density relationships (compaction tests) shall be conducted on bioretention soil. Bioretention soil for the permeability test shall be compacted to 85 to 90 percent of the maximum dry density (ASTM D1557).

(ii) Constant head permeability testing in accordance with ASTM D2434 shall be conducted on a minimum of two samples with a 6-inch mold and vacuum saturation.

MULCH FOR BIORETENTION FACILITIES

Three inches of mulch is recommended for the purpose of retaining moisture, preventing erosion and minimizing weed growth. Projects subject to the State's Model Water Efficiency Landscaping Ordinance (or comparable local ordinance) will be required to provide at least three inches of mulch. Aged mulch, also called compost mulch, reduces the ability of weeds to establish, keeps soil moist, and replenishes soil nutrients. Aged mulch can be obtained through soil suppliers or directly from commercial recycling yards. It is recommended to apply 1" to 2" of composted mulch, once a year, preferably in June following weeding.

EXHIBIT C: COMPOSTED WOOD MULCH SPECIFICATION FOR STORMWATER BIOTREATMENT AREAS

Overview: This specification for composted wood-based mulch was developed for use in engineered stormwater biotreatment areas. The specification provides for a consistent mulch product that enhances water quality; improves water retention and plant health; has been treated to reduce any potential pathogens, insects or invasive weed seeds; and has reduced floating and migration potential. There are three parts of the specification: feedstocks, processing and testing.

A. Feedstocks: This mulch shall be derived from plant debris with at least 90% consisting of clean (minimal trash) woody vegetation such as "Arbor Mulch" (i.e., tree trunks, branches, stumps, and brush). Up to 10% by volume may be derived from other clean source-separated feed stocks, such food scraps, and/or other woody materials, such as clean uncoated lumber.[1]

B. Processing: These feedstock materials shall be: 1) composted; 2) meet the PFRP (Process to Further Reduce Pathogens) standard to reduce weed seeds, pathogens, and deleterious materials under 14 CA Code of Regs §17868.3 (i.e., reaching the required minimum temperature of 55 degrees Celsius for the required length of time[2]); and 3) screened to meet the specifications in Table 1 below[3]. No dyes or gorilla hair (fiber mulch) shall be used in the finished mulch product.

C. Testing and laboratory-related requirements: All testing of the mulch product shall be completed within 120 days prior to delivery to the site by an STA Program-approved laboratory[4]. A 3- to 4-gallon sample of the mulch product shall be submitted to the laboratory for testing, to provide enough fines from the product to complete the specific testing procedures.

Table 1: Specifications for Composted Wood Mulch for Stormwater Biotreatment Areas

Property	Test Method/Units[5]		Requirement	
1. pH	TMECC 04.11-A	Elastomeric pH 1:5 slurry method (pH units)	6.0 – 8.5	
2. Soluble salts	TMECC 04.10-A	Electrical conductivity 1:5 slurry method (dS/m or mmhos/cm)	≤ 6.0	
3. Moisture Content	TMECC 03/09-A	Total solids & moisture at 70±5 °C (% wet weight basis)	30-55%	
4. Organic matter content	TMECC 05.07-A	Loss-on-ignition organic matter method (% dry weight basis)	≥ 65	
5. Maturity	TMECC 05.05-A	Germination and vigor (% relative to positive control)	--	
		Seed emergence	≥ 80	
		Seedling vigor	≥ 80	
6. Stability	TMECC 05.08-B	Carbon dioxide evolution rate (mg CO_2-C/g OM per day)	≤ 5	
7. Pathogen	TMECC 07.01-B	Salmonella (MPN per 4 grams, dry weight basis)	< 3	
8. Pathogen	TMECC 07.01-B	Fecal coliform bacteria (MPN per gram, dry weight basis)	< 1,000	
9. Physical contaminants	TMECC 02.02-C	Human-made inert removal and classification: plastic, glass, and metal (% > 4 mm fraction)	combined total: < 0.5%	
10. Physical contaminants	TMECC 02.02-C	Film plastic: (% > 4 mm fraction)	< 0.1%	
11. Sizing	TMECC 02.02-B	Sample sieving for aggregate size classification (% dry weight basis)	**Min**	**Max**
		Pass 3-inch sieve	100%	--
		Pass 2-inch sieve	90%	--
		Pass 3/8-inch sieve	20%	40%

[1] Unacceptable feedstocks: dyed mulches, plywood, laminated wood products, glued laminated timber (Glulam), oriented strand board (OSB), painted wood, stained wood, pressure-treated wood or other treated wood waste (TWW), or any other manufactured wood products with non-wood ingredients, such as adhesives, or wood treated with chemicals of any kind. Metal concentrations in compost must not exceed the maximum listed in 14 CA Code of Regs §17868.2.

[2] https://govt.westlaw.com/calregs (§17868.3. Pathogen Reduction)

[3] Based on the Caltrans specification for "Coarse Compost" with modifications for use in biotreatment systems.

[4] List of approved testing laboratories: www.compostingcouncil.org/page/CertifiedLabs

[5] TMECC refers to "Test Methods for the Examination of Composting and Compost," published by the United States Department of Agriculture and the United States Compost Council (USCC).

Section 32 12 43 – Porous Asphalt Concrete

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Green text corresponds to notes to the designer.

PART 1 GENERAL

1.01 SUMMARY

A. This section includes:

1. Porous Asphalt Pavement

2. Pavement Base

3. Geotextile for Soil Separation

B. Related Sections:

DESIGNER NOTE: The designer should list any additional specification sections which relate to the porous asphalt work (i.e., traffic control, temporary erosion control, utilities, earthwork, etc.)

1.02 STANDARDS AND CODES

A. Reference Standards: This section incorporates by reference the latest revisions of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications (published by State of California Business, Transportation, and Housing Agency, Department of Transportation)
San Francisco DPW	Engineering Standard Specifications
AASHTO	Standards of the American Association of State Highway and Transportation Officials, 1998 or latest edition
ASTM	Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition.
NAPA IS 115	Design, Construction, and Maintenance of Open-Graded Asphalt Friction Courses
NAPA IS 131	Porous Asphalt Pavements for Stormwater Management, Design, Construction, and Maintenance.

1. Caltrans Standard Specifications: Any references to Caltrans Standard Specifications invoke technical specifications in Section 39 for material, construction, and quality control and quality assurance only. Caltrans contractual requirements, general specifications, and measurement and payment do not apply.

2. Caltrans Standard Specifications Term Equivalencies

Terms Equivalencies	
Term or Clause in Caltrans Standard Specifications	**Term or Clause in These Specifications**
The Department	The Owner
OGFC	Porous Asphalt

1.03 REFERENCES

DESIGNER NOTE: Designer to provide references to related industry manuals and guidance and all project specific documents (e.g., geotechnical report).

1.04 SUBMITTALS

A. Bid Submittals: The Contractor shall submit to the Owner the following as part of the bid proposal:

1. Project experience and personnel qualification examples as specified in Section 1.05.B for the contractor and personnel assigned to this project.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

B. Pre-Installation Submittals: Submittals shall conform to the requirements of Caltrans Standard Specifications including:

1. Proposed job mix formula per Section 1.05.B of this Specification.

2. Proposed QC plan per Section 39-1.04A (General Requirements for Contractor Quality Control) and Section 39-2.02A (Quality control plan requirements for the "Standard Construction Process"). The QC Plan shall satisfactorily test the porous asphalt for compliance with Section 39-2.02B (Quality Control for Standard Construction Process) of the Caltrans Standard Specifications, with the following modifications and additions:

a. Aggregate durability index shall be tested in accordance with Caltrans Test Method 229 at least one time per each 750 tons of porous asphalt.

b. Aggregate cleanliness value shall be tested in accordance with Caltrans Test Method 227 at least one time per each 750 tons of porous asphalt.

c. Air voids shall be tested for by determining the bulk specific gravity in accordance with ASTM D6752 or AASHTO T275, the maximum theoretical specific gravity with AASHTO T209, and the voids by test ASTM D3203.

d. Draindown shall be tested in accordance with ASTM D6390.

e. Retained tensile strength shall be tested in accordance with AASHTO 283.

f. Three (3) surface infiltration tests per ASTM C1701 shall be conducted per 10,000 square feet of porous asphalt, in place and one (1) additional test per 5,000 square feet of porous asphalt, or fraction thereof, in place. Document and record the results of each field infiltration test with a designated test number. Include infiltration rate, date pavement was placed, date test was taken, and location on the site (via stationing or other means) where test was performed in each test record. If minimum required field infiltration rate is not achieved at any location as defined in this Section, re-test for field infiltration rate at a new location for each failed field infiltration test. Coordinate location with Owner's Representative.

The QC plan shall be consistent with the Caltrans Quality Control Quality Assurance Manual for Asphalt Concrete Production and Placement (latest version).

In addition to the Caltrans submittal requirements, the Contractor shall submit the following:

3. Source certificates, gradations, R-values, LA abrasion, and cleanness values of aggregates for base and reservoir course materials performed within one (1) month of product delivery to site.

4. Product data sheets for geotextiles.

5. Testing agency qualifications as specified in Section 1.05.A.

1.05 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect asphalt materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

DESIGNER NOTE: This specification does not include a test panel/mockup due to the difficulty of installation and because physical properties of the material are known from the plant test. Consider whether project design objectives warrant the cost of a test panel/mockup.

1. Contractor and Personnel Qualifications

DESIGNER NOTE: The designer should adjust the required qualifications for the contractor and personnel based on the availability of qualified bidders and project size, complexity, and risk.

a. Contractor qualification: The Contractor shall provide documentation showing one of the following for the general contractor or paving subcontractor:

1) One (1) example owner-accepted porous asphalt project, similar (or greater) in extent to the proposed project, completed in the last one (1) year with reference.

OR

2) Three (3) example owner-accepted open graded friction course projects completed in the last one (1) year with references.

Documentation shall include name and address of project, and contact information for project owner.

b. Personnel qualification: The Contractor or paving subcontractor shall provide a qualified foreman with experience installing porous asphalt and documentation showing with following:

1) One (1) example owner-accepted porous asphalt project, similar (or greater) in extent to the proposed project, completed in the last one (1) year with reference.

Documentation shall include name and address of project, and contact information for project owner.

The qualified foreman shall be onsite for the duration of asphalt work including preparation, placement, testing, and completion.

c. Testing agency qualification: Agencies that perform testing on porous asphalt materials shall meet the requirements of Caltrans Standard Specification Section 39-1.03A or be accredited by the AASHTO Accreditation Program (AAP) for the scope and standard being evaluated.

d. Plant qualification: Batch or continuous mixing plants used for porous asphalt shall meet the requirements of Caltrans Standard Specification Section 39-1.08A.

B. Authorized Job Mix Formula (JMF): The mix design process shall conform to Caltrans Specification Section 39-1.03 except as noted below.

1. The final paragraph under Section 39-1.03A is deleted and replaced with the following:

a. Submit a complete JMF submittal including identification of asphalt binder percentage in form CEM-3511 Contractor Job Mix Formula Proposal. Determine the optimum asphalt binder content using California Test 368 in a lab that meets the requirements of 1.05.A. of these specifications.

The products used in the JMF shall meet the requirements in Section 2.01 of this Specification.

The JMF shall meet the quality characteristics defined in Section 39-2.02B (Quality Control for Standard Construction Process) with the modified and additional quality characteristics listed in the table below.

Quality Characteristics	Test Method	Requirement
Aggregate Durability Index	CT 229	DI >= 35
Aggregate Cleanness Value	CT 227	CV >= 75
Air Void Content by Corelok (%)[1]	ASTM D6752 (with AASHTO T209 and ASTM D3203)	16–20%
Air Void Content by Paraffin Wax (%)[1]	AASHTO T275 (with AASHTO T209 and ASTM D3203)	18–22%
Draindown (% of total weight)	ASTM D6390	<= 3%
Retained Tensile Strength (%)	AASHTO 283	>= 80%
Infiltration Rate (Average Inches per Hour)	ASTM C1701	See Note 2.

[1] Either method of determining air void content is acceptable.

[2] The finish surface shall yield an infiltration rate that is consistent with the following: The average infiltration rate from three (3) infiltration tests conducted per ASTM C1701 shall be greater than 100 inches per hour with no single test less than 50 inches per hour. Water shall infiltrate rapidly and uniformly through the surface without formation of large puddles when applied at a rate of 5 gallons per minute (gpm).

2. Once verified and accepted by the Engineer, the JMF meeting the criteria above shall become the Authorized JMF. Acceptance of the JMF shall be per Caltrans Standard Specification Section 39-1.03G, except that verification of the JMF by the City of San Francisco shall be considered equivalent to verification of the JMF by Caltrans. Any adjustments or renewals of the JMF shall be per Caltrans Standard Specifications Section 39-1.03 (Hot Mix Asphalt Mix Design Requirements). Submit a letter from the asphalt supplier with the recommended temperature ranges for mixing, laying, breakdown rolling, and finished rolling, as well as the recommended maximum temperature of the finished mat before placement of subsequent lifts.

C. Responsibilities of Contractor

1. General: Conform to the requirements set forth in Section 39-1.04 (Contractor Quality Control) and Section 39-2.02 (Standard Construction Process Contractor Quality Control) of the Caltrans Standard Specifications.

2. Pre-Placement Conference: A mandatory pre-placement conference will take place, including at a minimum the Engineer, the Owner, the general Contractor, and paving subcontractor, to review preparation, placement, testing procedures, and responsibilities.

3. Quality Control: Contractor quality control inspection and testing of porous asphalt shall be conducted in accordance with the approved QC plan.

4. Load Slip: Provide a load slip certified by a licensed weightmaster showing combined mixture weight for each load of porous asphalt transported to the location.

5. Infiltration Rate Testing: Perform surface infiltration tests per ASTM C1701 as described below.

    a. Three (3) test locations per 10,000 square feet of porous asphalt in place.

    b. One (1) additional test location per 5,000 square feet of porous asphalt, or fraction thereof, in place.

    DESIGNER NOTE: Designer to specify the number and location(s) of required post-construction infiltration tests.

6. Required Inspections: Notify the Engineer at least 5 business days prior placement of porous asphalt.

7. Failed Tests: Each test shall meet the acceptance criteria as defined in this section. For any single quality characteristic except smoothness, if two consecutive quality control test results do not comply with the action limits or specifications:

    a. Stop production.

    b. Notify the Engineer.

    c. Take corrective action.

    d. Demonstrate compliance with the specifications before resuming production and placement.

DESIGNER NOTE: The following table is a Sample Contractor Quality Control Sampling and Testing Plan; it is provided to illustrate the type and frequency of testing that may be required The Contractor will need to develop a similar table as part of their QC plan. Frequency and standard for all tests should be project specific.

Sample Contractor Quality Control Sampling and Testing Plan						
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Contractor Responsibility**	**Attribute or Tolerance**	
Plant Operations						
Aggregate Gradation	CT 202	1/750 tons	Plant	Plant Inspector	1/2"	TV ± 6
					3/8"	TV ± 6
					No. 4	TV ± 7
					No. 8	TV ± 5
					No. 30	TV ± 4
					No. 200	TV ± 2
Asphalt Binder Content	CT 382	Daily	Plant	Plant Inspector	Design ± 0.5%	
Percent of crushed particles coarse aggregate (%, min) One fractured face Two fractured faces Fine aggregate (%, min) (Passing no. 4 sieve and retained on no. 8 sieve.) One fractured face	CT 205	1/project	Plant	Plant Inspector	 90 75 90	
Los Angeles Rattler (%, max) Loss at 100 rev. Loss at 500 rev.	CT 211	1/project	Plant	Plant Inspector	 12 40	
Aggregate Durability Index	CT 229	1/750 tons	Plant	Plant Inspector	DI > 35	
Aggregate Cleanness Value	CT 227	1/750 tons	Plant	Plant Inspector	CV > 75	
Asphalt Temp.	Recorded	Continuous	Plant	Plant Inspector	120–190	
Plant Mix Temperature	Recorded	Continuous	Plant	Plant Inspector	165 Maximum	
Aggregate moisture content	CT 226	2/day	Plant	Plant Inspector	For adjusting the plant controller at the HMA plant	
Flat and elongated particles (%, max by weight @ 5:1)	CT 235	1/project	Plant	Plant Inspector	Report Only	

Sample Contractor Quality Control Sampling and Testing Plan					
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Contractor Responsibility**	**Attribute or Tolerance**
Street Operations					
Subgrade Preparation	Visual	Daily	Jobsite	Field Inspector	Smooth and Clean
Asphalt Paver & Hopper	Visual and Measure	Daily	Jobsite	Field Inspector	Manufacturer Standards
Compaction Equipment	Visual and Measure	Daily	Jobsite	Field Inspector	Manufacturer Standards
Compaction Process	Visual	Continuous	Jobsite	Field Inspector	Per Specifications
Pavement Temp. at Breakdown	Temperature Equipment	Hourly	Mat Behind Paver	Field Inspector	Per Specifications
Asphalt Binder Content	CT 382	Daily	Mat Behind Paver	Field Inspector/Tester	Design ± 0.5%
HMA Moisture Content (%, max)	CT 226	Daily	Mat Behind Paver	Field Inspector/Tester	1.0
Lift Thickness	Measured	Hourly	Mat Behind Paver	Field Inspector	Per Specifications
Pavement Temp. at Finish	Temperature Equipment	Daily	At Finish Roller	Field Inspector	Per Specifications
Air Void Content by Paraffin Wax (%)	AASHTO T275 (with AASHTO T209 and ASTM D3203)	Daily	Cores of Finished Surface	Field Inspector	16–20%
Tensile Strength	AASHTO 283	Daily	Cores of Finished Surface	Engineer	>= 80%
Long./Transverse Joints	Visual	Continuous	Pavement Joints	Field Inspector	Industry Standards
Smoothness	10 ft straightedge	Hourly	Finished Surface	Field Inspector	Per Specifications

Sample Contractor Quality Control Sampling and Testing Plan					
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Contractor Responsibility**	**Attribute or Tolerance**
Street Operations (continued)					
Infiltration Rate (average Inches per hour)	ASTM C1701	Three (3) test locations per 10,000 square feet of pervious asphalt, in place One (1) additional test location per 5,000 square feet of pervious asphalt, or fraction thereof, in place	Finished Surface	Field Inspector	Each Test: 50”/hr min Daily Avg.: 100”/hr min
Pavement Transitions	Visual	Daily	AC Transitions	Field Inspector	Per Specifications

D. Acceptance: Acceptance of porous asphalt shall be determined based on the criteria defined in Section 39-2.03A (Acceptance) of the Caltrans Standard Specifications, with the following modifications and additions:

1. Source aggregate will not be subject to acceptance testing once is has been approved as part of the JMF, unless samples are requested by the Engineer.

2. Air Voids: Air voids shall be tested for by determining the bulk specific gravity in accordance with ASTM D6752 or AASHTO T275, the maximum theoretical specific gravity with AASHTO T209, and the voids by test ASTM D3203.

3. Retained Tensile Strength: Retained tensile strength shall be tested in accordance with AASHTO 283.

Test results for air voids, draindown, and retained tensile strength shall be consistent with the characteristics of the approved JMF.

4. Infiltration Testing

a. Infiltration Rate Testing: The average of all surface infiltration tests shall be greater than 200 inches per hour with no single test less than 100 inches per hour.

DESIGNER NOTE: The designer should adjust infiltration rates to reflect project specific conditions such as anticipated sediment loading based on pavement use (e.g., vehicular, pedestrian) and design run-on from adjacent surfaces. The recommended criteria are as follows:

- For porous asphalt that will accept run-on from adjacent impervious and/or pervious surfaces OR pavement that will be subject to vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 200 inches per hour with no single test less than 100 inches per hour
- For porous asphalt not subject to run-on OR vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 100 inches per hour with no single test less than 50 inches per hour

b. Infiltration Visual Testing: Visual flood testing of the surface shall be conducted by application of clean water at the rate of at least 5 gpm over the surface, using a hose or other distribution devise. Water used for the test shall be clean, free of suspended solids and deleterious liquids and will be provided at no extra cost to the Owner. All applied water shall infiltrate directly without large puddle formation or surface runoff, and shall be observed by the

Engineer. The Engineer shall mark areas where large puddles form in the field. Areas with slow infiltration shall not exceed 10 percent of the total surface.

DESIGNER NOTE: Smoothness specification should be revised as needed to reflect project design objectives (e.g., smoothness specifications from Section 212 of the City Streets and Highways specifications).

5. Smoothness: Porous asphalt smoothness shall be checked with a 10-foot straightedge. Vertical measurement shall be taken between the pavement's determined plane and straight edge in a direction perpendicular and parallel to the centerline. The finished pavement shall be uniform to a degree such that no variations greater than 3/8-inch are present between the straightedge and pavement surface.

6. Grade: Porous asphalt shall be true to designed spot elevations plus or minus ½ inch and shall not deviate from designed slope more than ¼ inch in ten (10) feet. Where abutting existing facilities such as sidewalks, walkways, curbs, driveways or other pavements, the porous asphalt shall be flush.

7. Line: Porous asphalt margins shall be true to designed lines plus or minus ½ inch at any point.

8. Slope: Porous asphalt shall be sloped as shown on the Plans. Slope shall be consistent to within 1/4 inch in ten (10) feet.

9. Thickness: Each core sample shall be equal to the minimum section depth or more as specified on the Plans.

DESIGNER NOTE: Revise the load slip specification as needed to align with the measurement and payment specifications.

10. Load Slip: Each load of porous asphalt transported to the location of placement shall have a load slip delivered with the load that is certified by a licensed weightmaster and includes the combined mixture weight.

DESIGNER NOTE: Designer should specify consequences of any failed acceptance tests (e.g., reduced payment for lower infiltration rate and lower percent voids, reduced payment for failed smoothness tests) or if consequences are full replacement.

11. Reduced Payment Factors: The reduced payment factors in Caltrans Standard Specification 39-2.03A (Testing) do not apply.

DESIGNER NOTE: The following table is a Sample Owner Quality Assurance Sampling and Testing Plan is provided to illustrate the type and frequency of testing that may be required. Frequency and standard for all tests should be project specific.

Sample Owner Quality Assurance Sampling and Testing Plan					
Quality Characteristic	**Test Standard**	**Frequency**	**Sample Location**	**Responsibility**	**Attribute or Tolerance**
Plant Operations					
Street Operations					
Asphalt Binder Content	CT 382	Daily	Hopper	Engineer	Design ± 0.5%
HMA Moisture Content (%, max)	CT 226	Daily	Hopper	Engineer	1.0
Lift Thickness	Measured	Hourly	Cores of Finished Surface	Engineer	Per Specifications
Air Void Content by Paraffin Wax (%)	AASHTO T275 (with AASHTO T209 and ASTM D3203)	Daily	Cores of Finished Surface	Engineer	16–20%
Tensile Strength	AASHTO 283	Daily	Cores of Finished Surface	Engineer	>= 80%
Long./Transverse Joints	Visual	Continuous	Pavement Joints	Engineer	Per Specifications
Smoothness	10 ft straightedge	Hourly	Finished Surface	Engineer	Per Specifications
Infiltration Rate (average inches per hour)	ASTM C1701	3/day	Finished Surface	Engineer	Each Test: 50"/hr min Daily Avg.: 100"/hr min
Pavement Transitions	Visual	Daily	AC Transitions	Engineer	Per Specifications

PART 2 PRODUCTS

DESIGNER NOTE: If a product is not available, the designer needs to ensure that the desired voids and surface texture will meet the desired pavement characteristics for surface smoothness, voids, and bonding.

2.01 POROUS ASPHALT

Porous Asphalt mixture must comply with the approved Job Mix Formula (See Section 1.05 of this Specification). The components of the asphalt mixture must comply with the specifications below.

A. Asphalt Binder: Asphalt binder must comply with Caltrans Specification Section 92 except as noted below.

1. Performance Graded (PG) Asphalt Binder: PG asphalt binder must be PG 70-10 per Caltrans Specification Section 92-1.02B.

2. PG Polymer Modified Asphalt Binder:

PG polymer modified asphalt binder must be PG 76-22 PM per Caltrans Specification Section 92-1.02B for use in vehicular applications.

PG polymer modified asphalt binder must be either PG 64-28 PM or PG 76-22 PM per Caltrans Specification Section 92-1.02B for use in pedestrian applications.

B. Aggregates: Aggregates shall conform to Caltrans Specification Section 39-1.02E for Open Graded Friction Course (OGFC) with the following additions and modifications:

1. Durability Index: 35 (minimum) tested in accordance with California Test 229 at least once per 750 tons of porous asphalt.

2. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 750 tons of porous asphalt.

3. Aggregate for porous asphalt shall meet the following gradation:

Porous Asphalt Aggregate Gradation	
Sieve[1]	**Percent Passing by Weight**
3/4 inch	100
1/2 inch	85 to 100
3/8 inch	55 to 75
No. 4	10 to 25
No. 8	5 to 12
No. 30	0 to 10
No. 200	0 to 3

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

C. Materials Not to Be Used: The following materials shall not be used unless approved in advance by the Engineer.

1. Geosynthetic pavement interlayer

2. Tack Coat (except on vertical faces of curbs, edges of PCC structures, or when paving over areas with impermeable bases).

3. Asphalt Rubber Binder.

4. Crumb Rubber Modifier.

5. Reclaimed Asphalt Pavement.

6. Paint Binder per Section 212.06 of the DPW Standard Specifications

D. Job Mix Formula (JMF): The JMF shall comply with the requirements of Section 1.05.C of this Specification.

2.02 PAVEMENT BASE

A. Pavement Base Material shall consist of clean, mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Recycled materials are not permitted. The Material shall be obtained only from a source(s) approved by the Engineer. Written

requests for source approval shall be submitted to the Engineer not less than 10 Working Days prior to the intended use of the Material. Should the proposed source be one that the Engineer has no history of Material performance with, the Engineer reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract. The Engineer shall reserve the right to sample and test Material at any time including at the source.

B. Pavement Base shall consist of up to two (2) layers as specified on the Plans and included herein:

1. "Base Course" shall be ASTM No. 3 (modified) or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide structural (load bearing) capacity to the pavement.

2. "Reservoir Course" shall be ASTM No. 2 (modified), ASTM No. 3 (modified), or ASTM No. 57 (modified) stone per Section 2.02.C.

DESIGNER NOTE: This layer of the pavement base is intended to provide storage and drainage of the pavement, structural support, and a capillary break. The materials specified should be crushed, clean, washed gravel to provide the desired structural capacity, maintain good drainage, function as a capillary barrier, and minimize clogging of the subgrade due to export of fines.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying coarser graded materials or reduction in permeability relative to the underlying material. Refer to the SFPUC aggregate filter criteria guidance document for information on selecting appropriate alternate materials.

C. Pavement Base Material shall meet the following specifications for grading and quality.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 500 cubic yards of base material.

Sieve[1]	Percent Passing by Weight			
	ASTM No. 2 (modified)	ASTM No. 3 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)
3 inch	100	–	–	–
2 1/2 inch	90 to 100	100	–	–
2 inch	35 to 70	90 to 100	–	–

Sieve[1]	Percent Passing by Weight			
	ASTM No. 2 (modified)	ASTM No. 3 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)
1 1/2 inch	0 to 15	35 to 70	–	100
1 inch	–	0 to 15	–	95 to 100
3/4 inch	0 to 5	–	–	–
1/2 inch	–	0 to 5	100	25 to 60
3/8 inch	–	–	85 to 100	–
No. 4	–	–	10 to 30	0 to 10
No. 8	–	–	0 to 10	0 to 5
No. 16	–	–	0 to 5	–
No. 100[2]	0 to 2	0 to 2	0 to 2	0 to 2

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Gradation modified from ASTM for portion passing the No. 100 sieve.

2. R-Value: 78 (minimum) tested in accordance with California Test 301.

3. L.A. Abrasion: 30 percent (maximum) tested in accordance with ASTM C 131.

4. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.

5. Crushed Particles: 90 percent (minimum) with two (2) or more fractured faces tested in accordance with California Test 205.

6. The combined portion of Material retained on the U.S. No. 4 sieve shall not contain more than 0.1 percent wood waste by weight. The portion of Material passing a U.S. No. 10 sieve shall not have wood waste that results in more than 250 parts per million of organic matter by calorimetric tests when tested. The color shall be measured after the sample has been in the test solution for 1 hour.

2.03 GEOTEXTILE FOR SOIL SEPARATION

DESIGNER NOTE: Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of reservoir course and native soil.

A. Geotextile shall be woven, consisting only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation. The geotextile shall conform to the properties specified herein:

Geotextile Property	Test Method	Requirement
Grab Tensile Strength, minimum in weakest direction	ASTM D4632	200 lbs/in
Apparent Opening Size (AOS)	ASTM D4751	40 to 50
Ultraviolet (UV) Radiation Stability, minimum strength retained after 500 hours in weatherometer	ASTM D4355	50%
Flow Rate, minimum	ASTM D4491	140 gal/min/ft^2

DESIGNER NOTE: The designer should consider including specifications for signage and pavement markings in this section.

PART 3 EXECUTION

3.01 SUBGRADE PREPARATION AND PROTECTION

A. Construct subgrade to +/- ¾ inch of the grades and slopes specified on the Plans.

B. Grading of subgrade shall be with low ground pressure equipment when within six (6) inches of final subgrade elevation.

C. Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g., permeability, stiffness) and performance requirements for the pavement section (e.g., traffic loading, infiltration, cost).

D. Areas of the subgrade which are over-compacted, as determined by the Geotechnical Engineer, shall be ripped/tilled to a depth of 12 inches (minimum) or as directed by the Geotechnical Engineer, and shall be recompacted in accordance with 3.01.C. Contractor shall locate all utilities within pavement footprint prior to ripping and re-compacting subgrade

E. Proof-roll prepared subgrade with loaded dump truck, remove soft spots, and replace with permeable structural fill as directed by the Engineer to achieve uniform subgrade.

F. After compaction and proof roll, scarify subgrade ¼ to ½ inch deep by hand rake. Once scarified, materials or equipment shall not be permitted within the prepared subgrade area so as to avoid recompaction or clogging of the scarified subgrade.

G. The subgrade shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the subgrade during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

H. Areas of subgrade over-compacted by construction traffic or other impacts by the Contractor or Subcontractors shall be ripped/tilled and re-compacted in accordance with Section 3.01.D. All work and materials required to correct the over-compacted subgrade, including utility locates within the pavement footprint, shall be at the Contractor's expense.

I. Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor's expense.

J. The subgrade shall be inspected and accepted by the Engineer prior to placement of the geotextile or pavement base.

K. Place geotextile, if required, on scarified subgrade. Care shall be taken to provide full coverage and to prevent the geotextile from being torn. Damaged geotextile shall be repaired as indicated by the manufacturer and to the satisfaction of the Engineer, at the Contractor's expense. Overlaps of the geotextile shall be a minimum of 1 foot or to the manufacturer's recommendation, whichever is greater.

DESIGNER NOTE: The use of geotextile under permeable pavement systems should be avoided unless required by the project geotechnical engineer as it can be prone to subsurface clogging.

3.02 PAVEMENT BASE

A. Construct pavement base to the lines, grades, and thicknesses shown on the Plans.

B. Place the pavement base so as to prevent loaded dump trucks from driving directly on the prepared subgrade.

C. Compact pavement base, in six (6)-inch (maximum) lifts, by making a minimum of three passes over the pavement base material with a ten (10)-ton vibratory roller, or as directed by the Geotechnical Engineer. The first two (2) passes (minimum) shall be in vibratory mode. The final pass shall be in static mode. Acceptance of the pavement base will be based on Engineer's observation of aggregate movement during final compaction pass. Compaction equipment shall be accepted by the Engineer prior to use.

DESIGNER NOTE: For areas or sites that cannot accommodate a vibratory roller compactor, consider allowing compaction of pavement base with a 13,500 lbf (60 kN) minimum vibratory plate compactor with a compaction indicator. At least two passes should be made over each lift of the aggregates.

D. Pavement base shall be true to the designed grade and slope, +/- 0.05 feet, after compaction for each layer. In the event of low spots additional material

shall be added and recompacted. In the event of high spots, excess material shall be removed and the area recompacted.

E. The pavement base shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the pavement base during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

F. Any damage to the pavement base (including contamination by silty run-off) shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Contaminated pavement base shall be removed and replaced to the limits as determined by the Engineer.

G. The pavement base shall be inspected and accepted by the Engineer prior to placing any porous asphalt.

3.03 POROUS ASPHALT PREPARATION

DESIGNER NOTE: Designer should specify where a tack coat should be applied, if at all. See 3.03.A.2 for list of potential locations.

A. Preparation for placement of porous asphalt pavement shall comply with Section 39-1.09 of the Caltrans Standard Specifications, except as noted below.

1. Pavement Base: Confirm that the completed pavement base conforms to these specifications.

2. Tack Coat: Shall not be used except on vertical faces of curbs, edges of PCC structures, or when paving over areas with impermeable bases.

3. Geosynthetic Pavement Interlay: Shall not be used.

4. Environmental Conditions: Do not place porous asphalt when the ambient temperature is less than 60 degrees Fahrenheit, on any wet surface, or when the average ground surface temperature is less than 45 degrees Fahrenheit.

5. Qualified Personnel: The qualified foreman as defined in 1.05.B.2 shall be onsite for the duration of porous asphalt preparation.

3.04 POROUS ASPHALT PLACEMENT

DESIGNER NOTE: Designer should specify where a tack coat should be applied (e.g., face of curb, structures,) if at all.

A. Porous asphalt equipment, transportation, spreading, and compacting shall comply with the Caltrans Specification applicable to Open Graded Friction

Course (OGFC), except as noted below or as specified in the approved mix design.

B. Qualified Personnel: The qualified foreman as defined in 1.05.B.2 shall be onsite for the duration of porous asphalt placement.

C. Spreading and Compacting Equipment: shall conform to Section 39-1.10 of the Caltrans Standard Specifications except that pneumatic tire rollers shall not be used.

DESIGNER NOTE: The compaction could be established by the contractor rather than prescribed below depending on whether the contracting agency prefers to take a prescriptive approach or performance based approach. Prescriptive is used here because full depth porous asphalt is an emerging technology and there are limited density specifications for open graded (porous) asphalt mixtures. But care must be taken to ensure this prescriptive specification is compatible with the acceptance criteria.

D. Spreading and Compacting:

The type of rollers to be used and their relative position in the compaction sequence shall be dictated by the contractor provided the requirements below are met and the completed porous asphalt meets the required quality characteristics specified in Section 1.05. Deviation from the requirements below must be approved in advance by the Engineer.

1. The porous asphalt shall be laid in lifts of up to 4 inches in thickness using approved equipment to achieve the total thickness indicated in the Plans.

DESIGNER NOTE: Designer should consider using thinner lifts to the extent practical to ensure better compaction.

2. The temperature of the Porous HMA mix during laying, breakdown rolling, and finished rolling, shall be within the supplier-recommended temperature range.

3. Breakdown rolling shall be performed with one or two passes of a 7.5- to 10-ton vibratory roller operated in low amplitude mode when the mix temperature is within the supplier-recommended temperature range.

4. Finished rolling shall be performed with a double-drum finish roller operated in static mode when the mix temperature is within the supplier-recommended temperature range.

5. Finished paving shall be even, without pockets, and graded to elevations shown on the Plans. Finished porous asphalt shall meet the acceptance criteria for Smoothness set forth in Section 1.05.D.

DESIGNER NOTE: Designer should specify details of the straightedge test and tolerance if different than specified in Section 1.05E.

6. The Contractor shall take care to insure that the porous asphalt lifts join completely to previous lifts. The Contractor shall keep the time between lift placements to a minimum, keeping the surface of the previous lift clear from dust and moisture between lifts, and restrict traffic from initial lifts until the full depth of asphalt pavement has been placed.

7. Sufficient time shall be allowed between lifts to allow the asphalt to set and cool to at or below the supplier recommended maximum temperature for placement of subsequent lifts.

3.05 OPENING TO TRAFFIC

A. After final rolling, no vehicular traffic of any kind shall be permitted on the pavement surface until cooling and hardening has taken place, and in no case within the first six (6) hours. Provide traffic control measures as necessary to prevent vehicular use and remove when no longer required.

3.06 PROTECTION OF PAVEMENT

A. Hardened porous asphalt pavement surface shall be kept clean and free of clogging debris and soils from the Contractor's operations and all upstream and adjacent debris. If debris or soils contaminate the porous pavement voids, the pavement shall be cleaned at the Contractor's expense and to the satisfaction of the Engineer. If porous asphalt pavement cannot be unclogged, it shall be removed and replaced at the Contractor's expense and to the satisfaction of the Engineer.

3.07 REJECTION

A. Porous asphalt that does not meet the acceptance criteria set forth in Section 1.05.E will be rejected by the Engineer. Porous asphalt that has been rejected by the Engineer shall be removed and replaced at the Contractor's expense.

END OF SECTION

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints.

DESIGNER NOTE: Green text corresponds to notes to the designer. Blue text corresponds to requirements taken directly from ACI 522.1.

PART 1 GENERAL

1.01 SUMMARY

A. This section includes:

1. Pervious Concrete
2. Pavement Base
3. Geotextile for Soil Separation

B. Related Sections:

DESIGNER NOTE: The designer should list any additional specification sections which relate to the pervious concrete work (i.e., temporary erosion control, utilities, earthwork, etc.)

1.02 STANDARDS AND CODES

A. Reference Standards This section incorporates by reference the latest versions of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications
San Francisco DPW	Engineering Standard Specifications
AASHTO	Standards of the American Association of State Highway and Transportation Officials, 1998 or latest edition
ACI 522.1	Specifications for Pervious Concrete Pavement
ACI 301	Specifications for Structural Concrete
ACI 305.1	Standard Specifications for Hot Weather Concreting
ACI 306.1	Standard Specifications for Cold Weather Concreting
ACI 308.1	Standard Specifications for Curing Concrete
ASTM	Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, PA, 1997 or latest edition.

1.03 REFERENCES

DESIGNER NOTE: Designer to provide references to related industry manuals and guidance and all project specific documents (e.g., geotechnical report).

1.04 SUBMITTALS

A. Bid Submittals: The Contractor shall submit to the Owner the following as part of the bid proposal:

1. National Ready Mix Concrete Association (NRMCA) Pervious Concrete Contractor Certifications and project experience as specified in Section 1.05.A for the crew assigned to this project.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

B. Pre-Installation Submittals: The Contractor shall submit to the Engineer the following a minimum of 20 calendar days prior to the construction of the pervious cement concrete pavement:

1. NRMCA Certifications for the batch plant to be used in the production of pervious concrete for this project.

2. Proposed mix design including the following:

a. Batch weights of all constituents.

b. Portland cement type and brand.

c. Non-Portland cement pozzolan type and source.

d. Microfiber brand and type.

e. Admixture type and brand.

f. Aggregate source(s), gradation(s), LA abrasion, and cleanness value(s).

g. Fresh density of the pervious concrete per ASTM C1688.

No concrete shall be placed until the Engineer has provided written acceptance of the mix design per Section 1.05.B.

3. Source certificates, gradations, R-values, LA abrasion, and cleanness values of aggregates for base and reservoir course materials performed within one (1) month of product delivery to site.

DESIGNER NOTE: Consider revising acceptable age of sieve test depending on scale of project. On a larger project it may be appropriate to require testing by an independent lab with samples taken at the supplier's yard from the stockpile to be used for the project.

4. Product data sheets for all proposed admixtures and geotextiles.

5. A detailed plan of the proposed paving pattern showing the location and type (saw cut or rolled in plastic concrete) of all planned joints. No deviation from the jointing pattern shown on the Plans will be allowed without written approval of the Engineer.

6. A detailed procedure for the production, transportation, placement, protection, curing, and temperature monitoring of concrete for hot

and/or cold weather, unless written approval of the Engineer waiving the requirement is received.

7. Field technician qualifications as specified in Section 1.05.A.

8. Testing agency qualifications as specified in Section 1.05.A.

9. Density of fresh pervious concrete, length of cores, and density of cores for one (1) reference panel. Reference panel shall be placed, jointed, cured, and tested as specified in Section 1.05.D.1 and be within tolerance of the required thickness defined by the Contract Documents.

1.05 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect concrete materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

1. Contractor and Personnel Qualifications

a. Contractor qualification: Unless otherwise approved by Engineer, Contractor shall provide evidence of employment for one (1) NRMCA certified Pervious Concrete Installer and four (4) NRMCA certified Pervious Concrete Technicians who must be on site, working as members of each placement crew, during all concrete placement.

For all projects where the total pervious concrete pavement area exceeds 20,000 square feet (sf), the Contractor shall provide evidence of employment for at least one (1) NRMCA certified Pervious Concrete Craftsman who must be onsite, working as part of the placement crew, during all concrete placement. Additionally, for every 10,000 sf of pavement area over 20,000 sf, one (1) additional NRMCA certified Pervious Concrete Installer is required on site, working as part of the placement crew.

The Contractor shall provide documentation showing three (3) successful pervious concrete projects completed in the last three (3) years collectively totaling more than 20,000 square feet. Documentation shall include name and address of project, and contact information for project owner.

DESIGNER NOTE: The designer should adjust as required based on the availability of qualified bidders and the size of the project.

b. Field technician qualification: Field tests of concrete required in the responsibilities of the testing agency shall be performed by an individual certified as both an NRMCA Certified Pervious Concrete Technician, or equivalent, and an ACI Concrete Field Testing Technician – Grade I, or equivalent.

DESIGNER NOTE: The designer should adjust as required based on the availability of qualified personnel and the size of the project.

c. Testing agency qualification: Agencies that perform testing on concrete materials shall meet the requirements of ASTM C1077 and provide evidence of employment for at least one (1) NRMCA Certified Pervious Concrete Technician, responsible for testing, or providing direct oversight of testing, of all concrete materials. Agencies inspecting the Work shall meet the requirements of ASTM E329. Testing agencies performing the testing shall be accepted by the Engineer before performing any Work.

d. Batch plant qualification: Batch plant used for pervious concrete shall be a semi-automatic or automatic batching plant with a current NRMCA certification.

DESIGNER NOTE: Volumetric (truck mounted) Site Mixed Mobile Mixers may be used at the designers discretion. Mixing operations should be per manufactures directions. Designer should specify certification and calibration requirements for Volumetric Mobile Mixers including, but not limited to:

- Proof of Volumetric Mixer Manufacturer Bureau (VMMB) certification, compliance with VMMB 100-01 Volumetric Mixer Standards, and associated VMMB rating plate, or equal
- Provisions for calibration of Volumetric Mobile Mixers performed with aggregate manufactured for the project and recalibrated with each restocked stock pile

Additionally, the designer should specify required quality control measures to ensure aggregates, cementitious material, and admixtures are free from contamination from deleterious material or other stockpiles/storage containers, protected from damage by equipment, vehicles, or weather, and properly batched in lieu of batch ticket (e.g., labeling of aggregate bins to ensure correct aggregate is fed into appropriate mixer material compartment.

B. Approved Mix Design: Once accepted by the Engineer, the mix design meeting the criteria specified in Section 2.01.F shall become the Approved Mix Design and shall not be modified in any way. The Approved Mix Design shall be determined from information submitted under Section 1.04 and from results of reference panel testing as described in Section 1.05.D.1.

Modifications to the Approved Mix Design will not be allowed and any modified mix placed in the Work will be rejected. Proposed modifications to the Approved Mix Design shall be submitted as a new mix design and shall require a new reference panel to validate the proposed mix design and determine the new Approved Mix Design. If accepted by the Engineer, the

new mix design shall become the Approved Mix Design. The requirement for a new reference panel may be waived at the discretion of the Engineer. Only one (1) Approved Mix Design shall be valid at any time. Admixture and water dosages may be modified as needed to maintain mix properties.

C. Responsibilities of Contractor

1. Pre-Placement Conference: A mandatory pre-placement conference will take place including at a minimum the Engineer, the Owner, general contractor, pervious concrete installer, concrete supplier, and field testing agency representative. The document Checklist for the Concrete Pre-Construction Conference (available from the National Ready Mix Concrete Association) will be used to review all materials, personnel qualifications, concrete production, delivery, maintaining moisture retention of fresh mixture, preparation, placing, curing (including timing, placement, and securing of curing cover), jointing, testing procedures, and responsibilities. Meeting emphasis will be on how pervious concrete differs from conventional concrete.

2. Reference Panel: Place reference panels on the project site, on a subgrade and base prepared as specified, using the material and construction requirements for pavement in this Specification. Each panel must have a surface area of at least 225 square feet, and a width and thickness as specified for the pavement in the Contract Documents. The Engineer shall observe and accept each element of the pervious concrete construction. Construction and evaluation of the reference panel(s) will occur as follows:

   a. Notify the Engineer at least ten (10) Working Days before installing pervious concrete reference panel.

   b. Coordinate the location of the reference panel with the Engineer.

   c. Notify the Engineer when each element of the reference panel is ready for inspection.

   d. Remove, replace, and dispose of any unsatisfactory portions of reference panel as determined by the Engineer and at no additional cost to the Owner.

   e. Retain and maintain approved reference panels during construction in an undisturbed condition as a standard for judging completed portions of the final installations.

   Approved reference panels may remain as final installations of the Work at the discretion of the Engineer. If not retained, the reference panel shall be removed and disposed of at no additional cost to the Owner.

3. Testing facilitation: Owner's use of testing services will not relieve Contractor of the responsibility to furnish materials and construction in full compliance with the Contract Documents. Unless otherwise

specified in the Contract Documents, Contractor shall assume the following duties and responsibilities:

a. Furnish the materials to be tested, including concrete cores.

b. Furnish any necessary labor to assist Owner's testing agency in obtaining and handling samples, including concrete cores, at the project site or at the source of materials.

c. Provide measures to collect slurry and debris during coring operation in order to avoid sealing adjacent pavement.

d. Fill core holes in accordance with Section 1.05.D.2.

e. Advise Owner's testing agency at least 24 hours in advance of operations to allow for completion of quality tests and for assignment of personnel.

4. Pressure wash testing: Before final acceptance by the Engineer, the Contractor shall pressure wash the pervious concrete. Pressure washing shall be provided and completed by using portable washer equipment working at a minimum of 3,000 psi at 2.0 to 2.5 gpm. The nozzle shall be a zero degree nozzle and be held a maximum of three (3) inches off the concrete surface. The Contractor shall pressure test three (3) locations per lot or as determined by the Engineer. Any sections of pervious concrete that breaks up, ravels, or does not infiltrate shall be removed and replaced with acceptable pervious concrete to the nearest joints. The Engineer will reject the concrete if the pressure washing dislodges aggregate particles from more than two (2) percent of the pervious concrete in a single panel (joint to joint) or dislodges aggregates from a contiguous area of the pavement surface exceeding five times the nominal maximum aggregate size in any direction.

   The Contractor shall decide, after placing the pervious concrete, when to perform the quality assurance pressure wash testing for the acceptance.

DESIGNER NOTE: The designer should consider requiring verification of subgrade infiltration rate and provision to increase reservoir course depth based on results.

D. Testing

1. Reference Panel: Testing for the reference panel shall adhere to the requirements for testing of Pavement per Section 1.05.D.2 for approval by the Engineer. Each test shall meet the acceptance criteria for Reference Panel as defined in Section 1.05.E.1.

   The Engineer shall inspect and approve the reference panel prior to the placement of additional pervious concrete.

Failure to install acceptable reference panels of pervious concrete will indicate an unqualified installer.

Production sections of this Work shall not be placed until achieving a complete reference panel that fully complies with the Plans and Specifications and has written acceptance issued by the Engineer.

The completed and accepted reference panels shall be maintained and protected throughout the duration of the Work and may not be demolished and disposed of without written permission from the Engineer. If a reference panel is incorporated into the Work, it shall remain in place and be accepted as a single lot.

Unless otherwise determined by the Engineer, density testing of fresh concrete and hardened cores will be used to validate the mix design per the design criteria set forth in Section 1.04.B and the acceptance criteria in Section 1.05.E.1.

The average fresh density and average hardened density of the cores shall be the densities used for the Approved Mix Design.

2. Pavement: The following testing shall be conducted for approval by the Engineer for each reference panel and each lot of pervious concrete placed, where a lot is defined as the lesser of one (1) day's production or 5,000 square feet of pervious concrete, in place, unless otherwise specified below:

   a. Density testing of at least one (1) cubic foot of fresh concrete in accordance with ASTM C1688.

   b. Thickness testing of three (3), four- (4)-inch hardened concrete cores in accordance with ASTM C174 and adhering to the following requirements:

      1) Removed not less than seven (7) days after placement of pervious concrete.

      2) Location selected in accordance with ASTM D3665.

      3) Cut in accordance with ASTM C42.

   c. Density and void content testing of the three (3) hardened concrete cores extracted for thickness testing and trimmed to produce flat core ends per ASTM C42 paragraph 7.4.1 and 7.4.2. Samples shall be tested in accordance with ASTM C1754.

   d. Surface infiltration tests per ASTM C1701 and at the frequency described below.

      1) Three (3) test locations per 10,000 square feet of pervious concrete, in place

      2) One (1) additional test location per 5,000 square feet of pervious concrete, or fraction thereof, in place

DESIGNER NOTE: Designer to specify the number and location(s) of required post construction infiltration tests.

Core holes shall be filled with solid concrete, pre-blended grout, or pervious concrete and shall match adjacent pavement color, and grade. At the Engineer's discretion, a sacrificial panel for cores may be required or allowed.

Each test shall meet the acceptance criteria for Pavement as defined in Section 1.05.E.2.

E. Acceptance

1. Reference Panel: Acceptance of the reference panel will be based on the criteria for acceptance of Pavement per Section 1.05.E.2 with the following deviations:

   a. Hardened Density: The density of each core shall be within five (5) pounds per cubic foot of the average hardened density of the three (3) cores.

   b. Fresh Density: The fresh density shall be within or equal to five (5) pounds per cubic foot of the average fresh density of the three (3) samples.

2. Pavement: Acceptance of a lot of pervious concrete will be based on the following criteria:

   a. Smoothness: Pervious concrete pavement smoothness shall be checked with a 10-foot straightedge. Vertical measurement should be taken between the pavement's determined plane and straight edge, discounting surface void and roughness irregularities, in a direction perpendicular and parallel to the centerline. The finished pavement shall be uniform to a degree such that no variations greater than 3/8-inch are present between the straight edge and pavement surface over a distance of at least 6 inches.

   b. Grade: Pervious concrete shall be true to designed spot elevations plus or minus ½ inch and shall not deviate from designed slope more than ¼ inch in ten (10) feet. Where abutting existing facilities such as sidewalks, walkways, curbs, driveways or other pavements, the pervious concrete shall be flush.

   c. Line: Pervious concrete margins shall be true to designed lines plus or minus ½ inch at any point.

   d. Slope: Pervious concrete shall be sloped as shown on the Plans. Slope shall be consistent to within 1/4 inch in ten (10) feet.

   e. Thickness: Each core sample shall be equal to the minimum section depth or more as specified on the Plans.

f. Hardened Density: The density of the core samples for each lot shall be within five (5) pounds per cubic foot of the density as accepted in the reference panel.

g. Void Content: The total void content of the core samples for each reference panel and lot shall be twenty (20) percent, plus or minus five (5) percent, in place, as constructed.

h. Infiltration Rate: The average of all surface infiltration tests shall be greater than 250 inches per hour with no single test less than 100 inches per hour.

DESIGNER NOTE: The designer should adjust infiltration rates to reflect project specific conditions such as anticipated sediment loading based on pavement use (e.g., vehicular, pedestrian) and design run-on from adjacent surfaces. The recommended criteria are as follows:

- For permeable pavement that will accept run-on from adjacent impervious and/or pervious surfaces OR pavement that will be subject to vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 250 inches per hour with no single test less than 100 inches per hour
- For permeable pavement not subject to run-on OR vehicular traffic:
  - The average of all surface infiltration tests shall be greater than 100 inches per hour with no single test less than 75 inches per hour

i. Fresh Density: The fresh density shall be within or equal to five (5) pounds per cubic foot of the fresh density indicated by the Approved Mix Design.

j. Batch Ticket: Each load of pervious concrete transported to the location of placement shall have a Batch Ticket delivered with the load. Batch Tickets shall be provided upon request for each load and shall be in accordance with ASTM C94, with the following additions:

1) Batch weights of all constituents in the mix, including cement, aggregate, admixtures, water, and fibers

2) Signature of responsible representative of the concrete producer, affirming the accuracy of the information provided

k. Appearance: Each lot of finished pervious concrete will be inspected for appearance by the Engineer after completion of pressure wash testing per Section 1.05.C.4. The pervious concrete shall have a consistent surface texture, shall have no

more than five (5) percent of the surface area within each panel (joint to joint) filled with paste, shall be free of ridges or other surface imperfections, shall have joints that are in the specified location and are constructed per specification, shall be free of cracks and shall not be raveled.

A panel will be considered raveled if aggregate is dislodged from a contiguous area of the pavement surface or longitudinally along a joint exceeding five times the nominal maximum aggregate size in any direction OR if aggregate particles are dislodged from more than two (2) percent of the pervious concrete within each panel (joint to joint).Raveling occurring during the first three (3) months after installation is subject to complete removal and replacement of affected panels with acceptable pervious concrete at the Owner's discretion and Contractor's expense. Requirement to replace affected panels shall continue until three (3) months after the date of replacement. Written notification of defects is the sole responsibility of the Owner.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

I. Conformance to Approved Mix Design: The pervious concrete used shall conform to the Approved Mix Design within the limits set forth in ASTM C94.

3. Required Inspections: Notify the Engineer at least 48 hours prior to required inspections specified in Sections 3.01, 3.02, and 3.03.B.

PART 2 PRODUCTS

DESIGNER NOTE: Designers should maximize the use of regionally available materials.

2.01 PERVIOUS CONCRETE

DESIGNER NOTE: No reinforcing bars or tie bars will be used in the installation of pervious concrete.

Pervious Concrete shall comply with ASTM C94, except sections 4.2, 6.1.2, 6.1.3, 6.1.4, 6.1.5, 7, 8, 16, 17, 18, 19, 20 and the requirements specified herein. The volume of fresh concrete in a given batch shall be determined from the total mass of the batch divided by the design density of the concrete. The total mass of the batch shall be determined as the net mass of the concrete in the batch as delivered, including the total mixing water as defined in ASTM C94 Paragraph 9.3.

A. Cement: Cement in the mix design shall conform to the requirements for Portland Cement or Blended Hydraulic Cement as specified herein:

1. Portland Cement: Portland Cement shall meet the requirements of ASTM C150 Type I, II, or V Portland cement.

2. Blended Hydraulic Cement: Blended Hydraulic Cement shall be Type IP or IS Cement conforming to ASTM C595. Type IP(X), Portland Pozzolan Cement, and IS(X) where (X) dictates pozzolan and slag percentage, respectively, shall be Portland Cement and Pozzolan. The pozzolan shall be limited to fly ash or ground granulated blast furnace slag.

   The fly ash or ground granulated blast furnace slag constituent content in the finished cement shall not vary more than plus or minus 5 percent by weight of the finished cement from the certified value.

3. Supplementary cementitious material shall be as specified herein:

   a. Fly Ash: Fly ash shall conform to the requirements of ASTM C618, Class F or C.

   b. Slag Cement: Slag cement shall meet the requirements of ASTM C989, Grade 100 or Grade 120.

   c. Silica Fume: Silica fume shall meet the requirements of ASTM C1240.

B. Aggregates: Aggregates shall conform to ASTM C33 except as specified herein, unless otherwise approved by the Engineer.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 300 cubic yards of concrete.

Sieve[1]	Percent Passing by Weight				
	Coarse Aggregate				Fine Aggregate
	ASTM No. 7	ASTM No. 8	ASTM No. 89	ASTM No. 9	
2 inch	–	–	–	–	–
1 1/2 inch	–	–	–	–	–
1 inch	–	–	–	–	–
3/4 inch	100	–	–	–	–
1/2 inch	90 to 100	100	100	–	–
3/8 inch	40 to 70	85 to 100	90 to 100	100	100
No. 4	0 to 15	10 to 30	22 to 55	85 to 100	95 to 100
No. 8	0 to 5	0 to 10	5 to 30	10 to 40	80 to 100
No. 16	–	0 to 5	0 to 10	0 to 10	50 to 85
No. 30	–	–	0 to 5	0 to 5	25 to 60
No. 50	–	–	–	–	5 to 30
No. 100	–	–	–	–	0 to 10
No. 200	–	–	–	–	0 to 3

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

In individual tests, a variation of 4 percent under the minimum percentages or over the maximum percentages will be allowed. The average of three successive tests shall be within the

percentages stated above. Aggregate shall contain no pieces larger than two times the maximum sieve size for the specified grading measured along the line of greatest dimension.

2. Coarse Aggregate

   a. LA Abrasion: 35 percent (maximum) tested in accordance with ASTM C131 at least once per 300 cubic yards of concrete.

   b. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 300 cubic yard of concrete.

3. Acceptance of grading and quality of the aggregate may be based on samples taken from stockpiles at the concrete plant or a submitted gradation report at the discretion of the Engineer. The point of acceptance will be determined in the field by the Engineer.

C. Admixtures

1. Air Entraining Admixtures: Air entraining admixtures shall meet the requirements of ASTM C260.

2. Water Reducing Admixtures: Water reducing admixtures shall meet the requirements of ASTM C494, Type A.

3. Hydration Stabilizing Admixtures: Hydration stabilizing admixtures shall meet the requirements of ASTM C494, Type B or Type D.

4. Superplasticizers: Superplasticizers and retarders shall meet the requirements of ASTM C494, Type F or Type G and ASTM C1017, Type 1.

5. Viscosity Modifying Admixtures: Viscosity modifying admixtures may be used if approved by the Engineer.

6. Color Pigment: Color pigment shall meet the requirements of ASTM C979 for integrally colored concrete. Pigments shall be color stable, non-fading, and resistant to lime and other alkalis.

   DESIGNER NOTE: Designer to specify color, as indicated by manufacturer's designation, architect's sample, etc. with provision for approved equal color.

D. Water: Clean potable water or water conforming to ASTM C1602 shall be used in the mix design and on the jobsite. The use of hot water is not permitted.

E. Microfibers: Microfibers shall conform to the requirements of ASTM C1116, Type III and shall be monofilament and ½ inch in length.

F. Mix Design:

1. General: The Contractor shall propose a mix design for pervious concrete and shall submit the mix design to the Engineer for acceptance prior to constructing the reference panels. Pervious concrete shall not

be placed in the reference panels without a mix design that has been reviewed and accepted by the Engineer.

2. Mix Design Criteria: The Contractor shall include the following elements and results of the described procedures in the proposed mix design:

   a. The cementitious content, including pozzolans if used, shall be a minimum of 480 and a maximum of 600 pounds per cubic yard.

   b. The mix may incorporate up to 5 percent fine aggregate, by weight.

   c. The mix shall incorporate a hydration stabilizing admixture.

   d. The mix may incorporate microfibers or fibers per Manufacturer's recommendations.

   e. The mix shall be designed to meet the acceptance criteria for Void Content per Section 1.05.F.2 as determined by the testing methods specified in Section 1.05.E.2.

   f. The water/cement ratio shall be between 0.27 and 0.35.

   g. Up to 50 percent of cementitious material in the mix, by weight, may be fly ash, slag cement, or a combination of silica fume and either or both of the above, with silica fume not exceeding 10 percent.

   Deviations from this mix design, such as the use of internal curing admixtures, cementitious content outside of the range specified, or finer aggregate gradations may be permitted at the sole discretion of the Engineer provided the Contractor can demonstrate the viability of the mix design through past successful installations or sound science.

2.02 PAVEMENT BASE

A. Pavement Base Material shall consist of clean, mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Recycled materials or round river gravel are not permitted. Material shall be obtained only from a source(s) approved by the Engineer. Written requests for source approval shall be submitted to the Engineer not less than Working 10 days prior to the intended use of the Material. Should the proposed source be one that the Engineer has no history of Material performance with, the Engineer reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract. The Engineer shall reserve the right to sample and test Material at any time including at the source.

B. Pavement Base shall consist of up to two (2) layers as specified on the Plans and included herein:

1. "Base Course" shall be ASTM No. 3 (modified) or ASTM No. 57 (modified) stone per Section 2.02.C.

   DESIGNER NOTE: This layer of the pavement base is intended to provide structural (load bearing) capacity to the pavement.

2. "Reservoir Course" shall be ASTM No. 2 (modified), ASTM No. 3 (modified), or ASTM No. 57 (modified) stone per Section 2.02.C.

   DESIGNER NOTE: This layer of the pavement base is intended to provide storage and drainage of the pavement, structural support, and a capillary break. The materials specified should be crushed, clean, washed rock to provide the desired structural capacity, maintain good drainage, function as a capillary barrier, and minimize clogging of the subgrade due to export of fines.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying courser graded materials or reduction in permeability relative to the underlying material. Refer to the SFPUC aggregate filter criteria guidance document for information on selecting appropriate alternate materials.

C. Pavement Base Material shall meet the following specifications for grading and quality.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 500 cubic yards of base material.

Sieve[1]	Percent Passing by Weight			
	ASTM No. 2 (modified)	ASTM No. 3 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)
3 inch	100	–	–	–
2 1/2 inch	90 to 100	100	–	–
2 inch	35 to 70	90 to 100	–	–
1 1/2 inch	0 to 15	35 to 70	–	100
1 inch	–	0 to 15	–	95 to 100
3/4 inch	0 to 5	–	–	–
1/2 inch	–	0 to 5	100	25 to 60
3/8 inch	–	–	85 to 100	–
No. 4	–	–	10 to 30	0 to 10
No. 8	–	–	0 to 10	0 to 5
No. 16	–	–	0 to 5	–
No. 100[2]	0 to 2	0 to 2	0 to 2	0 to 2

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Gradation modified from ASTM for portion passing the No. 100 sieve.

2. R-Value: 78 (minimum) tested in accordance with California Test 301.
3. L.A. Abrasion: 30 percent (maximum) tested in accordance with ASTM C131.
4. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.
5. Crushed Particles: 90 percent (minimum) with two (2) or more fractured faces tested in accordance with California Test 205.
6. The combined portion of Material retained on the U.S. No. 4 sieve shall not contain more than 0.1 percent wood waste by weight. The portion of Material passing a U.S. No. 10 sieve shall not have wood waste that results in more than 250 parts per million of organic matter by calorimetric tests when tested. The color shall be measured after the sample has been in the test solution for 1 hour.

2.03 GEOTEXTILE FOR SOIL SEPARATION

DESIGNER NOTE: Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of reservoir course and native soil.

A. Geotextile shall be woven, consisting only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation. The geotextile shall conform to the properties specified herein:

Geotextile Property	Test Method	Requirement
Grab Tensile Strength, minimum in weakest direction	ASTM D4632	200 lbs/in
Apparent Opening Size (AOS)	ASTM D4751	40 to 50
Ultraviolet (UV) Radiation Stability, minimum strength retained after 500 hours in weatherometer	ASTM D4355	50%
Flow Rate, minimum	ASTM D4491	140 gal/min/ft^2

DESIGNER NOTE: The designer should consider including specifications for signage and pavement markings in this section.

PART 3 EXECUTION

3.01 SUBGRADE PREPARATION AND PROTECTION

A. Construct subgrade to +/- ¾ inch of the grades and slopes specified on the Plans.

B. Grading of subgrade shall be with low ground pressure equipment when within six (6) inches of final subgrade elevation.

C. Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g., permeability, stiffness) and performance requirements for the pavement section (e.g., traffic loading, infiltration, cost).

D. Areas of the subgrade which are over-compacted, as determined by the Geotechnical Engineer, shall be ripped/tilled to a depth of 12 inches (minimum) or as directed by the Geotechnical Engineer and shall be recompacted in accordance with Section 3.01.C. Contractor shall locate all utilities within pavement footprint prior to ripping and re-compacting subgrade.

E. Proof-roll prepared subgrade with loaded dump truck, remove soft spots, and replace with permeable structural fill as directed by the Engineer to achieve uniform subgrade.

DESIGNER NOTE: Other subgrade verification methods may be required if site conditions limit proof rolling. Consult with geotechnical engineer for acceptable methods.

F. After compaction and proof roll, scarify subgrade ¼- to ½-inch deep by hand rake. Once scarified, materials or equipment shall not be permitted within the prepared subgrade area so as to avoid recompaction or clogging of the scarified subgrade.

G. The subgrade shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the subgrade during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

H. Areas of subgrade over-compacted by construction traffic or other impacts by the Contractor or Subcontractors shall be ripped/tilled and re-compacted in accordance with Section 3.01.D. All work and materials required to correct over-compacted subgrade, including utility locates within the pavement footprint, shall be at the Contractor's expense.

I. Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor's expense.

J. The subgrade shall be inspected and accepted by the Engineer prior to placement of the geotextile or pavement base.

K. Place geotextile, if required, on scarified subgrade. Care shall be taken to provide full coverage and to prevent the geotextile from being torn. Damaged geotextile shall be repaired as indicated by the manufacturer and to the satisfaction of the Engineer at no additional cost to the Owner. Overlaps of the geotextile shall be a minimum of one (1) foot or to the manufacturer's recommendation, whichever is greater.

DESIGNER NOTE: The use of geotextile under permeable pavement systems should be avoided unless required by the project geotechnical engineer as it can be prone to subsurface clogging.

3.02 PAVEMENT BASE

A. Construct pavement base to the lines, grades, and thicknesses shown on the Plans.

B. Place the pavement base so as to prevent loaded dump trucks from driving directly on the prepared subgrade.

C. Compact pavement base, in six (6) inch (maximum) lifts, by making a minimum of three passes over the pavement base material with a ten (10) ton vibratory roller, or as directed by the Geotechnical Engineer. The first two (2) passes (minimum) shall be in vibratory mode. The final pass shall be in static mode. Acceptance of the pavement base will be based on Engineer's observation of aggregate movement during final compaction pass. Compaction equipment shall be accepted by the Engineer prior to use.

DESIGNER NOTE: For areas or sites that cannot accommodate a vibratory roller compactor, consider allowing compaction of pavement base with a 13,500 lbf (60 kN) minimum vibratory plate compactor with a compaction indicator. At least two passes should be made over each lift of the aggregates.

D. Pavement base shall be true to the designed grade and slope, +/- 0.05 feet, after compaction for each layer. In the event of low spots, additional material shall be added and recompacted. In the event of high spots, excess material shall be removed and the area recompacted.

E. The pavement base shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the pavement base during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

F. Any damage to the pavement base (including contamination by silty run-off) shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Contaminated pavement base shall be removed and replaced to the limits as determined by the Engineer.

G. The pavement base shall be inspected and accepted by the Engineer prior to placing any pervious concrete.

DESIGNER NOTE: Consider developing a testing plan for the required testing and inspection of the pavement base. Verification of the in place density/compaction of the open graded base materials is typically not possible with the use of a nuclear densometer due to nature of these materials. Therefore other means to verify these materials are firm and unyielding (such as observation of the compaction process by a geotechnical engineer) are necessary.

DESIGNER NOTE: Consider requiring the Contractor to compact aggregates without crushing them.

3.03 MIXING, PLACEMENT & CURING OF PERVIOUS CONCRETE

A. Pervious concrete formwork

1. Forms shall be made of steel or wood and shall be in good condition, clean, and capable of being anchored in place so as to ensure pavement placement true to the grades, lines and slopes as specified on the Plans.
2. Forms that are bent, warped, unclean, or otherwise deemed inadequate by the Engineer shall not be used.
3. Existing curbs, structures, or the vertical face of previously placed pervious concrete may be used as a form.
4. Set, align, and brace forms to satisfy the lines, grades, and slopes on the Plans.
5. Apply form-release agent to the form face immediately before placing concrete.
6. No pervious concrete shall be placed until the forms are inspected and accepted by the Engineer.
7. Slip forming is an acceptable method for placement of pervious concrete.

B. Batching, mixing, and delivery

1. Pervious concrete shall be batched and centrally mixed at a batching plant meeting the requirements set forth in Section 1.06.A.4. Pervious concrete shall not be shrink mixed or transit mixed.
2. Begin mixing immediately after cement has been added to aggregates. Batch and mix concrete in compliance with ASTM C94, with the following exceptions:

a. Placement of concrete shall occur no more than 60 minutes from the time water or aggregate is added to the cement.

b. If a hydration-stabilizing admixture is used, up to 60 minutes may be added to the placement time, resulting in a maximum placement time of 120 minutes.

Additional water may be added on site, but the fresh density must still meet the requirements of Section 2.01.F.2 after water addition.

C. Placing and consolidation

1. Pervious concrete shall not be placed on standing water or frozen pavement base.

2. Wet the pavement base with water before concrete placement such that the material is saturated but without any standing water on the prepared base immediately before concrete placement.

3. Place pervious concrete on the prepared pavement base as close to its final position as possible, either directly from the transporting equipment or by conveyor, unless otherwise specified. Spread the concrete using mechanized equipment or hand tools, without segregation.

4. Strike off concrete between forms using a form riding paving machine or roller screed at the appropriate height, as determined by the Contractor, to allow for compaction to finished grade. Equipment used for striking off the pervious concrete shall leave a smooth surface, free of ridges or other imperfections, without drawing excessive paste to the surface. Vibratory screeds are not permitted. Other strike-off devices may be used when accepted by the Engineer.

5. Compact pervious concrete with a purpose built pervious concrete cross roller or alternate method approved by the Engineer. Rollers shall be of sufficient weight and width to compact the fresh pervious concrete to grade, leaving a smooth surface, free of ridges or other imperfections, without drawing excessive paste to the surface. Compacted pervious concrete shall meet the acceptance criteria for Smoothness set forth in Section 1.05.E.2.

6. Contractor's personnel shall take care to avoid foot traffic in the pervious concrete to prevent non-uniform compaction and to keep contaminated material from entering the pavement mix. Foot traffic on the fresh concrete shall not be allowed after it has been struck off.

7. Place pervious concrete continuously. Where placement has been halted for a period of 15 minutes, a header shall be placed between the forms and a construction joint formed. The construction joint shall be located at a contraction joint location, unless otherwise approved by the Engineer. The pervious concrete shall be compacted and finished to the header before placement may continue. Upon resuming placement, the header may be carefully removed and a construction joint formed at

that location. Any sloughing or sagging of the previously placed pervious concrete at the header location shall be corrected prior to placing new pervious concrete against the joint.

D. Edging: Edging of the top surface shall be completed in plastic concrete to a radius of not less than 1/4 inch. Defects shall be repaired immediately.

E. Jointing: Joints shall be of three (3) types: construction, contraction, and isolation. Wherever possible, the angle between intersecting joints shall be between 80 and 100 degrees. Construct joints at the locations and to the horizontal dimensions indicated on the Plans.

1. Construction Joints: Construction joints shall be formed at the end of a day's work or when necessary to stop production for any reason.

   a. Construction joints shall be located as near as possible to the location of a planned contraction or isolation joint.

   b. Construction joints are to be formed by placing a header between the forms, at right angles, to the full depth of the finished pervious concrete, and set to the height of the forms. Pervious concrete shall be placed against the header and compacted and finished as normal, including edging.

   c. Upon resuming paving, the header shall be carefully removed and new pervious concrete placed directly against the existing pervious concrete. The new pervious concrete shall be compacted and finished against the hardened pervious concrete as if it were a form.

   d. If an isolation joint is planned at this location, then the premolded joint filler shall be placed against the existing pervious concrete and the new pervious concrete shall be placed against the premolded joint filler. The joint shall be tooled on both sides of the premolded joint filler.

2. Contraction Joints: Contraction joints shall be used to control random cracking.

   a. Contraction joints shall be placed every 15 feet unless otherwise shown on the Plans.

      DESIGNER NOTE: Designer should consider size and aspect ratio of panels when locating joints.

   b. Plastic Formed Joints: Contraction joints may be formed in the plastic concrete using a roller designed for this purpose or by other methods accepted by the Engineer.

      1) Rollers shall have sufficient weight to produce the joint and shall not otherwise damage or mar the surface.

      2) Plastic formed joints shall be a minimum depth of 1 and 3/4 inches and have a width of no more than 1/8 inch.

3) Joints shall be tooled on both sides of the joint with a radius not less than 1/4 inch.

c. Saw Cut Joints: At the option of the Contractor, contraction joints may be saw cut provided joints are early-entry dry-cut type.

1) Joints shall be cut using purpose built early-entry saw cutting equipment.

2) Saw cut joints shall be a minimum depth of 1/4 of the pervious concrete thickness, up to a maximum required depth of 1 and 1/4 inches, and have a joint width of no more than 1/8 inch.

3) Saw cutting shall occur as soon as the concrete is sufficiently cured so that it may be cut without raveling or dislodging aggregate from the finished surface, no longer than four (4) hours after placement of pavement.

4) Remove cuttings from surface immediately after saw cutting of joints.

5) To minimize drying, curing materials shall be removed only as needed to make cuts and shall be replaced immediately after cutting. The exposed pervious concrete shall be kept moist for the entire duration of exposure.

3. Isolation Joints: Isolation joints shall be used where the pervious concrete abuts existing facilities or where shown on the Plans.

a. Isolation joints shall continue through the depth of the pervious concrete using a 3/8 inch premolded joint filler.

b. Isolation joints may be formed by inserting the premolded joint filler into the plastic concrete or by forming a construction joint and affixing the premolded joint filler against one side of the joint and placing fresh pervious concrete against it.

c. Isolation joints and filler shall be flush with the surrounding pervious concrete and shall not deviate from the acceptance criteria for Grade as specified in Section 1.05.E.2.

d. The edges of the pervious concrete on either side of the premolded joint filler shall be hand tooled to a radius not less than 1/4 inch.

F. Curing

1. Begin curing within 20 minutes of concrete discharge from the truck, unless otherwise specified or approved by the Engineer.

2. Completely cover the pavement surface and all exposed edges with a minimum six- (6)-mil-thick white polyethylene sheet, unless otherwise specified or approved by the Engineer. No wetted burlap or cloth shall be used.

3. Thoroughly secure a polyethylene sheet at all exterior edges and interior laps without using soil. The method of securing the cover material shall prevent wind from removing the sheet and from blowing under the sheet across the surface of the concrete.
4. Curing compound shall not be used on any pervious cement concrete surface.
5. Cure pavement for a minimum of 7 uninterrupted days, unless otherwise specified or approved by the Engineer.
6. With the exception of saw cutting equipment, all traffic shall be kept off of the pervious concrete during the curing period.
7. Any testing for acceptance shall not occur until the end of the curing period.

G. Cold-weather construction

1. Protect concrete from freezing and record concrete temperature no less than twice per 24-hour period in accordance with ACI 306.1.

3.04 OPENING TO TRAFFIC

A. No traffic shall be allowed on the pervious cement concrete pavement for 10 days.

3.05 PROTECTION OF PAVEMENT

A. Cured and exposed pervious cement concrete pavement surface shall be kept clean and free of clogging debris and soils from the Contractor's operations and all upstream and adjacent debris. If debris or soils contaminate the pervious pavement voids, the pavement shall be cleaned at the Contractor's expense and to the satisfaction of the Engineer. If pervious cement concrete pavement cannot be unclogged, it shall be removed and replaced at the Contractor's expense and to the satisfaction of the Engineer.

3.06 REJECTION

A. Pervious concrete that does not meet the acceptance criteria set forth in Section 1.05.E.2 will be rejected by the Engineer on a lot-by-lot basis. Pervious concrete that has been rejected by the Engineer or the Contractor shall be removed and replaced at no additional cost to the Owner.

END OF SECTION

DESIGNER NOTE: The specifications below are based on the best available information. Designer should modify the specifications to satisfy project-specific constraints. The City uses the term “Permeable Unit Pavers” when infiltration achieved via aggregate filled joints and “Porous Unit Pavers” when infiltration is achieved through the paver material itself.

DESIGNER NOTE: Green text corresponds to notes to the designer.

PART 1 GENERAL

1.01 SUMMARY

A. This section Includes:

1. Permeable/Porous Unit Pavers
2. Joint Filter Aggregate
3. Pavement Base
4. Edge Restraints
5. Geotextile for Soil Separation

B. Related Sections

DESIGNER NOTE: The designer should list any additional specification sections which relate to the permeable/porous unit paver work (i.e., temporary erosion control, utilities, earthwork, etc.)

1.02 STANDARDS AND CODES

A. Reference Standards: This section incorporates by reference the latest version of the following documents. These references are a part of this section as specified and modified.

Reference	Title
Caltrans	Standard Specifications
San Francisco DPW	Engineering Standard Specifications
ASTM C67	Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM C13	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136	Method for Sieve Analysis for Fine and Coarse Aggregate
ASTM C140	Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
ASTM D448	Standard Classification for Sizes of Aggregate for Road and Bridge Construction

ASTM C936	Standard Specification for Solid Interlocking Concrete Pavers
ASTM C979	Specification for Pigments for Integrally Colored Concrete
ASTM C1781	Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems
ASTM E2835	Standard Test Method for Measuring Deflections using a Portable Impulse Plate Load Test Device

1.03 REFERENCES

DESIGNER NOTE: Designer to provide references to related industry manuals and guidance and all project specific documents (e.g., geotechnical report).

A. Interlocking Concrete Pavement Institute (ICPI)

1. Permeable Interlocking Concrete Pavement manual.

DESIGNER NOTE: The designer should consider the use of the ICPI Permeable Design Pro software for structural design and determination of adequate depth for the pavement section.

1.04 SUBMITTALS

A. Bid Submittals: The Contractor shall submit to the Owner the following as part of the bid proposal:

1. Paver Installation Subcontractor:

a. A copy of Subcontractor's current certificate from the Interlocking Concrete Pavement Institute's Concrete Paver Installer Certification program.

b. Job references from three (3) projects of a similar size and complexity. Provide Owner/Client/General Contractor names, postal address, phone number, and email address.

DESIGNER NOTE: The designer should incorporate by reference these requirements in Division 00 of the Specifications.

B. Pre-Installation Submittals: The Contractor shall submit to the Engineer the following a minimum of 20 calendar days prior to the construction of the permeable/porous unit pavers:

1. Paver manufacturer's/installation subcontractor's drawings and details indicating perimeter conditions, junctions with other materials, expansion and control joints, paver layout/patterns, joint spacing and/or tabs, color arrangement, and installation [and setting] procedures. Drawings and details shall also indicate layout, pattern and relationship of paving joints to fixtures and project formed details.

2. Source certificates, gradations, R-values, LA abrasion, and cleanness values of aggregates for base, reservoir course, and joint filler materials performed within one (1) month of product delivery to site.

   DESIGNER NOTE: Consider revising acceptable age of sieve test depending on scale of project. On a larger project it may be appropriate to require testing by an independent lab with samples taken at the supplier's yard from the stockpile to be used for the project.

3. Product data sheets for unit pavers and geotextiles.

4. Laboratory test reports certifying compliance of the concrete pavers with ASTM C936.

5. Manufacturer's certification of concrete pavers by ICPI as having met applicable ASTM standards.

DESIGNER NOTE: Especially when using colored pavers, consider requiring submittal of full-size samples of each paver type, thickness, color, and finish. Require submittal of samples indicating the range of color expected in the finished installation. Accepted samples would become the standard of acceptance for the work of this Section.

1.05 QUALITY CONTROL AND QUALITY ASSURANCE

A. General: Test and inspect permeable/porous unit paver materials and operations as Work progresses as described in this section. Failure to detect defective Work or materials at any time will not prevent rejection if a defect is discovered later, nor shall it constitute final acceptance.

1. Paver Installation Subcontractor Qualifications:

2. Installer shall provide documentation showing three (3) successful permeable/porous unit paver installations completed in the last three (3) years, collectively totaling more than 10,000 square feet. Documentation shall include name and address of project, and contact information for project owner.

3. Installer shall utilize job foremen holding a record of completion from the Interlocking Concrete Pavement Institute PICP Installer Technician Course.

DESIGNER NOTE: Consider changing these requirements to match scale and complexity of project including a minimum total amount of pavers placed.

B. Responsibilities of Contractor

1. Pre-Placement Conference: A mandatory pre-placement conference will take place, including at a minimum the Engineer, the Owner, general Contractor, and paver installer, to review the manufacturers' quality control plan, personnel qualifications, and the paver installers' Method Statement and Quality Control Plan.

2. Reference Panel: Place reference panels on the project site, on a subgrade and base prepared as specified, using the material and construction requirements for pavement in this Specification. Each panel must have a surface area of at least 100 square feet (sf), and a width and thickness as specified for the pavement in the Contract Documents. The Engineer shall observe and accept each element of the paver construction prior to the placement of additional pavement. Failure to install acceptable reference panels of permeable/porous unit pavers will indicate an unqualified installer. Construction and evaluation of the reference panel(s) will occur as follows:

   a. Notify the Engineer at least ten (10) Working Days before installing paver reference panel.

   b. Coordinate the location of the reference panel with the Engineer.

   c. Notify the Engineer when each element of the reference panel is ready for inspection.

   d. Remove, replace, and dispose of any unsatisfactory portions of reference panel as determined by the Engineer and at no additional cost to the Owner.

   e. Retain and maintain approved reference panel during construction in an undisturbed condition as a standard for judging completed portions of the final installations.

   Approved reference panels may remain as final installations of the Work at the discretion of the Engineer. If not retained, the reference panel shall be removed and disposed at no additional cost to the Owner.

   DESIGNER NOTE: Mechanized installations may require a larger mock up area. Consult with the paver installation (Sub) Contractor on the size of the reference panel.

   DESIGNER NOTE: Use this panel to determine expected settlement (surcharge) of the leveling course, joint sizes, and lines, laying pattern, color and texture of the job.

   DESIGNER NOTE: The designer should consider requiring verification of subgrade infiltration rate and provision to increase reservoir course depth based on results.

3. Infiltration Testing: Perform surface infiltration tests per ASTM C1781 as described below.

   a. Three (3) test locations per 10,000 square feet of permeable/porous unit pavers, in place

   b. One (1) additional test location per 5,000 square feet of permeable/porous unit pavers, or fraction thereof, in place

   DESIGNER NOTE: Designer to specify the number and location(s) of required post construction infiltration tests.

C. Acceptance

1. The surface elevation of pavers shall be 1/8 to 1/4 inch (3 to 6 mm) above adjacent drainage inlets, concrete collars or channels.
2. Lippage: No greater than 1/8 inch (3 mm) difference in height between adjacent pavers.
3. Bond lines for paver courses shall be within ½ inch (± 15 mm) over a 50-foot (15 m) string line.
4. The final surface tolerance of compacted pavers shall not deviate more than ± 3/8 inch (10 mm) under a 10-foot (3 m) long straightedge.
5. Infiltration Rate: The average of all tests shall be greater than 50 inches per hour with no single test less than 25 inches per hour.

   DESIGNER NOTE: The designer should adjust infiltration rates to reflect project specific conditions such as anticipated sediment loading based on pavement use (e.g., vehicular, pedestrian) and design run-on from adjacent surfaces. The recommended criteria are as follows:

   - For permeable/porous unit pavers that will accept run-on from adjacent impervious and/or pervious surfaces OR pavement that will be subject to vehicular traffic:
     - The average of all surface infiltration tests shall be greater than 100 inches per hour with no single test less than 50 inches per hour
   - For permeable pavement not subject to run-on OR vehicular traffic:
     - The average of all surface infiltration tests shall be greater than 50 inches per hour with no single test less than 25 inches per hour

DESIGNER NOTE: The surface of the pavers may be 1/8 to 1/4 inch (3 to 6 mm) above the final designed elevations after compaction. This helps compensate for possible minor settling normal to pavements.

1.06 DELIVERY, STORAGE, AND HANDLING

A. General: Comply with Division 1 Product Requirement Section.

B. Comply with manufacturer's ordering instructions and lead-time requirements to avoid construction delays.

C. Delivery: Deliver materials in manufacturer's original, unopened, undamaged container packaging with identification tags intact on each paver bundle.

1. Coordinate delivery and paving schedule to minimize interference with normal use of buildings adjacent to paving.
2. Deliver concrete pavers to the site in steel banded, plastic banded, or plastic wrapped cubes capable of transfer by forklift or clamp lift.

D. Unload pavers at job site in such a manner that no damage occurs to the product or existing construction.

E. Storage and Protection: Store materials in a protected area such that they are kept free from mud, dirt, and other foreign materials.

1.07 MAINTENANCE

DESIGNER NOTE: Consider requiring the provision of additional pavers to be retained and stored by the Owner for future maintenance.

- Extra materials: Provide [Specify area] [Specify percentage] additional material for use by Owner for maintenance and repair.
- Extra pavers shall be from the same production run as installed materials.

PART 2 PRODUCTS

DESIGNER NOTE: Some projects may include permeable/porous and solid unit pavers. Specify each product, as required.

2.01 PERMEABLE/POROUS UNIT PAVERS

A. Manufacturer: [Specify manufacturer name.].

1. Contact: [Specify ICPI member manufacturer contact information.].

B. Permeable/Porous Unit Paver Type: [Specify name of product group, family, series, etc.].

1. Material Standard: Comply with ASTM C 936.
2. Color [and finish]: [Specify color.] [Specify finish].
3. Color Pigment Material Standard: Comply with ASTM C979.
4. Size: [Specify.] inches [({Specify.}mm)] x [Specify.] inches [({Specify}mm)] x [Specify.] inches [({Specify.} mm)] thick.
5. Joint Gap Size: [Specify.] inches
6. Joint Gap Mechanism: [Specify if integral spacer, or other paver spacer.] type
7. Bevel Size: [Specify.] inches, [Specify.] type

DESIGNER NOTE: Concrete pavers with spacers integral to each unit are recommended for mechanically installed pavers and pavers subject to vehicular traffic. Verify with manufacturer that overall dimensions do not include spacers.

2.02 JOINT FILLER AGGREGATE

A. Crushed Particles: 90 percent (minimum) tested in accordance with California Test 205.

B. LA Abrasion: Less than 40 tested in accordance with ASTM C131.

C. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.

D. Rounded river gravel may not be used.

E. Permeable Unit Paver: The following aggregate shall be used to fill joints unless manufacturer recommends otherwise. Aggregate gradations shall be per Section 2.03.C.1. If manufacturer recommendation is different from the gradations shown below the Contractor shall be notified at least 48 hours prior to placement of the joint filler.

Gap Width	Aggregate Gradation
3/8" or ½"	ASTM No. 8 (modified)
¼"	ASTM No. 89 (modified)
1/8"	ASTM No. 10 (modified)

F. Porous Unit Pavers: Joint filler shall be per manufacturer's recommendation.

2.03 PAVEMENT BASE

A. Pavement Base Material shall be consist of clean, mechanically crushed stone, substantially free from adherent coatings. Materials shall be washed thoroughly to remove clay, organic matter, extraneous debris, or objectionable materials. Recycled materials or rounded river gravel are not permitted. Material shall be obtained only from a source(s) approved by the Engineer. Written requests for source approval shall be submitted to the Engineer not less than ten (10) Working Days prior to the intended use of the Material. Should the proposed source be one that the Engineer has no history of Material performance with, the Engineer reserves the right to take preliminary samples at the proposed source, and make preliminary tests, to first determine acceptability of the new source and then perform the applicable Material approval testing. Continued approval of a source is contingent upon the Materials from that source continuing to meet Contract requirements. Materials shall meet the Standard Specifications for grading and quality for use in the Work; however, allowable exceptions may be specified in the Contract. The Engineer shall reserve the right to sample and test Material at any time including at the source.

B. Pavement Base shall consist of up to three (3) layers as specified on the Plans and included herein:

1. "Leveling Course" shall be ASTM No. 8 (modified) stone per Section 2.03.C.

   DESIGNER NOTE: This layer of the pavement base is intended to provide a smooth, level surface for placement of pavers.

2. "Base Course" shall be ASTM No. 57 (modified) stone per Section 2.03.C.

   DESIGNER NOTE: This layer of the pavement base is intended to provide structural (load bearing) capacity to the pavement.

3. "Reservoir Course" shall be ASTM No. 2 (modified), ASTM No. 3 (modified), or ASTM No. 57 (modified) stone per Section 2.03.C.

   DESIGNER NOTE: This layer of the pavement base is intended to provide water storage and drainage of the pavement, structural support, and a capillary break. The materials specified should be crushed, clean, washed rock to provide the desired structural capacity, maintain good drainage, function as a capillary barrier, and minimize clogging of the subgrade due to export of fines.

   DESIGNER NOTE: ASTM No. 2 stone is preferred.

DESIGNER NOTE: If the designer chooses to specify materials that differ from those provided herein, the designer should check their filter criteria to evaluate the likelihood of finer-graded material migration into underlying courser graded materials or reduction in permeability relative to the underlying material. Refer to SFPUC aggregate filter criteria guidance document for information on selecting appropriate alternate materials.

C. Pavement Base Material shall meet the following specifications for grading and quality.

DESIGNER NOTE: If the designer chooses to specify materials per the procedure above, provide the required gradation the in the table below.

1. Aggregate Gradation tested in accordance with ASTM C136 at least once per 500 cubic yards of base material.

Sieve[1]	Percent Passing by Weight					
	ASTM No. 10 (modified)	ASTM No. 89 (modified)	ASTM No. 8 (modified)	ASTM No. 57 (modified)	ASTM No. 3 (modified)	ASTM No. 2 (modified)
3 inch	–	–	–	–	–	100
2 1/2 inch	–	–	–	–	100	90 to 100
2 inch	–	–	–	–	90 to 100	35 to 70
1 1/2 inch	–	–	–	100	35 to 70	0 to 15
1 inch	–	–	–	95 to 100	0 to 15	–
3/4 inch	–	–	–	–	–	0 to 5
1/2 inch	–	100	100	25 to 60	0 to 5	–
3/8 inch	100	90 to 100	85 to 100	–	–	–
No. 4	85 to 100	20 to 55	10 to 30	0 to 10	–	–
No. 8	–	5 to 30	0 to 10	0 to 5	–	–
No. 16	–	0 to 10	0 to 5	–	–	–
No. 30	–	–	–	–	–	–
No. 50	–	0 to 5	–	–	–	–
No. 100[2]	10 to 30	–	0 to 2	0 to 2	0 to 2	0 to 2
No. 200[2]	0 to 2	0 to 2	–	–	–	–

[1] Sieve provided in nominal size square openings or United States Standard Sieve Series sizes.

[2] Gradation modified from ASTM for portion passing the No. 100 and 200 sieve, as shown.

2. R-Value: 78 (minimum) tested in accordance with California Test 301.
3. L.A. Abrasion: 30 percent (maximum) tested in accordance with ASTM C131.
4. Cleanness Value: 75 (minimum) tested in accordance with California Test 227 at least once per 500 cubic yards of base material.
5. Crushed Particles: 90 percent (minimum) with two (2) or more fractured faces tested in accordance with California Test 205.
6. The combined portion of Material retained on the U.S. No. 4 sieve shall not contain more than 0.1 percent wood waste by weight. The portion of Material passing a U.S. No. 10 sieve shall not have wood waste that results in more than 250 parts per million of organic matter by calorimetric tests when tested. The color shall be measured after the sample has been in the test solution for 1 hour.

2.04 ACCESSORIES

A. Provide accessory materials as follows: Edge Restraints

1. Manufacturer: [Specify manufacturer.].
2. Material(s): [Pre-cast concrete] [Cut stone] [steel].
3. Material Standard: [Specify material standard.].
4. Configuration: [Specify geometry, manufacturer's model number, stakes or spikes, paver spacers, coatings, color, etc.]

DESIGNER NOTE: Curbs will typically be cast-in-place concrete or precast set in concrete haunches. Cast in place concrete curbs should be specified in another Section. Do not use plastic edging with steel spikes to restrain unit pavers for vehicular applications.

2.05 GEOTEXTILE FOR SOIL SEPARATION

DESIGNER NOTE: See ICPI publication, Permeable Interlocking Concrete Pavements for guidance on geotextile selection. Geotextile is not typically required under permeable pavement applications unless recommended by a geotechnical engineer. Geotextile can be placed vertically for material separation between side walls of reservoir course and native soil.

A. Geotextile shall be woven, consisting only of long chain polymeric fibers or yarns formed into a stable network such that the fibers or yarns retain their position relative to each other during handling, placement, and design service life. At least 95 percent by weight of the material shall be polyolefins or polyesters. The material shall be free from defects or tears. The geotextile shall also be free of any treatment or coating which might adversely alter its hydraulic or physical properties after installation. The geotextile shall conform to the properties specified herein:

Geotextile Property	Test Method	Requirement
Grab Tensile Strength, minimum in weakest direction	ASTM D4632	200 lbs/in
Apparent Opening Size (AOS)	ASTM D4751	40 to 50
Ultraviolet (UV) Radiation Stability, minimum strength retained after 500 hours in weatherometer	ASTM D4355	50%
Flow Rate, minimum	ASTM D4491	140 gal/min/ft^2

DESIGNER NOTE: The designer should consider including specifications for signage and pavement markings in this section.

PART 3 EXECUTION

3.01 SUBGRADE PREPARATION AND PROTECTION

A. Construct subgrade to +/- ¾ inch of the grades and slopes specified on the Plans.

B. Grading of subgrade shall be with low ground pressure equipment when within six (6) inches of final subgrade elevation.

C. Compact subgrade to 90 percent (+/- 2 percent) of the maximum dry density per standard Proctor test (ASTM D698), or as directed by the Geotechnical Engineer. Determination of in-place density shall be made using a nuclear gauge per ASTM D6939.

DESIGNER NOTE: The designer should set compaction requirements based on consideration of site specific geotechnical properties of the native soil (e.g., permeability, stiffness) and performance requirements for the pavement section (e.g., traffic loading, infiltration, cost).

D. Areas of the subgrade which are over-compacted, as determined by the Geotechnical Engineer, shall be ripped/tilled to a depth of 12 inches (minimum) or as directed by the Geotechnical Engineer and shall be recompacted in accordance with Section 3.01.C. Contractor shall locate all utilities within pavement footprint prior to ripping and re-compacting subgrade.

E. Proof-roll prepared subgrade with loaded dump truck, remove soft spots, and replace with permeable structural fill as directed by the Engineer to achieve uniform subgrade.

DESIGNER NOTE: Other subgrade verification methods may be required if site conditions limit proof rolling. Consult with geotechnical engineer for acceptable methods.

F. After compaction and proof roll, scarify subgrade ¼- to ½-inch deep by hand rake. Once scarified, materials or equipment shall not be permitted within the prepared subgrade area so as to avoid recompaction or clogging of the scarified subgrade.

G. The subgrade shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the subgrade during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

H. Areas of subgrade over-compacted by construction traffic or other impacts by the Contractor or Subcontractors shall be ripped/tilled and re-compacted in accordance with Section 3.01.D. All work and materials required to correct the over-compacted subgrade, including utility locates within the pavement footprint, shall be at the Contractor's expense.

I. Areas of subgrade contaminated by the accumulation of silty material following rains or other debris or contamination shall be removed and disposed at the Contractor's expense.

J. The subgrade shall be inspected and accepted by the Engineer prior to placement of the geotextile or pavement base.

K. Place geotextile, if required, on scarified subgrade. Care shall be taken to provide full coverage and to prevent the geotextile from being torn. Damaged geotextile shall be repaired as indicated by the manufacturer and to the satisfaction of the Engineer, at no additional cost to the Owner. Overlaps of the geotextile shall be a minimum of 1 foot or to the manufacturer's recommendation, whichever is greater.

DESIGNER NOTE: The use of geotextile under permeable pavement systems should be avoided unless required by the project geotechnical engineer as it can be prone to subsurface clogging.

3.02 PAVEMENT BASE

A. Construct pavement base to the lines, grades, and thicknesses shown on the Plans.

B. Place the pavement base so as to prevent loaded dump trucks from driving directly on the prepared subgrade.

C. Compact pavement base, in six (6)-inch (maximum) lifts, by making a minimum of three passes over the pavement base material with a ten (10)-ton vibratory roller, or as directed by the Geotechnical Engineer. The first two (2) passes (minimum) shall be in vibratory mode. The final pass shall be in static mode. Acceptance of the pavement base will be based on Engineer's observation of aggregate movement during final compaction pass. Compaction equipment shall be accepted by the Engineer prior to use.

DESIGNER NOTE: For areas or sites that cannot accommodate a vibratory roller compactor, consider allowing compaction of pavement base with a

13,500 lbf (60 kN) minimum vibratory plate compactor with a compaction indicator. At least two passes should be made over each lift of the aggregates.

D. Pavement base shall be true to the designed grade and slope, +/- 0.05 feet, after compaction for each layer. In the event of low spots, additional material shall be added and recompacted. In the event of high spots, excess material shall be removed and the area recompacted.

E. Pavement base materials shall be protected from over-compaction or contamination by silty run-off or other contaminants.

1. Provide physical barriers or direct traffic to eliminate unnecessary vehicular traffic on the pavement base during construction in accordance with SFMTA and SFDPW ordinances and specifications.

2. Do not subject placed and compacted gravel leveling course to any pedestrian or vehicular traffic before unit paver installation begins.

3. Provide flow diversion and erosion control measures to protect the permeable pavement area from sedimentation until the upstream catchment area is thoroughly stabilized.

F. Any damage to the pavement base (including contamination by silty run-off) shall be repaired to the satisfaction of the Engineer at the Contractor's expense. Contaminated pavement base shall be removed and replaced to the limits as determined by the Engineer.

G. The pavement base shall be inspected and accepted by the Engineer prior to placing any pavers.

DESIGNER NOTE: Consider developing a testing plan for the required testing and inspection of the pavement base. Verification of the in place density/compaction of the open graded base materials is typically not possible with the use of a nuclear densometer due to nature of these materials. Therefore other means to verify these materials are firm and unyielding (such as observation of the compaction process by a geotechnical engineer) are necessary.

DESIGNER NOTE: Consider requiring the Contractor to compact aggregates without crushing them.

3.03 PAVERS AND JOINT/OPENING FILL MATERIAL

A. Lay the unit pavers in the pattern(s) and joint widths shown on the Plans. Maintain straight pattern lines.

B. Fill gaps at the edges of the paved area with cut units. Cut pavers subject to tire traffic shall be no smaller than 1/3 of a whole unit.

C. Cut pavers and place along the edges with a double-bladed splitter or masonry saw.

D. Fill all openings and joints with joint filler aggregate conforming to Section 2.02.

E. Remove excess aggregate on the surface by sweeping pavers clean.

F. Compact and seat the pavers into the bedding material using a low-amplitude, 75 to 90 Hz plate compactor capable of at least 5,000 lbf (22 kN). This will require at least two passes with the plate compactor.

G. Do not compact within 6 feet (2 m) of the unrestrained edges of unit pavers.

H. Apply additional joint filler aggregate to the openings and joints if needed, filling them completely. Remove excess aggregate by sweeping, then compact the pavers. This will require at least two passes with the plate compactor.

I. All pavers within 6 feet (2 m) of the laying face must be left fully compacted and joints must be filled at the completion of each working day.

J. Compacted unit pavers shall meet the acceptance criteria set forth in Section 1.05.C.

3.04 PROTECTION OF PAVEMENT

A. Pavement surface shall be kept clean and free of clogging debris and soils from the Contractor's operations and all upstream and adjacent debris. If debris or soils contaminate the pavers/joints, the pavement shall be cleaned at the Contractor's expense and to the satisfaction of the Engineer. If pavement cannot be unclogged, it shall be removed and replaced at the Contractor's expense and to the satisfaction of the Engineer.

B. Paver installation (Sub) Contractor shall return to the site after 6 months from the completion of the Work and provide the following as needed to fully meet the specifications described herein: fill paver joints with stones, replace broken or cracked pavers, and re-level settled pavers to initial elevations. **Any additional work shall be considered part of the original bid price and with no additional compensation.**

3.05 REJECTION

A. Pavers that do not meet the acceptance criteria set forth in Section 1.05.C will be rejected by the Engineer on a lot by lot basis. Permeable/porous unit pavers that have been rejected by the Engineer or the Contractor shall be removed and replaced at no additional cost to the Owner.

END OF SECTION