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CITY OF STOCKTON & COUNTY OF SAN JOAQUIN

Stormwater Quality Control Criteria Plan

PREPARED BY:

LARRY WALKER ASSOCIATES
science | policy | solutions

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1.1 PURPOSE & GOALS

The *2020 Stormwater Quality Control Criteria Plan (2020 SWQCCP)* for the City of Stockton (City) and County of San Joaquin (County) is an update to the 2009 SWQCCP. The 2020 SWQCCP reflects the most recent Phase I municipal stormwater National Pollutant Discharge Elimination System (NPDES) permit requirements (NPDES Permit) (**Section 1.3**) and new statewide trash control requirements (**Section 1.6**).

The 2020 SWQCCP was prepared to accomplish the following goals:

- Protect water resources of the City and County from the adverse impacts of urban stormwater runoff;
- Ensure that the implementation of the measures in the SWQCCP is consistent with the NPDES permit and other State requirements, including trash control;
- Provide clear development standards for developers, design engineers, agency engineers, and planners to use in the selection and implementation of appropriate control measures;
- Emphasize the implementation of low-impact development (LID)-based strategies; and
- Provide maintenance procedures to ensure that the selected control measures will be maintained to provide effective, long-term pollution control.

1.2 BACKGROUND

In 1972, the Federal Clean Water Act (CWA) was amended to prohibit the discharge of pollutants to waters of the United States from any point source unless the discharge complies with an NPDES permit. In 1987, further amendments to the CWA added Section 402(p), which established a framework for regulating municipal and industrial stormwater discharges under the NPDES program through a two-phase regulatory approach:

- Phase I regulations, promulgated in 1990, required all medium and large municipal separate storm sewer systems (MS4s) with a population greater than one hundred thousand (100,000) and specific categories of industrial facilities to obtain an NPDES permit for stormwater discharges.
- Phase II regulations, promulgated in 1999, required all small MS4s greater than 10,000 or located within an urbanized area to obtain an NPDES permit for stormwater discharges.

In 2002, the City and urbanized portions of the County received a Phase I municipal NPDES permit (Order No. R5-2002-0181) issued by the Central Valley Regional Water Quality Control Board (Regional Water Board) for stormwater discharges from the Stockton Urbanized Area (SUA). The SUA[1] encompasses the stormwater drainage system operated by the City, the

1 Portions of the County of San Joaquin outside of the SUA are covered by the NPDES Phase II regulations. As such, development projects located outside of the SUA may not fall under the provisions of the SWQCCP. The SWQCCP is separate and distinct from the Multi-Agency Post-Construction Stormwater Standards Manual for the Cities of Lathrop, Lodi, Manteca, Patterson, and the Phase II portions of the County of San Joaquin (June 2015).

urbanized areas of the County that are enclosed within the City, and the urbanized areas of the County that surround the City that meets the CWA definition.

The 2002 NPDES permit required the City and the County to develop, administer, implement, and enforce a Planning and Land Development Program to reduce pollutants in runoff from new development and redevelopment to the maximum extent practicable (MEP). To address this requirement, the City and the County developed separate SWQCCPs in 2003. The City's SWQCCP was revised in 2005 and again in 2008.

In December 2007, the Regional Water Board issued the third term NPDES Permit (Order No. R5-2007-0173) to the City and the County, which required the submittal of a revised/functionally updated SWQCCP to the Regional Water Board. The third term permit required new development and significant redevelopment to integrate LID strategies and use a combination of stormwater control measures. As a result, the 2009 SWQCCP merged the City and County documents into one combined SWQCCP and identified how new development and significant redevelopment could meet these requirements by using a Volume Reduction Requirement (VRR). The VRR must be met through the combination of Volume Reduction Measures (VRMs) (e.g., rain barrels) and LID Treatment Controls (e.g., bioretention areas) to maintain the runoff volume from the proposed project site for a specified design storm depth at or below pre-project runoff volumes. The VRR is a separate and independent requirement from the Stormwater Quality Design Volume (SQDV) or Stormwater Quality Design Flow (SQDF), the primary required design criteria used to size Treatment Controls.

1.3 REGION-WIDE PERMIT REQUIREMENTS

The Regional Water Board adopted a Region-wide municipal stormwater NPDES Permit (Region-wide Permit; Order No. R5-2016-0040) in June 2016. Phase I Permittees enroll under the Region-wide Permit as their current individual permits expire and Phase II Permittees may enroll, if desired.

The City and County enrolled under the Region-wide Permit in 2016 and were subsequently issued Order Nos. R5-2016-0040-002 and R5-2016-0040-003, respectively. The City and County elected the Pollutant Prioritization approach for the development and implementation of their stormwater program. As such, they are subject to Attachment J of the Region-wide Permit, which includes LID and hydromodification requirements. The SWQCCP has been modified to ensure that it is consistent with the Region-wide NPDES Permit and, as such, minimizes the short- and long-term impacts on receiving water quality from new development and redevelopment.

1.3.1 Hydromodification Requirements

The Region-wide Permit requires that the City and County address hydromodification to mitigate the potential impacts of stormwater runoff on receiving waters. Where hydromodification needs to be addressed, the Region-wide Permit requires the development of a Hydromodification Management Plan to ensure that Priority Projects discharging to natural drainage systems implement hydrologic measures that will prevent downstream erosion and protect stream habitat.

Attachment J of the Region-wide Permit identifies conditions in which a Permittee may be exempt from "implementation of hydromodification controls where assessments of downstream channel conditions and proposed discharge hydrology indicate that adverse hydromodification effects to beneficial users of natural drainage systems are unlikely." The City and County are exempt from implementing hydromodification controls and developing a Hydromodification Management Plan because the natural drainage watersheds in the Stockton SUA are tidal freshwater bodies with a one- to three-foot tide range, meeting exemption iv of Attachment J of the Region-wide Permit.[2]

However, this SWQCCP emphasizes the broader concept of LID, which works to replicate pre-project hydrology in a post-project environment through the VRR and requirements to implement best management practices (BMPs) that promote retaining rainfall on-site through infiltration, evapotranspiration, or harvest and use. These requirements for projects will mitigate or eliminate the volume of stormwater runoff from a post-project site that is discharged to the receiving water and thereby mitigate potential hydromodification impacts. In cases where the VRR cannot be fully met, the project proponent must demonstrate technical infeasibility and apply alternative compliance methods for the remaining stormwater volume that is not retained on-site.

As such, the 2020 SWQCCP is consistent with and meets the requirements for hydromodification within Attachment J[3].

1.4 LOW-IMPACT DEVELOPMENT STRATEGIES

Historically, stormwater management has consisted of a network of impervious surfaces (e.g., rooftops, walkways, patios, driveways, parking lots, roads or concrete, and asphalt paving) connected to a storm drain system designed to convey stormwater off the urban landscape quickly. Dozens of studies have documented the impacts of connected impervious cover on the natural hydrologic cycle (CWP, 2003). In a natural setting, most rainfall is either infiltrated into the soil or lost to evapotranspiration. However, with urbanization, pervious surfaces (such as forests and meadows) are converted into impervious cover and rainfall is converted into stormwater runoff. This increases the volume and flow of runoff to water bodies (**Figure 1-1**). If not managed correctly, this increased stormwater runoff may adversely impact local water bodies.

[2] Page 2 of Order No. R5-2015-0024.

[3] Finding 16 of the 2016 Region-wide Permit notes "Properly designed, installed, and maintained LID measures are a primary method to address the causes of hydromodification."

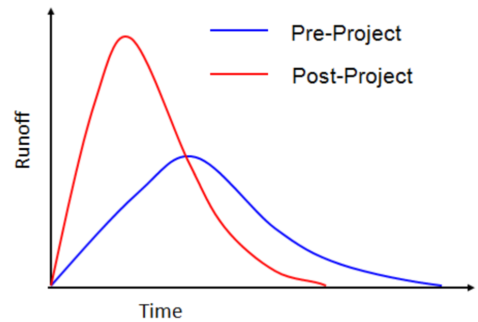


Figure 1-1. Pre vs. Post Project Hydrograph. *Modified from Source: Haltiner, Jeffrey, Philip Williams & Associates, Ltd. Hydromodification: An Introduction and Overview Presentation. (2006, May).*

To mitigate these impacts, conventional BMPs, such as detention basins, were implemented to temporarily detain stormwater runoff by releasing the flow over time (**Figure 1-2**).

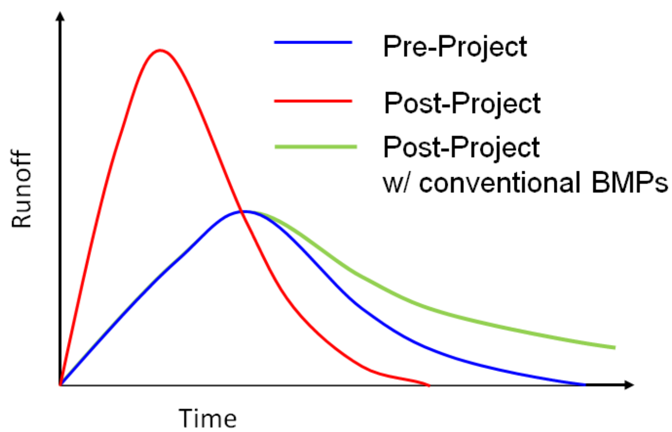


Figure 1-2. Hydrograph with Conventional BMPs. *Modified from Source: Haltiner, Jeffrey, Philip Williams & Associates, Ltd. Hydromodification: An Introduction and Overview Presentation. (2006, May).*

To improve pollutant removal and groundwater recharge benefits, LID-based strategies have been incorporated into an overall stormwater management approach. LID is defined as, "a stormwater management and land development strategy that emphasizes conservation and the use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely reflect pre-project hydrologic functions. LID strategies include retention practices that do not allow runoff, such as infiltration, rain-water harvesting and use, and evapotranspiration."[4]

LID is a decentralized approach to stormwater management that mimics the site's natural hydrology by retaining rainfall onsite. The idea is to eliminate the shaded areas, as shown in **Figure 1-3,** by reducing the peak volume and flow duration through site design and VRMs. The benefits of the reduced stormwater volume include reduced pollutant loading and increased groundwater recharge and evapotranspiration rates.

[4] 2016 Region-wide Permit, Attachment C.

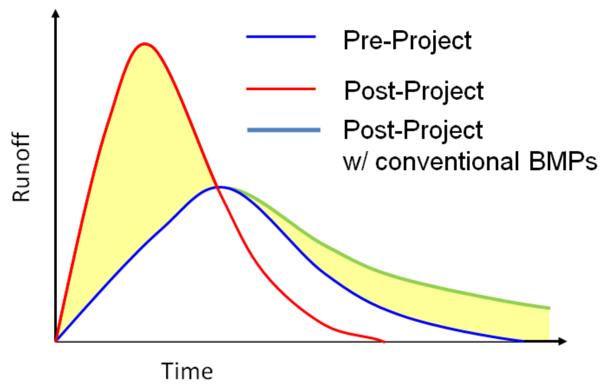


Figure 1-3. Goal of LID is to Mimic Pre-Project Hydrography through Reduction in Peak Runoff Volume and Flow. *Modified from Source: Haltiner, Jeffrey, Philip Williams & Associates, Ltd. Hydromodification: An Introduction and Overview Presentation. (2006, May).*

Additionally, LID strategies can decrease the cost associated with stormwater management and treatment by reducing the number of materials needed for pavement, the need for curbs and gutters, and by reducing stormwater volume, which will correspond to smaller flood-control structures.

A study by the US Environmental Protection Agency (USEPA) in 2007 examined seventeen case studies to compare the projected or known costs of LID strategies with those of conventional development practices. The study found that most projects realized significant savings due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping.

1.5 LOW IMPACT DEVELOPMENT STRATEGIES AND THE STORMWATER QUALITY CONTROL CRITERIA PLAN: KEY CONCEPTS

The 2009 SWQCCP introduced the concept of VRR and emphasized LID-based strategies. The VRR provides a design criterion to implement LID at a proposed development project. This allows developers and plan reviewers to determine when LID is achieved and what constitutes adequate stormwater management.

Key concepts associated with the VRR include:

- New Development and Significant Redevelopment Priority Projects (Priority Projects) must apply four categories of stormwater pollution controls measures:
    a. Site Design Controls (**Section 3**);
    b. Source Controls (**Section 4**);
    c. VRMs (**Section 5**); and
    d. Treatment Controls (**Section 6**).
- New Development Priority Projects must comply with the VRR. The VRR can be met by applying VRMs (BMPs that reduce runoff volume as outlined in **Section 5**) and LID Treatment Controls (BMPs that provide Treatment Control and reduce runoff volume as outlined in **Section 6**).

- The VRR is determined by subtracting the pre-project runoff volume from the post-project runoff volumes for the 0.51-inch storm depth, which is the average 85th percentile, 24-hour storm depth estimated for the SUA.
- Significant Redevelopment Priority Projects must also comply with the VRR; however, credits may be applied based on the type of redevelopment. A credit of 0.05 inches from the 0.51-inch VRR may be applied to any of the following types of redevelopment. A maximum credit of 0.25 inch from the 0.51-inch VRR may be applied to any redevelopment type. Credits are issued in 0.05-inch increments based on five criteria:
    - Significant Redevelopment (as defined in **Section 2**)
    - Brownfield redevelopment
    - High density (>7 units per acre)
    - Vertical Density (Floor to Area Ratio (FAR) of 2 or >18 units per acre)
    - Mixed-use and Transit Oriented Development (within ½ mile of public transit)
- The runoff coefficients used to calculate the VRR should be based on the specific land use elements of the development site (e.g., as opposed to a blanket coefficient for all medium-density residential). The goal is to reduce or minimize impervious areas, and thus runoff coefficients, through site design strategies. Lower runoff coefficients will result in a smaller VRR. Fact Sheet G-4 in **Section 3** suggests strategies to minimize impervious cover. Minimizing or eliminating the use of curb and gutter, so that roadway runoff drains to swales and other VRMs or LID Treatment Controls is strongly encouraged where slope and density permit.
- To meet the VRR, projects must <u>first</u> apply VRMs. The Volume Reduction Measure fact sheets (**Section 5**) detail how volume reduction is calculated for each measure.
- VRMs also provide treatment benefits, which are recognized through tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls. The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of VRMs reduces effective impervious area and, thereby, the volume of water to be treated. The Volume Reduction Measure fact sheets (**Section 5**) detail how the tributary impervious area credit is calculated for each measure. The application of credits to determine an effective area for the design of Treatment Controls is described in **Section 6**.
- If a project does not fully meet the VRR through the application of VRMs, the project must use LID Treatment Controls to reduce stormwater runoff volumes further and treat the SQDF or SQDV. Calculation procedures for determining the volume reduction for LID Treatment Controls are provided within each fact sheet in **Section 6**.

- Treatment Controls are categorized into two groups: LID Treatment Controls (structural BMPs that reduce runoff volume) and Conventional Treatment Controls (structural BMPs that typically do not reduce runoff volume).
- If the VRR has been met through VRMs, projects may utilize either LID Treatment Controls or Conventional Treatment Controls to treat the SQDV or SQDF.
- The selection of Treatment Controls should be based on their ability to reduce runoff volumes and remove pollutants of concern. See **Table 6-2** in **Section 6** for pollutant removal efficiency of treatment controls.

- If the VRR is not entirely met through the combination of VRMs and LID Treatment Controls, the project must comply with the process described in **Section 5**.

1.6 TRASH CONTROL REQUIREMENTS

On April 7, 2015, the State Water Resources Control Board (State Water Board) adopted an Amendment to the Water Quality Control Plan for Ocean Waters of California to Control Trash and Part 1 Trash Provision of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries. Together, they are collectively referred to as "the Trash Amendments." The Trash Amendments apply to all stormwater permittees under the NPDES municipal stormwater program, including the City and County.

The Trash Amendments require agencies with regulatory authority over priority land uses (PLUs) to comply with the prohibition of trash discharge to receiving waters. As defined in the Statewide Trash Amendments, PLU areas include high-density residential, industrial, commercial, mixed urban, and public transportation stations (**Section 2**). As such, development and redevelopment projects within these PLU categories will be required to implement trash controls consistent with the Trash Amendment criteria (**Section 6**).

2. STORMWATER MANAGEMENT STANDARDS FOR NEW DEVELOPMENT AND SIGNIFICANT REDEVELOPMENT

This section provides an overview of the stormwater management standards for new development and significant redevelopment, contains information regarding development projects that are subject to the SWQCCP, and outlines the process that must be used to effectively incorporate stormwater control measures and satisfy the requirements of the permitting agencies within the City and County.

The control measures, often termed BMPs, were selected to optimize post-construction, on-site stormwater pollution control. All New Development and Significant Redevelopment Priority Projects must apply all four categories of stormwater pollution controls measures, which include:

- Site Design Controls (**Section 3**)
- Source Controls (**Section 4**)
- Volume Reduction Measures (**Section 5**)
- Treatment Controls (**Section 6**)

In addition, all Priority Projects and PLU Projects must apply trash control measures (**Section 6**).

2.1 PROCESS TO COMPLY WITH CITY AND COUNTY STANDARDS

A step-by-step process for incorporating these controls is illustrated in **Figure 2-1** for projects implemented in a PLU area (PLU Project) and **Figure 2-2** for Priority Projects (see Step 1 below for determining the type of project).

In addition to the requirements prescribed within the SWQCCP, development projects must also adhere to applicable drainage standards as specified in the City *Standard Specifications and Plans* or the County *Improvement Standards*.

Step 1: Determine Project Type

The first step is to identify whether the project is in the Stockton Urbanized Area (**Figure 2-3**) and:

A. A PLU Project;

B. A Priority Project; or

C. Both a Priority Project and a PLU Project.

Priority Projects and PLU Projects must implement the required controls as identified in the SWQCCP.

A. PLU Projects include the following:

1. **High-density residential** – All land uses with at least 10 developed dwelling units per acre. Note that not all Priority Projects under B.1 below are PLU Projects; only those projects that meet the density threshold defined here are also PLU Projects.
2. **Industrial** – Land uses where the primary activities on the developed parcels involve product manufacture, storage, or distribution (e.g., manufacturing businesses, warehouses, equipment storage lots, junkyards, wholesale businesses, distribution centers, or building material sales yards). Note that all Priority Projects under B.2 below are PLU Projects.
3. **Commercial** – Land uses where the primary activities on the developed parcels involve the sale or transfer of goods or services to consumers (e.g., business or professional buildings, shops, restaurants, theaters, vehicle repair shops, etc.). Note that all Priority Projects under B.2 below are PLU Projects.
4. **Mixed urban** – Land uses where high-density residential, industrial, and/or commercial land uses predominate collectively (i.e., are intermixed).
5. **Public transportation stations** – Facilities or sites where public transit agencies' vehicles load or unload passengers or goods (e.g., bus stations and stops).

B. Priority Projects[5] include the following:

1. **Residential subdivision of 10 housing units or more –** This category includes single-family homes, multi-family homes, condominiums, and apartments, as well as the related street and road paved surfaces that are used for the transportation of automobiles, trucks, motorcycles, and other vehicles (not including parking lots, see separate parking lot requirement below).
2. **Commercial and industrial developments greater than or equal to 5,000 square feet –** This category is defined as any development on private land that is not for residential uses, where the land area for development is greater than or equal to 5,000 square feet of impervious area (not including the parking lot, see separate parking lot requirement below) as well as the related street and road paved surfaces that are used for the transportation of automobiles, trucks, motorcycles, and other vehicles. The category includes but is not limited to industrial facilities, restaurants (Standard Industrial Classification (SIC) code 5182), automotive repair shops (SIC codes: 5013, 5014, 5541, 7532-7534, or 7536-7539), gas stations, hospitals, laboratories and other medical facilities, educational institutions

[5] Priority Development Projects are defined within Attachment C of the Region-wide Permit. It should be noted that the Attachment C category "Single-family hillside residences (includes development on any natural slope that is twenty five percent or greater)" does not apply within the SUA.

(including K-12 schools and secondary education facilities[6]), recreational facilities, commercial retail nurseries, multi-apartment buildings, car wash facilities, mini-malls, and other business complexes, shopping malls, hotels, office buildings, public warehouses, and other industrial facilities. Note that all Priority Projects in this category are also PLU Projects.

3. **Parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to urban runoff –** A parking lot is defined as a land area or facility for the temporary parking or storage of motor vehicles used personally, for business, or commerce.

4. **Significant redevelopment** – Significant redevelopment is defined as the *creation or addition of at least 5,000 square feet of impervious surfaces* on an already developed site. Significant redevelopment includes, but is not limited to, expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surfaces[7] that is not part of a routine maintenance activity[8]; and land disturbing activities related with structural or impervious surfaces. It does not include routine maintenance to maintain the original line and grade, hydraulic capacity, or emergency construction activities required to protect public health and safety immediately.

   In the case of an addition, if the addition constitutes less than 50 percent of the original development, post-construction stormwater requirements only apply to the addition.[9]

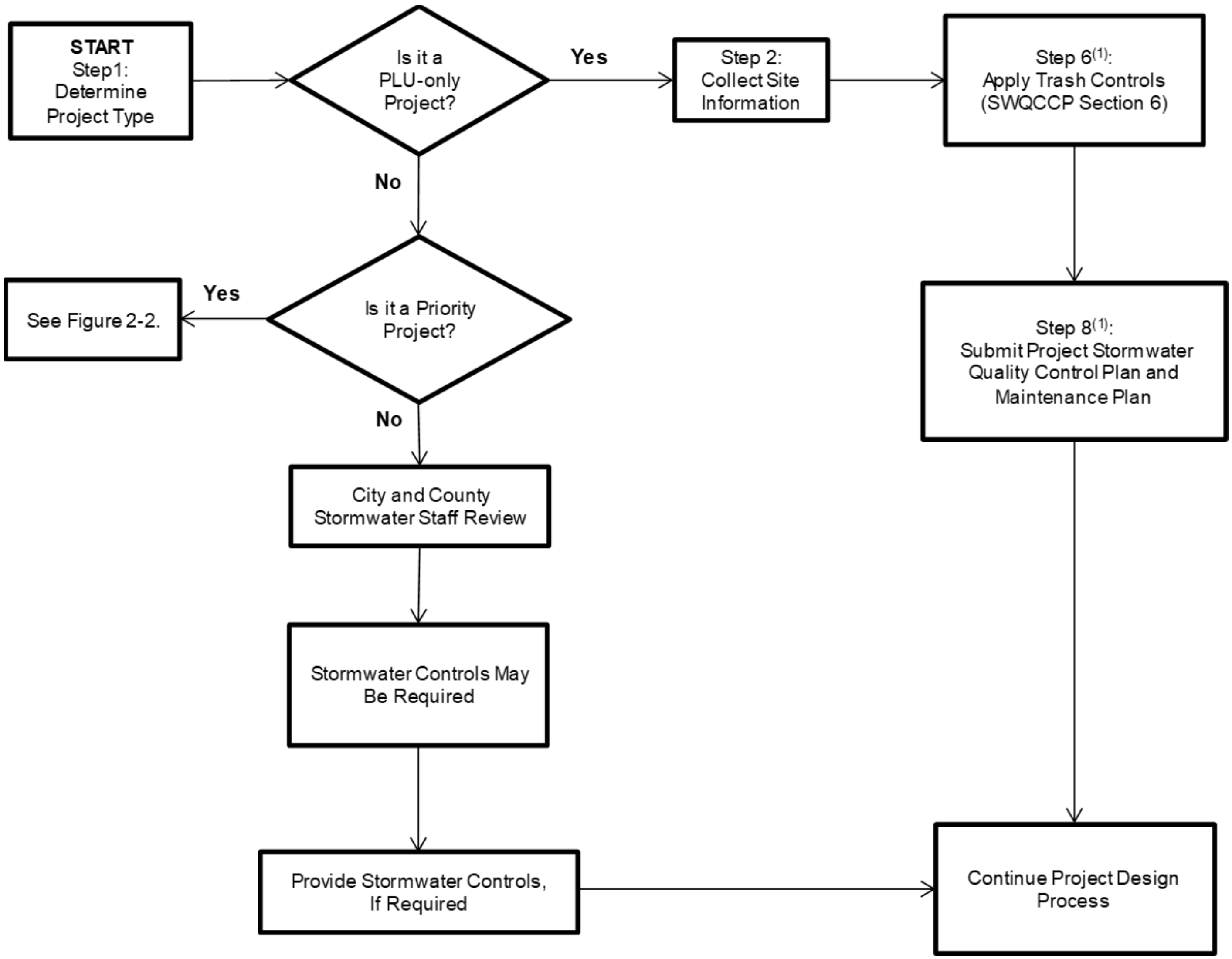
   The standards outlined in the SWQCCP shall apply to all new development and significant redevelopment projects falling under the Priority Project and/or PLU Project categories as specified above. Compliance with the SWQCCP should be discussed as early as possible in the design process. The project engineer and other design professionals (including architects) should be involved during the City's Tentative Map stage or the County's Site or Use Permit Approvals.

[6] K-12 schools are included within this category due to similar requirements that are or will be required of them consistent with the following documents/regulatory requirements. Examples of these requirements include the following: a) in the future, the Phase II Small MS4 Permit will require K-12 schools to obtain coverage and comply with the permit requirements including, but not limited to post construction controls for new development and significant redevelopment; b) Section XIII of the General Construction Permit (Order No. 2009-0009-DWQ) states "All dischargers shall comply with the following runoff reduction requirements unless they are located within an area subject to postconstruction standards of an active Phase I or II MS4 permit that has an approved Storm Water Management Plan."; and c) guidance for stormwater management principles and common capture practices has been developed specifically for schools Guidance for Stormwater and Dry Weather Runoff CAPTURE at Schools, December 2018.

[7] Replacement of impervious surfaces includes any activity where impervious materials are removed, exposing underlying soil during construction.

[8] Routine maintenance includes activities that are conducted to maintain original line and grade and/or hydraulic capacity. If the activity significantly disturbs the soil under the base then it is not considered routine maintenance.

[9] For example, if a 5,000 sq-ft addition is built for an existing 10,000 sq-ft building, post-construction stormwater requirements apply to the 5,000 sq-ft addition.



(1) Steps 3-5 and Step 7 do not apply to PLU-only projects.

Figure 2-1. Process for Meeting New Development & Significant Redevelopment Stormwater Standards for PLU-Only Projects

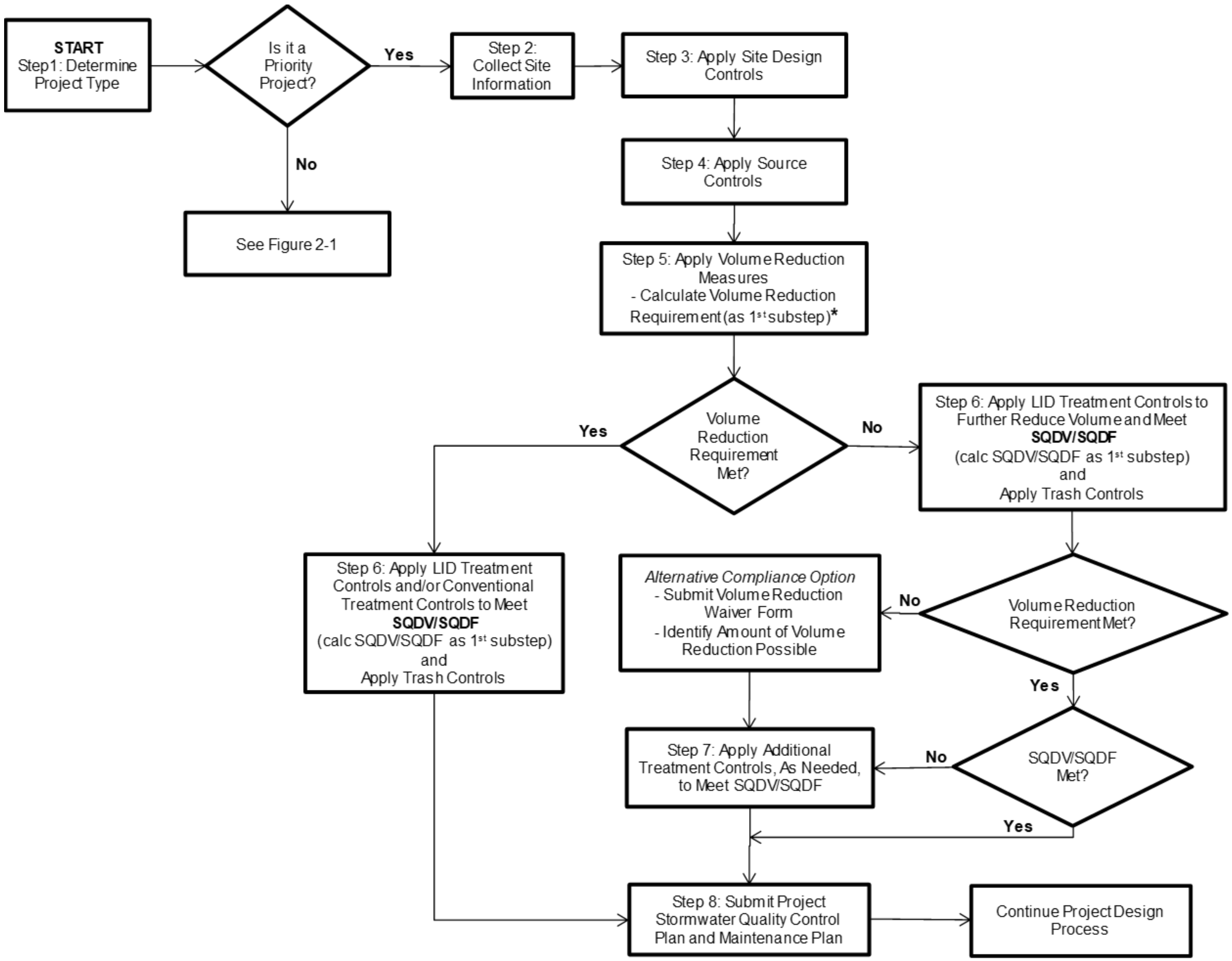


Figure 2-2. Process for Meeting New Development & Significant Redevelopment Stormwater Standards for Priority Projects

*Significant Redevelopment Priority Projects must also comply with the VRR; however, credits may be applied (See Step 5)

Step 2: Collect Site Information [Applies to PLU Projects and/or Priority Projects]

The next step is to collect site information that is critical for the selection of appropriate stormwater controls. The following information must be documented and submitted to the City of Stockton Municipal Utilities Department Stormwater Division or the San Joaquin County Department of Public Works at the onset of the application process. For PLU-only Projects, information is only necessary for items a-f.

a. Project Category (see Step 1)
b. Gross project area (acres)
c. Drainage areas (acreage and location via site map)
d. Impervious area (acreage and location via site map)
e. Location of discharge (to the storm drain system or local receiving water)
f. Location of the project within the Stockton Urbanized Area (see **Figure 2-3**)
g. Land use type, the density of the development project, and pollutants associated with that land use type (**Table 2-1**). Identify any additional pollutants expected to be present on-site at concentrations that pose potential water quality concerns
h. Activities expected to be on the site
i. Site conditions: topography, hydraulic head, groundwater and soils (see **Appendix F)**

Table 2-1. Priority Project and PLU Project Categories and Associated Pollutants of Concern

Project Category	Pollutant Category of Concern						
	Sediment	Nutrients	Metals	Trash	Oxygen Demand	Toxic Organics	Bacteria
Residential Development/ Home Subdivisions (≥ 10 units)	X	X	X[1]	X	X		X
Commercial and Industrial Developments (≥ 5,000 SF)	X	X	X	X	X	X	X
Parking Lots (≥ 5,000 SF or 25 spaces)	X	X	X	X	X		
High Density Residential				X			
Mixed Urban				X			
Public Transportation Stations				X			

X = Pollutant assumed to be present in stormwater runoff from project area unless applicant demonstrates otherwise.
1 – Metals are a pollutant category of concern for the street and road infrastructure portion of the residential development.

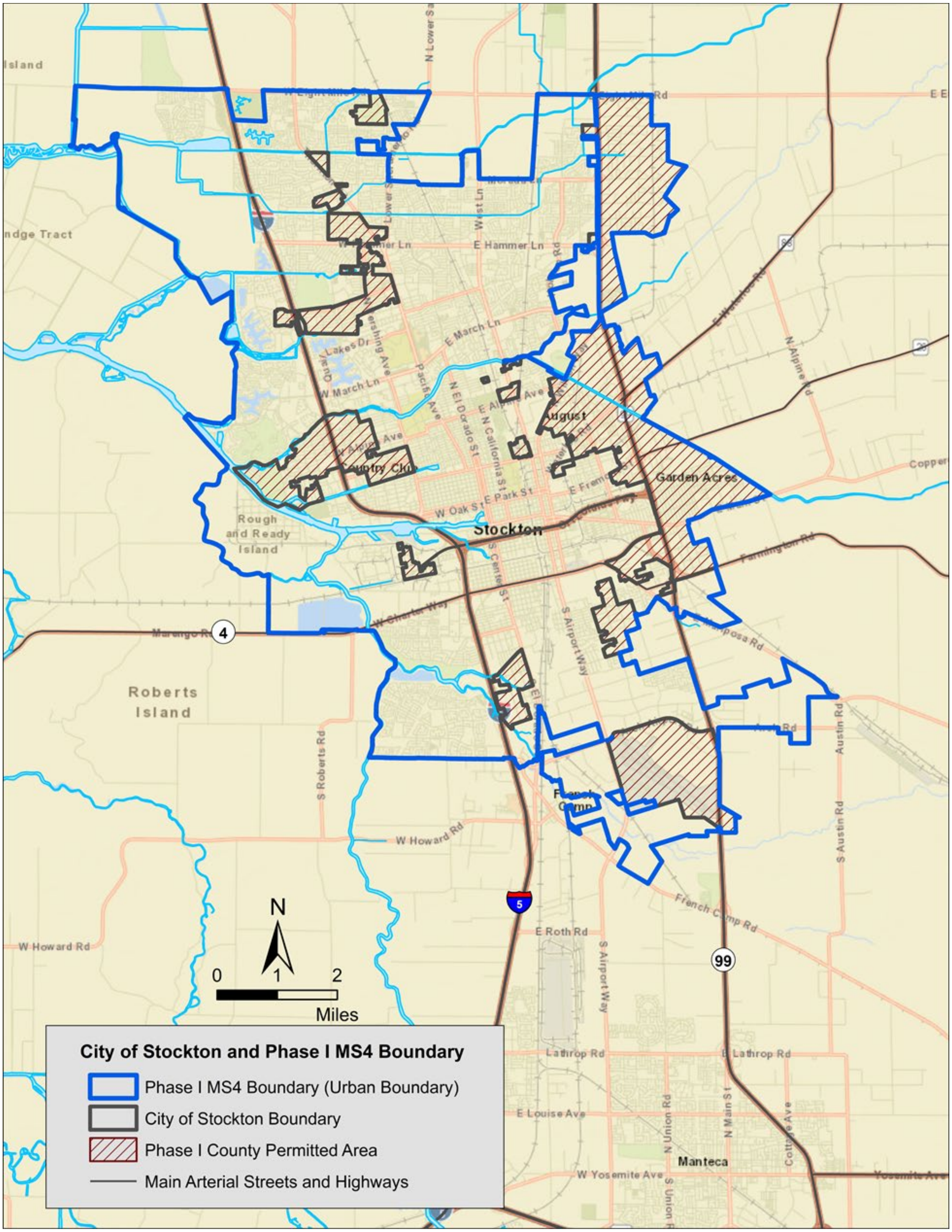


Figure 2-3. Stockton Urbanized Area. *Source: 2000 U.S. Census Bureau Topologically Integrated Geographic Encoding and Referencing system (TIGER) Data*

Step 3: Apply Site Design Controls [*Applies to Priority Projects*]

The third step is to apply the required Site Design Controls as specified in **Table 2-2**. Site Design Controls protect sensitive environmental features such as riparian areas, wetlands and steep slopes. Development should be located on the least sensitive portion of the site. Additionally, the project should minimize impervious cover and soil compaction. These controls will help reduce runoff volume and is the first step (and possibly the most inexpensive control measure) in meeting the VRR (see Step 5). Additional guidance on Site Design Controls can be found in **Section 3**. Minimizing or eliminating the use of curb and gutter so that roadway runoff drains to swales and other VRMs or LID Treatment Controls is strongly encouraged where the slope and density permit.

Step 4: Apply Source Controls [*Applies to Priority Projects*]

All New Development and Significant Redevelopment Priority Projects must implement applicable Source Controls. Source Controls are operational practices that prevent pollution by reducing potential pollutants at the source. The Priority Projects must implement the source control measures specified in **Table 2-2**.

Step 5: Apply Volume Reduction Measures [*Applies to Priority Projects*]

All New Development and Significant Redevelopment Priority Projects must apply VRMs (**Table 2-2**). VRMs are generally considered BMPs that can direct, retain, reuse, and/or infiltrate stormwater runoff (e.g., rain gardens, rain barrels). Guidance for implementing VRMs is presented in **Section 5**. As the first sub-step to Step 5, projects must calculate their VRR.

The **VRR** drives the application of VRMs. The VRR was developed in response to the 2009 NPDES Permit specifying the explicit use of LID strategies and a combination of stormwater control measures.

The **VRR** specifies that post-project runoff volumes must match pre-project runoff volumes for the 0.51-inch storm depth, the average 85th percentile 24-hour storm depth estimated for the SUA. In other words, the **VRR** equals the post-project runoff volume (without VRMs) minus the pre-project runoff volume. New Development Priority Projects can combine VRMs and LID Treatment Controls (see Step 6) to meet the VRR. Additional information on the VRR is presented in **Section 5**.

VRMs also provide treatment benefits recognized through tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls. The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of VRMs reduces the effective impervious area and, thereby, the volume of water to be treated.

The Volume Reduction Measure fact sheets (**Section 5**) detail how volume reduction and tributary impervious area credits are calculated for each measure. The application of credits to determine effective area for design of Treatment Controls is described in **Section 6**. **Appendix B** provides additional information on calculating and meeting the VRR.

Volume Reduction Requirement Credit for Significant Redevelopment

Significant Redevelopment Priority Projects must also comply with the VRR; however, an incentive in the form of credits may be applied based on the type of redevelopment. A maximum credit of 0.25 inch from the 0.51-inch VRR may be applied to any of the following types of redevelopment. Credits are issued in 0.05-inch increments based on five criteria:

- Significant Redevelopment (as defined in Step 1)
- Brownfield redevelopment
- High density (>7 units per acre)
- Vertical Density (FAR of 2 or >18 units per acre)
- Mixed-use and Transit Oriented Development (within ½ mile of public transit, such as a bus stop)

Step 6: Apply Treatment Controls [Applies to PLU Projects and/or Priority Projects]

Treatment controls are required for all Priority Projects and PLU Projects (**Table 2-2**). Treatment controls are engineered technologies designed to remove pollutants from stormwater runoff and must be designed to treat the SQDF or SQDV. All Treatment Controls, except those controls specifically implemented for trash, are designed to treat the runoff from the smaller storms and the first flush of large storms, which comprise 80-85 percent of annual runoff volumes.

For trash, the following types of controls may be implemented as long as they are designed to treat the peak flow rate from a one-year, one-hour storm (0.345 inches):

- Full Capture Systems (FCS)[10];
- Multi-Benefit Projects[11]; and
- Other Treatment Controls[12].

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets located within the parcel's boundaries and operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public Right of Way (RoW) if the City or County has agreed to enter into a maintenance agreement with the property owner (**Appendix D**).

The volume or flow in excess of the treatment design values is typically bypassed. Guidance on sizing the Treatment Controls is provided in **Section 6**. The selection of Treatment Controls should be based on their ability to reduce runoff volumes and remove the pollutants of concern. See **Table 6-2** for the typical removal efficiency of treatment controls.

[10] Full Capture System: A treatment control, or series of treatment controls, including but not limited to, a Multi-Benefit project or a LID control that traps all particles that are 5 mm or greater and has the 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 sub-drainage area, or b) appropriately sized to, and designed to carry at least the same flows as the corresponding storm drain. For a list of certified and/or agency-approved devices contact the City or County.

[11] Multi-Benefit Project: A treatment control project designed to achieve any of the benefits set forth in section 10562, subdivision (d) of the Water Code. For a list of certified and/or agency approved BMPs contact the City or County.

[12] Treatment Controls: Structural BMPs to either (a) remove pollutants and/or solids from stormwater runoff, wastewater, or effluent, or (b) capture, infiltrate or reuse stormwater runoff, wastewater, or effluent. Treatment Controls include FCS and LID controls.

As indicated in Step 5, New Development Priority Projects must meet the VRR. If the VRR has not been met through the use of VRMs, LID Treatment Controls must be used to reduce runoff volume further to meet the Requirement. If the VRR is fully met through VRMs, then a treatment control may be chosen from the lists of LID Treatment Controls or Conventional Treatment Controls.

If the VRR cannot be fully met due to site constraints, see “Alternative Compliance Option” in **Section 5**. New Development and Significant Redevelopment Priority Projects that cannot fully meet the VRR must select Treatment Controls with a medium to high removal efficiency for the pollutants of concern (see **Tables 2-1 and 6-2**).

Guidance on Volume Reduction is provided in **Appendix B** and throughout the Fact Sheets provided in **Sections 5 and 6**.

Step 7: Select Additional Treatment Controls as Needed to Meet Treatment Requirement [*Applies to Priority Projects*]

If the Treatment Requirement is not entirely met through a combination of VRMs and LID Treatment Controls, the project must apply Conventional Treatment Controls to meet the requirement. Guidance on the selection and design of Conventional Treatment Controls is provided in **Section 6**.

Regional Stormwater Facilities

New Development and Significant Redevelopment Projects that discharge stormwater runoff to City or County-approved, regional stormwater treatment control facilities that comply with the SQDV/SQDF requirements of the SWQCCP are not required to provide separate treatment controls. However, such projects are required to meet the VRR and provide site design, source, and VRMs following the SWQCCP.

Step 8: Submit Project Stormwater Quality Control Plan and Maintenance Plan [*Applies to PLU Projects and/or Priority Projects*]

Projects subject to the requirements of the SWQCCP, as defined in Step 1, are required to submit a Project Stormwater Quality Control Plan (SWQCP) that adequately demonstrates that the proposed project will conform to all requirements of the SWQCCP.

The SWQCP must be approved by the City of Stockton Municipal Utilities Department or the San Joaquin County Department of Public Works (whichever agency has jurisdiction over the project). Project SWQCPs should conform to the content and format requirements indicated in **Appendix E** of this document. Flow charts depicting the City and County’s project SWQCP review and approval process are provided in **Figures 2-4** and **2-5**, respectively.

The City and the County also require the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater controls prior to the final acceptance of a private project for projects using any of the Structural Source Controls that require maintenance (**Section 4**), VRMs (**Section 5**) and Treatment Controls (**Section 6**).

Maintenance Plans must include guidelines for how and when inspection and maintenance should occur for each control. **Section 7** and **Appendices D and E** provide additional information and guidance on compliance with maintenance requirements.

Table 2-2. Control Measure Selection Matrix for New Development and Significant Redevelopment Project Categories

Project Category	Site Design Controls				Source Controls							VRMs	Treatment Controls
	Conserve Natural Areas (G-1)	Protect Slopes and Channels (G-2)	Minimize Soil Compaction (G-3)	Minimize Impervious Area (G-4)	Storm Drain Message and Signage (S-1)	Outdoor Storage Area Design (S-2)	Trash Storage Area Design (S-3)	Loading/ Unloading Dock Area Design (S-4)	Repair/ Maintenance Bay Design (S-5)	Vehicle/ Equipment/ Accessory Washing Area Design (S-6)	Fueling Area Design (S-7)	Rain Garden (V-1) Rain Barrel/Cistern (V-2) Interception Trees (V-3) Grassy Channel (V-4) Vegetated Buffer Strip (V-5)	<u>LID Treatment Controls</u> Bioretention (L-1)[t] Stormwater Planter (L-2) Tree-well Filter (L-3) Infiltration Basin (L-4)[t] Infiltration Trench (L-5)[t] Porous Pavement Filter (L-6) Vegetated (Dry) Swale (L-7) Grassy Swale (L-8) Grassy Filter Strip (L-9) <u>Conventional Treatment Controls</u> Constructed Wetland (C-1) Extended Detention Basin (C-2)[t] Wet Pond (C-3) Proprietary Control Device (C-4) Trash Controls (C-5)
Residential Subdivisions (≥ 10 units)	R	R	R	R	R	R^1	-	-	-	-	-	S	S/T
High-Density Residential (> 10 DU/acre)													T
Commercial and Industrial Developments (<5,000 SF)	-	-	-	-	-	-	-	-	-	-	-	-	T
Commercial and Industrial Developments (≥ 5,000 SF)	R	R	R	R	R	R^1	R^1	R^1	R^1	R^1	R^1	S	S/T
Parking Lots (≥ 5,000 SF or 25 spaces)	R	R	R	R	R	R^1	R^1	-	-	-	-	S	S/T
Mixed Urban Development	-	-	-	-	-	-	-	-	-	-	-	-	T
Public Transportation Stations	-	-	-	-	-	-	-	-	-	-	-	-	T
Significant Redevelopment	R	R	R	R	R	R^1	R^1	R^1	R^1	R^1	R^1	S	S/T

R: required
R^1: required if outdoor activity is included in the project
S: select one or more applicable controls
[t]: can be modified to meet trash control requirements
S/T: select one or more applicable controls; trash control required
T: trash control required

Table 2-3. Control Measure Selection Matrix for Meeting Low Impact Development and Treatment Requirements

Control Measure	Assists in Meeting Requirements for:	
	Low Impact Development (1)	Treatment
Rain Garden (V-1)	✓	✓
Rain Barrel/Cistern (V-2)	(2)	
Interception Tree (V-3)	(2)	
Grassy Channel V-4)	(2)	(3)
Vegetated Buffer Strip (V-5)	(2)	(3)
Bioretention (L-1)	✓	✓
Stormwater Planter (L-2)	✓	✓
Tree-Well Filter (L-3)	✓	✓
Infiltration Basin (L-4)	✓	✓
Infiltration Trench (L-5)	✓	✓
Porous Pavement Filter (L-6)	✓	✓
Vegetated (Dry) Swale (L-7)	✓	✓
Grassy Swale (L-8)	✓	✓
Grassy Filter Strip (L-9)	✓	✓
Constructed Wetland (C-1)	✓	✓
Extended Detention Basin (C-2)		✓
Wet Pond (C-3)		✓
Proprietary Control Devices (C-4)		✓
Trash Capture Devices (C-5)		✓

(1) The SWQCCP emphasizes LID (which works to replicate pre-project hydrology in a post-project environment) by retaining rainfall on-site through infiltration, evapotranspiration, or harvest and use. These requirements mitigate or eliminate the volume of stormwater runoff from a post-project site that is discharged to the receiving water, thereby mitigating potential hydromodification impacts.

(2) Control measures may provide some LID benefits by mitigating some stormwater runoff volume. However, it must be coupled with other LID control measures to meet LID requirements.

(3) Control measures may provide some pollutant treatment to reduce pollutant load discharged off-site.

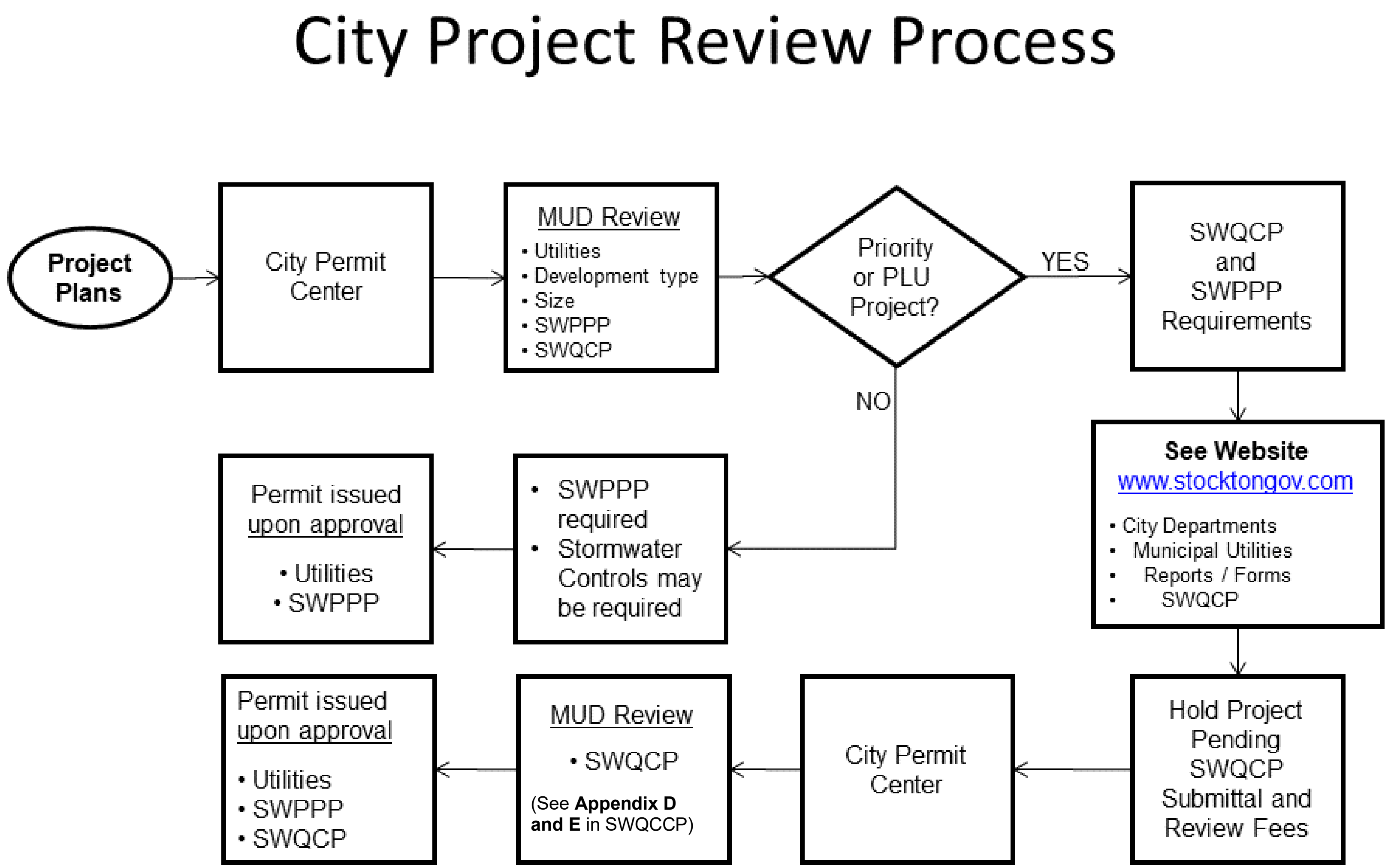


Figure 2-4. City SWQCP Review Process Flowchart

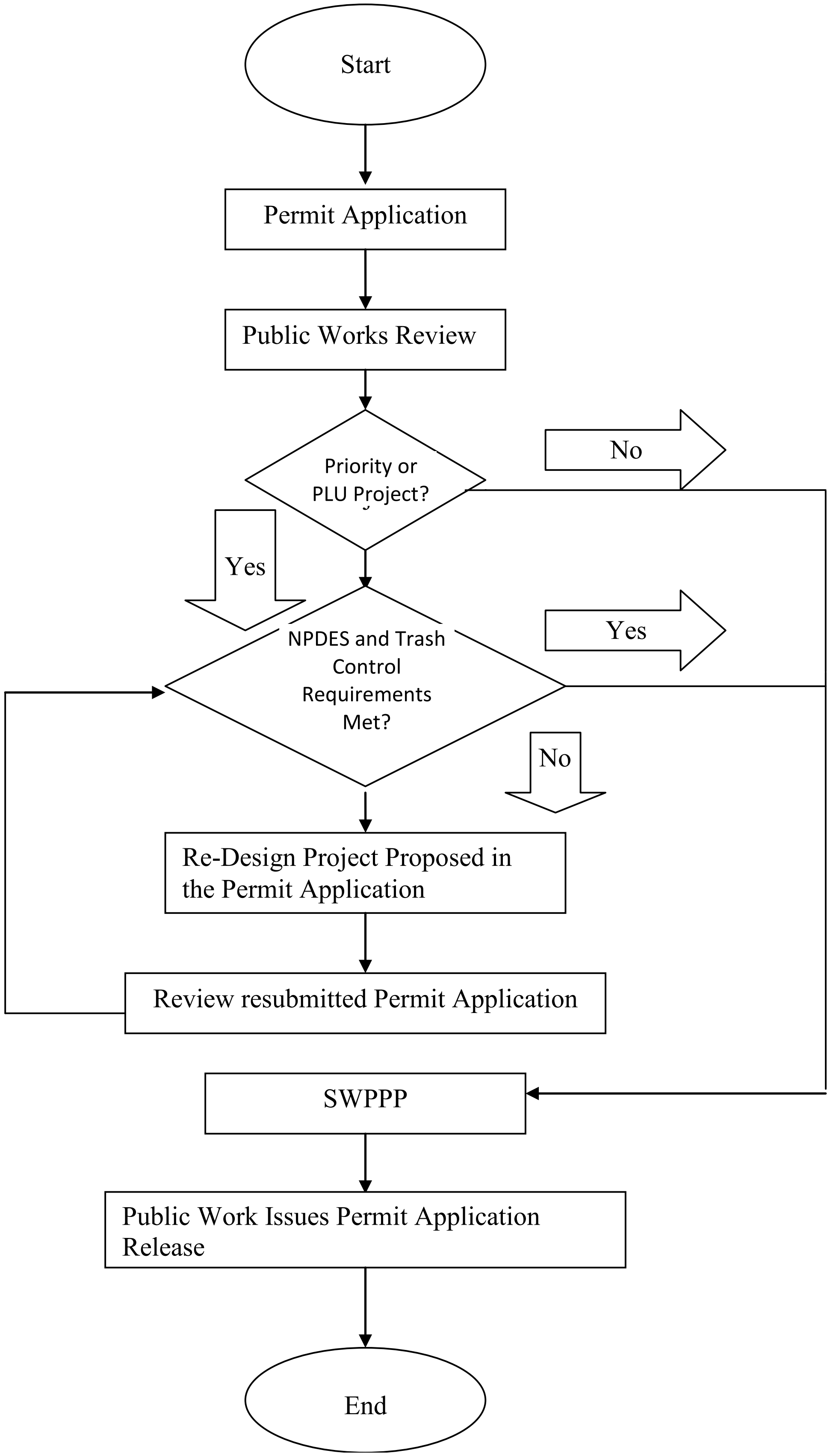


Figure 2-5. County SWQCP Review Process Flowchart

3. SITE DESIGN CONTROLS

3.1 INTRODUCTION

The principal objective of the Site Design Controls is to reduce stormwater runoff peak flows and volumes through appropriate site design. The benefits derived from this approach include:

- Reduced size of downstream treatment controls and conveyance systems;
- Reduced pollutant loading to treatment controls; and
- Reduced hydraulic impact on receiving streams.

Site Design Controls include the following design features and considerations designated as G-1 through G-4:

- G-1: Conserve Natural Areas
- G-2: Protect Slopes and Channels
- G-3: Minimize Soil Compaction
- G-4: Minimize Impervious Area

The Site Design Controls described in this section are required for all New Development and Significant Redevelopment Priority Projects unless the project proponent demonstrates to the satisfaction of the City or County that the particular measures do not apply to the proposed project or the project site conditions; making it infeasible to implement the site design control measure in question. The applicability of specific controls outlined within this section should be confirmed with the City or County.

3.2 DESCRIPTION

Detailed descriptions and design criteria for each Site Design Control are presented in the following fact sheets.

G-1: Conserve Natural Areas

Purpose

Each project site possesses unique topographic, hydrologic and vegetative features, some of which are more suitable for development than others. Locating development on the least sensitive portion of a site and conserving naturally vegetated areas can minimize environmental impacts in general and stormwater runoff impacts in particular.

Design Criteria

If applicable and feasible for the given site conditions, the following site design features or elements are required and should be included in the project site layout, consistent with applicable General Plan and Local Area Plan policies:

1. Preserve riparian areas and wetlands.
2. Concentrate or cluster development on least-sensitive portions of a site while leaving the remaining land in an undisturbed natural state.
3. Identify and avoid areas susceptible to erosion and sediment loss.
4. Limit clearing and grading of native vegetation at a site to the minimum amount needed to build lots, allow access, and provide fire protection. This area may be defined as the development envelope.
5. Maintain existing topography and existing drainage divides to encourage dispersed flow.
6. Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting native and/or drought-tolerant plants.
7. Promote natural vegetation by using parking lot islands and other landscaped areas.

Purpose

Erosion of slopes and channels can be a major source of sediment and associated pollutants, such as nutrients, if not properly protected and stabilized.

Design Criteria

Slope Protection

Slope protection practices must conform to design requirements or standards set forth by local agency erosion and sediment control (ESC) standards and design standards (the City ordinance can be found in Municipal Code Section 13.16.010 and County standards can be found in the County Improvement Standards). The design criteria described in this fact sheet are intended to enhance and be consistent with these local standards.

1. Slopes must be protected from erosion by safely conveying runoff from the tops of slopes.
2. Slopes must be vegetated (full-cover) with first consideration given to use of native or drought-tolerant species.

Channel Protection

The following measures should be implemented to provide erosion protection of unlined receiving streams. Activities and structures must conform to applicable standards and specifications of agencies with the jurisdiction (e.g., U.S. Army Corps of Engineers (COE), California Department of Fish and Wildlife).

1. Utilize natural drainage systems where feasible but minimize runoff discharge rate and volume to avoid erosive flows.
2. Stabilize permanent channel crossings.
3. In cases where beds and/or banks of receiving streams are fragile and particularly susceptible to erosion, special stabilization may be required.
    a. Small-grade control structures (e.g., drop structure) may be used to reduce the slope of the channel.
    b. Severe bends or cut banks may need to be hardened by lining them with grass or rock.
    c. Rock-lined, low-flow channels may be appropriate to protect fragile beds.
4. Install energy dissipaters, such as rock riprap, at the outlets of storm drains, culverts, conduits, or channels that discharge into unlined channels to lessen erosion potential.

Purpose

This control protects water quality by preserving some of the natural hydrologic functions of the site. Existing soils may contain organic material and soil biota that are ideal for storing and infiltrating stormwater. Clearing and grading equipment can remove existing compact soils and limit their infiltrative capacity. The design criteria presented below are not intended to supersede compaction requirements associated with building codes.

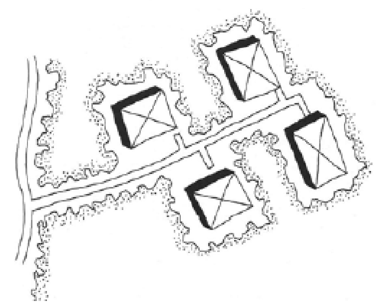


Image 3-1. Dynamic modelling of a single-stage high-rate anaerobic reactor—I. Model derivation. *Water Research. Source: Costello, D.J., Greenfield, P.F., & Lee, P.L. (1991).*

Design Criteria

1. Delineate and flag the development envelope for the site (e.g., identify the minimum area needed to build lots, allow access, and provide fire protection).
2. Restrict equipment access and storage of construction equipment to the development envelope.
3. Restrict storage of construction equipment within the development envelope.
4. Avoid the removal of existing trees and valuable vegetation as feasible.
5. It may be difficult for infill and redevelopment developments to avoid soil disturbance. The project should consider soil amendments to restore permeability and organic content in these cases.

Purpose

The potential for the discharge of pollutants in stormwater runoff from a project site increases as the percentage of the impervious area within the project site increases because impervious areas increase the volume and rate of runoff flow. Pollutants deposited on impervious areas tend to be easily mobilized and transported by runoff flow. Minimizing impervious areas through site design is an important means of minimizing stormwater pollutants of concern. In addition to the environmental and aesthetic benefits, a highly pervious site may allow a reduction in the size of downstream conveyance and treatment systems, yielding savings in development costs.

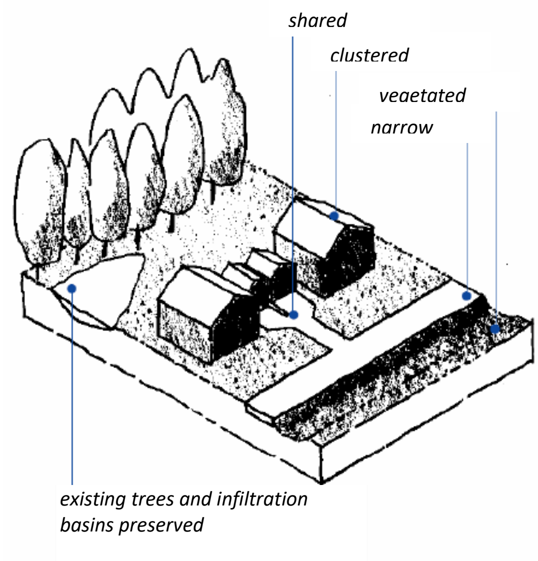


Image 3-2. *Source: Low Impact Development Handbook Stormwater Management Strategies. (2014, July). https://www.sandiegocounty.gov/content/dam/sdc/dpw/WATERSHED_PROTECTION_PROGRAM/watershedpdf/S-BMP/Filtration_O&M_Form.pdf.*

Design Strategies

Some aspects of site design are directed by local agency building and fire codes and ordinances. The design strategies suggested in this fact sheet are intended to enhance these local codes and ordinances. Minimizing impervious surfaces at every possible opportunity requires the integration of many small strategies. Suggested strategies for minimizing impervious surfaces through site design include the following:

1. Use minimum allowable roadway and sidewalk cross sections, driveway lengths and parking stall widths (refer to City Standard Specifications and Plans or the County Improvement Standards for roadway and sidewalk specifications).
2. Minimize or eliminate the use of curb and gutter, so that roadway runoff drains to swales and other VRMs or LID Treatment Controls are strongly encouraged where slope and density permit.
3. Use two-track/ ribbon driveways or shared driveways.
4. Include landscape islands in cul-de-sacs (where approved).
5. Reduce the footprints of buildings and parking lots.
6. Cluster buildings and paved areas to maximize pervious area.
7. Maximize tree preservation or tree planting.
8. Avoid compacting or paving over soils with high infiltration rates (see G-3).
9. Use pervious pavement materials where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobbles (Ref. BASMAA, 1999 for descriptions of pervious pavements options).
10. Use grass-lined channels or surface swales to convey runoff instead of paved gutters (see **Fact Sheet V-5** in **Section 5**).

4. SOURCE CONTROLS

4.1 INTRODUCTION

Source controls are practices designed to prevent pollutants from contacting stormwater runoff or to prevent the discharge of contaminated runoff to the storm drainage system. This section addresses structural source controls consisting of specific design features or elements. Non-structural source controls, such as good housekeeping and employee training, are not included in the SWQCCP. The California Stormwater BMP Handbooks may be consulted for information on non-structural source controls (CASQA, 2003). The City and County may require additional source controls not included in the SWQCCP for specific pollutants, activities, or land uses.

This section describes control measures for activities identified as potentially significant sources of pollutants in stormwater. Each measure specified in this section should be implemented with appropriate non-structural source controls to optimize pollution prevention.

This section's source controls apply to stormwater and non-stormwater discharges. Non-stormwater discharges discharge any substance, such as cooling water, irrigation water, process wastewater, etc., to the storm drainage system or water body that is not composed entirely of stormwater. Stormwater that is mixed or commingled with other non-stormwater flows is considered non-stormwater. Discharges of stormwater and non-stormwater to the storm drainage system or a water body may be subject to local, state, or federal permitting prior to the commencement of any discharge. The appropriate agency should be contacted prior to any discharge. Discuss the matter with the City of Stockton Municipal Utilities Department, Stormwater Division, or the San Joaquin County Department of Public Works, if you are uncertain as to which agency should be contacted.

Some source controls presented in this section require a connection to the sanitary sewer system. Connection and discharge to the sanitary sewer system without prior approval or obtaining the required permits is prohibited. Contact the City of Stockton Municipal Utilities Department, Stormwater Division, or the San Joaquin County Department of Public Works to obtain information regarding obtaining sanitary sewer permits from the City or County. Discharges of certain types of flows to the sanitary sewer system may be cost-prohibitive. The designer is urged to contact the City or County before completing the facility's site and equipment design.

4.2 DESCRIPTION

Source control measures and associated design features specified for various sites and activities are summarized in **Table 4-1**. Fact sheets are presented in this section for each source control measure. These sheets include design criteria established by the City and County to ensure the effective implementation of the required source control measures.

Table 4-1. Summary of Source Control Design Features

Source Control[1]	Design Feature or Element						
	Signs, placards, stencils, stamps	Surfacing (compatible, impervious)	Covers, screens	Grading/berming to prevent run-on	Grading/berming to provide secondary containment	Sanitary sewer connection	Emergency Storm Drain Seal
Storm Drain Message and Signage (S-1)	X						
Outdoor Material Storage Area Design (S-2)		X	X	X	X		X
Outdoor Trash Storage and Waste Handling Area Design (S-3)	X	X	X	X		X	
Outdoor Loading/Unloading Dock Area Design (S-4)		X	X	X	X		
Outdoor Repair/Maintenance Bay Design (S-5)		X	X	X	X		X
Outdoor Vehicle/Equipment/ Accessory Washing Area Design (S-6)		X	X	X	X	X	X
Fueling Area Design (S-7)		X	X	X	X		X

[1]Refer to Fact Sheets in **Section 4** for detailed information and design criteria

Purpose

Waste materials dumped into storm drain inlets can adversely impact surface and ground waters. Posting notices regarding discharge prohibitions at storm drain inlets can educate the public and prevent waste dumping. This fact sheet contains details on the installation of storm drain messages at storm drain inlets located in new or redeveloped commercial, industrial, and residential sites.

Design Criteria

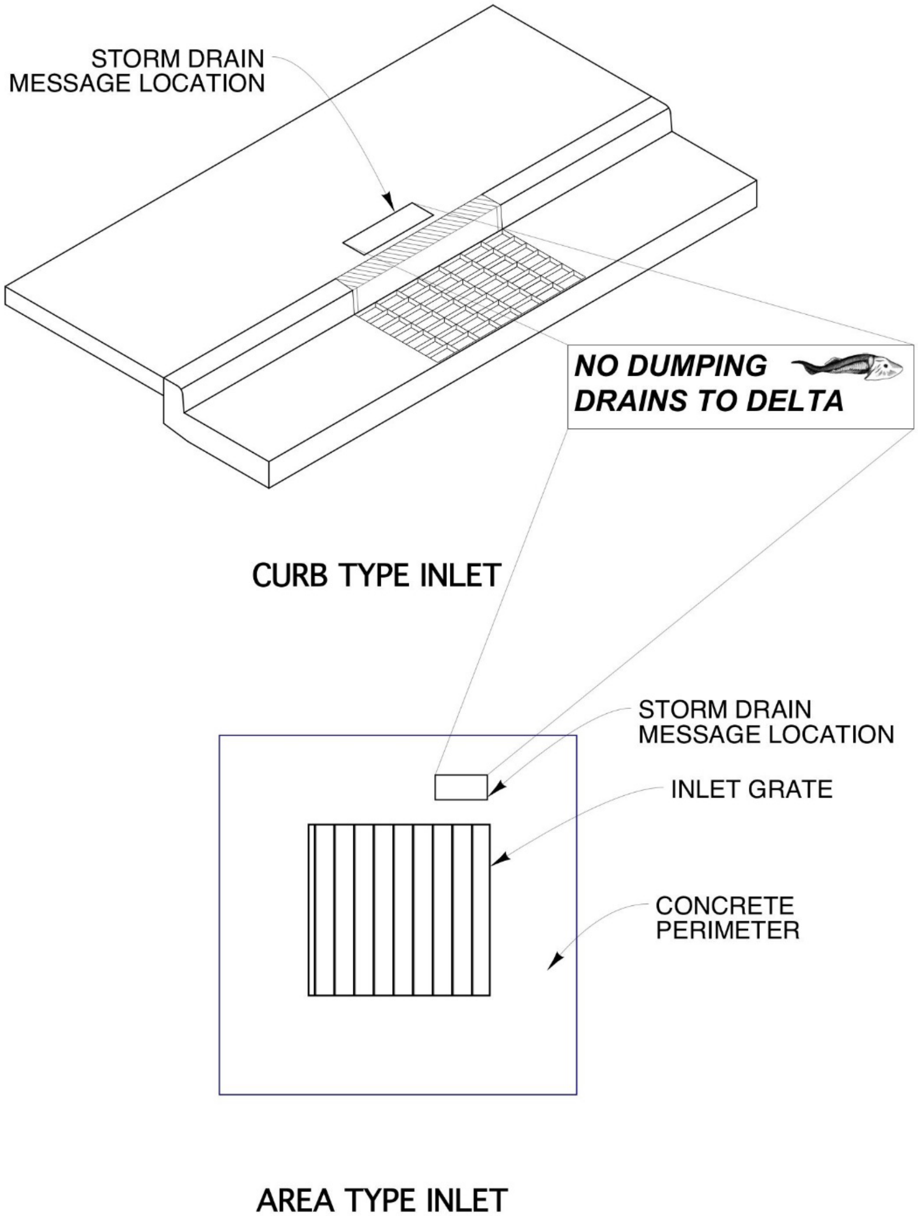
Storm drain messages have become a popular method of alerting the public about the effects of and the prohibitions against waste disposal into the storm drain system. The signs are typically stenciled or affixed near the storm drain inlet. The message simply informs the public that dumping wastes into storm drain inlets is prohibited and/or the drain that discharges to receiving water.

Storm drain message markers, placards, or concrete stamps are required at all storm drain inlets within the boundary of the development project. Markers should be placed in clear sight adjacent to inlets (see **Figure 4-1**). All storm drain inlet locations must be identified on the development site map.

Signs with language and/or graphical icons, which prohibit illegal dumping, shall be posted at designated public access points along channels and streams within a project area. Consult the City of Stockton Municipal Utilities Department, Stormwater Division, or the San Joaquin County Department of Public Works to determine specific signage requirements.

Maintenance Requirements

Legibility of markers and signs shall be maintained.



NOTES:

1. **DESIGN OF STORM DRAIN MESSAGE SHALL BE IN ACCORDANCE WITH DETAILS SHOWN ABOVE.**
2. **FOR NEW DEVELOPMENT, MESSAGE AND SYMBOL SHALL BE PERMANENTLY PLACED WITH THE USE OF BOMANITE, STAMPED INTO THE CONCRETE, OR OTHER METHODS APPROVED BY THE CITY ENGINEER.**
3. **FOR REDEVELOPMENT, MESSAGE AND SYMBOL SHALL BE PLACED WITH THE USE OF THERMOPLASTIC PAVEMENT MARKINGS.**
4. **PAINTING SHALL NOT BE ALLOWED FOR NEW DEVELOPMENT OR REDEVELOPMENT. PAINTING SHALL ONLY BE ALLOWED IN EXISTING AREAS FOR COMMUNITY AWARENESS ACTIVITIES. LETTERS SHALL BE 1-1/2 INCHES IN HIEGHT. OUTSIDE DIMENSION OF PUBLIC NOTICE BACKGROUND SHALL FIT BACK OF INLET OR BE PLACED IN SIDEWALK IMMEDIATELY BEHIND INLET AND SHALL BE 8 INCHES X 24 INCHES MINIMUM. LETTERING AND GRAPHIC SHALL BE BLACK WITH GRAY BACKGROUND UNLESS OTHERWISE APPROVED BY CITY ENGINEER.**
5. **DRIVEWAY INLETS SHALL HAVE NOTICE IN DRIVEWAY ADJACENT TO INLET.**

Figure 4-1. Storm Drain Message Location

Purpose

Materials, such as raw, finished, or waste products, stored outdoors can become sources of pollutants in stormwater runoff if not handled or stored properly. The type of pollutants associated with the materials will vary depending on the commercial or industrial activity.

Some materials are more of a concern than others. Toxic and hazardous materials must be prevented from coming in contact with stormwater. Non-toxic or non-hazardous materials, such as debris and sediment, can significantly impact surface waters if discharged in significant quantities.

Applicability

Materials are placed into three categories based on the potential risk for pollutant release associated with stormwater contact – high risk, low risk, and non-risk. The general types of materials under each category are listed below. City of Stockton Municipal Utilities Department, Stormwater Division, or the San Joaquin County Department of Public Works will make final determinations regarding category listings, if necessary.

High-Risk Materials	Low-Risk Materials	Non-Risk Materials
• Recycled materials with effluent potential • Corrosives • Food items • Chalk/gypsum products • Feedstock/grain • Fertilizer • Pesticides • Lime/lye/soda ash • Animal/human wastes	• Recycled materials without effluent potential • Scrap or salvage goods • Metal • Sawdust/bark chips • Sand/soil • Unwashed gravel/rock • Compost • Asphalt	• Washed gravel/rock • Finished lumber (non-pressure treated) • Rubber or plastic products • Clean, precast concrete products • Glass products (new) • Inert products • Gaseous products • Products in containers that prevent contact with stormwater (fertilizers and pesticides excluded)

Design Criteria

Design requirements for material storage areas are governed by Building and Fire Codes and current City and County ordinances and zoning requirements. Source controls described in this fact sheet are intended to enhance and be consistent with these code and ordinance requirements. The following design features should be incorporated into the design of outdoor material storage areas when stored materials could potentially contribute significant pollutants to the storm drain. The level of controls required varies relative to the risk category of the material stored.

Design Feature	Design Criteria
Surfacing	• High-Risk Materials: ○ Construct or pave the storage area base with a material that is chemically resistant to the materials being stored and impervious to leaks and spills. • Low-Risk and Non-Risk Materials: ○ No requirement for surfacing
Covers	• High-Risk Materials: ○ Cover the storage area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the storage area. Direct runoff from the cover away from the storage area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of this manual. ○ Covers 10 feet high or less shall have a minimum overhang of 3 feet measured from the perimeter of the hydraulically isolated storage area. ○ Cover higher than 10 feet shall have a minimum overhang of 5 feet measured from the perimeter of the hydraulically isolated storage area. • Low-Risk Materials: ○ At a minimum, completely cover erodible material with temporary plastic sheeting during rainfall events.
Hydraulic Isolation and Drainage	• High-Risk Materials: ○ Hydraulically isolate the storage area by means of grading, berms, or drains to prevent run-on of stormwater from surrounding areas or roof drains. ○ Direct runoff from surrounding areas away from the hydraulically isolated storage area to a stormwater disposal point that meets all applicable requirements of this manual and codes. ○ Drainage facilities are not required for the hydraulically isolated storage area. However, if drainage facilities are provided, drainage from the hydraulically isolated storage area must be directed to an approved City or County sanitary sewer or approved collection point. • Low-Risk Materials: ○ Drainage from storage area may be to an approved treatment control measure or possibly to an approved standard stormwater drain(s). ○ For erodible material, provide grading and a structural containment barrier on at least three sides of each stockpile to prevent run-on of stormwater from the surrounding area and to prevent migration of material due to wind erosion.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of per applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City or County regarding permits for the discharge of contaminated accumulated water.

Purpose

Stormwater runoff from areas where trash is stored or disposed of can convey pollutants. In addition, loose trash and debris can be easily transported by water or wind into nearby storm drain inlets, channels, and/or creeks. Waste handling operations that may be sources of pollutants include dumpsters, litter control, and waste piles. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in stormwater runoff associated with trash storage and handling.

Design Criteria

Design requirements for waste handling areas are governed by Building and Fire Codes and current local agency ordinances and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Hazardous waste should be handled under legal requirements established in Title 22 of the California Health and Safety Code.

Wastes from commercial and industrial sites are typically hauled away for disposal by either public or commercial carriers that may have design or access requirements for waste storage areas. The design criteria listed below are recommendations and are not intended to conflict with requirements established by the waste hauler. The waste hauler should be contacted prior to the design of your site trash collection area. Conflicts or issues should be discussed with the City of Stockton Municipal Utilities Department, Stormwater Division or the San Joaquin County Department of Public Works.

The following trash storage area design controls were developed to enhance the local agency codes and ordinances and should be implemented depending on the type of waste and the type of containment:

Source Control Design Feature	Design Criteria
Surfacing	• Construct the storage area base with a material impervious to leaks and spills.
Screens/Covers	• Install a screen or wall around the trash storage area to prevent off-site transport of loose trash. • Use lined bins or dumpsters to reduce the leaking of liquid wastes. • Use water-proof lids on bins/dumpsters or provide a roof to cover the enclosure (City and County discretion) to prevent rainfall from entering containers.
Grading/Drainage	• Berm or grade the waste handling area to prevent run-on of stormwater. • Locate storm drains at least 35 feet from the waste handling area.
Signs	• Post signs inside enclosure and/or on all dumpsters prohibiting the disposal of liquids and hazardous materials therein.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If the City or County requires maintenance agreements or deed restrictions to be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for further guidance regarding maintenance agreements and plans.

Purpose

Materials spilled, leaked, or lost during loading or unloading may collect on impervious surfaces or in the soil and be carried away by runoff or when the area is cleaned. Also, rainfall may wash pollutants from machinery used to load or unload materials. Depressed loading docks (truck wells) are contained areas that can accumulate stormwater runoff. Discharges of spills or contaminated stormwater to the storm drain system is prohibited. This fact sheet contains details on specific measures recommended to prevent or reduce pollutants in stormwater runoff from outdoor loading or unloading areas.

Design Criteria

Design requirements for outdoor loading/unloading materials are governed by Building and Fire Codes and current local agency ordinances and zoning requirements. Source controls described in the fact sheet are meant to enhance and be consistent with these code and ordinance requirements. Companies may have design or access requirements for loading docks. The design criteria listed below are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with the City of Stockton Municipal Utilities Department, Stormwater Division, or the San Joaquin County Department of Public Works.

The following design criteria should be followed when developing construction plans for material loading/unloading areas:

Design Feature	Design Criteria
Surfacing	• Construct floor surfaces with paving material that is impervious and chemically resistant to materials being handled in the loading/unloading area.
Covers	• Cover outdoor loading/unloading areas to a distance of at least 10 feet beyond the loading dock or building face if there is no raised dock. • For interior transfer bays, provide a 10-ft minimum “no obstruction zone” to allow trucks or trailers to extend at least 5 feet inside the building. Identify “no obstruction zone” clearly on building plans and paint zone with high visibility floor paint. • If covers or interior transfer bays are not feasible, install a seal or door skirt and provide a rain cover to shield all material transfers between trailers and building.

Design Feature	Design Criteria
Hydraulic Isolation and Drainage	• For outdoor loading/unloading areas, hydraulically isolate the first 6 feet of paved area measured from the building or dock face by means of grading, berms, or drains to prevent run-on of stormwater from surrounding areas or roof drains. Direct runoff and drainage from surrounding areas away from hydraulically isolated area to a stormwater discharge point that meets all applicable requirements of this manual. • For interior transfer bays or bay doors, prevent stormwater runoff from surrounding areas from entering the building by means of grading or drains. Do not install interior floor drains in the “no obstruction zone”. Hydraulically isolate the “no obstruction zone” from any interior floor drains. • Direct drainage from the hydraulically isolated loading/unloading area to an approved sediment/oil/water separator system connected to an approved City or County sanitary sewer or other approved collection point. Provide a manual emergency spill diversion valve upstream of the separator system to direct flow in the event of a spill to an approved spill containment vault sized to contain a volume equal to 125% of largest container handled at the facility.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces, such as depressed loading docks. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City or County regarding permits for the discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If the City or County requires maintenance agreements or deed restrictions to be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for further guidance regarding maintenance agreements and plans.

Purpose

Activities that can contaminate stormwater include engine repair, service and parking (leaking engines or parts). Oil and grease (O&G), solvents, car battery acid, coolant and gasoline from the repair/maintenance bays can adversely impact stormwater if allowed to come into contact with stormwater runoff. This fact sheet details the specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment maintenance and repair areas.

Design Criteria

Design requirements for vehicle maintenance and repair areas are governed by Building and Fire Codes and current local agency ordinances and zoning requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment maintenance and repair. All hazardous and toxic wastes must be prevented from entering the storm drainage system.

Source Control Design Feature	Design Criteria
Surfacing	• Construct the vehicle maintenance/repair floor area with Portland cement concrete (PCC).
Covers	• Cover areas where vehicle parts with fluids are stored. • Cover or enclose all vehicle maintenance/repair areas.
Grading/Contouring	• Berm or grade the maintenance/repair area to prevent run-on and runoff of stormwater or runoff of spills. • Direct runoff from downspouts/roofs away from maintenance/repair areas. • Grade the maintenance/repair area to drain to a dead-end sump for collection of all wash water, leaks and spills. Direct connection of maintenance/repair area to the storm drain system is prohibited. • Do not locate storm drains in the immediate vicinity of the maintenance/repair area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of following applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City or County regarding permits for the discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If the City or County requires maintenance agreements or deed restrictions to be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for further guidance regarding maintenance agreements and plans.

S-6: Outdoor Vehicle/Equipment/Accessory Washing Area Design

Purpose

Washing vehicles and equipment in areas where the wash water flows onto the ground can adversely impact receiving waters. Wash waters can contain high concentrations of O&G, solvents, phosphates, and high suspended solids loads. Sources of contamination include outside vehicle/equipment cleaning or wash water discharge to the ground. This fact sheet contains details on the specific measures required to prevent or reduce pollutants in runoff from vehicle and equipment washing areas.

Design Criteria

Building and fire codes and current local agency ordinances and zoning requirements govern vehicle and equipment washing area design requirements. The design criteria described in the fact sheet are meant to enhance and be consistent with these code requirements.

The following design criteria are required for vehicle and equipment washing areas. All hazardous and toxic wastes cannot enter the storm drain system.

Design Feature	Design Criteria
Surfacing	• Construct the vehicle/equipment wash area floors with PCC.
Covers	• Provide a cover that extends at least 3 feet beyond the hydraulically isolated area for cover heights less than or equal 10 feet and at least 5 feet beyond the hydraulically isolated area for cover heights greater than 10 feet.
Grading/Drainage	• Hydraulically isolate the maintenance/repair area using berms or grading to prevent run-on and runoff of stormwater or runoff of spills. • Grade or berm the wash area to contain the wash water within the covered area and direct the wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the City or County before discharging to the sanitary sewer. • Direct runoff from downspouts/roofs away from wash areas. • Do not locate storm drains in the immediate vicinity of the wash area.
Emergency Storm Drain Seal	• Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drainage system.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of in accordance with applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City or County regarding permits to discharge contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If the City or County requires maintenance agreements or deed restrictions to be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for further guidance regarding maintenance agreements and plans.

Purpose

Spills at vehicle and equipment fueling areas can be a significant source of pollutants because fuels contain toxic materials and heavy metals that are not easily removed by stormwater treatment devices. When stormwater mixes with fuel spilled or leaks onto the ground, it becomes contaminated with petroleum-based materials that harm humans, fish and wildlife. This contamination can occur at large industrial sites or small commercial sites such as gas stations and convenience stores. This fact sheet details specific measures required to prevent or reduce pollutants in stormwater runoff from vehicle and equipment fueling areas, including retail gas outlets.

Design Criteria

Design requirements for fueling areas are governed by Building and Fire Codes and by current local agency ordinances and zoning requirements. The design requirements described in this fact sheet are meant to enhance and be consistent with these code and ordinance requirements.

Design Feature	Design Criteria
Surfacing	• Pave fuel dispensing and maintenance area with PCC. The fuel dispensing area is defined as extending 6.5 feet from the corner of each fuel dispenser, or the length at which the hose and nozzle assemble may be operated plus 1 foot, whichever is greater. The paving around the fuel dispensing area may exceed the minimum dimensions of the “fuel dispensing area” stated above. • Use asphalt sealant to protect asphalt paved areas surrounding the fuel dispensing or maintenance area.
Covers	• Cover the fuel dispensing or maintenance area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the fuel dispensing area. Direct runoff from the cover away from the fuel dispensing area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of this manual. ○ Covers 10 feet high or less shall have a minimum overhang of 3 feet measured from the perimeter of the hydraulically isolated fuel dispensing area. ○ Cover higher than 10 feet shall have a minimum overhang of 5 feet measured from the perimeter of the hydraulically isolated fuel dispensing area. • For facilities designed to accommodate very large vehicles or equipment that would prohibit the use of covers, hydraulically isolate the uncovered fuel dispensing or maintenance area and direct drainage from the area through upstream controls to a sanitary sewer as described below.
Hydraulic Isolation and Drainage	• Design the fuel dispensing or maintenance area pad with zero slope (flat) to keep minor spills and leaks on the pad and encourage use of proper cleanup methods. Proper cleanup methods shall consist of dry cleanup methods, such as sweeping for removal of litter and debris and use of absorbents for liquid spills and leaks. • Hydraulically isolate the paved fuel dispensing or maintenance area to prevent run-on of stormwater from surrounding areas or roof drains by one of the following methods. Design should conform to applicable ADA requirements for disabled access:

Design Feature	Design Criteria
	• Berms: Design the berm height four (4) inches above the surface of the fuel dispensing or maintenance area pad such that the pad will serve as spill containment area. • Perimeter trench drains: Locate trench drains around the perimeter of the pad. Direct drainage from the perimeter drains to one of the following: • An approved City/County sanitary sewer. Provide an approved automatic shutoff valve installed upstream of the sanitary sewer connection and below grade in a manhole or similar concrete containment structure. The valve shall be designed to close automatically when the structure's maximum oil/fuel storage capacity is reached. • An approved below-grade containment vault with at least 60 ft3 of storage capacity. The vault must be emptied, as required, and the contents disposed of by applicable laws. • Direct runoff and drainage from surrounding areas away from hydraulically isolated area to a stormwater discharge point that meets all applicable requirements of this manual. Locate stormwater drains for surrounding areas at least 10 feet from the hydraulically isolated fuel dispensing or maintenance area.

Accumulated Stormwater and Non-stormwater

Stormwater and non-stormwater will accumulate in containment areas and sumps with impervious surfaces. Contaminated accumulated water must be disposed of following applicable laws and cannot be discharged directly to the storm drain or sanitary sewer system without the appropriate permit. Contact the City or County regarding permits for the discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, and signs) must be maintained by the owner/operator. Maintenance agreements between the City or County and the owner/operator may be required. If the City or County requires maintenance agreements or deed restrictions to be executed by the owner/operator before improvement plans are approved. Refer to **Appendix D** for further guidance regarding maintenance agreements and plans.

5. VOLUME REDUCTION MEASURES

5.1 INTRODUCTION

VRMs are required to minimize potential water quality impacts from stormwater. VRMs are BMPs used to direct, retain, reuse and/or infiltrate stormwater runoff (e.g., rain gardens and rain barrels). The type of VRM to be implemented at a site depends on several factors, including the type of potential pollutants in the stormwater runoff, the quantity of stormwater runoff to be treated, project site conditions (e.g., soil type and permeability, groundwater levels); and receiving water conditions. Land area requirements and costs to design, construct and maintain VRMs vary.

5.2 VOLUME REDUCTION REQUIREMENT

The application of VRMs is driven, in part, by the **VRR**. The VRR is a new requirement developed in response to the recent municipal stormwater NPDES Permit specifying the use of LID and a combination of non-structural and structural controls.

The VRR specifies that post-project runoff volumes be reduced to match pre-project levels for the 0.51-inch storm depth, the average 85th percentile/24-hour storm depth estimated for the Stockton area. New Development Priority Projects may apply a combination of VRMs and LID Treatment Controls (see Step 6) to meet the VRR. A summary of controls that reduce runoff volumes is provided in **Table 5-1**. As indicated in **Table 5-1,** some controls are better suited for reducing the volume associated with rooftop runoff (e.g., Rain Barrels). In contrast, others are more suited for reducing the volume associated with pavement runoff (e.g., Interception Trees). Suggested applications of VRMs are illustrated in **Figures 5-1a and b**.

Table 5-1. Summary of Volume Reduction and LID Treatment Controls

Control	Function		Disconnection Application	
	Volume Reduction	Treatment	Rooftop	Pavement
VRMs (Section 5)				
Rain Garden (V-1)	Primary	Secondary	X	X
Rain Barrel/Cistern (V-2)	Primary	Secondary	X	
Interception Trees (V-3)[1]	Primary	Secondary		X
Grassy Channel (V-4)[1]	Primary	Secondary	X	X
Vegetated Buffer Strip (V-5)[2]	Primary	Secondary	X	X
LID Treatment Controls (Section 6)				
Bioretention (L-1) [1]	Secondary	Primary	X	X
Stormwater Planter (L-2)	Secondary	Primary	X	X
Tree-well Filter (L-3)	Secondary	Primary		X
Infiltration Basin (L-4) [1]	Secondary	Primary	X	X
Infiltration Trench (L-5) [1]	Secondary	Primary	X	X
Porous Pavement Filter (L-6)	Secondary	Primary		X
Vegetated (Dry) Swale (L-7)	Secondary	Primary	X	X
Grassy Swale (L-8)	Secondary	Primary	X	X
Grassy Filter Strip (L-9)	Secondary	Primary	X	X

[1] This control may be modified to meet the trash control design criteria

[2] Disconnected rooftops (rooftops allowed to drain to lawn as opposed to impervious area) should utilize the Vegetated Buffer Strip (V-6) in order to receive credit towards the VRR.

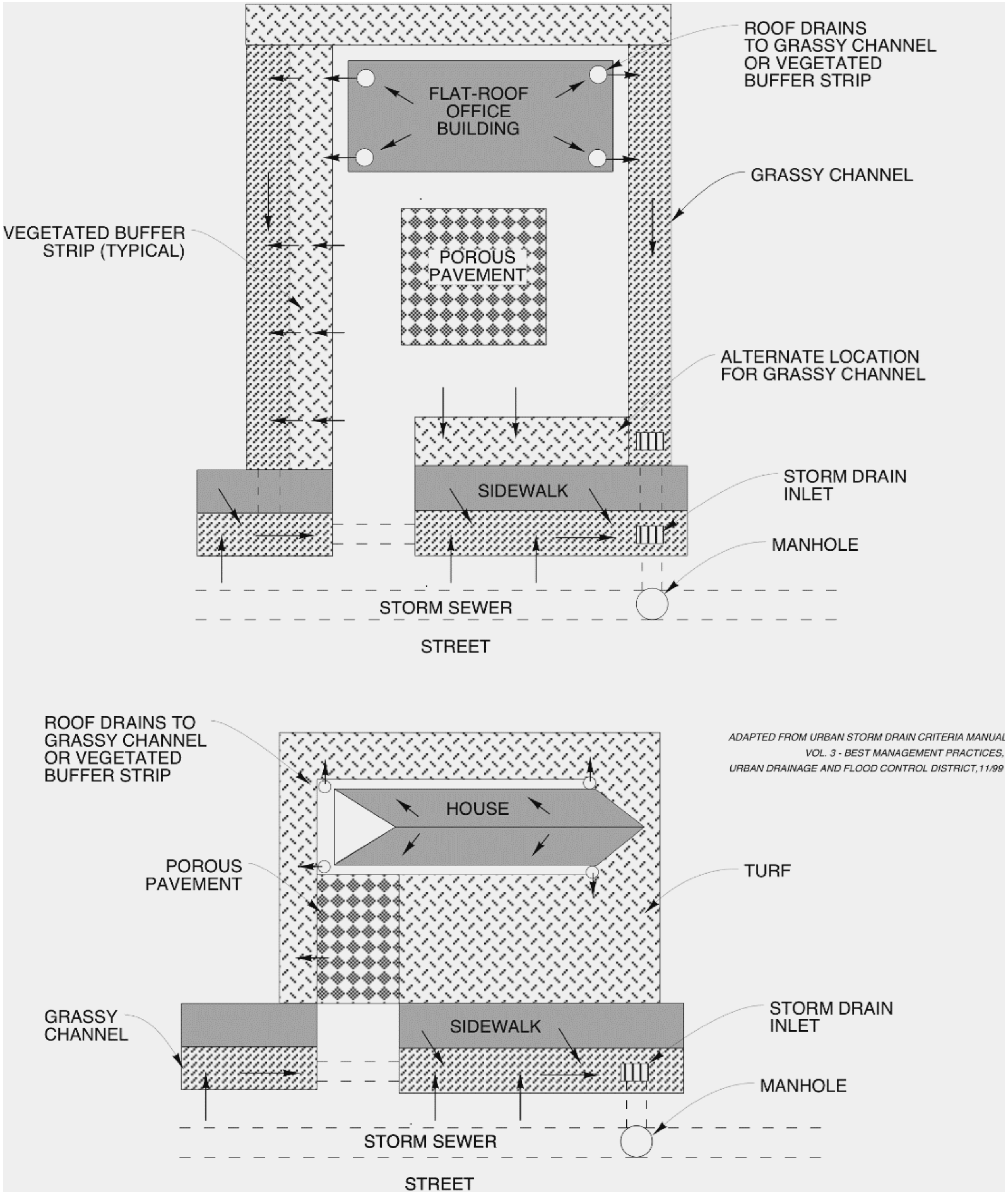


Figure 5-1a. Suggested Applications of Runoff VRMs. *Source: Home. Low Impact Development. (2002, November). Retrieved October 5, 2021, from https://lowimpactdevelopment.org/.*

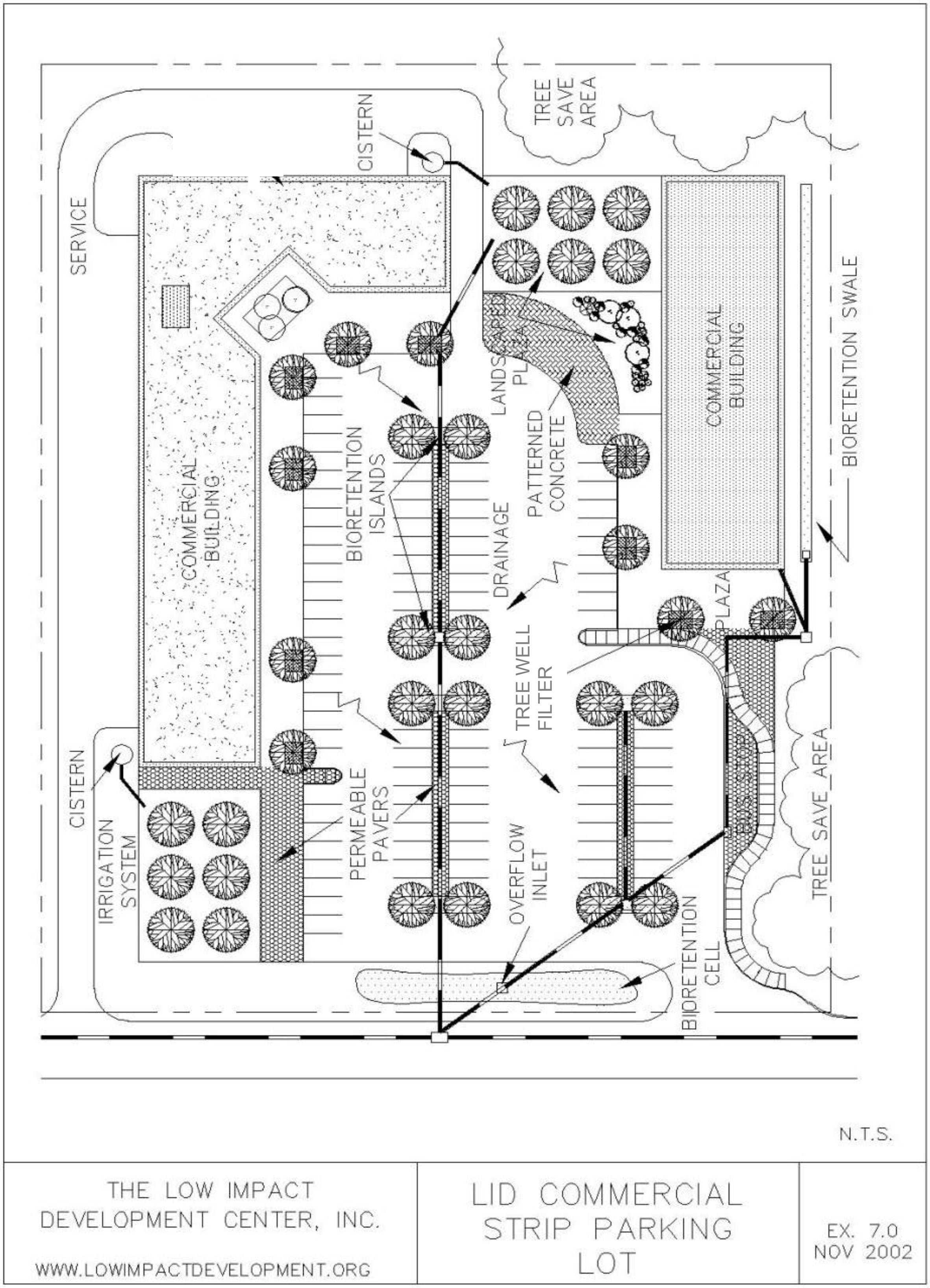


Figure 5-1b. Suggested Applications of Runoff VRMs. Source: Home. Low Impact Development. (2002) November). Retrieved October 5, 2021, from https://lowimpactdevelopment.org/.

To assist Priority Projects, **Appendix B** provides additional information on calculating and meeting the VRR. Projects may use the worksheet to help track compliance with the VRR. Compliance with the VRR can be demonstrated through the following steps:

1. Determine the volume of runoff from the site under pre-project conditions and the volume of runoff from the site under post-project conditions for the 0.51-inch storm depth. **Appendix B** provides additional information on calculating and meeting the VRR.

Runoff Volume Calculation Procedure:

Runoff Volume (ft^3) = 0.51"/12" x Site weighted runoff coefficient (C_{ra}) x Site area (ft^2)

   - Significant Redevelopment Priority Projects must also comply with the VRR; however, an incentive in the form of credits may be applied based on the type of redevelopment. A maximum credit of 0.25 inch from the 0.51-inch VRR may be applied to any of the following types of redevelopment. Credits are issued in 0.05-inch increments based on five criteria:
     a. Significant Redevelopment (as defined in **Section 2.1**)
     b. Brownfield redevelopment
     c. High density (>7 units per acre)
     d. Vertical Density (FAR of 2 or >18 units per acre)
     e. Mixed-use and Transit Oriented Development (within ½ mile of public transit, such as a bus stop)

2. Calculate the VRR as the difference between the pre-project runoff volume and the post-project runoff volume (i.e., post–pre).
3. Select applicable VRMs (e.g., Interceptor Trees, Rain Barrels). Each VRM has a certain volume reduction "credit" that can be applied toward the VRR. The VRM fact sheets detail the calculation procedure for volume reduction.

An example calculation is provided in **Appendix J** to illustrate the application of the VRR, VRMs, tributary impervious area credit and LID Treatment Controls.

4. Determine the remaining VRR not met by the VRMs, if any. This remaining VRR must be met by the application of LID Treatment Controls as described in Step 6.
5. Determine tributary impervious area credits associated with the selected VRMs. These area credits can be applied to reduce the effective design area for treatment controls described in Step 6. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the VRMs for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the treatment controls to which they are applied.
6. Apply LID Treatment Controls
   - If the VRR is not entirely met using VRMs, the project must apply LID Treatment Controls to reduce further the runoff volume to meet the VRR. LID Treatment Controls must be designed to treat the SQDV or SQDF as discussed in **Section 6**. The SQDV or SQDF is calculated using the effective tributary drainage area, which is determined by

subtracting area credits (see Step 5) from the actual tributary drainage area for the treatment control under design.

- If the VRR is met through the use of VRMs, the project may meet the Treatment Control requirement through the use of LID Treatment Controls and/or Conventional Treatment Controls.

7. If the VRR is not entirely met through the combination of VRMs and LID Treatment Controls, the project must demonstrate technical infeasibility and submit a VRR Waiver Form as described below. New Development and Significant Redevelopment Priority Projects that cannot fully meet the VRR must select Treatment Controls with a medium to high removal efficiency for the pollutant of concern (**Table 6-2** in **Section 6**).

Technical Infeasibility and Alternative Compliance

Alternative designs may be allowed if the VRR cannot be fully met due to site constraints. However, even if the project cannot meet the full VRR, the project must still reduce the volume of the MEP. Meeting the VRR is an iterative process. Designers should return to prior steps to explore alternative combinations of VRMs and LID Treatment Controls. The burden of proof is on the project applicant to show that it is technically infeasible to meet the VRR. **Economic hardship is not an acceptable reason for infeasibility.**

In order to demonstrate technical infeasibility, the applicant must show that the project cannot reliably meet the VRR. Technical infeasibility may result from conditions including the following:

- The corrected in-situ infiltration rate is less than 0.3 inch per hour, and it is not technically feasible to amend the in-situ soils to improve it;
- Locations with shallow groundwater, with less than 10 feet separation between the bottom of the infiltration device and the seasonal high groundwater elevation;
- Locations within 100 feet of a groundwater well used for drinking water;
- Brownfield development sites where infiltration poses a risk of pollutant mobilization or other locations where pollutant mobilization is a documented concern (e.g., at or near properties that are contaminated or store hazardous substances underground);
- Locations with potential geotechnical hazards;
- Historic sites, structures, or landscapes that cannot alter their original configuration in order to maintain their historical integrity;
- Locations where infiltration may adversely impact biological resources; or
- Locations where infiltration may cause health and safety concerns.

If meeting the VRR is infeasible, the Applicant must propose an alternative compliance design. Under all such designs, the portion of the design volume that cannot be reliably retained on-site must be stored on-site, treated, and released once the storm event passes. Projects located in a watershed with a 303(d) listed waterbody must select Treatment Controls with a medium to high removal efficiency for the pollutant of concern (**Table 6-2** in **Section 6**).

Projects that are not able to fully meet the VRR must fill out and submit the VRR Waiver Form, available in **Appendix C**. The Waiver must demonstrate technical infeasibility and describe the alternative compliance design.

The City of Stockton Municipal Utilities Department, Stormwater Division or the San Joaquin County Department of Public Works can reject a Volume Reduction Waiver request if VRMs and/or LID Treatment Controls are considered feasible at the project site or if adequate alternative compliance design is not proposed.

5.3 SELECTION OF VOLUME REDUCTION MEASURES

Various factors must be considered when selecting VRMs. In addition to reducing volume, site considerations such as the size of the drainage area, depth between the water table and the control, soil type and permeability, slope and need for vegetation irrigation are important factors in selecting the proper VRMs. Vector breeding considerations must also be addressed because of nuisance and potential human health effects. The applicability of specific controls outlined within this section should be confirmed with the City of Stockton Municipal Utilities Department, Stormwater Division, or the San Joaquin County Department of Public Works. The site constraints used to select VRMs are provided in **Table 5-2**.

Table 5-2. Site Constraints for VRMs

VRM	Drainage Area (acres)	Depth to Water Table (ft)	Soil Type[1]		Slope (%)	Irrigation Required	Vector Control Frequency	Maintenance Frequency
			A/B	C/D				
Rain Garden (V-1)	<0.05	10 ft[2]	X	X	n/a	Y	L	M
Rain Barrel/Cistern (V-2)	<0.25	n/a	n/a	n/a	n/a	N	H[3]	L
Interception Trees (V-3)	n/a	n/a	X	X	n/a	Y	L	L
Grassy Channel (V-4)	<1	n/a	X	X	≤4%	Y	L	M[4]
Vegetated Buffer Strip (V-5)	<1	n/a	X	X	<5%	Y	L	M[4]

X: BMP is suitable for listed site condition
1: Type A soils are sands and gravels with typical infiltration rates of 1.0-8.3 inch/hour. Type B soils are sandy loams with moderately fine to moderately coarse textures and typical infiltration rates of 0.5-1.0 inch/hour. Type C soils are silty loams or soils with moderately fine to fine texture and typical infiltration rates of 0.17-0.27 inch/hour. Type D soils are clays with infiltration rates of 0.02-0.10 inch/hour.
2: Applies if rain garden is allowed to infiltrate
3: Concerns may be mitigated through design features; see the corresponding fact sheet.
4: Once vegetation is established, maintenance is low.
n/a: Not applicable – this site condition does not affect the applicability of this VRM
Y = Yes; N = No
H= High; M = Medium; L = Low

Image 5-1. *Source: Rain Gardens & Rebate program. Flows to Bay. (n.d.). Retrieved October 5, 2021, from https://www.flowstobay.org/preventing-stormwater-pollution/at-home/rain-gardens/.*

Description

A rain garden is a planted depression designed to receive, retain, and infiltrate rainwater runoff from impervious areas, such as rooftops and pavement. Runoff is initially captured in a ponding zone above the vegetated surface. Captured runoff infiltrates the surface layer of the garden and filters through a planting soil layer before entering the groundwater or being collected by an under-drain system. The garden may include a gravel retention zone below the planting soil layer to facilitate infiltration. Treatment of the runoff occurs through various natural mechanisms as the runoff filters through the root zone of the vegetation. Part of the water held in the root zone of the garden is returned to the atmosphere through transpiration by plants. Rain gardens are typically planted with native, drought-tolerant vegetation that does not require fertilization and can withstand wet soils for at least 24 hours, such as wildflowers, sedges, rushes, ferns, shrubs and small trees. Root systems of the plants enhance infiltration, moisture redistribution, and diverse microbial populations involved in biofiltration.

RAIN GARDEN

A rain garden is similar in most respects to a bioretention area but differs in the level of engineering design criteria specified for subsurface soil matrix and construction and, thus the level of treatment provided.

Other Names*: Micro-bioretention, biofiltration*

Advantages

- Low installation cost.
- Enhances site aesthetics.
- Reduces stormwater volume and pollutant discharge.
- Potential water conservation.
- Easy to maintain.

Limitations

- Volume reduction may be limited by space available.
- Requires underdrains for low permeability soils.
- Requires individual owners/tenants to perform maintenance.
- Not suitable for industrial sites or sites where spills may occur unless an impermeable liner prevents infiltration.

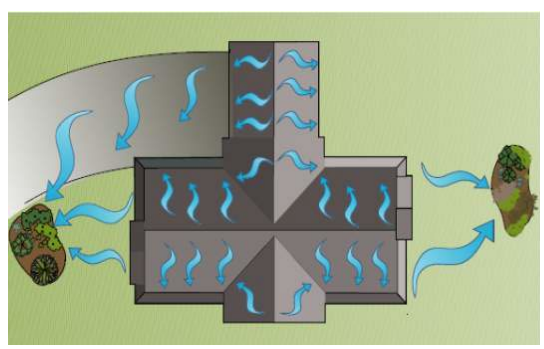


Image 5-2. *Source: Hinman, C. (2007). (rep.). Rain Garden Handbook for Western Washington Homeowners (p. 9).*

Planning and Siting Considerations

- Locate rain gardens at least 10 feet from the building foundations.
- Maintain a slope of at least one (1) percent from the impervious surface to rain garden inlet.
- Provide for overflow discharge that drains away from building foundations to the storm drain system or, if possible, to vegetated surfaces (e.g., grassy buffers, grassy swales/channels) or more suitable infiltration areas.

Design Criteria

Design criteria for rain gardens are listed in **Table 5-3**. A schematic showing the basic elements of a typical rain garden is presented in **Figure 5-2**.

Table 5-3. Rain Garden Design Criteria

Design Parameter	Criteria	Notes
Surface area of ponding zone	20 to 30%	Typical percentage of impervious area draining to rain garden. Smaller percentages are acceptable with overflow drainage provided
Maximum depth of ponding zone (D_{RG})	6 inches	Depth above top of mulch layer
Depth of top mulch layer	2 - 3 inches	Shredded hardwood or softwood or compost
Depth of planting media	12 - 18 inches	Mix: 60-65% loamy sand + 35-40% compost or 30% loamy sand + 30% course sand + 40 % compost
Depth of retention zone (optional)	9 - 12 inches	Washed drain rock (0.5 – 1.5 inch diameter). Use with under drain
Under drainpipe (optional)	4-inches	Perforated PVC or HDPE. Use with C and D soils
Excavation side slope of (H:V)	3:1	Maximum steepness

Volume Reduction and Tributary Impervious Area Credit

Rain Gardens provide volume reduction through water retention in the pore spaces of the planting soil layer (detention/filtration zone) and infiltration into the underlying soil. Rain gardens may be used to help meet the VRR and can also be used to reduce the size of required treatment controls (**Section 6**). The calculation procedure for volume reduction and tributary impervious area credits for rain gardens is presented in **Table 5-4. Appendix B** provides additional information on calculating and meeting the VRR.

Rain Gardens can also be used to reduce the required treatment control size by applying tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (**Section 6**). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementing Rain Gardens reduces effective impervious area and, thereby, the volume of water to be treated. The credit is based on the volume reduction ratio to the SQDV for the Rain Garden drainage area. Note that these credits must be applied to treatment controls in the same tributary drainage area as the Rain Garden for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Rain Garden. **Table 5-4** details how the tributary impervious area credit is calculated for Rain Gardens.

Table 5-4. Rain Garden Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
<u>Rain Garden without Subsurface Drain</u> **1. Volume Reduction for rain garden ($Vol_{reduction}$)** **a) Depth of ponding zone (D_{PZ})** **b) Area of ponding zone (A_{PZ})** **c) Depth of detention zone (D_{DZ})** **d) Area of detention zone (A_{DZ})** **e) $Vol_{reduction}$= (D_{PZ} x A_{PZ}) + (D_{DZ} x A_{DZ} x 0.1)**	D_{PZ} =_____________ ft A_{PZ} = _____________ ft^2 D_{DZ} =_____________ ft A_{DZ} =_____________ ft^2 $Vol_{reduction}$ = ____ ft^3	Infiltration allowance for water in ponding zone water = 1.0 Available Water Holding Capacity of soil in detention zone = 0.1 x volume
<u>Rain Garden with Subsurface Drain</u> **2. Volume Reduction for rain garden ($Vol_{reduction}$)** **a) Depth of ponding zone (D_{PZ})** **b) Area of ponding zone (A_{PZ})** **c) Depth of detention zone (D_{DZ})** **d) Area of detention zone (A_{DZ})** **e) Depth of retention zone (D_{RZ})** **f) Area of retention zone (A_{RZ})** **g) $Vol_{reduction}$= (D_{PZ} x A_{PZ} x 0.25) + (D_{DZ} x A_{DZ} x 0.10) + (D_{RZ} x A_{RZ} x 0.30)**	D_{PZ} =_____________ ft A_{PZ} =_____________ ft^2 D_{DZ} =_____________ ft A_{DZ} =_____________ ft^2 D_{RZ} =_____________ ft A_{RZ} =_____________ ft^2 $Vol_{reduction}$ =_____ ft^3	Infiltration allowance for water in ponding zone water = 0.25 Available Water Holding Capacity of soil in detention zone = 0.10 x volume Retention zone is optional. Porosity of retention zone = 0.30
3. Impervious area tributary to rain garden (A_{imp})	A_{imp} =_____________ft^2	

4. SQDV for A_{imp} based on 12-h drawdown **SQDV = 0.32 in x A_{imp} / 12 in/ft**	SQDV =_______________ft^3	Unit basin storage volume for 12-h drawdown at 100% imperviousness (0.95 Runoff Coefficient) = 0.32 in. (see Figure 6-1). Adjust value for A_{imp} < 100% impervious
5. Tributary Impervious Area Credit for rain garden ($Area_{credit}$) **$Area_{credit}$ = A_{imp} x $Vol_{reduction}$ / SQDV**	$Area_{credit}$ =_____________ ft^2	Maximum allowable $Area_{credit}$ = A_{imp}

Construction Considerations

See Fact Sheet L-1: Bioretention.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner before final acceptance of a private development project, including VRMs such as Rain Gardens. Such agreements will typically include requirements like those outlined in **Table 6-10** in Fact Sheet L-1: Bioretention in **Section 6**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the VRM and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

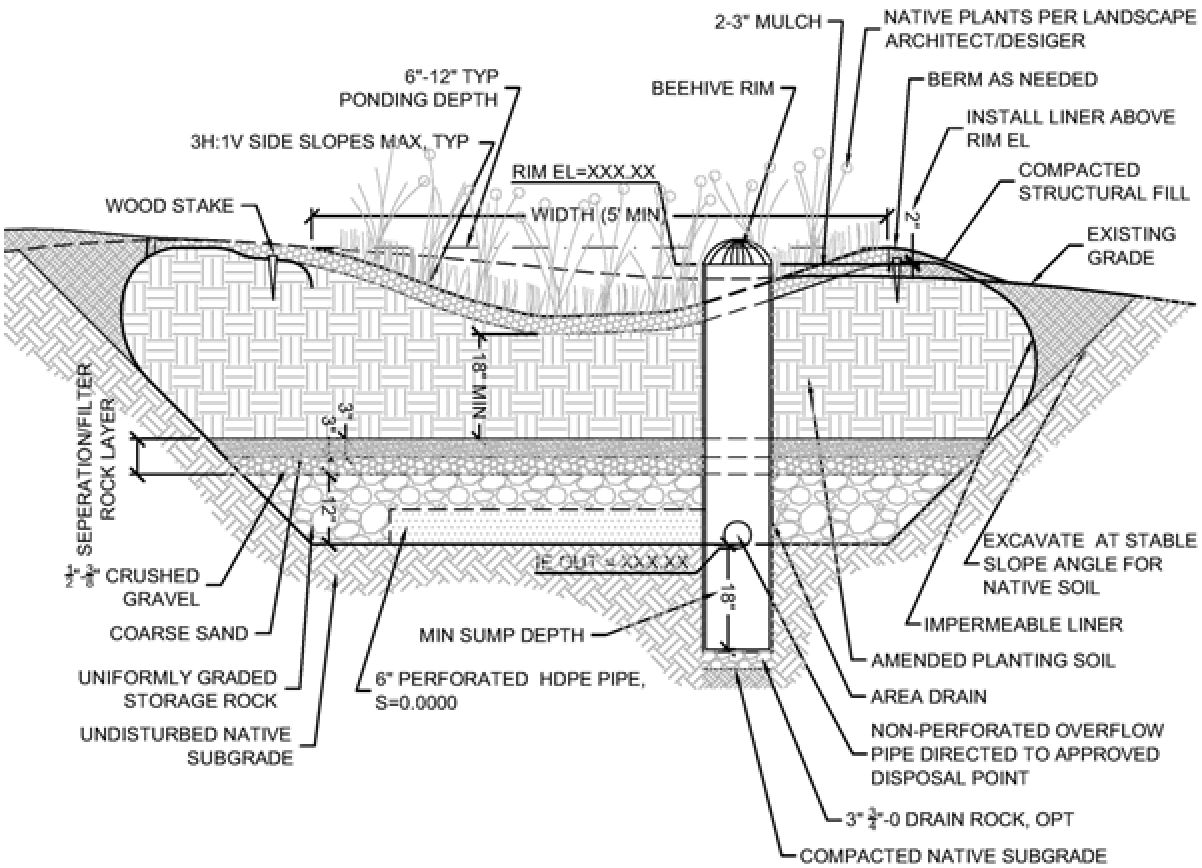


Figure 5-2. Example Rain Garden. *Source: Oregon State University. (n.d.). Choose the right Rain Garden. Retrieved October 6, 2021, from https://extension.oregonstate.edu/node/119221/printable/print.*

Image 5-3.
Source: Communications, I. F. A. S. (n.d.). Rain barrels. Rain Barrels - UF/IFAS Extension. Retrieved October 6, 2021, from http://sfyl.ifas.ufl.edu/sarasota/gardening-and-landscaping/horticulture-residential/florida-yards-and-neighborhoods/rain-barrels/.

Description

A wide variety of manufactured rain barrels are available for purchase or units can be made at home.

Rain barrels and cisterns collect and store rainwater from rooftop drainage systems that would otherwise be lost to runoff and diverted to storm drains. Rain barrels are placed above-ground beneath a shortened downspout next to a home or building and typically range in size from 50 to 180 gallons. Cisterns are larger storage tanks that may be sited above or below ground. Rain barrels are equipped with a removable cover to allow access for maintenance, a screened inlet opening to trap debris and exclude mosquitoes, an outlet spigot typically fitted for garden hose attachment and an overflow outlet with discharge pipe or hose (**Figure 5-3**). Stored rainwater is typically used for landscape irrigation but can be used for washing. Water stored in rain barrels and cisterns should not be discharged to the storm drain system.

Advantages

- Low installation cost.
- Small footprint.
- Reduces stormwater volume and pollutant discharge.
- Potential water conservation.
- Easy to maintain.

Image 5-4. *Source: Chesapeake Bay Foundation*

Limitations

- Storage volume may be limited.
- Stored water is not suitable for human or pet consumption.
- Contact of stored water with fruits and vegetables should be avoided due to unknown risks.
- It may not be compatible with site aesthetics.
- Potential for mosquito breeding if not properly covered and maintained.
- Requires individual owners/tenants to perform maintenance and empty rain barrels between storms.

Planning and Siting Considerations

- Locate rain barrels and cisterns to allow easy access for maintenance.
- Elevate the rain barrel above-ground surface with a sturdy platform to provide spigot clearance.
- Provide screens or deflectors on rain gutters to minimize the discharge of debris to rain barrels.
- Direct cistern overflow discharge to drain away from building foundations and to vegetated areas.

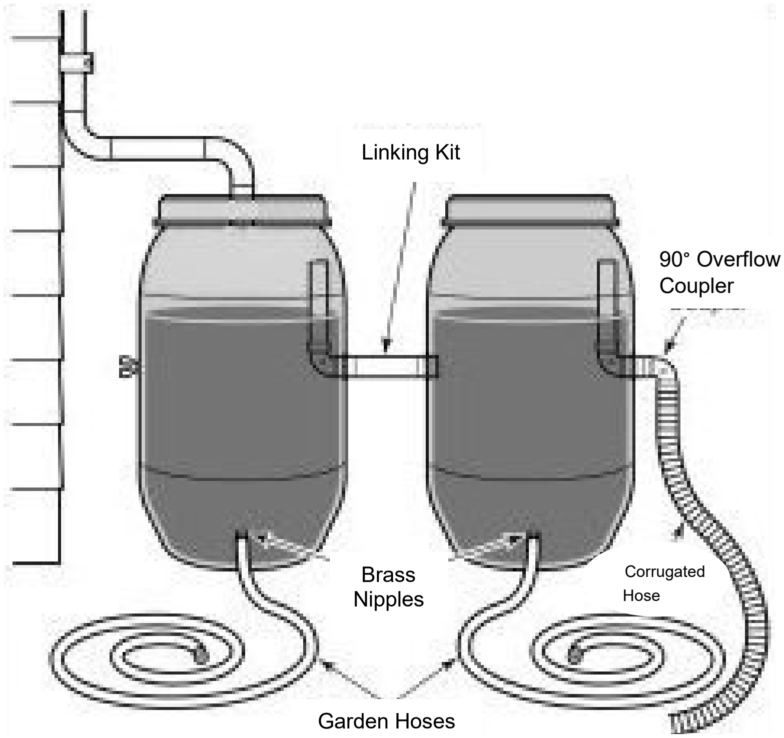


Figure 5-3. Rain Barrel Schematic. *Source: Home. Low Impact Development. (2002, November). Retrieved October 5, 2021, from https://lowimpactdevelopment.org/.*

Volume Reduction and Tributary Impervious Area Credit

Rain Barrels and Cisterns reduce volume by storing water in a container. Rain Barrels and Cisterns may help meet the VRR and reduce the size of required treatment controls (**Section 6**). The calculation procedure for volume reduction and area reduction for rain barrels and cisterns is presented in **Table 5-5. Appendix B** provides additional information on calculating and meeting the VRR.

Rain Barrels can also be used to reduce the required treatment control size by applying for tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (**Section 6**). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Rain Barrels reduces effective impervious area and thereby the volume of water to be treated. The credit is based on the volume reduction ratio to the SQDV for the Rain Barrel drainage area. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Rain Barrel for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Rain Barrel. **Table 5-5** details how the tributary impervious area credit is calculated for Rain Barrels.

Table 5-5. Rain Barrel/Cistern Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Volume reduction for rain barrel ($Vol_{reduction}$) **a. Total storage volume of rain barrels (V_s)** **b. Effectiveness factor (Eff) = 75%** **c. $Vol_{reduction} = V_s \times Eff$**	V_s = ______ ft^3 Eff = 0.75 ________________ $Vol_{reduction}$ = ______________ ft^3	The effectiveness factor considers that storage container may not be emptied between each storm
2. Total roof area (A_{roof})	A_{roof} = _________ ft^2	
3. SQDV for roof area based on 12-h drawdown **SQDV = 0.32 in x A_{roof} / 12 in/ft**	SQDV = ________ ft^3	Unit basin storage volume for 12-h drawdown at 100 % imperviousness (C_r= 0.95) = 0.32 in (see **Figure 6-1**)
4. Tributary Impervious Area Credit for rain barrel ($Area_{credit}$) **$Area_{credit} = A_{roof} \times Vol_{reduction}$ / SQDV**	$Area_{credit}$ = _________ ft^2	Maximum allowable $Area_{credit}$ = A_{roof}

Construction Considerations

Stormwater should not be diverted to the rain barrel or cistern until the overflow discharge area has been stabilized.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner before final acceptance of a private development project, including VRMs such as rain barrels and cisterns. Such agreements will typically include requirements such as those outlined in **Table 5-6**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the VRM and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

Table 5-6. Inspection and Maintenance Requirements for Rain Barrels and Cisterns

Activity	Schedule
Inspect: roof connection; gutter; downspout, rain barrel/ cistern, mosquito screen, and overflow pipes for leaks and obstructions.	Twice per year. Repair as required
Inspect insect and debris screens. Clean as required.	Following significant rainfall events

Description

Image 5-5. *Source: Stringham, T.K., Snyder, K.A., Snyder, D.K., Lossing, S.S., Carr, C.A., and Stringham, B.J. (2018). Rainfall interception by singleleaf piñon and Utah juniper: implications for stand-level effective precipitation. Rangeland Ecology & Management 71(3):327-335.*

Interception trees are used in residential and commercial settings to reduce stormwater runoff volume. Tree canopies can intercept a significant fraction of rainfall (10-40%) depending on the type of tree and climate. Tree canopies that project over impervious areas provide the greatest volume reduction benefit. **Figure 5-4** illustrates the rainfall interception and evaporation benefits received through a tree's hydrologic cycle.

Broadleaf evergreens and conifers intercept more rainfall than deciduous species where winter rainfall patterns

Advantages

- Reduces stormwater volume and pollutant discharge.
- Enhances site aesthetics.
- Increases property values.
- Provides shading and cooling.
- Improves air quality.
- It can be used to also meet local parking lot landscaping requirements.

Limitations

- Fire safety may be a consideration for sites with increased fire risk.

Planning and Siting Considerations

- Trees should be selected that maximize tree canopy, are low maintenance, drought tolerant, and appropriate for local soil conditions. Recommended trees can be found in Appendix D of the Sacramento Stormwater Quality Design Manual (2014).
- Locate trees at appropriate distances from buildings and infrastructure to avoid damage by roots and interference by branches.
- Locate trees such that canopies project over impervious areas to the maximum extent possible.

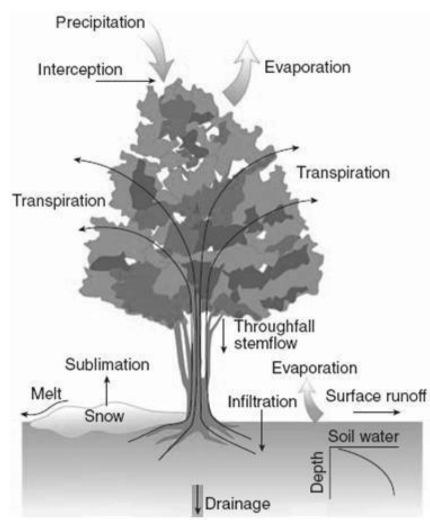


Figure 5-2. *Source: Ekhuemelo, David. (2016). Importance Of Forest and Trees in Sustaining Water Supply And Rainfall. Nigeria Journal of Education, Health And Technology Research (Njehetr).*

Volume Reduction and Tributary Impervious Area Credit

Interception Trees provide volume reduction through the storage of water in the leaves, branches and stem of the tree. Interception Trees may be used to help meet the VRR and reduce the size of required treatment controls (**Section 6**). The calculation procedure for volume reduction and tributary impervious area credit for Interception Trees is presented in **Table 5-7. Appendix B** provides additional information on calculating and meeting the VRR.

Interception Trees can also be used to reduce the required treatment control size by applying for tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (**Section 6**). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementing Interception Trees reduces effective impervious area and, thereby the volume of water to be treated. The credit based on the area of canopy projection over impervious areas and the percentage of rainfall interception allowed for the type of tree selected. **Table 5-7** details how the tributary impervious area credit is calculated for Interception Trees.

Table 5-7. Interception Tree Volume and Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Percent rainfall interception by tree (Int) a. **Evergreen tree Int = 40%** b. **Deciduous tree Int = 20 %**	Int = ______________ %	
2. No. of trees	No. of trees = __________	Provide separate total for each type of tree
3. Canopy projected over impervious area/tree	$Area_p$ =____________ ft^2	
4. Design storm depth (d)	d= ______________ in	d = 0.51 inch
5. Volume reduction for interception ($Vol_{reduction}$) $Vol_{reduction}$ = d x $Area_p$ x Int x No. of trees /12 in/ft	$Vol_{reduction}$ = ___________ ft^3	Provide separate calculation for each type of tree with different canopy and Int value
6. Tributary Impervious Area Credit for tree interception $Area_{credit}$ = $Area_p$ x Int	$Area_{credit}$ =_____________ ft^2	Provide separate calculation for each type of tree with different canopy and Int value.

Construction Considerations

Urban tree mortality can be high. The following construction considerations can help to increase the life expectancy of urban trees:

- Utilize planting arrangements that allow shared rooting spaces
- Provide at least 400-cubic (optimally 1,000) feet of soil for large trees (Urban, 1999)
- Limit the use of heavy equipment in planting areas to prevent soil compaction
- Use tree cages to protect trees from lawnmowers, heavy foot traffic and vehicles
- Select drought-tolerant tree species

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner before the final acceptance of a private development project, including VRMs such as Interception Trees. Such agreements will typically include requirements such as those outlined in **Table 5-8**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the VRM and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

Table 5-8. Inspection and Maintenance Requirements for Interception Trees

Activity	Schedule
Remove and replace any diseased or dying trees	Annually
Maintain trees (watering, pruning)	As needed

Image 5-6. Grassy channel. *Source: Fairfax County Virginia. (n.d.). Control Heavy Runoff - Solving Drainage and Erosion Problems. Retrieved October 6, 2021, from https://www.fairfaxcounty.gov/soil-water-conservation/drainage-problem-control-runoff.*

Description

Grassy Channels are densely vegetated drainage ways with gentle side slopes and gradual longitudinal slopes in the direction of flow that receives runoff from impervious areas and slowly conveys the runoff to downstream points of treatment or discharge. Grassy Channels allow infiltration, reduce peak flows from impervious areas, and provide a degree of pollutant removal. Where development density, topography and soils permit, Grassy Channels are preferable to curb and gutter and storm drains as a stormwater conveyance system. The features and function of Grassy Channels are similar to the full treatment Grassy Swale described in Fact Sheet L-8 in **Section 6**.

Grassy Channels are appropriate for use in residential, commercial, industrial, and institutional settings, as illustrated in **Figure 5-1**. They can be used in conjunction with Grassy Filter Strips and are located adjacent to impervious areas to be mitigated. Drainage areas are typically less than 5 acres. Several Grassy Channels may be used on a single site, each designed to receive flow from different impervious areas. Grassy channels can also provide pretreatment for other stormwater treatment controls, such as bioretention areas.
Irrigation and regular mowing are required to maintain the turf grass cover. Options for the types of vegetation that can be used are provided in **Appendix G**.

> A grassy channel is similar in most respects to a grassy swale, but differs in the level of engineering design criteria specified contact time, depth of flow, and flow velocity.

Other Names: *Grassy Swale, Bioswale*

Advantages

- Low installation cost.
- Compatible with site landscaping.
- Reduces stormwater volume and pollutant discharge.
- Easy to maintain.
- A preferred alternative to curb and gutter, where feasible.

Limitations

- Not suitable for areas that receive substantial to full shade.
- Not suitable for industrial sites or sites where spills may occur unless infiltration is prevented by an impermeable liner.
- Requires individual owners/tenants to perform maintenance.

Design Criteria

Design elements, construction considerations and maintenance requirements of Grassy Channels are similar in most respects to those of full treatment Grassy Swales presented in Fact Sheet L-8 in **Section 6**. Grassy Channels typically differ in terms of the values used for the three principal design parameters that govern treatment performance:

- Contact time, which is a function of swale length
- Depth of flow
- Flow velocity

Key design criteria and reference values for Grassy Channels are listed in **Table 5-9,** along with reference values for use in the calculation of credits for reducing the effective impervious area. The design and reference values ratios are used in the calculation of credits for reducing effective impervious area.

Table 5-9. Grassy Channel Design Criteria and Reference Values

Design Parameter	Criteria	Notes
Longitudinal slope (flow direction)	4% 0.5%	Maximum Minimum
Maximum bottom width	6 ft	
Maximum side slopes (H:V)	4:1	Side slopes to allow for ease of mowing.
Roughness coefficient (n) for treatment design	0.2	Reflects the roughness of swale when depth of flow is below the height of the grass.
Roughness coefficient (n) for conveyance design	0.1	Reflects the roughness of swale when depth of flow is above the height of the grass. Used to determine capacity of swale to convey peak hydraulic flows.
Vegetation	–	Turf grass (irrigated, not artificial)
Vegetation height (typical)	4 to 6 in.	Vegetation should be maintained at a height greater than the depth of flow at design flow rate but sufficiently low to prevent lodging or shading of the vegetation.
Reference Values for Credit Calculation	**Criteria**	**Notes**
Reference Design Flow ($SQDF_{ref}$)	SQDF	SQDF = 0.20 in/hr × C × A (see **Section 6**)
Reference contact time (t_{ref})	7 min	
Reference flow depth (D_{ref})	3 in	In flow direction
Reference flow velocity (v_{ref})	1 ft/sec	In flow direction

Volume Reduction and Tributary Impervious Area Credit

Grassy Channels provide volume reduction through water infiltration during conveyance and retaining water in the vegetative layer. Grassy Channels may be used to help meet the VRR and reduce the size of required treatment controls (**Section 6**). Volume reduction achieved with C and D soils is less than that achieved with A and B soils because less infiltration will occur with C and D soils. The calculation procedure for volume reduction and tributary impervious area credit for Grassy Channels is presented in **Table 5-10. Appendix B** provides additional information on calculating and meeting the VRR, and an example is provided below.

Grassy Channels can also be used to reduce the required treatment control size by applying tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (**Section 6**). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementation of Grassy Channels reduces effective impervious area and, thereby the volume of water to be treated. The credit is based on the volume reduction ratio to the SQDF for the Grassy Channel drainage area. Note that these credits must be applied to treatment controls that are in the same tributary drainage area as the Grassy Channel for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Grassy Channel. **Table 5-10** details how the tributary impervious area credit is calculated for Grassy Channels.

Table 5-10. Grassy Channel Volume and Tributary Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Determine reference SQDF **a. Impervious tributary area** **b. Impervious area runoff coefficient (C_{imp})** **c. $SQDF_{ref}$ = 0.2 x A_{imp} x C_{imp} / 43,560**	A_{imp} =_______________ ft^2 C_{imp} =_______________ $SQDF_{ref}$ = _______cfs	C_{imp}= 0.95
2. Design bottom width of Grassy Channel (W_{GC})	W_{GC} =__________________ ft	
3. Design longitudinal slope (s_{GC})	s_{GC} = _______________ ft/ft	
4. Design length of Grassy Channel (L_{GC})	L_{VBS} =__________________ ft	
5. Flow geometry @ SQDF from Manning equation **a. Design flow depth (D_{GC})** **b. Design flow area (A_{GC})** **c. Design flow velocity (v_{GC})**	D_{GC} =__________ ft A_{GC} =__________________ ft^2 v_{GC} =__________ ft/sec	
6. Contact time @ SQDF (t_{GC}) **t_{GC} = L_{GC} / v_{GC} / 60 sec**	t_{GC} =__________________ min	
7. Impervious Area credit for Grassy Channel (A_{credit}) **i) $A_{credit} = (D_{aref}/D_{GC})^2 \times (V_{ref}/V_{GC})^2 \times (t_{GC}/t_{ref}) \times A_{imp}$**	A_{credit} =________________ ft^2	If calculated values of (q_{aref}/q_a), (V_{ref}/V_{GC}), or (t_{GC}/t_{ref}) are > 1.0, the value is set to 1.0
8. Volume Reduction for Grassy Channel ($Vol_{reduction}$) **a. V_{soils} for A and B soils = 0.50** **b. V_{soils} for C and D soils = 0.25** **c. $Vol_{reduction}$ = (A_{credit}) x V_{soils} x (0.51/12)**	V_{soils} =________________ ft^3 $Vol_{reduction}$ = ____________ ft^3	V_{soils} is volume reduction factor allowed for infiltration, which varies with soil permeability

Credit Calculation Examples

Examples of volume reduction and tributary impervious area credit calculations are presented below.

Step 1 – Calculate SQDF for impervious area tributary to Grassy Channel

Using procedures described in **Section 6**, determine SQDF for area tributary to Grassy Channel.

$$SQDF_{ref} = i \times C \times A$$

where

SQDF = Stormwater Quality Design Flow, cfs

i = Design storm intensity = 0.20 in/hr

C_{imp} = Runoff coefficient for impervious area tributary to Grassy Channel

A_{imp} = impervious area tributary to Grassy Channel, acres

Example:

C_{imp} = 0.95

A_{imp} = 4,000 ft^2

$SQDF_{ref}$= 0.20 x 0.95 x 4,000/43,560 = 0.0174 cfs

Step 2 – Determine design bottom width of Grassy Channel (W_{GC})

Note: Design width of Grassy Channel is not restricted to any value, but the ease of mowing and maintenance should be considered.

Example:

W_{GC} = 0.5 ft

Step 3 – Determine longitudinal design slope of Grassy Channel (s_{GC}) and side slope (H:V)

s_{GC} = 4% maximum; 0.5% minimum

H:V = 4:1

Example:

s_{GC} = 1% = 0.01ft/ft

Step 4 – Determine design length of Grassy Channel (L_{GC})

Note: Design length of Grassy Channel is not restricted to any minimum value

Example:

L_{GC} = 20 ft

Step 5 – Calculate design depth of flow and flow velocity at SQDF using Manning's Equation

$$Q = \frac{1.49}{n}\frac{A^{5/3}}{P^{2/3}} \times s^{1/2}$$

where

$Q = SQDF_{ref}$

A = Cross sectional area of flow

P = Wetted perimeter of flow

s = Bottom slope in flow direction

n = Manning's n (roughness coefficient) = 0.2 for depth < 6 in

Solve Manning's equation by trial and error to determine the depth of flow, flow area, and flow velocity at the SQDF and the design channel geometry

Example:

D_{GC} = 1.5 in

A_{GC} = 0.0625 ft^2

v_{GC} = Q_{SQDF} / A_{GC} = 0.0174 cfs / 0.0625 ft^2

v_{GC} =0.28 ft/sec

Step 6 – Calculate contact time for Grassy Channel (t_{GC})

t_{GC} = L_{GC} / v_{GC}

t_{GC} = 20 ft / 0.28 ft/sec / 60 sec

t_{GC} = 1.19 min

Step 7 – Calculate impervious area credit for Grassy Channel (A_{credit})

A_{credit} = $(D_{ref}/D_{GC})^2$ x $(v_{ref}/v_{GC})^2$ x (t_{GC}/t_{ref}) x A_{imp}

Note: The ratios, (D_{ref}/D_{GC}) and (v_{ref}/v_{GC}) are squared to account for reduced efficiency of full treatment systems at higher hydraulic loading rates.

If calculated values of (D_{ref}/D_{GC}), (v_{ref}/v_{GC}),or (t_{GC}/t_{ref}) are > 1.0, the value is set to 1.0

The maximum allowable value of A_{credit} = A_{imp}

Example:

A_{credit} = $(3/1.5)^2$ x $(1/0.28)^2$ x (1.19/7) 4,000

A_{credit} = $(1)^2$ x $(1)^2$ x 0.17 x 4,000 ft^2

A_{credit} = 680.3 ft^2

Step 8 – Calculate volume reduction credit for 0.51-inch storm depth

$Vol_{reduction}$ = (A_{credit}) x V_{soils} x (0.51/12)

Example:

V_{soils} = 0.25 for C and D soils

$Vol_{reduction}$= 680.3 x 0.25 x (0.51/12) = 7.2 ft^3

Construction Considerations

See Fact Sheet L-8: Grassy Swale in **Section 6**.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner before final acceptance of a private development project, including VRMs such as Grassy Channels. Such agreements will typically include requirements such as those outlined in **Table 6-30** in Fact Sheet L-8: Grassy Swale in **Section 6**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the VRM and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

Description

A Vegetated Buffer Strip for rooftop and pavement disconnection is a gently sloped soil surface planted with dense turf grass or groundcover designed to receive and convey flow from rooftop drainage systems and adjacent paved areas. Runoff volume reduction is achieved through the retention of a portion of the flow in the surface soil and thatch layer of the strip and infiltration. Some pollutant removal is also achieved as the runoff flows through the vegetation and over the soil surface at a shallow depth by a variety of physical, chemical, and biological mechanisms.

A Vegetated Buffer Strip is similar in most respects to a Grassy Filter Strip (L-9), but differs in the level of engineering design criteria specified for minimum flow length and maximum application rates.

For rooftop drainage disconnection, splash runoff away from the building foundation and disperse flow to the strip. As shown in the figure below, Buried extensions with pop-up outlets can be used for the same purpose. To increase the effectiveness of a strip, the concentrated flow from the roof drain should be dispersed across the top of the strip to the extent possible to maximize the width of flow down the length of the strip. A pea gravel level spreader can be used for this purpose if slope of the strip exceeds 4 percent (See **Figure 6-14** in Fact Sheet L-9: Grassy Filter Strip in **Section 6**).

Other Names: *Vegetated Filter Strips, Grassy Buffer Strips, Grassy Filter Strips*

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping.
- Reduces peak flows and runoff volume.
- Easy to maintain.

Limitations

- Not suitable for industrial sites or sites where spills may occur unless an impermeable liner prevents infiltration.

Planning and Siting Considerations

- Select a location where site topography allows for the design of buffer strips with proper slopes in the flow direction.
- Integrate Vegetated Buffer Strips into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- Irrigation is typically required to maintain the viability of the buffer strip vegetation. Coordinate the design of the general landscape irrigation system with the Vegetated Buffer Strip, as applicable.

Design Criteria

Design elements, construction considerations and maintenance requirements of Vegetated Buffer Strips are similar in most respects to those of full-treatment Vegetated Buffer Strips presented in Fact Sheet L-9 in **Section 6**. Grassy Channels typically differ in terms of the values used for the two principal design parameters that govern treatment performance:

- Length of the strip in the direction of flow
- Application rate across the top of the strip

Key design criteria and reference values for Grassy Channels are listed in **Table 5-11,** along with reference values for use in the calculation of credits for reducing the effective impervious area. The design and reference values ratios are used in calculating credits for volume reduction and effective impervious area reduction.

Table 5-11. Vegetated Buffer Strips Design Criteria and Reference Values

Design Parameter	Criteria	Notes
Minimum design length (L_{VBS})	3 ft	In flow direction
Slope (flow direction)	4% 0.5%	Maximum Minimum
Vegetation	–	Turf grass or dense ground cover (irrigated)
Vegetation height (typical)	1 – 3 in.	
Reference Values for Credit Calculation	**Criteria**	**Notes**
Reference Design Flow ($SQDF_{ref}$)	SQDF	SQDF = 0.20 in/hr x C x A (see **Section 6**)
Reference linear application rate (q_{aref})	0.005 cfs/ft width	
Width for normal to flow (default value)	3 ft	Greater flow widths will increase credit values and can be achieved with flow spreader devices.
Reference length (in flow direction) (L_{ref})	20 ft	Maximum length for credit. Longer lengths receive no additional credit
Runoff coefficient for VBS	0.18 0.25	A and B soils C and D soils

Volume Reduction and Tributary Impervious Area Credit

Vegetated Buffer Strips provide volume reduction through water infiltration during conveyance and retaining water in the vegetative layer. Vegetated Buffer Strips may be used to help meet the VRR and can also be used to reduce the size of required treatment controls (**Section 6**). The calculation procedure for volume reduction and tributary impervious area credit for Vegetated Buffer Strips is presented in **Table 5-12. Appendix B** provides additional information on calculating and meeting the VRR; an example is provided below.

Vegetated Buffer Strips can also be used to reduce the required treatment control size by applying for tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the SQDV or SQDF, which are the primary design criteria used to size Treatment Controls (**Section 6**). The SQDV is calculated by multiplying the effective impervious area by the unit basin volume (measured in watershed inches). The SQDF is calculated by multiplying the effective impervious area by the design rainfall intensity (measured in inches per hour). Implementing Vegetated Buffer Strips reduces effective impervious area and, thereby, the volume of water to be treated. The credit is based on the ratio of volume reduction for the Vegetated Buffer Strip to the volume reduction estimated for reference Vegetated Buffer Strip that would provide full treatment for the drainage area (see L-9: Grassy Filter Strip). Note that these credits must be applied to treatment controls in the same tributary drainage area as the Vegetated Buffer Strip for which the credits are determined and the credits cannot be greater than the tributary drainage areas of the Grassy Vegetated Buffer Strip. **Table 5-12** details how the tributary impervious area credit is calculated for Vegetated Buffer Strips.

Table 5-12. Vegetated Buffer Strip Volume and Impervious Area Credit Calculation

Design Parameter	Criteria	Notes
1. Determine reference SQDF **a. Impervious tributary area** **b. Impervious area runoff coefficient (C_{imp})** **c. $SQDF_{ref} = 0.2 \times A_{imp} \times C_{imp} / 43,560$**	Aimp =________ ft2 Cimp =________ SQDFref = ________cfs	Cimp= 0.95
2. Design width of Vegetated Buffer Strip (W_{vbs})	WVBS = _________ ft	Minimum default width = 3.0 ft
3. Design linear application rate (q_a) **$q_a = SQDF_{ref} / W_{VBS}$**	qa =__________ cfs/ft	Reference qa = 0.005 cfs/ft
4. Design length of Vegetated Buffer Strip (L_{VBS})	LVBS =_________ ft	Reference LVBS = 20 ft, which is max length allowed for credit
5. Tributary Impervious Area credit for Vegetated Buffer Strip (A_{credit}) **$A_{credit} = (q_{aref}/q_a)^2 \times (L_{VBS}/L_{ref}) \times A_{imp}$**	Acredit =________ ft2	If calculated values of (qaref/qa) or (LVBS/Lref) are > 1.0, the value is set to 1.0. Maximum allowable credit = Aimp
6. Volume Reduction for Vegetated Buffer Strip ($Vol_{reduction}$) **$Vol_{reduction} = (A_{credit}) \times (C_{imp} - C_{VBS}) \times (0.51/12)$**	Volreduction = _______ ft3	CVBS = 0.18 for A and B soils CVBS = 0.25 for C and D soils

Credit Calculation Examples

Examples of volume and area credit calculations are presented below.

Step 1 – Calculate SQDF for impervious area tributary to Vegetated Buffer Strip

Using **Fact Sheet T-0** in **Section 6**, determine SQDF for impervious area tributary to Vegetated Buffer Strip.

$SQDF_{ref}$ = i x C x A_{imp}

where

$SQDF_{ref}$ = Stormwater Quality Design Flow, cfs

i = Design storm intensity = 0.20 in/hr

C = Runoff coefficient for impervious area tributary to Vegetated Buffer Strip

A_{imp} = impervious area tributary to Vegetated Buffer Strip, acres

Example:

C = 0.95

A_{imp} = 3,600 ft^2

$SQDF_{ref}$= 0.20 x 0.95 x 3,600/43,560 = 0.0157 cfs

Step 2 – Determine design width of Vegetated Buffer Strip (W_{VBS})

Note: Design width of Vegetated Buffer Strip is not restricted to any value but runoff flow must be distributed uniformly across the width of the strip. The minimum default width is 3 feet. Wider values can be used if flow is dispersed with a spreader device

Example:

W_{VBS} = 3.0 ft

Step 3 – Calculate design linear application rate (q_a)

q_a = $SQDF_{ref}$/ W_{VBS}

Example:

q_a = 0.0157 cfs/3.0 ft = 0.005 cfs/ft

Step 4 – Determine design length of Vegetated Buffer Strip (L_{VBS})

Note: Design length of Vegetated Buffer Strip is not restricted to any maximum, but 20 feet is the maximum length for credit calculation.

Example:

L_{VBS} = 12.0 ft

Step 5 – Calculate impervious area credit for Vegetated Buffer Strip (A_{credit})

A_{credit} = $(q_{aref}/q_a)^2$ x (L_{VBS}/L_{ref}) ⍰ A_{imp}

Note: The ratio, (q_{aref}/q_a) is squared to account for reduced efficiency of full treatment systems at higher hydraulic loading rates.

If calculated values of (q_{aref}/q_a) or (L_{VBS}/L_{ref}) are > 1.0, the value is set to 1.0

The maximum allowable value of A_{credit} = A_{imp}

Example:

A_{credit} = (0.005/0.005)^2 x (12/20) x 3,600 ft^2

A_{credit} = (1.0)^2 x (12/20) x 3,600 ft^2

A_{credit} = 0.6 x 3,600 ft^2 = 2,160 ft^2

Step 6 – Calculate Volume reduction for 0.51-inch storm depth

$Vol_{reduction}$ = (A_{credit}) x C_{imp} – C_{VBS}) x (0.51/12)

Example:

C_{VBS} = 0.25 for C and D soils

$Vol_{reduction}$ = 2,160 x (0.95 – 0.25) x (0.51/12) = 64.3 ft^3

Construction Considerations

See Fact Sheet L-9: Grassy Filter Strip in **Section 6**.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner before final acceptance of a private development project, including VRMs such as Vegetated Buffer Strips. Such agreements will typically include requirements such as those outlined in **Table 6-31** in Fact Sheet L-9: Grassy Filter Strip in **Section 6**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement must provide the City or County with complete access to the VRM and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**.

6. TREATMENT CONTROLS

6.1 INTRODUCTION

Treatment Controls are required in addition to Site Design Controls, Source Controls and VRMs to reduce pollutants in stormwater discharges to the MEP. Treatment Controls are engineered technologies designed to remove pollutants from stormwater runoff. The type of Treatment Control(s) to be implemented at a site depends on several factors, including the type of pollutants in the stormwater runoff, the quantity of stormwater runoff to be treated, project site conditions (e.g., soil type and permeability, slope, etc.), receiving water conditions, Trash Control requirements, and State Industrial General Permit requirements, as applicable. Land requirements and costs to design, construct and maintain treatment controls vary by treatment control.

Unlike flood control measures designed to handle peak flows, stormwater treatment controls treat the more frequent, lower-flow storm events or the first-flush portions of runoff from larger storm events (typically referred to as the first-flush events). Small, frequent storm events represent most of the total average annual rainfall for the area. The flow and volume from such small events, referred to as the SQDF and SQDV, are targets for treatment. In addition, Trash Controls are designed to treat the peak flow rate from a one-year, one-hour storm (0.345 inches).

The treatment controls presented in the SWQCCP are designed based on flow rates or runoff volume. Those designed based on flow are designed for the SQDF, and those designed based on volume are designed for the SQDV. Definitions and calculation procedures to determine design flows and volumes are presented in this Section. Flows above design specifications are to be diverted around or through the treatment control.

Treatment Controls are categorized as either LID Treatment Controls or Conventional Treatment Controls (**Table 6-1**). LID Treatment Controls can reduce stormwater runoff volumes and may be used in combination with the VRMs described in **Section 5** to meet the VRR. Conventional Treatment Controls typically do not reduce stormwater runoff volumes.

Table 6-1. LID Treatment Controls and Conventional Treatment Controls

LID Treatment Controls	Conventional Treatment Controls
Bioretention (L-1)[1] **Stormwater Planter (L-2)** **Tree-well Filter (L-3)** **Infiltration Basin (L-4)**[1] **Infiltration Trench (L-5)**[1] **Porous Pavement Filter (L-6)** **Vegetated (Dry) Swale (L-7)** **Grassy Swale (L-8)** **Grassy Filter Strip (L-9)**	Constructed Wetland (C-1) Extended Detention Basin (C-2)[1] Wet Pond (C-3) Proprietary Control Device (C-4) Trash Full Capture Systems (C-5)

[1] These treatment controls may be designed to also meet the trash control requirements.

The stormwater treatment controls specified in this section are the more common non-proprietary measures being implemented nationwide. Studies have shown these measures to be reasonably effective if properly installed and maintained. Consequently, the application of these controls is considered to achieve compliance to control pollutants to the MEP and work towards attaining and/or maintaining water quality standards in receiving waters. The relative effectiveness of treatment controls specified in this section for reducing pollutants of concern is shown in **Table 6-2**.

The selection of Treatment Controls should be based on their ability to reduce runoff volumes and remove pollutants of concern. New Development and Significant Redevelopment Priority Projects that cannot fully meet the VRR must select Treatment Controls with a Medium to High removal efficiency for the pollutants of concern (see **Table 2-1 in Section 2 and Table 6-2**). All PLU and Priority Projects must include trash Treatment Controls.

Table 6-2. Efficiency of Treatment Controls for Reduction of Pollutants of Concern

Treatment Controls	Pollutant of Concern[1]				
	Bacteria	Pesticides	Oxygen Demanding Substances	Sediments	Trash
LID Treatment Controls					
Bioretention (L-1)	M	M	M	M	H[T]
Stormwater Planter (L-2)	M	M	M	M	L
Tree-well Filter (L-3)	M	M	M	M	L
Infiltration Basin (L-4)	H	M	M	H	H[T]
Infiltration Trench (L-5)	H	M	M	H	H[T]
Porous Pavement Filter (L-6)	M	M	M	H	L
Vegetated (Dry) Swale (L-7)	L[2]	L[2]	M	M	L
Grassy Swale (L-8)	L[2]	L[2]	M	M	L
Vegetated Buffer Strip (L-9)	M	M	M	H	L
Conventional Treatment Controls					
Constructed Wetland (C-1)	M	M	M	M	M
Extended Detention Basin (C-2)	M	M	M	M	H[T]
Wet Pond (C-3)	M	M	M	H	M
Proprietary Devices(C-4)[3]	–	–	–	–	-
Trash Full Capture Systems (C-5)	L	L	M	M	H

[1] H = >75% expected pollutant removal efficiency for typical urban stormwater runoff; M = 75% to 25% expected removal efficiency for typical urban stormwater runoff; L = <25% expected removal efficiency for typical urban stormwater runoff.
T = Treatment Control can be modified to meet trash control requirements.
[2] If the pollutants of concern (**Table 2-1**) are bacteria or pesticides, swales should only be used in combination (e.g., used in a treatment train) with Treatment Controls with a Medium to High removal efficiency for bacteria or pesticide removal efficiency.
[3] Effectiveness of proprietary devices varies depending on the manufacturer and type of device. Limited performance data are available.

6.2 SELECTION OF TREATMENT CONTROLS

Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The applicability of specific controls outlined within this Section should be confirmed with the City or County. The site constraints that are considered in the selection of treatment controls are presented in **Table 6-3**.

Volume Reduction Requirement

All Priority Projects must meet the VRR (see **Sections 2 and 5**) through a combination of VRMs and LID Treatment Controls. If project applicants do not fully meet the VRR through VRMs (Section 5), the project must use LID Treatment Controls to further reduce stormwater runoff volumes and treat the SQDF or SQDV. If the VRR has been met through VRMs, then a treatment control may be chosen from the LID Treatment Control or Conventional Treatment Control list. Calculation procedures for determining the volume reduction for LID Treatment Controls are provided within each fact sheet. Design Summary Worksheets are provided in **Appendix B** to aid the applicant in summarizing calculation results.

An example calculation is provided in **Appendix J** to illustrate the application of the VRR, VRMs, tributary impervious area reduction credits and LID Treatment Controls.

If the VRR cannot be fully met due to site constraints, see "Technical Infeasibility and Alternative Compliance" in **Section 5**. Projects that do not fully meet the VRR must select Treatment Controls with a Medium to High removal efficiency for the pollutant of concern (see **Table 2-1 in Section 2 and Table 6-2**).

6.3 MAINTENANCE AND MONITORING REQUIREMENTS FOR TREATMENT CONTROLS

Failure to properly operate and maintain the measures could result in reduced treatment of stormwater runoff or a concentrated loading of pollutants to the storm drain system. Unless otherwise agreed to by the City or the County, the landowner, developer, site operator, or successors-in-interest (e.g., homeowner's association) is responsible for the operation and maintenance of the treatment controls. The maintenance agreement and plan will provide the City or County designee with complete access to the Device and its immediate vicinity at any time.

Certification of Responsibility

Project developers/property owners are responsible for the maintenance of structural stormwater control measures implemented pursuant to the requirements of the SWQCCP until the property ownership is legally transferred or the stormwater or other agency assumes responsibility through annexation. A sample owner/developers' certification of responsibility is included in **Appendix D** of the Plan.

Maintenance Plan

To protect against failure of a treatment control, a Maintenance Plan must be developed and implemented for all treatment controls (see **Section 7**). Maintenance Plans must include guidelines for how and when inspection and maintenance should occur for each control. Guidelines for maintenance plans are provided in **Appendix E**. The Plan must be made submitted to the City or County as part of the Project SWQCP submittal.

Maintenance Entities and Agreements

Owners, developers, and/or successors-in-interest (ODS) must establish a maintenance entity acceptable to the City or County that will be responsible for funding and performing the long-term operation, maintenance, replacement, and administration of the proposed treatment controls. Maintenance entities may be either private or public, depending on the ownership of facilities.

Private Maintenance Entity

The ODS of treatment controls constructed and located in private facilities must execute a Maintenance Agreement with the City or County before obtaining a building permit for a development project. The ODS will remain responsible for funding and performing the long-term operation, maintenance, replacement, and administration of the treatment controls. A sample Maintenance Agreement is included in **Appendix D**.

Public Maintenance Entity

The ODS of any subdivision project that includes treatment controls pursuant to the SWQCCP and that will be annexed to the City is required to form a Zone within the Stockton Consolidated Storm Drainage Maintenance Assessment District No. 2005-1 (approved and adopted by City Council on July 26, 2005) to provide funding for the long-term operation, maintenance, replacement, and administration of the treatment controls and all assets of the distribution system (e.g., pump stations, inlets, outlets) constructed for the project. The Zone must be formed prior to the recording of a Final Map. Formation of the Zone requires submittal to and approval by the City of an Engineer's Report that shall contain a boundary map and an allocation of the costs referenced above.

Monitoring

Monitoring may be conducted by the site operator, the City/County, or both. Monitoring may be required for a period of time to help the City or County evaluate the effectiveness of treatment controls in reducing pollutants in stormwater runoff.

6.4 DESCRIPTION OF TREATMENT CONTROLS

This Section provides fact sheets for the design and implementation of recommended treatment controls. The fact sheets include siting considerations, design criteria, and maintenance requirements to ensure optimal performance of the measures. The SWQCCP also contains calculation fact sheets and worksheets to aid in the design of water quality treatment controls.

Table 6-3. Site Constraints for Treatment Controls

Treatment Control	Drainage Area		Depth to Groundwater		Soil Type[2]		Maximum Slope		Hydraulic Head	Vegetation Irrigation	Vector Control Frequency	Maintenance Frequency
	<10 acres	>10 acres	<10 feet	>10 feet	A or B only	A, B, C or D	~0%	<15%				
LID Treatment Controls												
Bioretention (L-1)[1]	X			X		X		X	M	Y	M	M
Stormwater Planter (L-2)	X		X	X		X		X	M	Y	M	M
Tree-well Filter (L-3)	X		X	X		X		X	M	Y	M	M
Infiltration Basin (L-4)[1]	X			X	X			X	H	Y*	L	M
Infiltration Trench (L-5)[1]	X			X	X			X	H	N	L	L
Porous Pavement Filter (L-6)	X		X	X		X		X	M	N	L	L
Vegetated (Dry) Swale (L-7)	X		X	X		X		X	L	Y	L	L
Grassy Swale (L-8)	X		X	X		X		X	L	Y	M	L
Grassy Filter Strip (L-9)	X		X	X		X		X	L	Y	L	L
Conventional Treatment Controls												
Constructed Wetland (C-1)		X	X	X		X	X		L	Y	H	H
Extended Detention Basin (C-2)[1]		X	X	X		X	X		L	Y*	M	M
Wet Pond (C-3)		X	X	X		X	X		L	Y*	H	M
Proprietary Devices[3](C-4)												
Trash Full Capture Systems[4] (C-5)												

X: indicates Treatment Control is suitable for listed site condition. H= high; M = medium; L = low; Y= yes; Y* = yes if vegetated; N= no

1. Treatment Control can be modified to meet trash control requirements
2. Type A soils are sands and gravels with typical infiltration rates of 1.0-8.3 inches/hour. Type B soils are sandy loams with moderately fine to moderately coarse textures and typical infiltration rates of 0.5-1.0 inches/hour. Type C soils are silty-loams or soils with moderately fine to fine texture and typical infiltration rates of 0.17-0.27 inches/hour. Type D soils are clays with infiltration rates of 0.02-0.10 inches/hour.
3. Suitability of proprietary devices varies depending on the manufacturer and type of device.
4. Trash Full Capture Devices are proprietary devices and their suitability depends on the manufacturer and type of device.

INTRODUCTION

With the exception of Trash Full Capture Systems (FCS) (C-5), the primary control strategy for all of the treatment control measures specified in this Section is to treat the SQDF or SQDV of the stormwater runoff. The following paragraphs present calculation procedures and design criteria necessary to determine the SQDF and SQDV, which are distinct and separate parameters from the VRR discussed in **Section 5**. The SQDF and SQDV are required design parameters used to size treatment controls. The VRR (**Section 5.2**) is a separate and independent requirement that the application of a combination of VRMs and LID Treatment Controls must meet.

The treatment controls specified in this Section are listed in **Table 6-4,** along with the basis of design, SQDF or SQDV, to be used for the listed control measure. Also listed in **Table 6-4** are the design drawdown periods for those treatment control measures that use the SQDV as the basis for design (**Figure 6-1**). LID-type treatment controls are identified as L-1, L-2, etc. Conventional treatment controls are identified as C-1, C-2, etc.

Table 6-4. Sizing Criteria for Treatment Controls

Treatment Control	Design Basis	Design Drawdown[2]
Bioretention (L-1)[1]	SQDV	12 hours
Stormwater Planter (L-2)[1]	SQDV	12 hours
Tree-well Filter (L-3)[1]	SQDV	12 hours
Infiltration Basin (L-4)	SQDV	48 hours
Infiltration Trench (L-5)[1]	SQDV	48 hours
Porous Pavement Filter (L-6)	SQDV	12 hours
Vegetative (Dry) Swale (L-7)	SQDV	12 hours
Grassy Swale (L-8)	SQDF	N/A
Grassy Filter Strip (L-9)	SQDF	N/A
Constructed Wetland (C-1)	SQDV	24 hours
Extended Detention Basin (C-2)	SQDV	48 hours
Wet Pond (C-3)	SQDV	12 hours
Proprietary Control Measures (C-4)	SQDV or SQDF	48 hours
Trash Full Capture Devices (C-5)	Flow rate for 1-hr, 1-yr storm	N/A

[1] Can be modified to meet trash control requirements.
[2] Design drawdown period used to determine Unit Basin Storage Volume (see **Figure 6-1**)

Determining Design Imperviousness, Runoff Coefficient and Effective Area

Calculation of the SQDV and SQDF requires the determination of the following parameters associated with the drainage area tributary to the treatment control under design:

- Weighted runoff coefficient (C_r) (without application of impervious area credits)
- The effective tributary area following the application of area credits (A_{eff})

Weighted Imperviousness and Runoff Coefficient Calculations

Projects typically comprise a variety of site elements that have variable values of imperviousness and associated runoff coefficients. The runoff coefficient is a function of imperviousness and the permeability of the soil if the runoff contacts the soil. Values of imperviousness and runoff coefficients to be used for calculating SQDV and SQDF under the 2009 SWQCCP are listed in **Table 6-5** for typical site elements. The weighted runoff coefficient value for a particular drainage area is determined as follows:

1. Determine area associated with each site element ($A_{element}$)
2. Determine sum of site element areas (A_{site})
3. Determine fraction of total area associated with each site element ($A_{element}/A_{site}$)
4. Determine the runoff coefficient (C_r) associated with each site element from **Table 6-5**.
5. Calculate weighted imperviousness (I_a) or runoff coefficient (C_{ra}):

$$I\ I_a = \Sigma\ I_i \times A_{element(i)} / A_{site}$$

$$C_{ra} = \Sigma\ C_r \times A_{element(i)} / A_{site}$$

Table 6-5. Values of Runoff Coefficients for Typical Site Elements[1,2]

Site Element	Runoff Coefficient (C_r)	
	A and B Soils	C and D Soils
Asphalt/concrete pavement	0.95	0.95
Roofs	0.95	0.95
Gravel pavement	0.35	0.35
Permeable pavement	Variable[3]	Variable[3]
Managed turf	0.18	0.25
Disturbed soils	0.18	0.25
Vegetated areas w/ amended Type A soil	0.03	n/a
Forest/undisturbed open space	0.03	0.05

[1] Adapted from Center for Watershed Protection, Ellicott City, MD.
[2] Not for design of storm drain system piping. Use City of Stockton Standard Drawing No. 76 for storm drain system design.
[3] Variable with product type. Consult manufacturer for appropriate design values.

Example calculations for weighted runoff coefficient for a site with Type D soils are shown in **Table 6-6.**

Table 6-6. Example Calculation Table for Weighted Runoff Coefficient

Site Element	Element Area[(a)], ft^2 ($A_{element}$)	Fraction of Total Area ($A_{element}/A_{site}$)	Element Runoff Coefficient (C_r)	Weighted Runoff Coefficient (C_{ra})
Asphalt/concrete pavement	40,000	0.40	0.95	0.38
Roofs	30,000	0.30	0.95	0.29
Permeable pavement	5,000	0.05	0.35	0.17
Managed turf	20,000	0.20	0.25	0.05
Area amended w/ Type A soil	5,000	0.05	0.03	0.01
Total Site (A_{site})	100,000			0.90

[1] Actual area without adjustment for tributary impervious area credits from VRMs

Effective Tributary Area Calculations

The effective tributary area is defined as the effective area to be used in calculations for SQDV and SQDF for a specific treatment control measure and is determined by subtracting the tributary impervious area credits earned for VRMs from the actual tributary drainage area served by the treatment control ($A_{eff} = A_{tributary} – A_{credit}$). Note that a tributary impervious area credit for a VRM must be applied to a treatment control that serves the same tributary drainage area as the VRM for which the credit is earned. The credits cannot be greater than the tributary drainage areas of the treatment controls to which they are applied. Example calculations for the effective area are shown in **Table 6-7**.

Table 6-7. Example Calculation Table for Effective Tributary Area

Site Element	Element Area, ft^2	Area Credit[1] (A_{credit}), ft^2	Effective Area (A_{eff}), ft^2
Asphalt/concrete pavement	40,000	10,000	30,000
Roofs	30,000	15,000	15,000
Permeable pavement[2]	5,000	0	5,000
Managed Turf	20,000	0	20,000
Amended Soil Area Type A	5,000	0	5,000

[1] Area Credit from VRMs (e.g. rain gardens, rain barrels, interception trees, grassy channel, or vegetated buffer strip)
[2] Credit for permeable pavement has already been provided in the form of a reduced runoff coefficient (see **Tables 6-5 and 6-6**).

Stormwater Quality Design Flow Calculation

Hydrologic calculations for the design of flow-based stormwater treatment controls shall be in accordance with the latest version of the City Standard Specifications (Red Book) and the County Improvement Standards and Hydrology Manual, together with the procedure set forth herein.

The SQDF is defined to be equal to the maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two. The 85th percentile hourly rainfall intensity for the Stockton area is estimated to be approximately 0.10 inches/hour, based on the cumulative frequency curve for Sacramento presented in the *California Storm Water Best Management Practices Handbook – New Development and Redevelopment* (2003) for representative rainfall gauges throughout California (not to be confused with the 85th percentile, 24-hour storm depth associated with the VRR). The curve for Sacramento is considered representative of rainfall intensities in the Stockton area.

Calculation Procedure

1. Determine the 85th percentile hourly rainfall intensity for the Stockton area. Use 0.10 in/hr.
2. Multiply the 85th percentile hourly rainfall intensity by a factor of two to obtain design rainfall intensity. Use i = 0.10 x 2 = 0.20 in/hr.
3. Determine the weighted runoff coefficient for the project area using the procedure illustrated in **Table 6-6**.
4. Determine the effective area (A_{eff}) of the drainage area using the procedure illustrated in **Table 6-7**.
5. Calculate the SQDF using the following equation.

   $$SQDF = i \times C_{ra} \times A_{eff} = 0.20 \times C_{ra} \times A_{eff}$$

   where

   SQDF = Stormwater Quality Design flow, cfs
   i = Design storm intensity = 0.20 in/hr
   C_{ra} = Weighted runoff coefficient for project area
   A_{eff} = Effective project drainage area, acres (Note: Area converted to acres for ease of calculation. Resulting conversion factor is approximately equal to 1.0)

Example Calculation

Project site conditions from previous example: A_{eff} = 75,000 ft^2; C_{ra} = 0.90

$$SQDF = 0.20 \times 0.90 \times 75{,}000/43{,}560 = 0.31 \text{ cfs}$$

Stormwater Quality Design Volume Calculation

Hydrologic calculations for the design of volume-based stormwater treatment controls shall be in accordance with the latest version of the City of Stockton Standard Specifications (Red Book) and the County of San Joaquin Improvement Standards and Hydrology Manual, together with the procedure set forth herein.

The SQDV is defined as the volume necessary to capture and treat 80 percent or more of the average annual runoff volume from the site at the design drawdown period specified in the Fact Sheet for the proposed treatment control. The SQDV volume should not be confused with the VRR, which is a separate requirement as defined in **Section 5**.

Calculation Procedure

1. Review the area draining to the proposed treatment control. Determine the drainage area's weighted runoff coefficient (Cra) using the procedure illustrated in **Table 6-6**.
2. **Figure 6-1** provides a direct reading of Unit Basin Storage Volumes required for 80% annual capture of runoff for values of “C_{ra}” determined in Step 1. Enter the horizontal axis of **Figure 6-1** with the “C_{ra}” value from Step 1. Move vertically up **Figure 6-1** until the appropriate drawdown period line is intercepted. (The design drawdown period specified in the respective Fact Sheet for the proposed treatment control). Move horizontally across **Figure 6-1** from this point until the vertical axis is intercepted. Read the Unit Basin Storage Volume along the vertical axis. **Figure 6-1** is based on rain gauge data from the SUA.
3. Determine the effective area of the drainage area using the procedure illustrated in **Table 6-7**.
4. The SQDV for the proposed treatment control is then calculated by multiplying the Unit Basin Storage Volume by the contributing drainage area. Due to the mixed units that result (e.g., acre-inches, acre-feet), the resulting volume is recommended to be converted to cubic feet for use during design.

$$SQDV = V_u \times A_{eff}$$

Example Calculation

Project site conditions from previous example: A_{eff} = 75,000 ft^2; C_{ra} = 0.90

1. Determine design drawdown period for proposed control measure.

   Example: L-1: Bioretention x Drawdown period = 12 hrs

2. Determine the Unit Basin Storage Volume for 80% Annual Capture, V_u using **Figure 6-1**.

   Example: for C_{ra} = 0.90 and drawdown = 12 hrs x V_u = 0.31 in

3. Calculate the SQDV for the basin.

   $SQDV = V_u \times A_{eff} = (0.31 \text{ in}) \times (75{,}000 \text{ ft}^2) \times (1 \text{ ft}/12 \text{ in}) = 1{,}938 \text{ ft}^3$

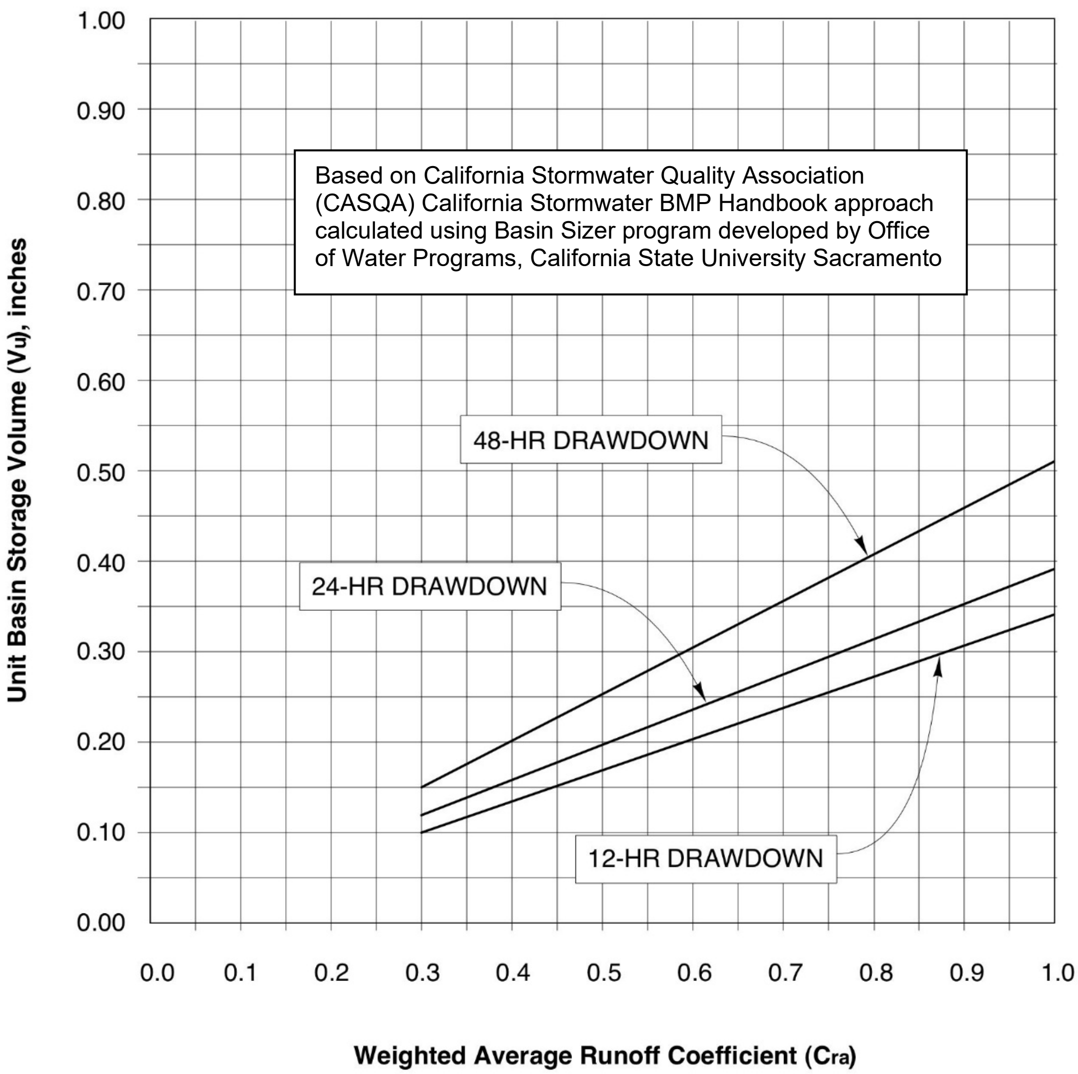


Figure 6-1. Unit Basin Storage Volume vs. Weighted Runoff Coefficient *Computing Stormwater Runoff Rates and Volumes. NJDEP New Jersey Department of Environmental Protection. (2004). Retrieved October 7, 2021, from https://www.njstormwater.org/bmp_manual2.htm.*

Description

Image 3**. *Roadway Bioretention Areas in Raleigh, NC.*** *Source: Raleighnc.gov. (n.d.). Retrieved October 6, 2021, from https://raleighnc.gov/SupportPages/roadway-bioretention-areas*.

A bioretention area is a vegetated shallow depression that is designed to receive, retain, and infiltrate rainwater runoff from downspouts, piped inlets, or sheet flow from adjoining paved areas. A shallow surcharge or ponding zone is provided above the vegetated surface for the temporary storage of the captured runoff. During stormwater events, runoff accumulates in the surcharge zone. It gradually infiltrates the surface and filters through the engineered soil matrix, filling the void spaces of the matrix before infiltrating the underlying soil or being collected by an underdrain system. Treatment of the runoff occurs through various natural mechanisms as the runoff filters through the root zone of the vegetation and during the detention of the runoff in the pore space of the engineered soil matrix. A portion of the water held in the root zone of the soil media is returned to the atmosphere through transpiration by the plants. Bioretention areas are typically planted with native, drought-tolerant plant species that do not require fertilization and can withstand wet soils for at least 24 hours, such as wildflowers, sedges, rushes, ferns, shrubs and small trees. Root systems of the plants enhance infiltration, moisture redistribution, and diverse microbial populations involved in biofiltration.

> Bioretention is similar in most respects to a rain garden but differs in the typical size and level of engineering design criteria specified for construction.

If underlying soils are rapidly permeable with a permeability greater than the engineered soil layers (typically types A or B soils), the bioretention area can be constructed without an underdrain pipe, in which case all of the captured runoff will infiltrate into the underlying soil profile. If less permeable underlying soils (types C or D) are present or slopes are steep, an underdrain is required to prevent excessive ponding.[13]

However, a portion of the captured runoff will infiltrate into the underlying soil, the amount of which will depend on the permeability of the underlying soil.

[13] Bioretention facilities are sometimes referred to as biofiltration (bioretention facility with an underdrain or elevated underdrain) or bioinfiltration (bioretention facility with no underdrain) facilities. These types of facilities are designed for partial or full infiltration and treatment of stormwater. The terminology continues to be further refined. https://stormwater.pca.state.mn.us/index.php/Bioretention_terminology

Advantages

Image 6-2. *Bioretention Systems Source: Bioretention System.* *New Jersey Future Green Infrastructure Developers Guide. (2020, May 7). Retrieved October 6, 2021, https://developersguide.njfuture.org/bmp/bioretention-system/.*

- Low installation cost.
- Enhances site aesthetics.
- Reduces stormwater volume and pollutant discharge.
- Potential water conservation.
- It can be designed to meet trash control requirements.
- Easy maintenance
- Limitations
- Not suitable for industrial sites or sites where spills may occur unless the impermeable liner prevents infiltration.
- Requires underdrains for low permeability soils or steep slopes.
- It may require individual owners/tenants to perform maintenance.
- Not appropriate for areas with steep slopes or high groundwater.

*Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in **Table 6-3**.*

Planning and Siting Considerations

Locate bioretention areas sufficiently far from structure foundations to avoid damage to structures (as determined by a structural or geotechnical engineer).

- Locate bioretention areas sufficiently far from structure foundations to avoid damage to structures (as determined by a structural or geotechnical engineer).
- Maintain a slope of at least 1 percent from the impervious surface to the bioretention areas inlet.
- Provide for overflow discharge that drains away from building foundations to a storm drain system or more suitable infiltration area.
- Provide underdrain pipe in areas with C and D soils.
- Provide underdrain pipes and impermeable liners in areas subject to spills or pollutant hot spots.

Design Criteria

Design criteria for bioretention are listed in **Table 6-8**. A typical cross-section illustrating design features is shown in **Figure 6-2**.

Table 6-8. Bioretention Design Criteria

Design Parameter	Criteria	Notes
Maximum depth of ponding zone (D_{PZ})	12 inches	Depth above top much layer
Depth of top mulch layer	2 - 3 inches	Shredded hardwood or softwood or compost
Depth of planting media	18 - 24 inches	Mix: 60-65% loamy sand + 35-40% compost or 30% loamy sand + 30% course sand + 40 % compost
Aggregate filter blanket	9 - 12 inches	For use with subsurface drainpipe
Subsurface drainpipe	4 - 8 inch	Slotted PVC per American Society for Testing Materials (ASTM) D1785 SCH 40. (Use with C and D soils)
Depth to groundwater	>10 feet	The depth to seasonal high groundwater level should be at least 10 feet from the bottom of the structure.
Excavation side slope of (H:V)	2:1	Maximum steepness

Design Procedure (for Trash Control see below)

Step 1 – Calculate Water Quality Volume (SQDV)

Using the procedures presented in Fact Sheet T-0, determine the SQDV based on a 12-hour drawdown period and the effective contributing area after allowance for impervious area credits.

Step 2 – Design average ponding depth (D_{PZ})

Select the average SQDV depth between six (6) and twelve (12) inches. The average depth is defined as water volume divided by the water surface area of the planter.

Step 3 – Calculate planter surface area (A_S)

The design surface area of the planter is determined from the design SQDV and D_{PZ} as follows:

A_S = SQDV/ D_{PZ}

Step 4 – Design base courses

Planting media layer – Provide a mix of 60-65% loamy sand + 35-40% compost or 30% loamy sand + 30% course sand + 40 % compost. The long-term hydraulic conductivity of the mix should be ≥ 1.0 in/hr at 80 percent compaction. This layer should be a minimum of 18 inches deep, but a deeper layer is recommended to promote healthy vegetation and improve nutrient removal.

Gravel envelope (for subsurface drainpipe) – Place drainpipe on a 3- ft wide, 6-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover the top and sides of the pipe with gravel to a minimum depth of 12 inches. Do not wrap pipe or gravel envelop with filter fabric to prevent clogging.

Step 5 – Select subbase liner

If expansive soils or rocks are a concern, chemical or petroleum products are handled or stored within the tributary catchment, or infiltration is not desired for any reason, use an impermeable liner at the bottom of the bioretention facility.

Step 6 – Design subsurface drainpipe (if required)

If C or D soils are present or infiltration is not desired, provide a subsurface drainpipe with a diameter sized for the required hydraulic capacity (4-in minimum). Use a heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect the subsurface drainpipe to the downstream open conveyance (e.g., swale), another bioretention cell, a dispersion area, or to the storm drain system.

Step 7 – Select vegetation

Select vegetation that:

- Is identified on the list of approved plants – **Appendix G**;
- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has a minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Avoid the use of bark or similar buoyant material that will tend to float when the vegetated area is inundated.

Step 8 – Design overflow device

Provide an overflow device with an inlet to open conveyance or to storm drainage system. Set the overflow inlet elevation above the SQDV surcharge water level. A drop inlet or an overflow standpipe with an inverted opening is an appropriate overflow device).

Design Procedure – Trash Control

The design of bioretention facilities can be enhanced to comply with the Statewide Trash Amendments. To meet these requirements, the bioretention facility must:

1. Trap trash particles that are 5 mm or greater, and include a screen at the inlet, overflow, or bypass outlet to trap these particles from either of the following:

a. The peak flow rate generated by the region-specific one-year, one-hour storm event (0.345 inches/hour) from the applicable subdrainage area, or

b. The flow capacity of the existing corresponding storm drain design.

A screen is not required if the BMP has the capacity to treat either of these flows through media filtration or infiltration into native or amended soils;

2. Have a minimum treatment capacity for either flow rates described in 1.a. or b. above. The Rational Equation method may be used to calculate the peak flow rate for runoff from a small subdrainage area that is approximately 50 acres or less. The Rational Equation is expressed as Q = CiA, where:

   Q = design peak runoff rate, cfs,

   C = runoff coefficient, dimensionless,

   i = rainfall intensity 0.345 inches/hour, and

   A = subdrainage area, acres.

   Other calculation methods for drainage areas greater than 50 acres are allowed, provided a registered California-licensed professional engineer documents the calculations within the design plans.

3. The bioretention BMP design plans must be stamped and signed by a registered California licensed professional civil engineer (see Bus. & Prof. Code Section 6702, et seq.).

The facility must meet State-sanctioned requirements detailed in the *Certified Multi-Benefit Treatment Systems Complying With Trash Full Capture System Requirements*, authorized March 9, 2018, and any subsequent revisions. Requirements can be accessed at https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html.

Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets located within the parcel's boundaries and operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City or County has agreed to enter into a maintenance agreement with the property owner (**Appendix D**).

Volume Reduction Calculation

Bioretention may be used to achieve the VRRs in addition to treatment control requirements. The volume reduction for a bioretention area is less if a subsurface drainpipe is provided, because less infiltration will occur. The calculation procedure for volume reduction for bioretention is presented in **Table 6-9.**

Table 6-9. Bioretention Volume Reduction Calculation

Design Parameter	Criteria	Notes
Bioretention with Subsurface Drainpipe		Required for C and D soils
1. Ponding Zone **Depth of ponding zone (D_{PZ})** **Area of ponding zone (A_{PZ})**	D_{PZ} =________________ ft A_{PZ} =________________ ft^2	Infiltration allowance for water in ponding zone water = 0.25
2. Planting Media Layer **Depth of planting media layer (D_{PM})** **Area of planting media layer (A_{PM})**	D_{PM} =________________ft A_{PM} =________________ft^2	Available Water Holding Capacity of planting media layer = 0.1 x volume
3. Gravel Zone **Depth of gravel below pipe (D_{GZ})** **Area of gravel below pipe (A_{GZ})**	D_{GZ} =________________ ft A_{GZ} =________________ ft^2	Porosity of gravel zone = 0.30 Minimum depth below pipe = 6 in Minimum width of gravel = 3 ft
4. Volume Reduction for bioretention ($Vol_{reduction}$) **$Vol_{reduction}$ = (D_{PZ} x A_{PZ} x 0.25) +** **(D_{PM} x A_{PM} x 0.1) +** **(D_{GZ} x A_{GX} x 0.3)**	$V_{reduction}$ = ___________ ft^3	
Bioretention without Subsurface Drainpipe		Recommended for A and B soils
1. Ponding Zone **Depth of ponding zone (D_{PZ})** **Area of ponding zone (A_{PZ})**	D_{PZ} =________________ ft A_{PZ} =________________ ft^2	
2. Planting Media Layer **Depth of planting media layer (D_{PM})** **Area of planting media layer (A_{PM})**	D_{PM} =________________ ft A_{PM} =________________ ft^2	Minimum depth = 18 inches
3. Volume Reduction for bioretention ($Vol_{reduction}$) **$Vol_{reduction}$ = (D_{PZ} x A_{PZ}) + (D_{PM} x A_{PM} x 0.10)**	$Vol_{reduction}$= ___________ ft^3	Available Water Holding Capacity of planting media layer = 0.1 x volume

Construction Considerations

- Divert runoff (other than necessary irrigation) during vegetation establishment. Where runoff diversion is impossible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the bioretention area to prevent high sediment loads from entering the area during ongoing construction activities.
- Avoid compaction of native soils below the planting media layer or gravel zone.

- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City or County may require execution of a maintenance agreement with the property owner before final acceptance of a private development project, including treatment controls such as Bioretention. Such agreements will typically include requirements such as those outlined in **Table 6-10**. The property owner or his/her designee is responsible for compliance with the agreement. Maintenance agreements and plans with shared controls or controls located on more than one property must address shared maintenance responsibilities. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-10. Inspection and Maintenance Requirements for Bioretention Areas

Activity	Schedule
Remulch void areas	As needed
Treat diseased trees and shrubs	As needed
Water plants daily for two weeks	At project completion
Inspect soil and repair eroded areas	Monthly
Remove litter and debris	Monthly
Remove and replace dead and diseased vegetation	Twice per year
Add additional mulch	Once per year
Replace tree stakes and wire	Once per year

If used for trash control, regular maintenance is required to maintain adequate trash capture capacity and to ensure that trapped trash does not migrate offsite. The owner should establish a maintenance schedule based on site-specific factors, including the size of the bioretention BMP, storm frequency, and estimated or measured trash loading area.

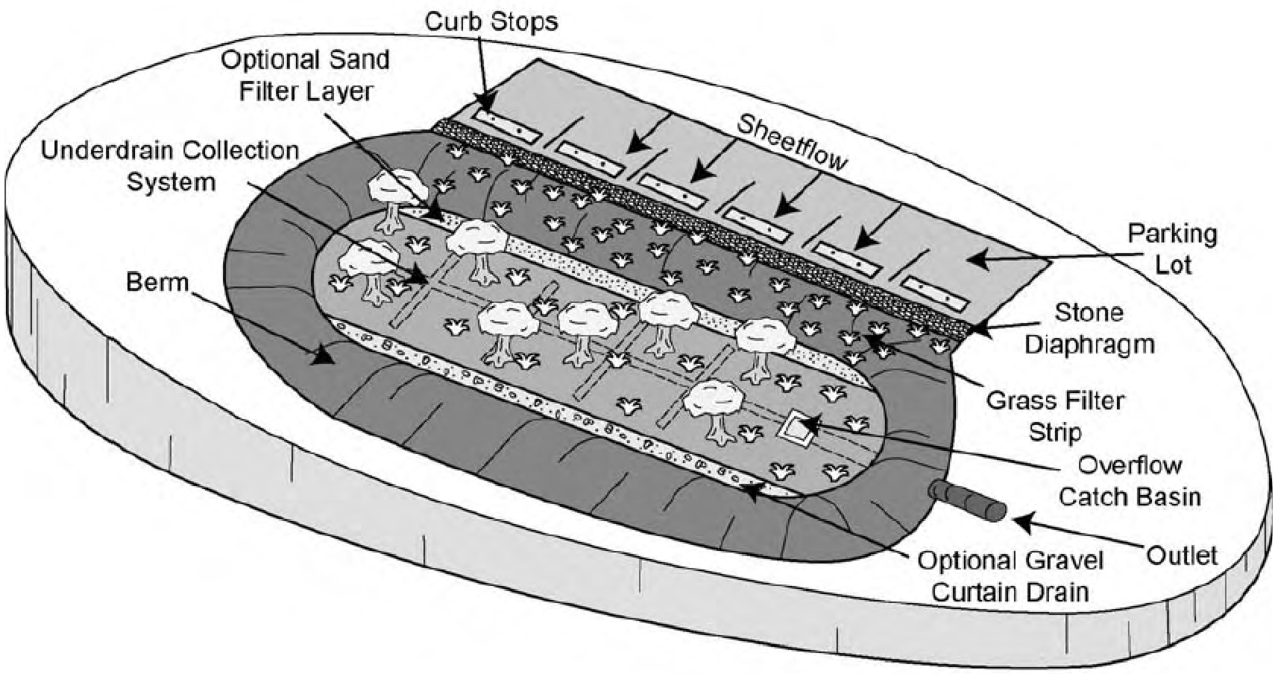


Figure 6-2a. Bioretention Schematic.

Source: Tom Schueler. (n.d.). (tech.). Urban Stormwater Retrofit Practices (3rd ed., Vol. 1, p. 184).

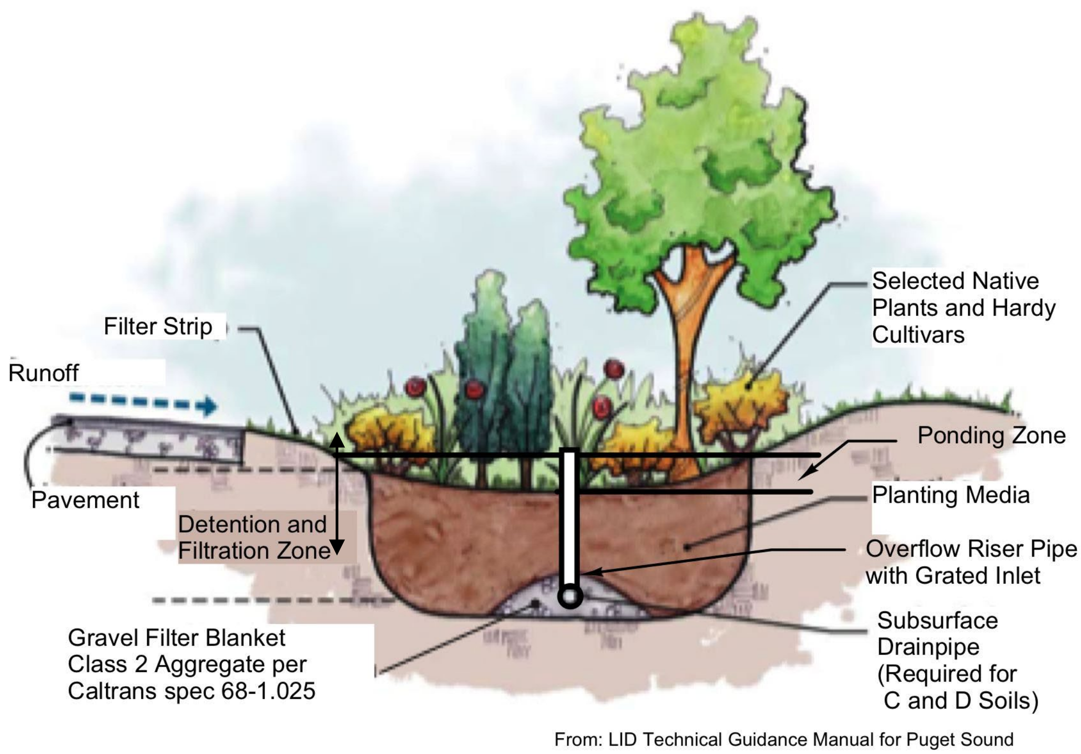


Figure 6-2b. Bioretention Schematic. *Source: Curtis Hinman. (2012). (rep.). Low Impact Development: Technical Guidance Manual for Puget Sound. Puyallup, WA.*

Image 4. Sidewalk Stormwater Planter
Source: California, S. of. (n.d.). Erosion control toolbox: Sidewalk Stormwater Planter. Erosion Control Toolbox: Sidewalk Stormwater Planter | Caltrans. Retrieved October 6, 2021, from https://dot.ca.gov/programs/design/lap-erosion-control-design/tool-1-lap-erosion-control-toolbox/tool-1kk-37-sidewalk-stormwater-planter.

Description

A Stormwater Planter is a vegetated in-ground or above-ground planter box containing an engineered soil matrix consisting of layers of topsoil, a sand/peat mixture, and gravel designed to receive and capture runoff from downspouts or piped inlets or sheet flow from adjoining paved areas. A shallow surcharge zone is provided above the vegetated surface to temporarily store the captured runoff. During rainfall events, runoff accumulates in the surcharge zone, gradually infiltrates the surface, and filters through the engineered soil matrix, filling the void spaces of the matrix before infiltrating the underlying soil or being collected by an underdrain system. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff infiltrates through the root zone of the vegetation and during the detention of the runoff in the underlying sand/peat bed. Stormwater Planters are typically planted with native, drought-tolerant vegetation that does not require fertilization and can withstand wet soils for at least 24 hours, such as wildflowers, sedges, rushes, ferns, shrubs and small trees.

If Infiltration Stormwater Planters are used, the volume of runoff can be reduced through infiltration into underlying soils. For planters underlain with expansive soils or located next to buildings where infiltration of runoff is undesirable, the Flow-through Stormwater Planter with an impermeable bottom liner should be employed. This type of planter features an impermeable bottom liner to prevent infiltration and a perforated underdrain pipe from collecting treated runoff. The underdrain gradually dewaters the sand/peat bed over the drawdown period and discharges the runoff to downstream conveyance. If infiltration of runoff is acceptable or desired, the Infiltration Stormwater Planter should be used. If underlying soils are rapidly permeable with permeability greater than the sand/peat layer (typically types A or B soils), the planter can be installed without an underdrain pipe, in which case the SQDV will infiltrate into the underlying soil profile. If less permeable underlying soils (types C or D) are present, an underdrain is required, but a portion of the infiltrated runoff will infiltrate into the underlying soil. See **Figures 6-3** and **6-4** for typical Stormwater Planter configurations.

Stormwater planters are similar in most respects to bioretention areas (see L-1) but differ in the design feature of structural side walls (typically concrete).

Other Names: Bioretention, Infiltration Planter, Flow-through Planter, Biofilter, Porous Landscape Detention, Rain Garden

Advantages

- Relatively inexpensive when integrated into site landscaping.
- Suitable for parking lots and sites with limited open areas for stormwater detention.
- Reduces peak flows during small storm events.
- Enhances site aesthetics.
- Easy maintenance.

Limitations

- Irrigation is typically required to maintain vegetation. It may conflict with water conservation ordinances or landscape requirements.
- Not appropriate for industrial sites or locations where spills may occur unless infiltration is prevented.
- Not suitable for steeply sloping areas.
- Potential increased cost associated with waterproofing of exterior building walls, if needed.

Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in **Table 6-3**.

Planning and Siting Considerations

- Select a location where site topography is relatively flat and allows runoff drainage to the Stormwater Planter.
- Integrate Stormwater Planters into other landscape areas when possible.
- Stormwater Planters may have a non-rectangular footprint to fit the site landscape design.
- In expansive soils, locate Stormwater Planters far enough from structure foundations to avoid damage to structures (as determined by a structural or geotechnical engineer), or use a Flow-through Stormwater Planter.

Design Criteria

Design criteria for Stormwater Planters are listed in **Table 6-11**.

Table 6-11. Stormwater Planter Design Criteria

Design Parameter	Criteria	Notes
Drainage area	≤ 1 acre	Ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features. Can be implemented on a larger scale.
Design volume	SQDV	See Fact Sheet T-0
Design drawdown time	12 hrs	Period of time over which SQDV drains from planter.
Design average surcharge depth (d_s)	6-12 in.	
Depth to groundwater	> 10 ft	From planter soil surface (without underdrain)
Topsoil layer	6 in. (minimum)	Sandy loam topsoil. Deeper layer recommended for better vegetation establishment. Note: planting media specified for Bioretention (L-1) may be used as an alternate for the topsoil and sand and peat layers.
Sand-peat layer	18 in. (minimum)	75% ASTM C-33 Sand + 25% peat
Gravel layer	9 in.	Class 2 Aggregate per Caltrans Spec 68-1.025

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using **Fact Sheet T-0**, determine the contributing area and SQDV based on a 12-hour drawdown period.

Step 2 – Design average ponding zone depth (D_{PZ})

Select the average SQDV depth between six (6) and twelve (12) inches. The average depth is defined as water volume divided by the water surface area of the planter.

Step 3 – Calculate planter surface area (A_S)

The design surface area of the planter is determined from the design SQDV and d_s as follows:

$A_S = SQDV/D_{PZ}$

Step 4 – Design base courses

Topsoil layer – Provide a sandy loam topsoil layer above the sand-peat mix layer. This layer should be a minimum of six (6) inches deep, but a deeper layer is recommended to promote healthy vegetation.

Sand/Peat layer – Provide an 18-inch (minimum) sand and peat layer over a 9-inch gravel layer as shown in **Figures 6-3** and **6-4**. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants. Note: The planting media mix specified for bioretention (Fact Sheet L-1) may be used as an alternative to the topsoil and sand/peat mix.

Gravel envelope (for subsurface drainpipe) – Place drainpipe on a 3- ft wide, 3-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover the top and sides of the pipe with gravel to a minimum depth of 6 inches. Place a strip of non-woven filter fabric on top of the gravel layer that extends 18 inches on either side of the drainpipe. Do not wrap the drainpipe or gravel envelope with filter fabric to prevent potential clogging.

Step 5 – Select sub base liner

If expansive soils or rocks are a concern, chemical or petroleum products are handled or stored within the tributary catchment, or infiltration is not desired for any reason, use a Flow-through Stormwater Planter with an impermeable liner (see **Figure 6-4**).

Step 6 – Design subsurface drainpipe (if required)

If C or D soils are present or impermeable liner is used, provide a subsurface drainpipe with a diameter sized for the required hydraulic capacity (4-in minimum). Use a heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect subsurface drainpipe to the downstream open conveyance (e.g. swale) or to the storm drain system.

Step 7 – Select vegetation

Select vegetation that:

- Is identified on the list of approved plants – **Appendix G**;
- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has a minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Avoid the use of bark or similar buoyant material that will tend to float when the vegetated area is inundated.

Step 8 – Design overflow device

Provide an overflow device with an inlet to storm drainage system. Set the overflow inlet elevation above the SQDV surcharge water level. A drop inlet or an overflow standpipe with an inverted or grated opening is appropriate overflow devices (see **Figures 6-3 and 6-4**).

Volume Reduction Calculation

Stormwater Planters may be used to achieve the VRRs in addition to treatment control requirements. The volume reduction for a stormwater planter is less if a subsurface drainpipe is provided, because less infiltration will occur. The calculation procedure for volume reduction for stormwater planters is presented in **Table 6-12**.

Table 6-12. Stormwater Planter Volume Reduction Calculation

Stormwater Planter with Subsurface Drainpipe		Required for C and D soils and impermeable liners
1. Ponding Zone **a. Depth of ponding zone (D_{PZ})** **b. Area of ponding zone (A_{PZ})**	D_{PZ} =________ ft A_{PZ} =________ ft^2	Infiltration allowance for water in ponding zone water = 0.25
2. Planting Media Layer **a. Depth of planting media layer (D_{PM})** **b. Area of planting media layer (A_{PM})**	D_{PM} =________ ft A_{PM} =________ ft^2	Available Water Holding Capacity of planting media layer = 0.1 x volume
3. Gravel Zone **a. Depth of gravel below pipe (D_{GZ})** **b. Area of gravel below pipe (A_{GZ})**	D_{GZ} =________ ft A_{GZ} =________ ft^2	Porosity of gravel zone = 0.30 Minimum depth below pipe = 6 in Minimum width of gravel = 3 ft
4. Volume Reduction for planters ($Vol_{reduction}$) $Vol_{reduction} = (D_{PZ} \times A_{PZ} \times 0.25) + (D_{PM} \times A_{PM} \times 0.1) + (D_{GZ} \times A_{GX} \times 0.3)$	$Vol_{reduction}$ = ________ ft^3	For planters with impermeable liners, volume reduction credit is only given for retention in the planting media layer: $Vol_{reduction} = (D_{PM} \times A_{PM} \times 0.1)$
Stormwater Planter without Subsurface Drainpipe		Recommended for A and B soils
1. Ponding Zone **a. Depth of ponding zone (D_{PZ})** **b. Area of ponding zone (A_{PZ})**	D_{PZ} =________ ft A_{PZ} =________ ft^2	Infiltration allowance for water in ponding zone water = 1.0
2. Planting Media Layer **a. Depth of planting media layer (D_{PM})** **b. Area of planting media layer (A_{PM})**	D_{PM} =________ ft A_{PM} =________ ft^2	Minimum depth = 18 inches
3. Volume Reduction for planters ($Vol_{reduction}$) $Vol_{reduction} = (D_{PZ} \times A_{PZ}) + (D_{PM} \times A_{PM} \times 0.10)$	$Vol_{reduction}$= ________ ft^3	Available Water Holding Capacity of planting media layer = 0.1 x volume

Construction Considerations

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the planter to prevent high sediment loads from entering the planter during ongoing construction activities.
- Avoid compaction of native soils below the planting media layer or gravel zone for infiltration planter.
- Repair, seed, or re-plant damaged areas immediately.
- For planters next to buildings, provide waterproofing of exterior building walls as directed by an architect or structural engineer.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner before final acceptance of a private development project, including treatment controls such as Stormwater Planters. Such agreements will typically include requirements such as those outlined in **Table 6-13**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-13. Inspection and Maintenance Requirements for Stormwater Planters

Activity	Schedule
Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation	As required
Remove litter and debris from landscape area	As required
Use integrated pest management (IPM) techniques	As required
Inspect the planter to determine if runoff is infiltrating properly	At least twice per year during storm events. Additional inspections after periods of heavy runoff are desirable.
If infiltration is significantly reduced, remove and replace topsoil and sand/peat layer	May be required every 5 to 10 years or more frequently, depending on sediment loads

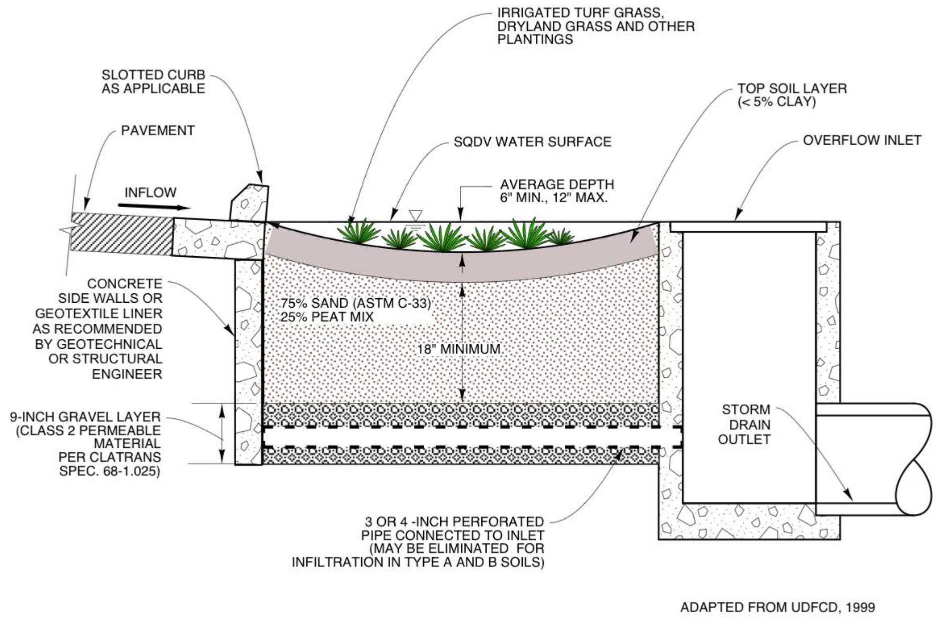


Figure 6-3. Infiltration Stormwater Planter Configuration. *Source: Urban Drainage and Flood Control District (UDFCD). (1999, rev. 2008). Drainage Criteria Manual (Vol 3). Denver, CO.*

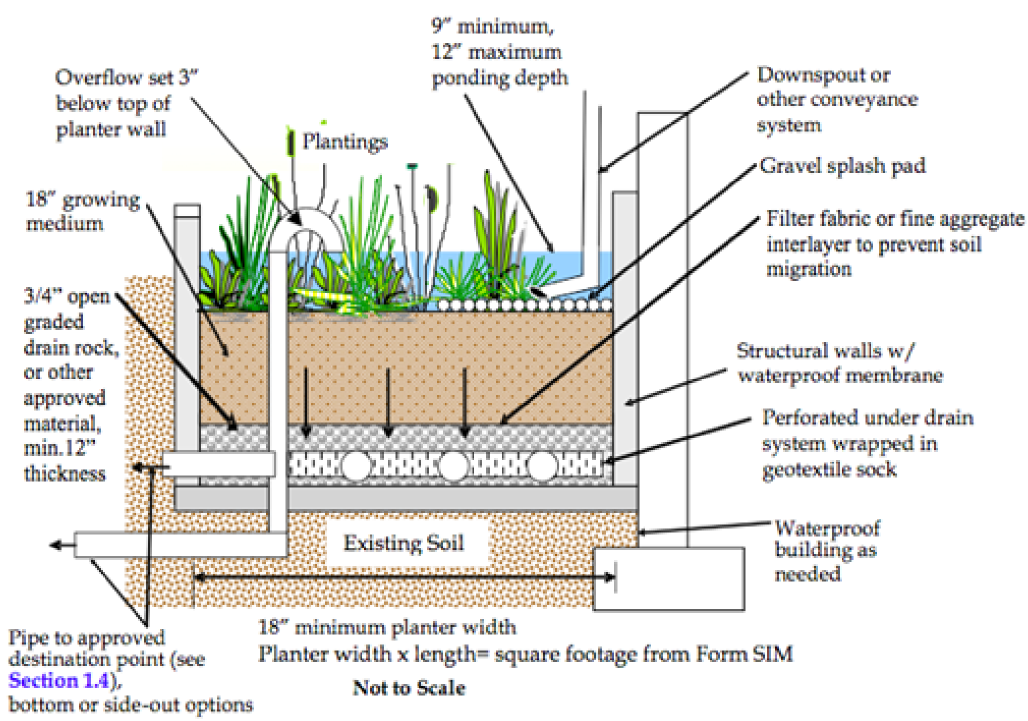


Figure 6-4. Flow-through Stormwater Planter Configuration. "Stormwater Planters." *Source: Stormwater Management Manual. [Eugene, Or.]: City of Eugene. (2008). 2-58--62. Print. http://ceppcontent.eugene1.net;7087/publishedcontent/publish/pw/stormwater/docs/ch2e.pdf*

(Top) **Image 6-4. A tree box installed with a speed bump to assist the flow of water towards the inlet.** *Source Photo: Pat Rector Rutgers, The State University of New Jersey, U.S. Department of Agriculture, and County Boards of Chosen Freeholders. Rutgers Cooperative Extension, a unit of the Rutgers New Jersey Agricultural Experiment Station, is an equal opportunity program provider and employer*

(Bottom) **Image 6-5.** *Source: MSD. (n.d.). Retrieved October 7, 2021, from https://louisvillemsd.org/comply-consent-decree.*

Description

A Tree-well Filter is similar to the Bioretention (L-1) and Stormwater Planters (L-2) and consists of one or multiple chambered pre-cast concrete boxes with a small tree or shrub planted in a bed filled with engineered soil media. A Tree-well Filter is installed along the edge of a parking lot or roadway, where street trees might normally be installed, and is designed to receive, retain, and infiltrate rainwater runoff from adjoining paved areas. During stormwater events, runoff flows into the chamber and gradually infiltrates the surface and filters through the engineered soil matrix, filling the void spaces of the matrix before infiltrating the underlying soil or being collected by an underdrain system. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff filters through the root zone of the vegetation and during the detention of the runoff in the pore space of the engineered soil matrix. A portion of the water held in the root zone of the soil media is returned to the atmosphere through transpiration by the vegetation.

A Tree-well Filter may be installed in open or closed bottom chambers. If underlying soils are rapidly permeable with a permeability greater than the engineered soil layers (typically types A or B soils), the Tree-well Filter can be constructed with an open bottom with an underdrain pipe. If less permeable underlying soils (types C or D) are present, an underdrain pipe is required. If infiltration must be avoided due to site constraints, an impermeable liner or concrete bottom should be provided as well as an underdrain pipe.

Other Names*: Stormwater Tree Pit, Tree Box Filter*

Advantages

- Enhances site aesthetics.
- Integrates well with street landscapes.
- Takes up very little space, may be ideal for highly developed sites.
- Adaptable, may be used in a variety of site conditions.
- Reduces stormwater volume and pollutant discharge.

Limitations

- May require individual owners/tenants to perform maintenance.
- Irrigation typically required to maintain vegetation. May conflict with water conservation ordinances for landscape requirements.
- Not appropriate for industrial sites or locations where spills may occur unless infiltration is prevented.

Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in ***Table 6-3****.*

Planning and Siting Considerations

- Select a location where site topography is relatively flat and allows runoff drainage to the Tree-well Filter.
- Integrate Tree-well Filters into other landscape areas when possible.
- Tree-well Filters may have a non-rectangular footprint to fit the site landscape design.
- Connect underdrain into storm drain system.

Design Criteria

Design criteria for Tree-well Filters are listed in **Table 6-14**. A Design Data Summary Sheet is provided at the end of this fact sheet.

Table 6-14. Tree-well Filter Design Criteria

Design Parameter	Criteria	Notes
Drainage area	≤ 1 acre	Ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features.
Design volume	SQDV	See Fact Sheet T-0
Design drawdown time	12 hrs	Period of time over which SQDV drains from tree well.
Design average ponding depth (d_s)	6-12 in.	
Depth to groundwater	> 10 ft	From tree-well soil surface (without underdrain)
Topsoil layer	6 in. (minimum)	Sandy loam topsoil. Deeper layer recommended for better vegetation establishment
Sand-peat layer	18 in. (minimum)	75% ASTM C-33 Sand + 25% peat. Note: planting media specified for Bioretention (L-1) may be used as an alternate for the topsoil and sand and peat layers.
Gravel layer	9 in.	Class 2 Aggregate per Caltrans Spec 68-1.025

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using **Fact Sheet T-0**, determine the contributing area and SQDV based on a 12-hour drawdown period.

Step 2 – Design average surcharge depth (d_s)

Select the average SQDV depth between six (6) and twelve (12) inches. The average depth is defined as water volume divided by the water surface area of the planter.

Step 3 – Calculate tree-well filter surface area (A_S)

The design surface area of the planter is determined from the design SQDV and d_s as follows:

$A_S = SQDV/d_s$

Step 4 – Design base courses

Sand/Peat layer – Provide a 24-inch (minimum) sand and peat layer over a 9-inch gravel layer, as shown in **Figures 6-5**. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants. Note: The planting media mix specified for bioretention (Fact Sheet L-1) may be used as an alternative to the topsoil and sand/peat mix.

Gravel envelope (for subsurface drainpipe) – Place drainpipe on a 3- ft wide, 3-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover the top and sides of the pipe with gravel to a minimum depth of 6 inches. Place a strip of non-woven filter fabric on top of the gravel layer that extends 18 inches on either side of the drainpipe. Do not wrap the drainpipe or gravel envelop with filter fabric to prevent potential clogging.

Step 5 – Select subbase liner

If expansive soils or rocks are a concern, chemical or petroleum products are handled or stored within the tributary catchment, or infiltration is not desired for any reason, use a Tree-well Filter with an impermeable liner.

Step 6 – Design subsurface drainpipe (if required)

If C or D soils are present or an impermeable liner is used, provide a subsurface drainpipe with a diameter sized for the required hydraulic capacity (4-in minimum). Use a heavy-walled, slotted PVC pipe (ASTM D1785 SCD 40) to allow pressure water cleaning and root cutting, if necessary. Connect the subsurface drainpipe to the downstream open conveyance (e.g., swale) or the storm drain system.

Step 7 – Select tree

Select a tree that:

- Is identified on the list of approved plants – **Appendix G**;
- Is suited to well-drained soil;
- Will be dense and strong enough to stay upright, even in flowing water;
- Has minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Avoid the use of bark or similar buoyant material that will tend to float when the vegetated area is inundated.

Step 8 – Design overflow device

Provide an overflow device with an inlet to storm drainage system. Set the overflow inlet elevation above the SQDV surcharge water level. A drop inlet or an overflow standpipe with an inverted or grated opening is appropriate overflow devices (see **Figure 6-5**).

Volume Reduction Calculation

Tree-well Filters may be used to achieve the VRRs in addition to treatment control requirements. The volume reduction for a tree-well filter is less if an impermeable bottom is used because less infiltration will occur. The calculation procedure for volume reduction for Tree-well Filter is presented in **Table 6-15.**

Table 6-15. Tree-well Filter Volume Reduction Calculation

Design Parameter	Criteria	Notes
Tree-well Filter with Subsurface Drainpipe		Required for C and D soils and impermeable bottoms
1. Ponding Zone **a. Depth of ponding zone (D_{PZ})** **b. Area of ponding zone (A_{PZ})**	D_{PZ} = ______________ ft A_{PZ} = ______________ ft^2	Infiltration allowance for water in ponding zone water = 0.25
2. Planting Media Layer **a. Depth of planting media layer (D_{PM})** **b. Area of planting media layer (A_{PM})**	D_{PM} = ______________ ft A_{PM} = ______________ ft^2	Available Water Holding Capacity of planting media layer = 0.1 x volume
3. Gravel Zone **a. Depth of gravel below pipe (D_{GZ})** **b. Area of gravel below pipe (A_{GZ})**	D_{GZ} = ______________ ft A_{GZ} = ______________ ft^2	Porosity of gravel zone = 0.30 Minimum depth below pipe = 6 in Minimum width of gravel = 3 ft
4. Volume Reduction for tree wells ($Vol_{reduction}$) **$Vol_{reduction}$ = (D_{PZ} x A_{PZ} x 0.25) +** **(D_{PM} x A_{PM} x 0.1) +** **(D_{GZ} x A_{GX} x 0.3)**	$Vol_{reduction}$ = ___ ft^3	For tree wells with impermeable liners, volume reduction credit is only given for retention in the planting media layer: $Vol_{reduction}$ = (D_{PM} x A_{PM} x 0.1)
Tree Well Filters without Subsurface Drainpipe		Recommended for A and B soils
1. Ponding Zone **a. Depth of ponding zone (D_{PZ})** **b. Area of ponding zone (A_{PZ})**	D_{PZ} = ___________________ ft A_{PZ} = ___________________ ft^2	Infiltration allowance for water in ponding zone water = 1.0
2. Planting Media Layer **a. Depth of planting media layer (D_{PM})** **b. Area of planting media layer (A_{PM})**	D_{PM} = ____________________ ft A_{PM} = ____________________ ft^2	Minimum depth = 18 inches
3. Volume Reduction for tree wells ($Vol_{reduction}$) **$Vol_{reduction}$ = (D_{PZ} x A_{PZ}) + (D_{PM} x A_{PM} x 0.10)**	$Vol_{reduction}$= ____________________ ft^3	Available Water Holding Capacity of planting media layer = 0.1 x volume

Construction Considerations

- Divert runoff (other than necessary irrigation) during vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the tree well to prevent high sediment loads from entering the planter during ongoing construction activities.
- Avoid compaction of native soils below the planting media layer or gravel zone.
- For projects within the City of Stockton, plant tree(s) in accordance with Standard Drawing R-77.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner before final acceptance of a private development project, including treatment controls such as Tree-well Filters. Such agreements will typically include requirements such as those outlined in **Table 6-16**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-16. Inspection and Maintenance Requirements for Tree-well Filters

Activity	Schedule
Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation	As required
Remove litter and debris from landscape area	As required
Use IPM techniques	As required
Inspect the planter to determine if runoff is infiltrating properly	At least twice per year during storm events. Additional inspections after periods of heavy runoff are desirable.
If infiltration is significantly reduced, remove and replace topsoil and sand/peat layer	May be required every 5 to 10 years or more frequently, depending on sediment loads

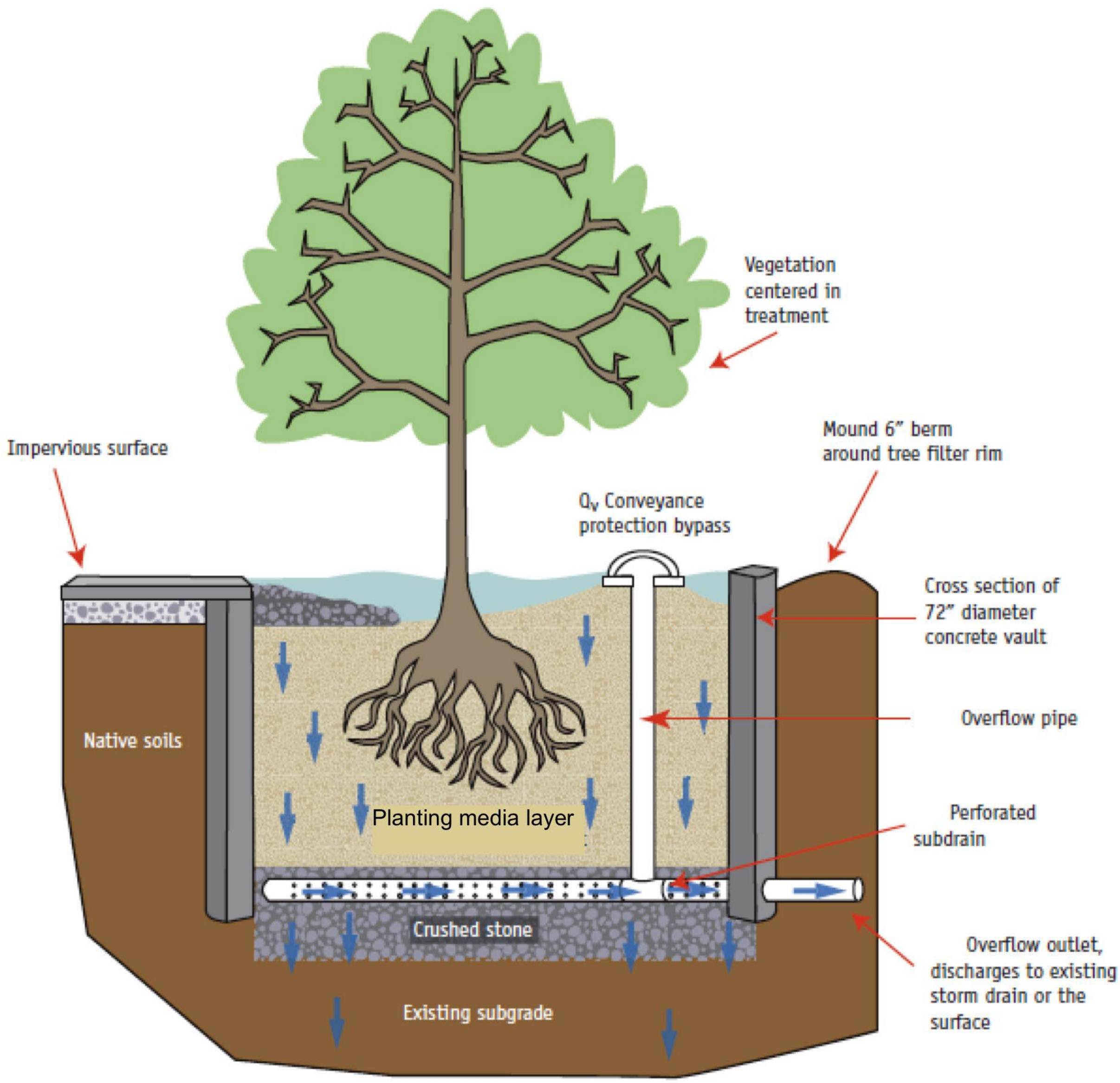


Figure 6-5. Tree-well Filter Schematic. *Source: University of New Hampshire, Stormwater Center. (2009) 2009 Biannual Report. p.22.*

Description

Image 6. *Source: Ball Field Infiltration Basin. Stormwater Discovery Tours. (2019, March 28). Retrieved October 7, 2021, from https://stormwater.cob.org/tour-squalicum-creek-park/site-ball-field-infiltration-basin/.*

Image 7. Source: Washington County, MD

An Infiltration Basin is a shallow earthen basin constructed in naturally pervious soils (type A or B) designed for infiltrating stormwater. An Infiltration Basin functions by retaining the SQDV and allowing the retained runoff to percolate into the underlying native soils and the groundwater table over a specified period. The bottoms of the basins are typically vegetated with dryland grasses or irrigated turf grass. Treatment of the runoff occurs through a variety of natural mechanisms as the water flows through the soil profile. To ensure adequate treatment, the depth of unsaturated soil between the Infiltration Basin bottom and the seasonal maximum groundwater surface level should be a minimum of 10 feet. A typical layout of an Infiltration Basin is shown in **Figure 6-6.**

Other Names*: Percolation Basin*

Advantages

- Reduces or eliminates stormwater discharge to surface waters during most storm events.
- Reduces peak flows during small storm events.
- Can be incorporated into site landscape features or multi-use facilities, such as parks or athletic fields.
- Can be designed to meet trash control requirements.

Limitations

- Not appropriate for areas with slowly permeable soils or high groundwater.
- Not appropriate for industrial sites or locations where spills may occur.
- Must be protected from high sediment loads. Once clogged with sediment, restoration of basin infiltration capacity may be difficult.
- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the basin is properly designed, constructed, and operated to maintain its infiltration capacity.
- Not appropriate on fill or steep slopes.

Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in ***Table 6-3****.*

Planning and Siting Considerations

- A qualified geotechnical engineer or geologist should determine soil permeability, and depth to groundwater and design safety factors to ensure that conditions conform to the criteria listed in **Table 6-17.**
- Integrate Infiltration Basins into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- Irrigation may be required to maintain the viability of vegetation on the slopes and bottom of the basin if vegetation is included in the design. Coordinate the design of the general landscape irrigation system with that of the basin, as applicable.
- Plan for setback requirements (see **Table 6-17**).

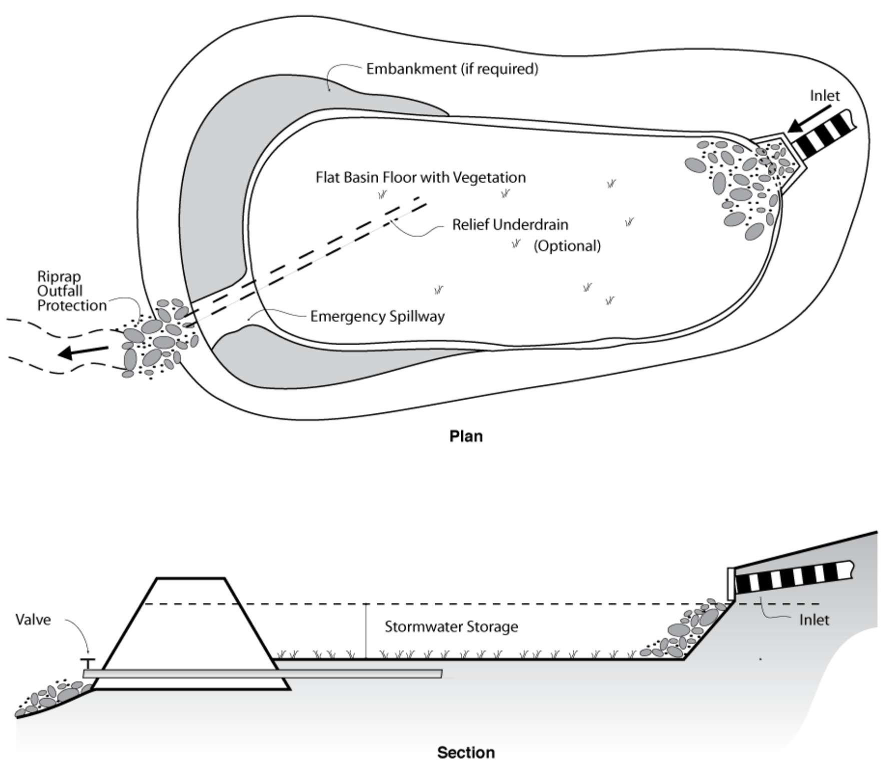


Figure. 6-6. Infiltration Basin. *Source: Henao Casas, Jose & Walther, Marc & Kalwa, Fritz & Rausch, Randolf. (2019). Numerical and Analytical Assessment of Stormwater Infiltration via Vadose Zone Wells and Infiltration Trenches. 10.13140/RG.2.2.14098.07368.*

Design Criteria and Procedure

Principal design criteria for infiltration basins are listed in **Table 6-17.**

Table 6-17. Infiltration Basin Design Criteria

Design Parameter	Unit	Design Criteria
Drawdown time for SQDV	hrs	48
SQDV	ac-ft	80% annual capture. Use **Figure 6-1** @ 48-hr drawdown
Soil permeability range	in/hr	0.6 - 2 (Saturated vertical permeability)
Bottom Basin Elevation	ft	10 ft above seasonally high groundwater table minimum.
Freeboard (minimum)	ft	1.0
Setbacks	ft ft	100 ft from wells, tanks, fields, springs 20 ft down slope or 100 ft up slope from foundations
Inlet/outlet erosion control	–	Energy dissipater to reduce inlet/outlet velocity
Embankment side slope (H:V)	–	≥ 4:1 inside/ ≥3:1 outside (without retaining walls)
Maintenance access ramp slope (H:V)	hrs	10:1 or flatter
Maintenance access ramp width	ft	16.0 – approach paved with asphalt concrete
Vegetation	–	Side slopes and bottom (may require irrigation during summer)

Design Procedure (for Trash Control see below)

Step 1- Calculate Water Quality Volume (SQDV)

Using the *Fact Sheet T-0*, determine the tributary drainage area and SQDV for 48-hour drawdown.

Step 2– Calculate design maximum depth of water surcharge in Infiltration Basin (D_{max})

$$D_{max} = \frac{t_{max} \times I}{12 \times s}$$

where

t_{max} = Maximum drawdown time = 48 hrs

I = Site infiltration rate (soil permeability) (in/hr)

s = Safety factor

In the formula for maximum allowable depth, the safety factor accounts for the possibility of inaccuracy in the infiltration rate measurement. The less certain the infiltration rate the larger the safety factor should be. Safety factors typically range between two (2) and ten (10) and should be determined by a qualified geotechnical engineer or geologist based on field measurements of saturated vertical permeability at the proposed site. Note that soils with a permeability greater than two (2) inches per hour may be used if full pretreatment is provided using one of the approved treatment controls.

Step 3- Calculate minimum surface area of Infiltration Basin bottom (A_{min})

A_{min} = SQDV/D_{max}

where

A_{min} = minimum area required (ft^2)

D_{max} = maximum allowable depth (ft)

Step 4 – Design forebay settling basin

The forebay provides a zone for the removal of course sediment by sedimentation. The volume of the forebay should be five (5) to ten (10) percent of the SQDV. The forebay should be separated from the basin by a berm or similar feature. An outlet pipe connecting the bottom of the forebay and the basin should be provided and sized to allow the forebay volume to drain within 45 minutes.

Step 5 – Design embankments

Interior slopes (H:V) should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

Step 6 – Design Maintenance Access

Provide all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be ten (10) percent and the minimum width should be ten (10) feet. Ramps should be paved with concrete colored to blend with the surroundings.

Step 7 – Design Security Fencing

Provide aesthetic security fencing around the Infiltration Basin to protect habitat except when specifically waived by the City of Stockton Municipal Utilities Department, Stormwater Division, or the San Joaquin County Department of Public Works. The fencing design shall be approved by the City or County.

Step 8 – Design Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Provide spillway or overflow structures, as applicable (see **Figure 6-6**).

Step 9 – Design Relief Drain

Provide 4-inch diameter perforated plastic relief underdrain with a valved outlet to allow removal of standing water in the event of loss of soil infiltration capacity.

Step 10 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix G**. Plant basin bottoms, berms, and side slopes with native grasses or with irrigated turf. Vegetation provides erosion protection and sediment entrapment.

Step 11 – Design irrigation system

Provide an irrigation system to maintain the viability of vegetation, if applicable.

Design Procedure – Trash Control

The design of infiltration basins can be enhanced to comply with the Statewide Trash Amendments. To meet these requirements, the infiltration basin must:

1. Trap trash particles that are 5 mm or greater, and include a screen at the BMP inlet, overflow, or bypass outlet to trap these particles from either of the following BMP designs:
   a. A flow-based design for:
      i. the peak flow rates generated by the one-year, one-hour storm event (0.345 inches/hour) from the applicable subdrainage area; or
      ii. the trash treatment capacity equal to or greater than the corresponding storm drain's design flow rate; or
   b. A volume-based design that includes a trash treatment capacity that is equal to or greater than the volume generated from a one-year, one-hour storm event (0.345 inches).

   A screen is not required if the BMP has capacity to treat either of these flows through media filtration or infiltration into native or amended soils.
2. Have a minimum treatment capacity for either of the flow rates described in 1.a. or b. above. The Rational Equation method may be used to calculate the peak flow rate for runoff from a small subdrainage area that is approximately 50 acres or less. The Rational Equation is expressed as Q = CiA, where:

   Q = design peak runoff rate, cfs,

   C = runoff coefficient, dimensionless,

   i = rainfall intensity 0.345 inches/hour, and

   A = subdrainage area, acres.

   Other calculation methods for drainage areas greater than 50 acres are allowed, provided a registered California-licensed professional engineer documents the calculations within the design plans.
3. The infiltration basin design plans must be stamped and signed by a registered California licensed professional civil engineer (see Bus. & Prof. Code Section 6702, et seq.).

The facility must meet State-sanctioned requirements detailed in the *Certified Multi-Benefit Treatment Systems Complying With Trash Full Capture System Requirements*, authorized March 9, 2018, and any subsequent revisions. Requirements can be accessed at https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html.

Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets located within the parcel's boundaries and operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City or County has agreed to enter into a maintenance agreement with the property owner (**Appendix D**).

Volume Reduction Calculation

Infiltration Basins may be used to achieve VRRs in addition to treatment control requirements. The volume reduction allowed for L-4 Infiltration Basins is equal to the SQDV for the infiltration basin calculated in Step 1 of the design procedure.

Construction Considerations

- If possible, stabilize the entire tributary area to the Infiltration Basin before construction begins. If this is not possible, divert flow around the basin to protect it from sediment loads during construction or remove the top two inches of soil from the basin floor after the entire site has been stabilized.
- Once construction is complete, stabilize the entire tributary area to the basin before allowing runoff to enter the infiltration facility.
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment.
- Construct basin using equipment with extra wide, low-pressure tires. Prevent construction traffic from entering basin to avoid compaction of the surface.
- Final grading shall produce a level basin bottom without low spots or depressions.
- After final grading, deep till the basin bottom.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City or County requires the execution of a maintenance agreement with the property owner before final acceptance of a private development project, including treatment controls such as Infiltration Basins. Such agreements will typically include requirements such as those outlined in **Table 6-18**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

For trash control, regular maintenance is required to maintain adequate trash capture capacity and to ensure that captured trash does not migrate offsite. The owner should establish a maintenance schedule based on site-specific factors, including the size of the infiltration trench BMP, storm frequency, and characterization of upstream trash and vegetation accumulation.

Table 6-18. Inspection and Maintenance Requirements for Infiltration Basins

Activity	Schedule
If erosion occurs within the basin, re-vegetate immediately and stabilize with erosion control mulch or mat until vegetation cover is established.	As required
Monitor infiltration rate in basin after storms by recording the drop in water depth versus time using a calibrated rod or staff gauge.	Several times during first year following installation. During subsequent seasons, at the beginning and end of wet season. Additional monitoring after periods of heavy runoff is desirable.
If drawdown time is observed to have increased significantly over the design drawdown time, clean, re-grade, and till basin bottom to restore infiltrative capacity. This maintenance activity is expensive and the need for it can be minimized through prevention of upstream erosion.	As required
Trim vegetation to prevent the establishment of woody vegetation and for aesthetic and vector control reasons.	At the beginning and end of the wet season
Monitor health of vegetation and replace.	As required
Remove litter and debris from Infiltration Basin area.	As required
Inspect basin to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
Remove accumulated sediment and re-grade when the accumulated sediment volume exceeds ten (10) percent of the basin volume. Note: scarification or other activities creating disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis.	As required for both forebay and basin

Image 6-7. Infiltration Trench. *Source: AWWA. (2019, February 1). Infiltration trench: Do-it-yourself conservation practices. Acton Wakefield Watersheds Alliance. Retrieved October 7, 2021, from https://awwatersheds.org/infiltration-trench-do-it-yourself-conservation-practices/.*

Description

An Infiltration Trench or Vault is a narrow trench constructed in naturally pervious soils (Type A or B soils) and filled with gravel and sand, although use of manufactured percolation tank modules may be considered in place of gravel fill. Runoff is stored in the trench until it infiltrates into the soil profile over a specified drawdown period. Overflow drains are often provided to allow drainage if the Infiltration Trench becomes clogged. Infiltration Vaults and Infiltration Leach Fields are subsurface variations of the Infiltration Trench concept in which runoff is distributed to the upper zone of the subsurface gravel bed utilizing perforated pipes.

An Infiltration Trench is designed to retain the stormwater quality volume in the trench and allow that volume to infiltrate into the native soil profile over the design drawdown period. Infiltrated water typically reaches the underlying groundwater. Treatment of the runoff occurs through various natural mechanisms as the water flows through the trench media and the soil profile. To ensure adequate treatment and protect groundwater, the depth of unsaturated soil between the trench bottom and the maximum groundwater surface level should be a minimum of 10 feet.

A typical Infiltration Trench configuration is shown in **Figure 6-7**. Configurations for the Infiltration Vault and Infiltration Leach Field variations of the Infiltration Trench are shown in **Figures 6-8** and **6-9**, respectively. Note that Infiltration Trenches are not allowed in areas under the jurisdiction of the County of San Joaquin without specific written approval from the Environmental Health Department.

Other Names: Percolation trench, dispersal trench

Advantages

- Provides effective water quality enhancement through settling and filtering while requiring relatively small space.
- Can be placed below ground.
- Suitable for use when water is not available for irrigation or base flow.
- Suited for most soil conditions. The presence of permeable soils is not a requirement.
- Reduces peak flows during small storm events.
- Can be designed to meet trash control requirements.

Limitations

- Potential for clogging of media. Upstream treatment controls to remove large sediment may be required to prevent or minimize media clogging. The cost of restorative maintenance can be high if the soil infiltration rates are significantly reduced due to sediment deposition.

- Not appropriate for areas with slowly permeable soils (C and D type) or high groundwater.
- Not appropriate for industrial sites or locations where spills may occur.

*Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in the selection of treatment controls are presented in **Table 6-3**.*

Planning and Siting Considerations

- Integrate Infiltration Trenches into open space buffers, undisturbed natural areas, and other landscape areas when possible
- Plan for setback requirements as listed in **Table 6-19**.
- Do not locate trenches under tree drip lines
- Pretreatment using grassy buffer strips is required to protect the trench from high sediment loads (see **Figure 6-7**).

Design Criteria

Design criteria for Infiltration Trenches are listed in **Table 6-19.**

Table 6-19. Infiltration Trench Design Criteria

Design Parameter	Criteria	Notes
Tributary Drainage Area	≤ 5 acres	
Design volume	SQDV	See *Fact Sheet T-0*
Maximum drawdown time for SQDV	48 hrs	Based on SQDV
Soil permeability range	0.6-2 in./hr	Saturated vertical permeability
Minimum groundwater separation	10 ft	Between trench bottom and seasonally high groundwater table
Maximum trench surcharge depth (D_{max})	10 ft	
Setbacks	100 ft 20 ft 100 ft –	From wells, tanks, fields, springs Downslope from foundations Upslope from foundations Do not locate under tree drip-lines
Trench media material size/type	1-3 in.	Washed gravel
Trench lining material	–	Geotextile fabric (see **Table 6-20**) prevents clogging
Observation well size	4-6 in.	Perforated PVC pipe with removable cap
Pretreatment grassy buffer strip length/slope	10 ft/5%	Minimum length/maximum slope in flow direction

Table 6-1. Geotextile Fabric Specifications

Property	Test Method	Unit	Specification
Material			Nonwoven geotextile fabric
Unit Weight		oz/yd3	8 (min.)
Filtration Rate		in/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	lbs.	125 (min.)
Mullen Burst Strength	ASTM D-751	psi	400 (min.)
Tensile Strength	ASTM-D-1682	lbs.	300 (min.)
Equiv. Opening Size	US Standard Sieve	No.	80 (min.)

Design Procedure (for Trash Control see below)

Step 1 – Calculate Water Quality Volume (SQDV)

Using the *Fact Sheet T-0* determine the tributary drainage area and SQDV for 48-hour drawdown.

Step 2 – Calculate minimum surface area of Infiltration Trench bottom (A_{min})

$$Area_{min} = \frac{SQDV \times s \times 12}{t_{max} \times I}$$

where

t_{max} = Maximum drawdown time = 48 hrs

I = Site infiltration rate (soil permeability) (in/hr)

s = Safety factor

In the formula for minimum surface area, the safety factor accounts for the variability in soil permeability at the site and the relative uncertainty in the infiltration rate measurements. The more variable the soil conditions and the less certain the infiltration rate, the higher the safety factor should be. Safety factors typically range between two (2) and ten (10) and should be determined by a qualified geotechnical engineer or geologist based on field measurements of saturated vertical permeability at the proposed site. Note that soils with a permeability greater than two (2) inches per hour may be used if full pretreatment is provided using one of the approved treatment controls from the 2009 SWQCCP.

Step 3 – Calculate design depth of water surcharge in Infiltration Trench (D_{max})

$$D_{max} = \frac{SQDV}{P \times Area_{min}}$$

where

P = Porosity of Infiltration Trench gravel material (use 0.30) (Note: use of manufactured percolation tank modules can provide greater porosity than gravel.)

$Area_{min}$ = minimum area required (ft^2)

Note: D_{max} should not exceed ten (10) feet. Increase A_{min} as necessary to keep $D_{max} \leq$ 10 ft

Step 4 – Design Observation Well

Provide a vertical section of perforated PVC pipe, four (4) to six (6) inches in diameter, installed flush with the top of the Infiltration Trench on a footplate and with a locking, removable cap. The observation well is needed to monitor the infiltration rate in the Infiltration Trench and is useful for marking the location of the Infiltration Trench.

Step 5 – Design Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV by means of a screened overflow pipe connected to downstream storm drainage or a grated overflow outlet.

Design Procedure – Trash Control

The design of infiltration trenches can be enhanced to comply with the Statewide Trash Amendments. To meet these requirements, the trench must:

1. Trap trash particles that are 5 mm or greater, and include a screen[14] at the BMP inlet, overflow, or bypass outlet to trap these particles from either of the following BMP designs:
    a. A flow-based design for:
        i. the peak flow rates generated by the one-year, one-hour storm event (0.345 inches/hour) from the applicable subdrainage area; or
        ii. the trash treatment capacity equal to or greater than the corresponding storm drain's design flow rate; or
    b. A volume-based design that includes a trash treatment capacity that is equal to or greater than the volume generated from a one-year, one-hour storm event (0.345 inches).

    A screen is not required if the infiltration trench has the capacity to treat either of these flows through media filtration or infiltration into native or amended soils.
2. Have a minimum treatment capacity for either of the flow rates described in 1.a. or b. above. The Rational Equation method may be used to calculate the peak flow rate for runoff from a small subdrainage area that is approximately 50 acres or less. The Rational Equation is expressed as $Q = CiA$, where:

    Q = design peak runoff rate, cfs,

    C = runoff coefficient, dimensionless,

    i = rainfall intensity 0.345 inches/hour, and

    A = subdrainage area, acres.

    Other calculation methods for drainage areas greater than 50 acres are allowed, provided a registered California-licensed professional engineer documents the calculations within the design plans.
3. The infiltration trench BMPs design plans must be stamped and signed by a registered California licensed professional civil engineer (see Bus. & Prof. Code Section 6702, et seq.).

[14] Upon approval by the Regional Water Quality Control Board Executive Officer, a 5mm screen will not be required if a) there is an external design feature or up-gradient structure designed to bypass flows exceeding the one-year, one-hour storm event (0.345 inch); or b) when the BMP's capacity exceeds flows generated by the one-year, one-hour storm event (0.345 inch).

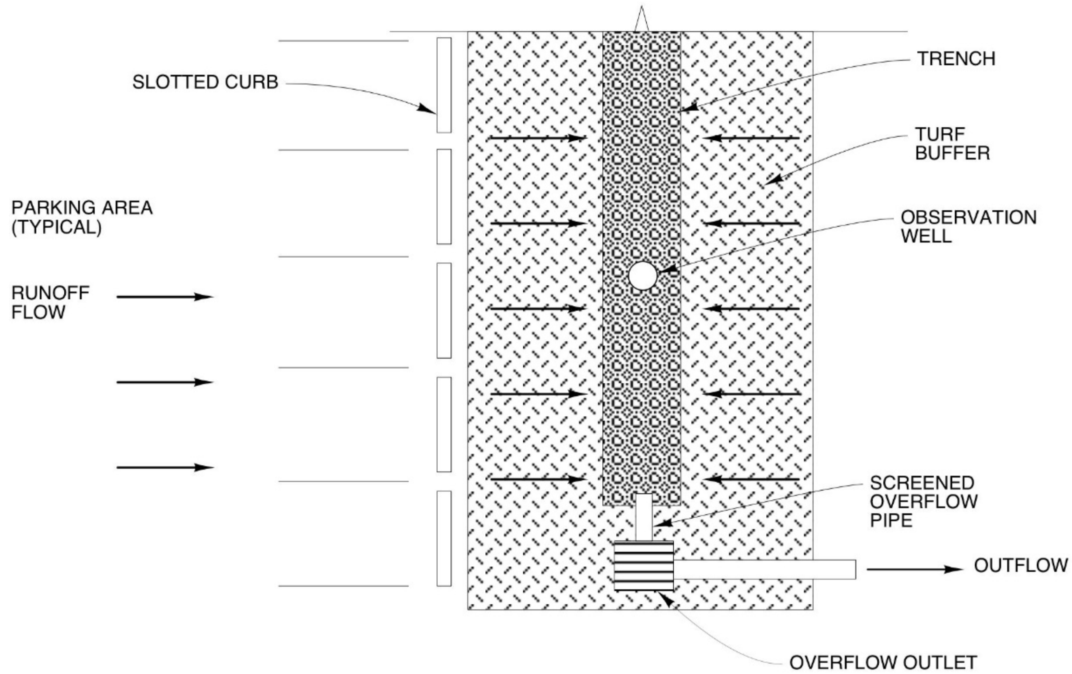
The facility must meet State-sanctioned requirements detailed in the *Certified Multi-Benefit Treatment Systems Complying With Trash Full Capture System Requirements*, authorized March 9, 2018, and any subsequent revisions. Requirements can be accessed at https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html.

Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects.

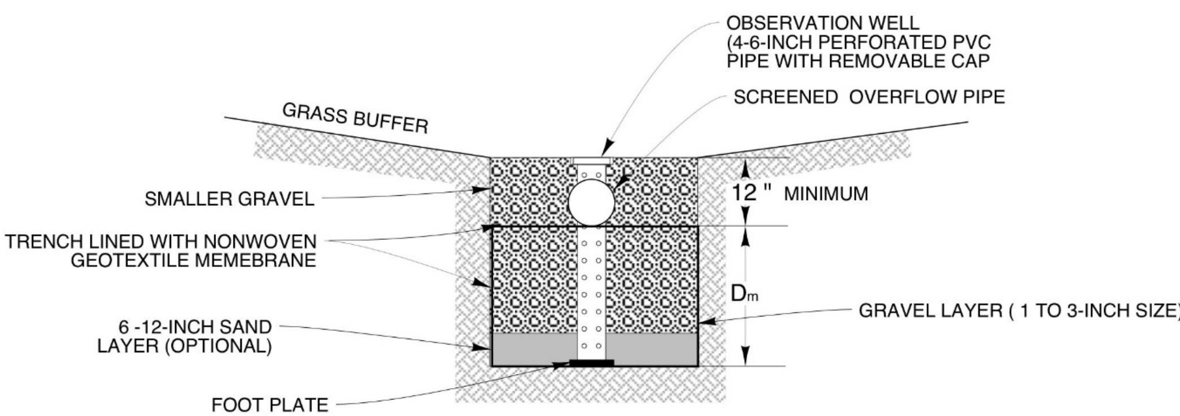
Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets that are located within the boundaries of the parcel and that are operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City or County has agreed to enter into a maintenance agreement with the property owner (**Appendix D**).

Volume Reduction

Infiltration Trenches may be used to achieve the VRR in addition to treatment control requirements. The volume reduction allowed for L-5 Infiltration Trench is equal to the SQDV for the infiltration trench calculated in Step 1 of the design procedure.



PLAN VIEW



SECTION VIEW

Figure 6-7. Infiltration Trench. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November)*

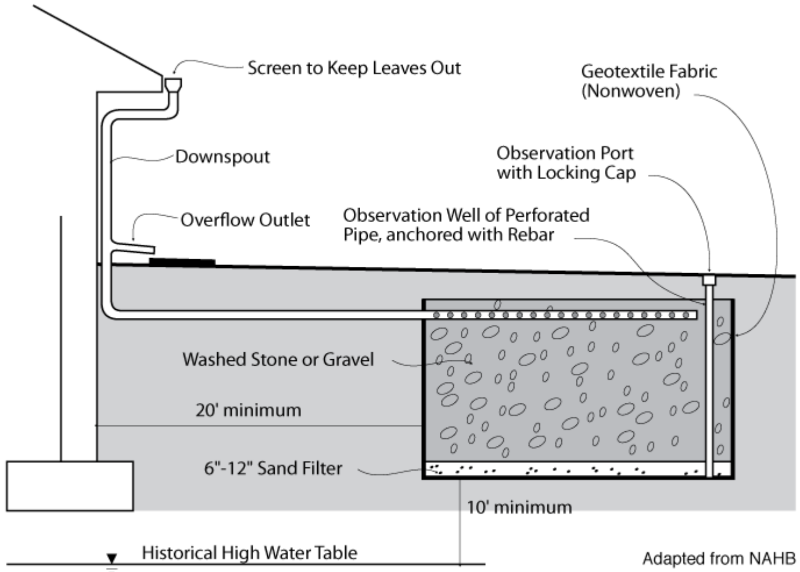


Figure 6-8. Infiltration Vault. *Adapted from NAHB*

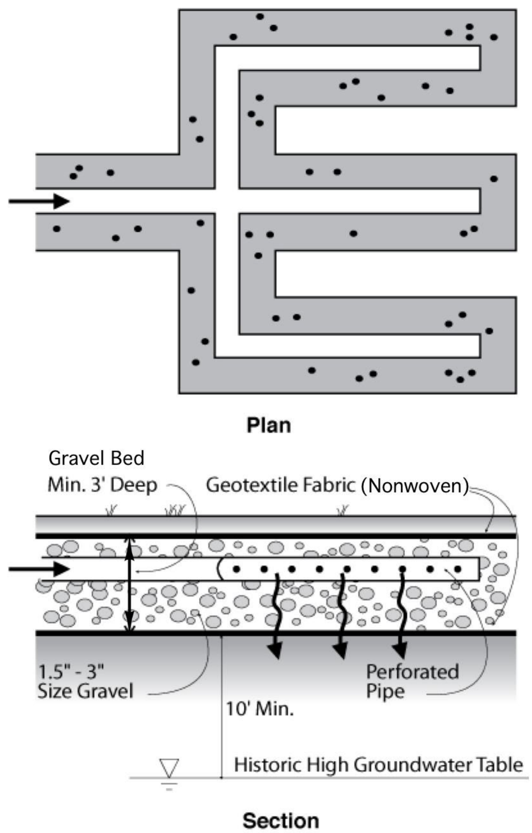


Figure 6-9. Leach Field. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Construction Considerations

- If possible, stabilize the entire tributary area to the Infiltration Trench before construction begins. If this is not possible, divert flow around the trench site to protect it from sediment loads during construction.
- Once construction is complete, stabilize the entire tributary area to the trench before allowing runoff to enter the trench facility.
- Install filter fabric on the sides, bottom, and one foot below the surface of the trench (see Figure 6-7). Provide generous overlap at all seams.
- Store excavated material at least 10 feet from the trench to avoid backsliding and cave-ins.
- Clean, washed gravel should be placed in the excavated trench in lifts and lightly compacted with a plate compactor. The use of unwashed gravel can result in clogging.

Long-term Maintenance

The City or County requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Infiltration Trenches. Such agreements will typically include requirements such as those outlined in **Table 6-21**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

For trash controls, regular maintenance is required to maintain adequate trash capture capacity and to ensure that captured trash does not migrate offsite. The owner should establish a maintenance schedule based on site-specific factors, including the size of the infiltration trench BMP, storm frequency, and characterization of upstream trash and vegetation accumulation.

Table 6-21. Inspection and Maintenance Requirements for Infiltration Trenches

Activity	Schedule
If erosion is occurring within the tributary area, re-vegetate immediately and stabilize with erosion control mulch or mat until vegetation cover is established	As required
Monitor the infiltration rate in trench during and after storms by recording the drop in water depth versus time using a calibrated rod or staff gauge.	Several times during first year following installation. During subsequent seasons, near the beginning and end of wet season. Additional monitoring after periods of heavy runoff is desirable.
Clean trench when loss of infiltrative capacity is observed. If infiltration rate is observed to have decreased significantly over the design rate, removal of sediment from the trench and replacement of the upper layer of filter fabric may be necessary. Clogging is most likely to occur near the top foot of the trench, between the upper gravel layer and the protective layer of filter fabric. Cleaning can be accomplished by removing the top layer of gravel and clogged filter fabric, installing a new layer of filter fabric, and replacing the gravel layer with washed gravel. This maintenance activity is expensive, and the need for it can be minimized through prevention of upstream erosion.	As required
Remove pioneer trees that sprout in the vicinity of the trench to prevent root puncture of filter fabric that could allow sediment to enter the trench	As required
Trim adjacent trees to prevent drip lines from extending over surface of trench	As required
Remove litter and debris from trench area	As required
Inspect trench to identify potential problems such as standing water, trash and debris, and sediment accumulation	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
Maintain grassy buffer strip in accordance with requirements listed in the Vegetated Filter Strip Fact Sheet	As required

Image 6-8. Pervious Pavers. *Source: Bay, A. for the C. (n.d.). Reduce your stormwater. Pervious Pavers. Retrieved October 7, 2021, from https://www.stormwater.allianceforthebay.org/take-action/installations/pervious-pavers.*

Image 6-9. Porous Asphalt. *Source: Cornell University Urban Horticulture Institute. (2007). Using Porous Asphalt and CU-Structural Soil®. Retrieved October 7, 2021, from http://www.hort.cornell.edu/uhi/outreach/pdfs/cu_porous_asphalt.pdf.*

Description

Porous Pavement Filter (PPF) consists of an installation of permeable interlocking concrete pavers, pervious concrete, or porous asphalt pavement that is flat in all directions and is provided with a surcharge zone to temporarily store the runoff draining from an adjacent area. Stormwater runoff infiltrates into the porous pavement and the sublayers of sand and gravel and slowly exits through an underdrain.

Permeable interlocking concrete pavement is comprised of a layer of durable concrete pavers or blocks separated by joints filled with small stones. Pervious concrete is made from carefully controlled amounts of water and cementitious materials used to create a paste that forms a thick coating around aggregate particles. Unlike conventional concrete, the mixture contains little or no sand, creating a substantial void content between 15% and 25%. Porous asphalt, or "open-graded" asphalt, pavement contains no fine aggregate particles, thereby creating void spaces in the pavement, which allows water to collect within and drain through the pavement. An alternative approach is to use stabilized grassy porous pavement consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel. A typical cross-section of a PPF system is shown in **Figure 6-10**.

Advantages

- Reduces runoff volume and peak flow during small storm events.
- It can serve functional and aesthetic purposes.

Limitations

- The cost of restorative maintenance can be somewhat high when the system seals with sediment and can no longer function properly as permeable pavement.
- Uneven driving surfaces and potential traps for high-heeled shoes are potential limitations.

*Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in **Table 6-3**.*

Planning and Siting Considerations

- It should only be installed on relatively flat surfaces.
- It may be used in low vehicle-movement zones. Potential applications include the following:
    - Low vehicle movement airport zones;
    - Parking aprons and maintenance roads;
    - Crossover/emergency stopping/parking lanes on divided highways;
    - Residential street parking lanes;
    - Residential driveways;
    - Maintenance roads and trails; and
    - Emergency vehicle and fire access lanes in apartment/multi-family/complex situations.
- Vehicle movement lanes that lead up to the porous pavement parking pads should be solid asphalt or concrete pavement.
- Grass can be used in the block voids, but it may require irrigation and lawn care.
- In cases when the subsoils are not free draining, an impermeable liner should be provided to contain the water in the gravel pack and to mitigate concerns about expansive soils.
- It should be located far enough from foundations in expansive soils so as to limit damage to potential structures.
- When a commercial or industrial site may be handling chemicals and petroleum products that may spill to the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

Design Criteria

The design Criteria for the PPF are summarized in **Table 6-22**.

Table 6-22. PPF Design Criteria

Design Parameter	Criteria	Notes
Drawdown time for SQDV	12 h	Minimum
SQDV	80% annual capture	Use Figure 6-1 12-hr drawdown
Surcharge storage volume above pavement	SQDV	
Depth of surcharge zone	2 in	Maximum depth above pavement
Imperviousness	<60%	Variable with pavement type
Permeable Paver Infill	ASTM No. 8 crushed aggregate	
Base courses	1-inch ASTM No. 8 over 9-inch ASTM No. 57	

Design Procedure

Step 1 – Determine Stormwater Quality Design Volume (SQDV)

Using the *Fact Sheet T-0*, determine the tributary drainage area and SQDV for a 12-hour drawdown.

Step 2 – Determine Filter Ponding Zone Storage Volume

The ponding zone storage volume above the pavement is equal to 100 percent of the SQDV.

$V_{PZ} = 1.0 \times SQDV$

Step 3 – Determine Filter Surface Area

Calculate the minimum required surface area based on a surcharge depth of 2 inches above the pavement as follows:

Surface Area = SQDV (ft^3)/0.17 (ft)

Step 4 – Select Pavement Type

For permeable pavers, select appropriate modular blocks that have no less than 40 percent of the surface area open. The manufacturer's installation requirements shall be followed with the exception that porous pavement infill material requirements and base course dimensions are adhered to.

Step 5 – Porous Pavement Infill

The Modular Block Pavement openings should be filled with ASTM No. 8 crushed stone.

Step 6 – Provide Base Courses

Provide 1-inch ASTM No. 8 crushed stone over 9-inch ASTM No. 57 aggregate base courses as shown in **Figure 6-10.**

Step 7 – Provide Perimeter Wall

Provide a concrete perimeter wall to confine the edges of the PPF area. The wall should be, at the minimum, 6 inches wide and at least 6 inches deeper than all the porous media and modular block depth combined.

Step 8 – Install Subbase

If expansive soils or rocks are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base course. Otherwise, install a non-woven geotextile membrane to encourage filtration.

Step 9 – Provide Overflow

Provide an overflow, possibly with an inlet to a storm sewer, set at a maximum of 2 inches above the level of the porous pavement surface. Make sure the 2-inch ponding depth is contained and does not flow out of the area at ends or sides.

Volume Reduction Calculation

PPF may be used to achieve the VRR in addition to treatment control requirements. The volume reduction for a PPF is less if a subsurface drainpipe is provided, because less infiltration will occur. If the PPF is constructed with an impermeable liner, no volume reduction credit is given. The calculation procedure for volume reduction for PPF is presented in **Table 6-23**.

Table 6-23. PPF Volume Reduction Calculation

Design Parameter	Criteria	Notes
PPF with Subsurface Drainpipe		Required for C and D soils
1. Volume Reduction for PPF ($Vol_{reduction}$) **$Vol_{reduction}$ = (SQDV x 0.25)**	$Vol_{reduction}$ =_____ ft^3	Infiltration allowance for water in ponding zone = 0.25 No volume reduction credit is given for PPFs with impermeable liners
PPF without Subsurface Drainpipe		Use with A and B soils only
1. Volume Reduction for PPF ($Vol_{reduction}$) **$Vol_{reduction}$ = (SQDV x 1.0)**	$Vol_{reduction}$ = _____ ft^3	Infiltration allowance for water in ponding zone water = 1.0

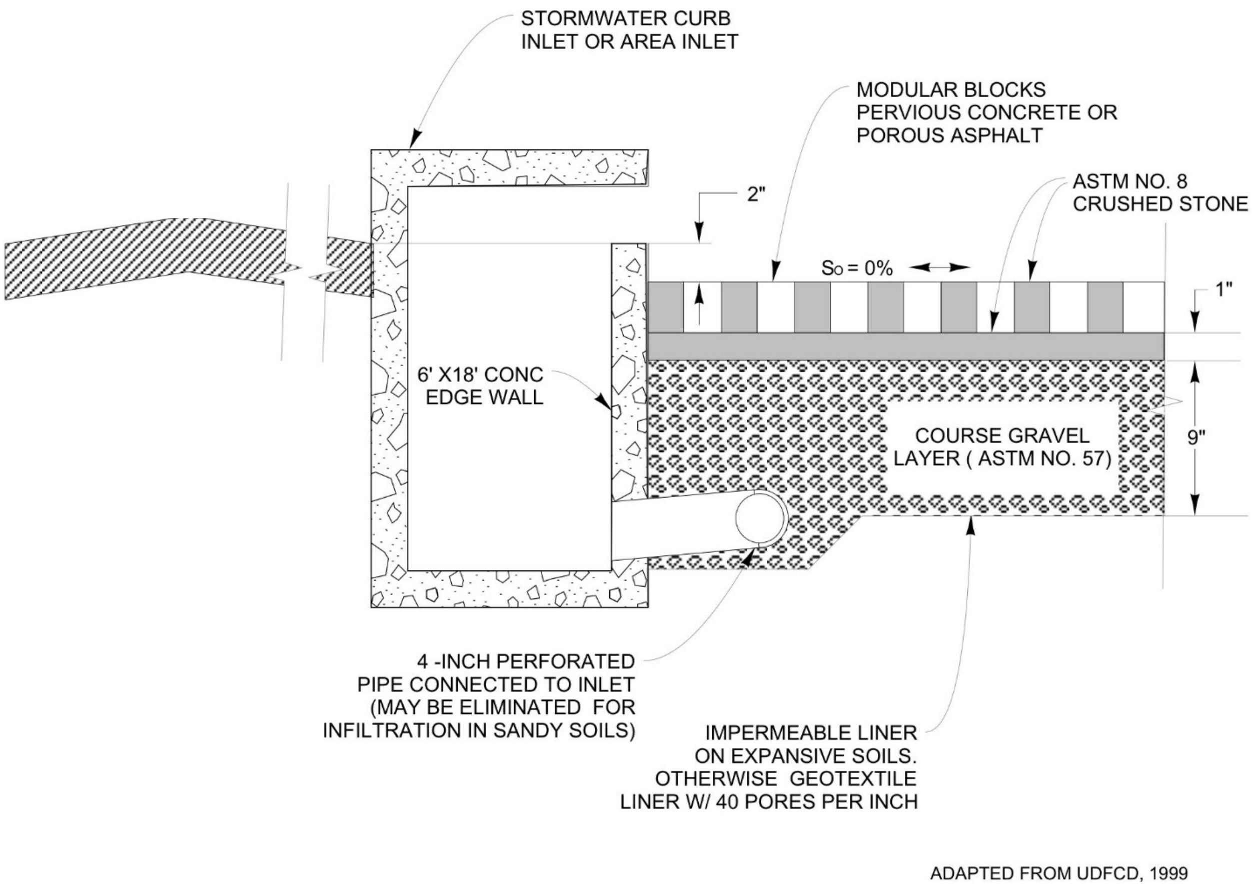


Figure 6-10. Porous Pavement Filter. *Source: Infiltration Stormwater Planter Configuration. Urban Drainage and Flood Control District (UDFCD). (1999, rev. 2008). Drainage Criteria Manual (Vol 3). Denver, CO***.**

Construction Considerations

- Before the entire site is graded, the area planned for the PPF should be roped off to prevent heavy equipment from compacting the underlying soils.
- Both prior to and during construction, diversions should be installed around the perimeter of the PPF as needed to prevent runoff and sediment from entering the site until the PPF is in place.

Maintenance Requirements

The City or County requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as PPFs. Such agreements will typically include requirements such as those outlined in **Table 6-24**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D.** See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-24. Inspection and Maintenance Requirements for PPF

Activity	Schedule
Inspect pavements to determine if runoff is infiltrating properly. If infiltration is significantly reduced, remove surface aggregate by vacuuming. Dispose of and replace old aggregate with fresh aggregate.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.
If stabilized grassy porous pavement is used, trim vegetation and remove weeds to limit unwanted vegetation.	As required.
Remove litter and debris from the pavement area.	As required.

Image 6-10. ***Vegetated Swale, Maria Cahill.*** *Water-quality swales: Low-impact development fact sheet. (2018, June 1). OSU Extension Catalog,Oregon State University. Retrieved October 7, 2021, from https://catalog.extension.oregonstate.edu/em9209/html.*

Description

Vegetated Swales are long, narrow, landscaped depressions used to collect and convey stormwater runoff. Pollutants are removed via settling and filtration as the water flows over the surface of the swale or infiltrates into the ground. Check dams are provided every 12 to 20 feet to slow flow and pool water to enhance treatment and infiltration. Vegetated Swales reduce the volume of runoff from a site through infiltration into underlying soils. The Vegetated Street Swale variation can be employed in a street setting. This type of swale is constructed between a standard sidewalk and a standard street curb with curb-cut spillways and features an underdrain system. See **Figures 6-11** and **6-12** for typical Vegetated Swale configurations.

> Do not confuse a Vegetated Swale with a Grassy Swale (L-8) or Bioretention (L-1). A Grassy Swale has steeper side slopes and treats runoff via grass filtration. Bioretention areas are level vegetated cells that feature only vertical flow of runoff into the soil medium.

Advantages

- Relatively inexpensive when integrated into site landscaping.
- Suitable for parking lots and sites with the limited open area available for stormwater detention.
- Reduces peak flows during small storm events.
- Enhances site aesthetics.
- Easy to maintain.

Limitations

- Irrigation is typically required to maintain vegetation. It may conflict with water conservation ordinances for landscape requirements.
- Not appropriate for industrial sites or locations where spills may occur unless infiltration is prevented.
- Not suitable for steeply sloping areas.

Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in ***Table 6-3****.*

Planning and Siting Considerations

- Can receive runoff from parking lots, rooftops, and streets.
- Integrate Vegetated Swales into the overall site design.
- Connection to the storm drain system or another treatment control must be provided at the end of the swale and possibly at points along the swale to allow the discharge of high flows and runoff that does not infiltrate.
- Slopes and depth should be kept as mild as possible to avoid safety risks and prevent erosion within the Vegetated Swale.
- When Vegetated Street Swales are used, all applicable requirements for other street elements (e.g., curbs, sidewalks, trees) must be met.

Design Criteria

Design criteria for Vegetated Swales are listed in **Table 6-25**. Note that the sizing of the Vegetated Swale is volume-based.

Table 6-25. Vegetated Swale and Vegetated Street Swale Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	Based on 12-hour drawdown. See Fact Sheet T-0 for calculation of SQDV.
Side slopes	3:1	H:V, Maximum
Flat bottom width	2 ft 4 ft	Minimum Minimum (Street Swale)
Top width	5 ft 7 ft	Minimum Minimum (Street Swale)
Longitudinal slope	6%	Maximum
Setbacks	5 ft 10 ft	From centerline of swale to property lines From building foundations (unless lined with impermeable fabric or approved by City or County
Check Dams **Length** **Width** **Height** **Spacing interval**	12 in. Width of swale 3 to 6 in. 12 to 20 ft	Use 12 ft for Street Swale
Water storage depth above bottom	6 in. 12 in.	Minimum Maximum
Distance from tire stops or curb cut	6 in.	Minimum
Curb cut clear flow area	12 in. x 12 in	Curbs for street swales should be designed for stability by a structural or geotechnical engineer
Topsoil layer	12 in.	Minimum
Permeable filter fabric	–	Optional for Vegetated Swale below top soil layer. Required for Street Swale below topsoil and gravel layers.
Overflow device	–	Required
Underdrain layer		Required for Street Swales and C and D soils
Bottom Slope	10:1	Slope to drain away from street (minimum)
Gravel layer depth	12 in.	Use 3/4” diameter drain rock
Permeable filter fabric	–	Use under gravel layer
Impermeable fabric	–	Use along street edge side of swale

Design Parameter	Criteria	Notes
Perforated PVC pipe diameter	6 in.	
Vegetation	No./100 ft2	Trees, shrubs, grasses, and groundcover. Quantity based on surface area of swale facility. See Design Procedure for minimum quantities.

Design Procedure

Step 1 – Calculate Stormwater Quality Design Volume (SDQV)

Using **Fact Sheet T-0**, determine the SQDV based on a 12-hour drawdown time, the contributing area, and the imperviousness of the contributing area.

Step 2 – Determine Swale Geometry

Based on criteria in **Table 6-25** and site conditions, determine appropiate values for the following swale geometry design elements:

- Bottom width
- Side slope
- Ponding zone storage depth (D_{PZ})
- Top width
- Longitudinal slope

Step 3 – Determine Cross-Sectional Area of Swale Storage

$$A_{storage} = D_{PZ} \times \frac{W_{bottom} + W_{top}}{2}$$

Step 4 – Determine Swale Length

$$L_{swale} = \frac{SQDV}{A_{storage}}$$

Step 5 – Design Inlet Controls

For flow introduced along the length of the swale through curb cuts, provide minimum curb cut widths of 12 inches. For swales that receive direct concentrated runoff at the upstream end, provide an energy dissipater, as appropriate, and a flow spreader such as a pea gravel diaphragm flow spreader at the upstream end of the swale. (See **Figure 6-14** in L-9: Grassy Filter Strip for a schematic of pea gravel flow spreader.)

Step 6 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix G**. Choose vegetation to cover the surface area of the swale, including the bottom and side slopes. Turf grass may be used to cover the entire swale surface area. At least 50 percent of the swale surface shall be planted with grasses or grass-like plants. If plantings are chosen to landscape the swale, the minimum plant material quantities per 100 square feet of swale area should be as follows:

Vegetation Type	Number	Containers	Notes
Large shrubs or small trees	4	3-gallon containers	Or equivalent
Shrubs or large grass-like plants	6	1-gallon containers	Or equivalent
Ground cover plants	1 per foot	4-inch pot (minimum)	On the center, triangular spacing, for the ground cover planting area only, unless seed or sod is specified

Wildflowers, native grasses, and ground covers used for Vegetated Swales should be designed to not require mowing. Where mowing is necessary, Vegetated Swales should be designed to require only annual mowing.

Step 7 – Design irrigation system

Provide an irrigation system to maintain the viability of Vegetated Swale landscaping.

Volume Reduction

Vegetated Swales may be used to achieve the VRR in addition to treatment control requirements. The volume reduction for Vegetated Swale is less if a subsurface drainpipe is provided because less infiltration will occur. The calculation procedure for volume reduction for a Vegetated Swale is presented in **Table 6-26.**

Table 6-26. Vegetated Swale Volume Reduction Calculation

Design Parameter	Criteria	Notes
Vegetated Swale with Subsurface Drainpipe		Required for C and D soils and Street Swale
1. Ponding Zone **a. Depth of ponding zone (D_{PZ})** **b. Surface Area of ponding zone (A_{PZ})**	D_{PZ} = ____________ ft A_{PZ} = ____________ ft^2	Infiltration allowance for water in ponding zone water = 0.25
2. Planting Media Layer **a. Depth of planting media layer (D_{PM})** **b. Area of planting media layer (A_{PM})**	D_{PM} = ____________ ft A_{PM} = ____________ ft^2	Available Water Holding Capacity of planting media layer = 0.1 x volume
3. Gravel Zone below drainpipe **a. Depth of gravel below pipe (D_{GZ})** **b. Area of gravel below pipe (A_{GZ})**	D_{GZ} = ____________ ft A_{GZ} = ____________ ft^2	Porosity of gravel zone = 0.30 Minimum depth below pipe = 6 in Minimum width of gravel = 3 ft
4. Volume Reduction for Swale ($Vol_{reduction}$) **$Vol_{reduction} = (D_{PZ} \times A_{PZ} \times 0.25) + (D_{PM} \times A_{PM} \times 0.1) + (D_{GZ} \times A_{GX} \times 0.3)$**	$Vol_{reduction}$ = ____________ ft^3	
Vegetated Swale without Subsurface Drainpipe		Recommended for A and B soils
1. Ponding Zone **a. Depth of ponding zone (D_{PZ})** **b. Area of ponding zone (A_{PZ})**	D_{PZ} = ____________ ft A_{PZ} = ____________ ft^2	Infiltration allowance for water in ponding zone water = 1.0
2. Planting Media Layer **a. Depth of planting media layer (D_{PM})** **b. Area of planting media layer (A_{PM})**	D_{PM} = ____________ ft A_{PM} = ____________ ft^2	Minimum depth = 18 inches
3. Volume Reduction ($Vol_{reduction}$) **$Vol_{reduction} = (D_{PZ} \times A_{PZ}) + (D_{PM} \times A_{PM} \times 0.10)$**	$Vol_{reduction}$= ____________ ft^3	Available Water Holding Capacity of planting media layer = 0.1 x volume

Construction Considerations

- Areas to be used for Vegetated Swales should be clearly marked before site work begins to avoid soil disturbance and compaction during construction.
- No vehicular traffic, except specifically used to construct the Vegetated Swale, should be allowed within 10 feet of swale areas.
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the planter to prevent high sediment loads from entering the planter during ongoing construction activities.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City or County requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Vegetated Swales. Such agreements will typically include requirements such as those outlined in **Table 6-27**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-27. Inspection and Maintenance Requirements for Vegetated Swales

Activity	Schedule
Trim vegetation and remove weeds (as applicable) to limit unwanted vegetation	As required
Remove litter and debris from the landscape area	As required
Use IPM techniques	As required
Inspect the swale to determine if runoff is infiltrating properly	At least twice per year during storm events. Additional inspections after periods of heavy runoff are desirable.
If infiltration is significantly reduced, remove and replace topsoil and (for Vegetated Street Swale) drain rocks	May be required every 5 to 10 years or more frequently, depending on sediment loads

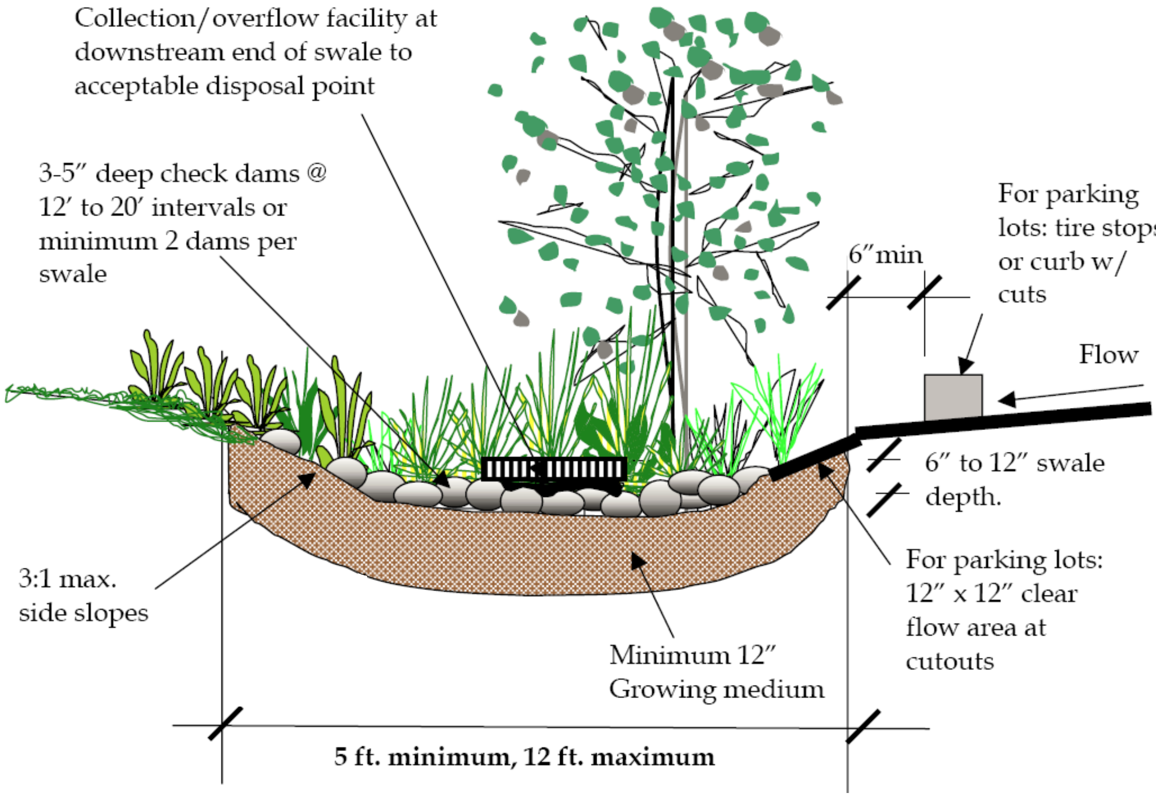


Figure 6-11. Vegetated Swale. *Source: Vegetated Swale Specifications. City of Sandy, Oregon. (2021, September 23). Retrieved October 7, 2021, from https://www.ci.sandy.or.us/publicworks/page/vegetated-swale-specifications.*

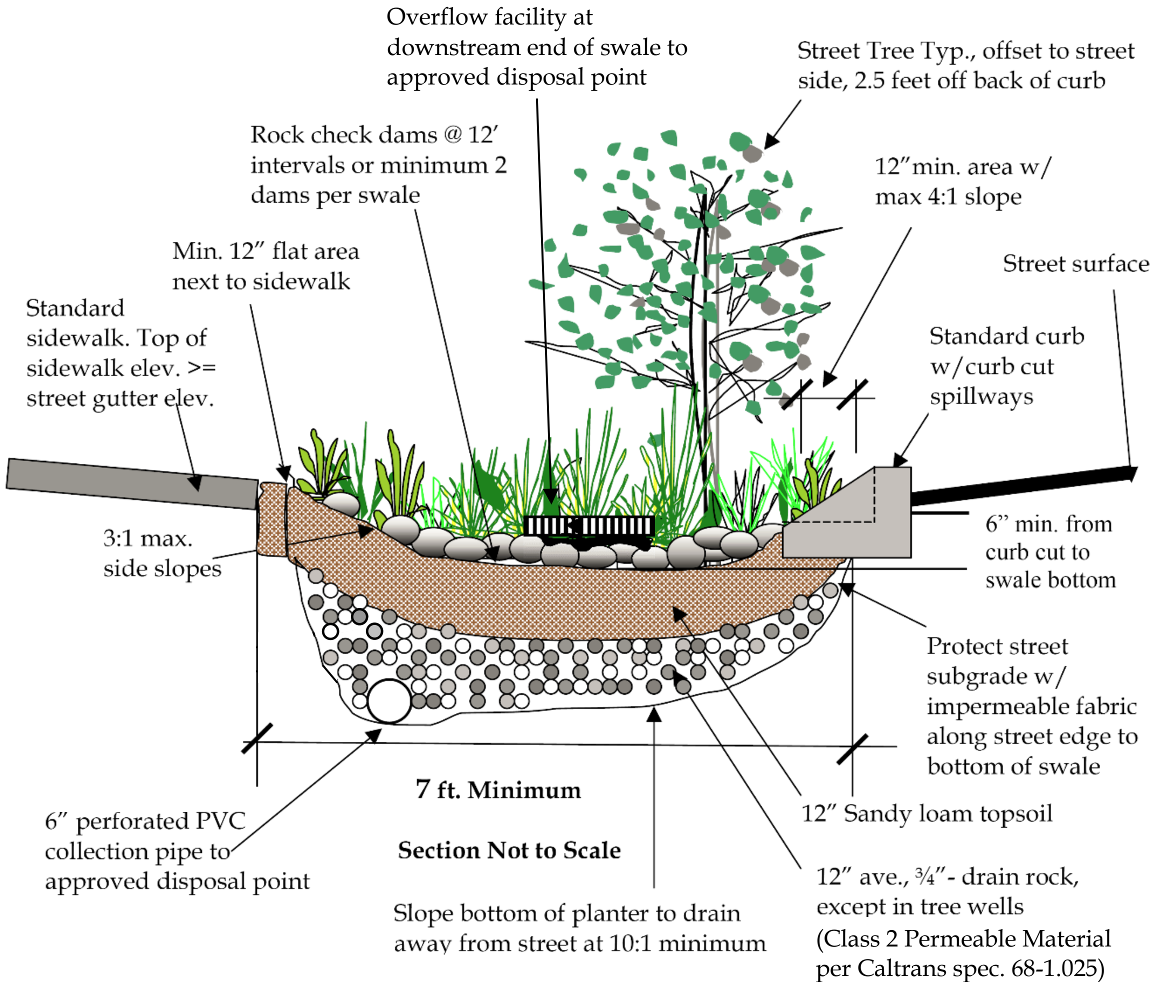


Figure 6-12. ***Vegetated Street Swale with Underdrain.*** *Source: Vegetated Swale Specifications. City of Sandy, Oregon. (2021, September 23). Retrieved October 7, 2021, from https://www.ci.sandy.or.us/publicworks/page/vegetated-swale-specifications.*

Description

Image 6-11. Grassy Swale. *Source: Ekka, S., & Hunt, B. (n.d.). Swale terminology for urban stormwater treatment: NC state extension publications. Swale Terminology for Urban Stormwater Treatment, NC State Extension Publications. Retrieved October 7, 2021, from https://content.ces.ncsu.edu/swale-terminology-for-urban-stormwater-treatment.*

A Grassy Swale is a shallow, open channel planted with dense, sod-forming vegetation and designed to accept runoff from adjacent surfaces. As the runoff slows and travels through the vegetation and over the soil surface, pollutants are removed by a variety of physical and chemical mechanisms, including sedimentation, filtration, adsorption, precipitation, and microbial degradation and conversion.

A Grassy Swale differs from a conventional drainage channel or roadside ditch due to the incorporation of specific features that enhance stormwater pollutant removal effectiveness. A Grassy Swale is designed to control flow velocities and depth through the vegetation in the swale and to provide sufficient contact time to promote settling and filtration of the runoff flowing through it. Greater surface area and contact time promote greater runoff treatment efficiencies. The volume of runoff can also be reduced through infiltration into underlying soils. See **Figure 6-13** for a typical Grassy Swale configuration.

Other Names: Vegetated Swale, Bioswale

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping.
- Provides both stormwater treatment and conveyance.
- Reduces peak flow rates during small storm events.
- Easy maintenance.

> Do not confuse a Grassy Swale with a *Grassy Filter Strip* (L-9), Vegetated Swale (L-7) or Grassy Channel (V-5), which is used as primarily as volume reduction practice. The latter provides only limited pollutant removal because of higher application rates, and it requires downstream treatment controls.

Limitations

- May conflict with water conservation ordinances for landscape irrigation requirements.
- May not be appropriate for industrial sites or locations where spills may occur unless liner is provided to prevent infiltration.

Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in ***Table 6-3****.*

Planning and Siting Considerations

- Select a location where site topography allows for the design of a channel with a sufficiently mild slope (unless small drop structures are used) and enough surface area to maintain non-erosive velocities in the channel.
- Integrate swales into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the swale and cars are allowed to overhang the swale.
- The required swale length to meet treatment criteria for a 1-acre project site is typically in the range of 75 to 100 feet. The length will vary depending on several variables, including the geometry of the swale and the runoff coefficient for the site.
- Liners may be required in areas where swales may be impacted by hazardous materials or where spills may occur (e.g., retail gasoline outlets, auto maintenance businesses, and processing/manufacturing areas).
- Surface flow into the swale is preferred over underground conveyance.
- Irrigation is typically required to maintain the viability of the swale vegetation. Coordinate the design of the general landscape irrigation system with that of the Grassy Filter Strip, as applicable.
- Vector Considerations: The potential for mosquitoes due to standing water will be greatly reduced or eliminated if the Swale is properly designed, constructed, and operated.

Design Criteria

The design criteria for the Grassy Swale are listed in **Table 6-28**.

Table 6-28. Grassy Swale Design Criteria

Design Parameter	Criteria	Notes
Tributary drainage area	≤ 10 acres	For larger areas, break up into sub-watersheds of 10 acres or less, with a swale for each sub-watershed.
Design flow	SQDF	See *Fact Sheet T-0*
Roughness coefficient (n) for treatment design	0.2	Reflects the roughness associated with shallow flow through dense vegetation.
Roughness coefficient (n) for conveyance design	0.1	Reflects the roughness of swale when depth of flow is above the height of the grass. Used to determine capacity of swale to convey peak hydraulic flows
Minimum contact time for treatment of the SQDF	7 minutes	Provide sufficient length to yield minimum contact time for the WQF
Minimum bottom width	0.5 ft	
Maximum bottom width	10 ft	Swales wider than 10 feet can be divided by internal berms to conform to maximum width criteria.
Maximum side slopes	3:1	Side slopes to allow for ease of mowing. Steeper slopes may be allowed with adequate slope stabilization.
Longitudinal slope	1-4%	
Check dams	As required	For longitudinal slope > 4% and as a means of promoting more infiltration. Space dams as required to maintain maximum longitudinal bottom slope ≤ 4%.
Underdrains	As required	For longitudinal slope < 1%
Maximum depth of flow at SQDF	3-5 in.	1 inch below top of vegetation
Maximum flow velocity (treatment)	1 ft/sec	Based on Manning's n = 0.20. Concentrated inlet flow must be spread
Inlet Design/Curb cuts	≥ 12 in. wide	To prevent clogging and promote flow spreading. Pavement should be slightly higher than swale. Include energy dissipaters.

Design Procedure

Step 1 – Determine the Grassy Swale's Function

The Grassy Swale can be designed to function as both a treatment control for the SQDF and as a conveyance system to pass the peak hydraulic design flows if the swale is located "online".

Step 2 – Calculate Stormwater Quality Design Flow (SQDF)

Using the *Fact Sheet T-0*, determine the contributing area and SQDF.

Step 3 – Provide for peak hydraulic design flows

*Using the Standard Calculations for Diversion Structure Design (**Appendix H**)*, calculate flows greater than SQDF to be diverted around or flow through the swale. Design the diversion structure, if needed.

Step 4 – Design the Grassy Swale Using Manning's Equation

Swales can be trapezoidal (as illustrated in **Figure 6-13**) or parabolic in shape. While trapezoidal channels are the most efficient channel for conveying flows, parabolic configurations provide good water quality treatment and may be easier to mow since they don't have sharp breaks in slope.

a. Use a roughness coefficient (n) of 0.20 with Manning's Equation to design the treatment area of a swale to account for the flow through the vegetation. To determine the capacity of the swale to convey peak hydraulic flows, use a roughness coefficient (n) of 0.10 with Manning's Equation.

Manning's Equation

$$Q = \frac{1.49}{n}\frac{A^{5/3}}{P^{2/3}} \times s^{1/2}$$

where

Q = SQDF

A = Cross-sectional area of flow

P = Wetted perimeter of flow

s = Bottom slope in flow direction

n = Manning's n (roughness coefficient)

For treatment design of a trapezoidal swale, solve Manning's equation by trial and error to determine a bottom width that yields a flow depth of 3 to 5 inches at the design SQDF and the swale geometry (i.e., side slope and s value) for the site under design. The minimum design bottom width is 0.5 ft.

b. Determine length necessary to provide the desired contact time (7 minutes minimum) for treatment of the SQDF.

$L = (t_c) \times (\text{flow velocity}) \times 60$

where

L = Length of swale, ft

t_c = Contact time, 7 minutes minimum

Step 5 – Design Inlet Controls

For flow introduced along the length of the swale through curb cuts, provide minimum curb cut widths of 12 inches and avoid short-circuiting the swale by providing a minimum contact time of 7 minutes.

For swales that receive direct concentrated runoff at the upstream end, provide an energy dissipater, as appropriate, and a flow spreader such as a pea gravel diaphragm flow spreader at the upstream end of the swale. (See **Figure 6-14** in L-9: Grassy Filter Strip for a schematic of pea gravel flow spreader.)

Step 6 – Select Vegetation

A full, dense cover of sod-forming vegetation is necessary for the Grassy Swale to provide adequate treatment.

Select vegetation that:

- Will be dense and strong enough to stay upright, even in flowing water;
- Has a minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

See **Appendix G** for recommended grasses for Grassy Swales. Do not use bark or similar buoyant material in the swale or around drain inlets or outlets.

Step 7 – Design irrigation system

Provide an irrigation system to maintain viability of Grassy Swale vegetation.

Volume Reduction

Grassy Swales may be used to achieve the VRR in addition to treatment control requirements. The calculation procedure for volume reduction for Grassy Swales is presented in **Table 6-29**.

Table 6-29. Grassy Swale Volume Reduction Calculation

Design Parameter	Criteria	Notes
1. SQDV for contributing area	SQDV = _______________ ft^3	See Fact Sheet T-0
2. Volume reduction factor for Grassy Swale (V_{soils})	V_{soils} = ____________________	V_{soils} for A and B soils = 0.50 V_{soils} for C and D soils = 0.25
3. Volume Reduction for Grassy Swale ($Vol_{reduction}$) **$Vol_{reduction}$ = (SQDV x V_{soils})**	$Vol_{reduction}$ = ___________________ ft^3	

Construction Considerations

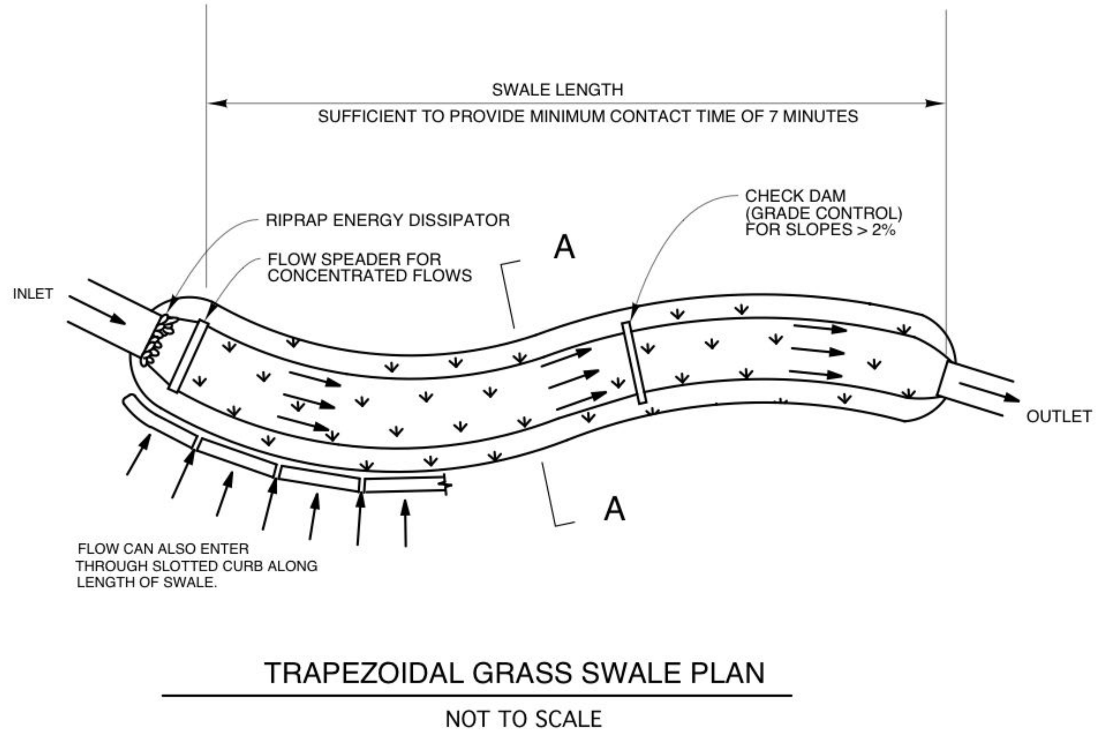
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the swale to prevent high sediment loads from entering the swale during ongoing upstream construction activities.
- Repair, seed, or re-plant damaged areas immediately.
- Apply erosion control measures as needed to stabilize side slopes and inlet areas.

Long-Term Maintenance

The City and the County require execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Grassy Swales. Such agreements will typically include requirements such as those outlined in **Table 6-30.** The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. A sample maintenance agreement is presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-30. Inspection and Maintenance Requirements for Grassy Swales

Activity	Schedule
Mow grass to maintain a height of 4 to 6 inches or above depth of flow at SQDF	As required
Remove grass clippings	As required
Use IPM techniques	As required
Remove trash and debris from the swale	As required
Inspect swale at for signs of erosion, vegetation damage/coverage, channelization problems, debris build-up, and excessive sedimentation in bottom of channel. Correct problems or remove debris and sediment as soon as possible.	At least twice annually. Schedule one inspection at the end of the wet season so that summer maintenance can be scheduled to prepare swale for wet season. Additional inspections after periods of heavy runoff are desirable.
Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the swale is retarded or blocked	As required
Repair ruts or holes in the channel by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.	As required
Inspect swale for obstructions (e.g., debris accumulation, invasive vegetation) and pools of standing water that can provide mosquito-breeding habitat. Correct observed problems as soon as possible.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.



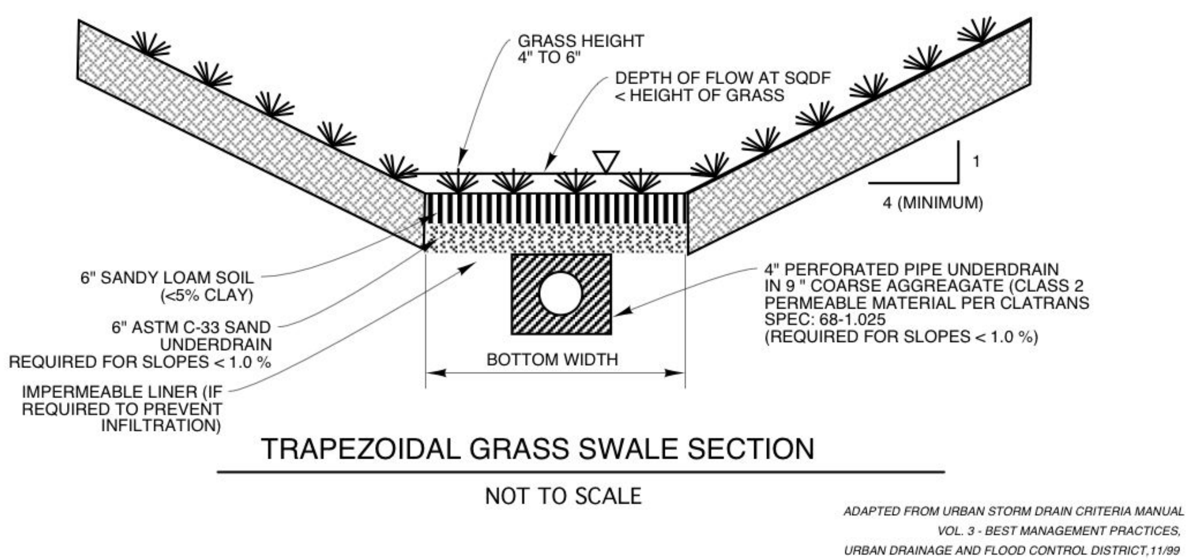


Figure 6-13. Grassy Swale. Source: Adapted from Urban Storm Drain Criteria Manual Vol. 3 – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).

Image 6-12. *Source: Filter strips/grassed riparian buffers (NRCS 393 & 390). AgBMPs. (n.d.). Retrieved October 7, 2021, from https://agbmps.osu.edu/bmp/filter-stripsgrassed-riparian-buffers-nrcs-393-390.*

Description

A Grassy Filter Strip is a gently sloped soil surface planted with dense, sod-forming vegetation and designed to receive and treat sheet flow runoff from adjacent surfaces. As the runoff flows through the vegetation and over the soil surface at a shallow depth, pollutants are removed by a variety of physical, chemical, and biological mechanisms, including sedimentation, filtration, adsorption, precipitation, and microbial degradation and conversion.

Greater surface area and contact time promote greater runoff treatment efficiencies. The volume of runoff can be reduced through infiltration into underlying soils. See **Figure 6-14** for a typical Grassy Filter Strip configuration.

Other Names: *Vegetated Filter Strips, Biofilter*

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping.
- Reduces peak flows during small storm events.
- Easy to maintain.

Limitations

- Possible conflicts with water conservation ordinances for landscape irrigation requirements.
- Not appropriate for industrial sites or locations where spills may occur.

> A Grassy Filter Strip should not be confused with a *Grassy Swale* (L-8) or Vegetated Buffer Strip (V-6), which is used as volume reduction practice. The latter provides only limited pollutant removal because of higher application rates, and, consequently, requires downstream treatment controls.

Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in ***Table 6-3****.*

Planning and Siting Considerations

- Select a location where site topography allows for the design of filter strips with proper slopes in the flow direction.
- Integrate Grassy Filter Strips into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the filter strip and cars are allowed to overhang the filter strip.
- Irrigation is typically required to maintain the viability of the filter strip vegetation. Coordinate the design of the general landscape irrigation system with that of the Grassy Filter Strip, as applicable.
- Vector Considerations: The potential for mosquitoes due to standing water will be greatly reduced or eliminated if the strip is properly designed, constructed, and operated.

Design Criteria

Design criteria for Grassy Filter Strips are listed in **Table 6-31**.

Table 6-31. Grassy Filter Strip Design Criteria

Design Parameter	Criteria	Notes
Drainage area	≤ 5 acres	For larger areas, break up into sub-watersheds of 5 acres or less with a filter strip for each.
Design flow	SQDF	See *Fact Sheet T-0*
Maximum linear application rate (q_a)	0.005 cfs/ft of width	Rate at which runoff is applied across the top width of filter strip. This rate, combined with the design flow, will define the design width of filter strip.
Minimum slope in flow direction	1%	Gentler slopes are prone to ponding of water on surface
Maximum slope in flow direction	4%	Steeper slopes are prone to channeling. Terracing may be used for slopes > 4%.
Minimum length in flow direction	20 ft	Most treatment occurs in the first 20 feet of flow. Longer lengths will typically provide somewhat higher levels of treatment
Vegetation height (typical)	2 – 4 in.	Vegetation should be maintained at a height greater than the depth of flow at design flow rate but sufficiently low to prevent lodging or shading of the vegetation.

Design Procedure

Step 1 – Calculate Water Quality Flow (SQDF)

Using Fact Sheet T-0, determine the contributing area and SQDF.

Step 2 – Calculate minimum width of Grassy Filter Strip (W_{GFS})

The design minimum width of the Grassy Filter Strip (W_{GFS}) normal to flow direction is determined from the design WQF and the minimum application rate (q_a), as follows:

W_{GFS} = (SQDF)/(q_a)

W_{GFS} = (SQDF)/0.005 cfs/ft (minimum)

Step 3 – Determine the minimum length of Grassy Filter Strip in the flow direction

The length of the filter strip in the flow direction must be a minimum of 20 feet. Greater lengths are desirable, as somewhat better treatment performance can typically be expected.

Step 4 – Determine design slope

The slope of the filter strip surface in the direction of flow should be between one (1) and four (4) percent to avoid ponding and channeling of flow. Terracing may be used to maintain a slope of four (4) percent in steeper terrain.

Step 5 – Design inlet flow distribution

Incorporate a device such as slotted curbing, modular block porous pavement, or other spreader devices at the upstream end of the filter strip to distribute flow evenly along the top width. Concentrated flow delivered to the filter strip must be distributed evenly by means of a level spreader as shown in **Figure 6-14.**

Step 6 – Select vegetation

A full, dense cover of sod-forming vegetation is necessary for the filter strip to provide adequate treatment.

Select vegetation that:

- Will be dense and strong enough to stay upright, even in flowing water;
- Has a minimum need for fertilizers;
- Is not prone to pests and is consistent with IPM practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

See **Appendix G** for recommended grasses for Grassy Filter Strips. Do not use bark or similar buoyant material in the filter strip or around drain inlets or outlets.

Step 7 – Design outlet flow collection

Provide a means for outflow collection and conveyance (e.g., grassy channel/swale, storm drain, gutter).

Step 8 – Design irrigation system

Provide an irrigation system to maintain the viability of filter strip grass.

Volume Reduction Calculation

Grassy Filter Strip may be used to achieve the VRR in addition to treatment control requirements. The calculation procedure for volume reduction for Grassy Filter Strip is presented in **Table 6-32**.

Table 6-32. Grassy Filter Strip Volume Reduction Calculation

Design Parameter	Criteria	Notes
1. SQDV for contributing area	SQDV = ____________________ ft^3	See Fact Sheet T-0
2. Volume reduction factor for Grassy Filter Strip (VRF)	VRF = ____________	VRF for A and B soils = 0.95 – 0.18 = 0.77 VRF for C and D soils = 0.95 – 0.25 = 0.70
3. Volume Reduction for Grassy Filter Strip ($Vol_{reduction}$) **$Vol_{reduction}$ = (SQDV x VRF)**	$V_{reduction}$= ________________________ ft^3	

Construction Considerations

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the filter strip to prevent high sediment loads from entering the filter strip during ongoing upstream construction activities.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City and the County may require execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Grassy Filter Strips. Such agreements will typically include requirements such as those outlined in **Table 6-33**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-33. Inspection and Maintenance Requirements for Grassy Filter Strips

Activity	Schedule
Mow grass to maintain a height of 2 to 4 inches (typical).	As required
Remove grass clippings.	As required
Use IPM techniques.	As required
Remove trash and debris from the filter strip.	As required
Inspect filter strip for signs of erosion, vegetation damage/coverage, channel formation problems, debris build-up, and excessive sedimentation on the surface of the strip. Correct problems or remove debris and sediment as soon as possible.	At least twice annually. Schedule one inspection at the end of the wet season so that summer maintenance can be scheduled to prepare filter strip for wet season. Additional inspections after periods of heavy runoff are desirable.
Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the filter strip is retarded or blocked.	As required
Repair ruts or holes in the strip by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.	As required
Inspect filter strip for obstructions (e.g., debris accumulation, invasive vegetation) and pools of standing water that can provide mosquito-breeding habitat. Correct observed problems as soon as possible.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.

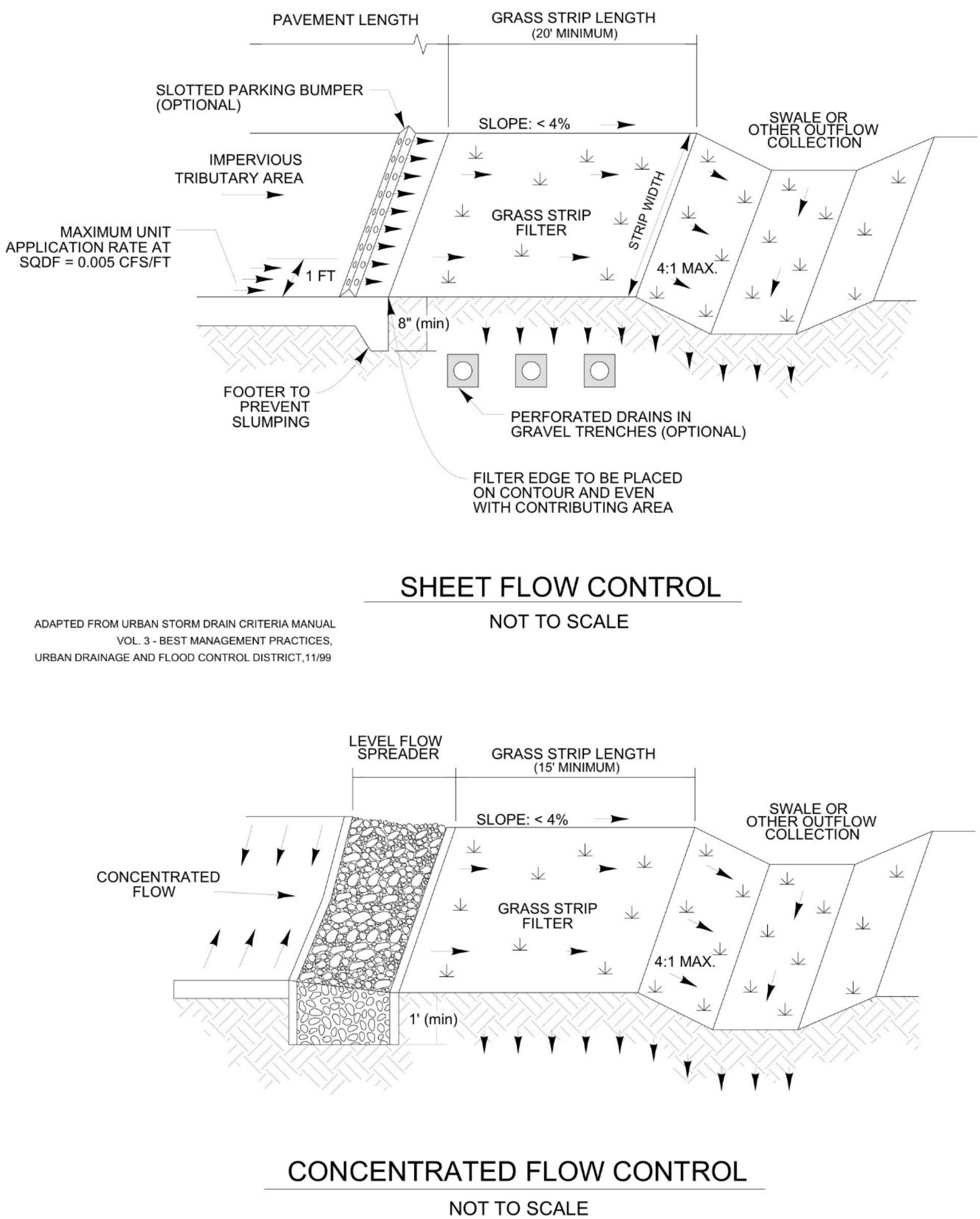


Figure 6-14. Grassy Filter Strip. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Description

Image 6-13. Constructed Wetland. *Source: Constructed wetlands (NRCS 656). AgBMPs.(n.d.). Retrieved October 7, 2021, from https://agbmps.osu.edu/bmp/constructed-wetlands-nrcs-656.*

A Constructed Wetland is a single-stage treatment system consisting of a forebay and a permanent pool with aquatic plants. Constructed wetlands function similarly to Wet Ponds in that influent runoff flow water mixes with and displace a permanent pool as it enters the basin. The surcharge volume above the permanent pool is slowly released over a specified period (24 hours for SQDV). Constructed Wetlands require a longer release period for the surcharge volume than Wet Ponds because the depth and volume of the permanent pool for Constructed Wetlands are less than for Wet Ponds. A base flow is required to maintain the permanent water pool. Constructed Wetlands also differ from Wet Ponds in terms of the extensive presence of aquatic plants. Plants provide energy dissipation and enhance pollutant removal by sedimentation and biological uptake. A conceptual layout of a Constructed Wetland is shown in **Figure 6-15.**

Constructed Wetlands differ from natural wetlands in that they are man-made and are designed to enhance stormwater quality. Diversion of stormwater directly to natural wetlands is not recommended because natural wetlands need to be protected from adverse effects of development. This is especially important because natural wetlands provide stormwater and flood control on a regional scale. Natural wetlands can be incorporated into the constructed wetlands system, but such action requires the approval of federal and state regulators. Constructed wetlands are generally not allowed to be used to mitigate the loss of natural wetlands.

Advantages

- Constructed wetlands can provide substantial wildlife habitat and passive recreation.
- Due to the presence of the permanent wet pool, constructed wetlands can provide significant water quality improvement for many constituents, including dissolved nutrients.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to stormwater flow.

Limitations

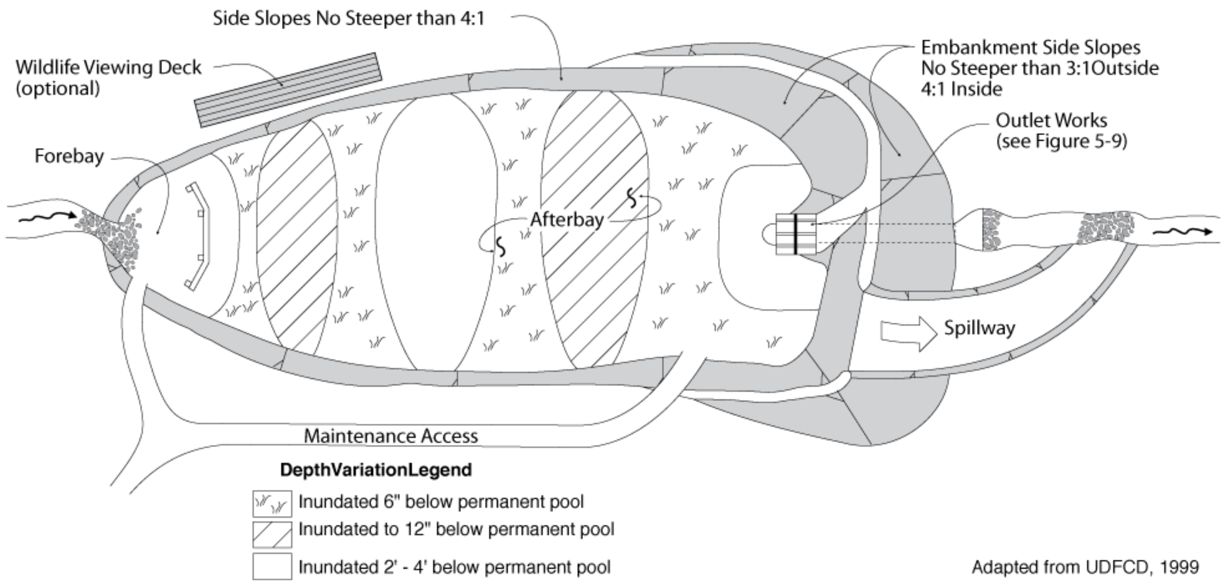
- Wetlands must have a continuous base flow to maintain aquatic plants.
- There may be some aesthetic concerns about a facility that looks swampy.

- There are concerns about safety when wetlands are constructed where there is public access.
- Mosquito and midge breeding is likely to occur in wetlands.
- Wetlands cannot be placed on steep, unstable slopes and require a relatively large footprint.

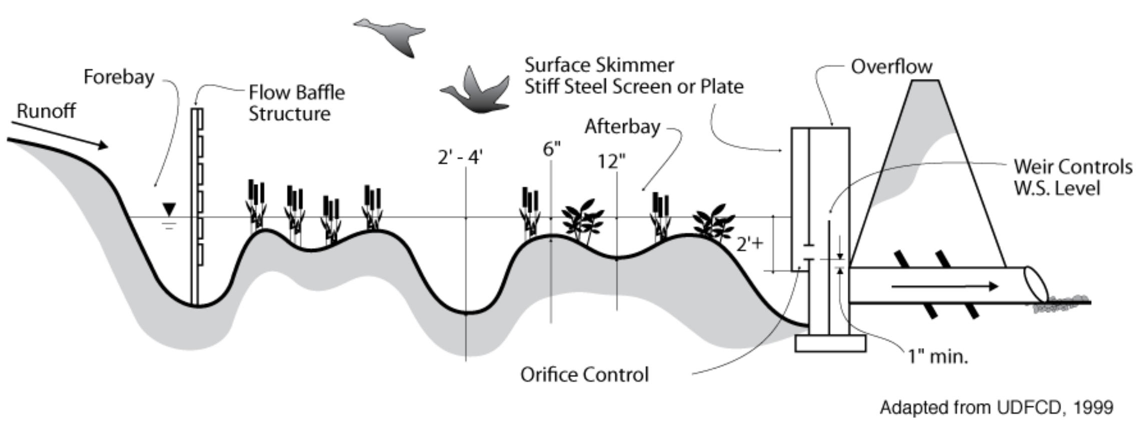
*Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in **Table 6-3**.*

Planning and Siting Considerations

- Appropriate land uses include large residential developments and commercial, institutional, and industrial areas where the incorporation of green space and a wetland into the landscape is desirable and feasible.
- It can be used effectively in combination with upstream treatment controls, such as vegetated buffer strips and vegetated swales.
- Requires relatively large areas (typically four to six percent of the tributary area) and are usually larger than Wet Ponds because the average depth is less.
- Most appropriate for sites with low-permeability soils (type C and D) that will support aquatic plant growth.
- Infiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland bottom.
- Wetland bottom channels require a near-zero slope.
- A base flow of water is required to maintain aquatic conditions.



Plan View



Section View

Figure 6-15. Conceptual Layout of Constructed Wetland. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Design Criteria

Design criteria for Constructed Wetland Basins are listed in **Table 6-34**. A Design Data Summary Sheet is provided at the end of this fact sheet.

Table 6-34. Constructed Wetland Basin Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	See standard calculation fact sheet
Maximum drawdown time for SQDV	24 hours	Based on SQDV
Minimum permanent pool volume	75%	Percentage of SQDV
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay **a. Volume** **b. Area** **c. Depth**	5-10% 5-10% 2-4 ft	Percentage of SQDV Percentage of permanent pool surface area
Open-water Zone **a. Area (including forebay)** **b. Depth**	10-40% 2-4 ft	Percentage of permanent pool surface area
Wetland Zone **a. Area** **b. Depth**	50-70% 0.5-1 ft	Percentage of permanent pool surface area 30 to 50% should be 0.5 ft deep
Outlet Zone **a. Area** **b. Depth**	5-10% 3 ft	Percentage of permanent pool surface area Minimum
Surcharge depth above permanent pool	2 ft	Maximum
Basin length to width ratio	2:1	Minimum (larger preferred)
Basin freeboard	1 ft	Minimum
Wetland zone bottom slope	10%	Maximum
Embankment side slope (H:V)	≥ 4:1 ≥ 3:1	Inside Outside (without retaining walls)
Maintenance access ramp slope (H:V)	10:1	or flatter
Maintenance access ramp width	16 ft	Minimum – paved with concrete or permeable pavers

Design Procedure

Step 1 – Calculate Water Quality Volume (SQDV)

Using the *Fact Sheet T-0*, determine the tributary drainage area and SQDV for 24-hour drawdown.

Step 2 – Determine Basin Minimum Volume for Permanent Pool

The volume of the permanent wetland pool (V_{pp}) shall be not less than 75% of the SQDV.

$V_{pp} \geq 0.75 \times SQDV$

Step 3 – Determine Basin Depths and Surface Areas

Distribution of the wetland area is needed to achieve desired biodiversity. Distribute component areas as follows:

Components	Percent of Permanent Pool Surface Area	Design Water Depth
Forebay	5-10%	2 to 4 feet
Open-water zone	10-40%	2 to 4 feet
Wetland zones with emergent vegetation	50-70%	6 to 12 inches (30% to 50% of this area should be 6 inches deep with bottom slope ≤ 10%)
Outlet zone	5-10%	3 feet (minimum)

a. Estimate average depth of permanent pool (D_{avg}) including all zones

b. Estimate the water surface area of the permanent pool (A_{pp}) based on actual V_{pp}

$A_{pp} = V_{pp} / D_{avg}$

c. Estimate water surface elevation of the permanent pool (WS $Elev_{pp}$) based on site elevations.

Step 4 – Determine Surcharge Depth of SQDV above Permanent Pool and Maximum Water Surface Elevation

The surcharge depth of the SQDV above the permanent pool's water surface (D_{SQDV}) should be ≤ 2.0 feet.

a. Estimate SQDV surcharge depth (D_{SQDV}) based on App.

$$D_{SQDV} = SQDV/A_{pp}$$

b. If $D_{SQDV} > 2.0$ feet, adjust value of V_{pp} and/or D_{avg} to increase A_{pp} and yield $D_{SQDV} \leq 2.0$.

The water surface of the basin will be greater than A_{pp} when the SQDV is added to the permanent pool.

c. Estimate maximum water surface area (A_{SQDV}) with SQDV based on basin shape.

d. Recalculate Final D_{SQDV} based on A_{SQDV} and A_{pp}. Note: V_{pp} and/or D_{avg} can be adjusted to yield Final $D_{SQDV} \leq 2.0$ feet.

Final $D_{SQDV} = SQDV/((A_{SQDV} + A_{pp})/2)$

e. Calculate maximum water surface elevation in the basin with SQDV.

WS $Elev_{SQDV}$ = WS $Elev_{pp}$ + Final D_{SQDV}

Step 5 – Determine Inflow Requirement

A net inflow of water must be available through a perennial base flow or supplemental water source. Use the following equation and parameters to estimate the quantity of monthly inflow required at various times of the year. The maximum monthly requirement will govern the design requirement.

$Q_{inflow} = Q_{E\text{-}P} + Q_{seepage} + Q_{ET}$

where

$Q_{E\text{-}P}$ = Loss due to evaporation minus the gain due to precipitation (acre-ft/mo.)

$Q_{seepage}$ = Loss or gain due to seepage to groundwater (acre-ft/mo.)

Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface) (acre-ft/mo.)

Step 6 – Design Basin Forebay

The forebay provides a location for the sedimentation of larger particles and has a solid bottom surface to facilitate the mechanical removal of accumulated sediment. The forebay is part of the permanent pool and has a water surface area comprising 5 to 10% of the permanent pool water surface area and a volume comprising 5 to 10% of the SQDV. The depth of the permanent pool in the forebay should be 2 to 4 feet. Provide forebay inlet with an energy dissipation structure and/or erosion protection. Trash screens at the inlet are recommended to reduce the dispersion of large trash articles throughout the basin.

Step 7 – Design Outlet Works

Provide outlet works that limit the maximum water surface elevation to WS $Elev_{SQDV}$. The Outlet Works are to be designed to release the SQDV over a 24-hour period. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. A single orifice outlet control is depicted in **Figure 6-18**.

a. For single orifice outlet control or a single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) (see **Figure 6-15**), use the orifice equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

Orifice Equation

$$Q = C \times A \times \sqrt{2gD}$$

where

Q = Flow rate

C = Orifice coefficient (use 0.61)

A = Area of orifice

g = Acceleration due to gravity (32.2 ft/sec^2)

D = Depth of water above orifice centerline (D_{SQDV})

The equation can be solved for A based on the SQDV and design drawdown time (t) using the following conversion of the orifice equation

$$A = \frac{SQDV}{60.19 \times D^{0.5} \times t}$$

where

t = drawdown period (hrs) = 24 hrs

b. For perforated pipe outlets or vertical plates with multiple orifices, use the following equation to determine required area per row of perforations, based on the SQDV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

Area/row (in^2) = SQDV/K_{24}

where

$K_{24} = 0.012D^2 + 0.14D - 0.06$ (from Denver UDFCD, 1999)

Select the appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches on center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

nr = 1 + (D x 3)

Calculate total outlet area by multiplying the area per row by the number of rows.

Total Orifice Area = area/row x nr

Step 8 – Design Basin Shape

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The length-to-width ratio should be between 2:1 to 4:1, with 3:1 recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

Step 9 – Design basin side slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and facilitate maintenance. Internal side slopes should be no steeper than 4:1; external side slopes should be no steeper than 3:1.

Step 10 – Design Maintenance Access

Provide all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be 10 percent, and the minimum width should be 16 feet. Ramps should be paved with concrete.

Step 11 – Design Security Fencing

Provide aesthetic security fencing around the basin to protect habitat except when specifically waived by the City of Stockton Municipal Utilities Department, Stormwater Division or the San Joaquin County Department of Public Works. The fencing design shall be approved by the City or County.

Step 12 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix G**. Select wetland vegetation appropriate for planting in the wetland bottom. A qualified wetland specialist should be consulted regarding the selection and establishment of plants. The shallow littoral bench should have a 4- to 6-inch layer of organic topsoil. Berms and side-sloping areas should be planted with native or irrigated turf grasses. The selection of plant species for a constructed wetland shall take into consideration the water fluctuation likely to occur in the wetland. The permanent pool water level should be controlled as necessary to allow the establishment of wetland plants and raised to the final operating level after plants are established.

Construction Considerations

- An impermeable liner may be required to maintain permanent pool levels in areas with porous soils.
- Install seepage collars on outlet piping to prevent seepage through embankments.

Maintenance Requirements

The City or County requires the execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment controls such as Constructed Wetland. Such agreements will typically include requirements such as those outlined in **Table 6-35**. The property owner or his/her designee is responsible for compliance with the agreement. Sample agreements are presented in **Appendix D**. The maintenance agreement and plan will provide the City/ County designee with complete access to the Device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-35. Inspection and Maintenance Requirements for Constructed Wetland Basins

Activity	Schedule
Remove litter and debris from Constructed Wetland Basin area.	As required
Inspect basin to identify potential problems such as trash and debris accumulation, damage from burrowing animals, and sediment accumulation.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If permitted by the Department of Fish and Wildlife or other agency regulations, stock basin with mosquito fish to enhance natural mosquito and midge control.	As required
Harvest vegetation for vector control and to maintain open water surface area.	Annually or more frequently if required
Remove sediment when accumulation reaches 10 percent of original design depth or if resuspension is observed. (Note: Sediment removal may not be required in the main pool area for as long as 20 years.)	Clean in early spring so vegetation damaged during cleaning has time to reestablish.
Clean forebay to minimize frequency of main basin cleaning.	As required

Image 6-14. Detention Basins. *Source: Detention basin retrofitting. Detention Basin Retrofitting | City of Elgin, Illinois - Official Website. (n.d.). Retrieved October 7, 2021, from https://www.cityofelgin.org/1275/Detention-Basin-Retrofitting.*

Description

Extended detention basins are permanent basins formed by excavation and/or construction of embankments to temporarily detain the SQDV of stormwater runoff to allow for the sedimentation of particulates to occur before the runoff is discharged. An extended detention basin serves to reduce peak stormwater runoff rates, as well as provide treatment of stormwater runoff. Extended detention basins are typically dry between storms, although a shallow pool, one to three feet deep, can be included in the design for aesthetic purposes and to promote biological uptake and conversion of pollutants. A bottom outlet provides a controlled slow release of the detained runoff over a specified time period. Extended detention basins can also be used to provide flood control by including additional detention storage. The basic elements of an extended detention basin are shown in **Figure 6-16**. This configuration is most appropriate for large sites.

Advantages

- May be designed to provide other benefits such as recreation (such as playfields), wildlife habitat, and open space. Safety issues must be addressed.
- Relatively easy and inexpensive to build and operate due to its simple design.
- Useful in retrofit situations where their low hydraulic head requirements allow them to be sited within the constraints of the existing storm drain system. It can be designed into flood control basins or sometimes retrofitted into existing flood control basins.
- It can be designed to meet trash control requirements.

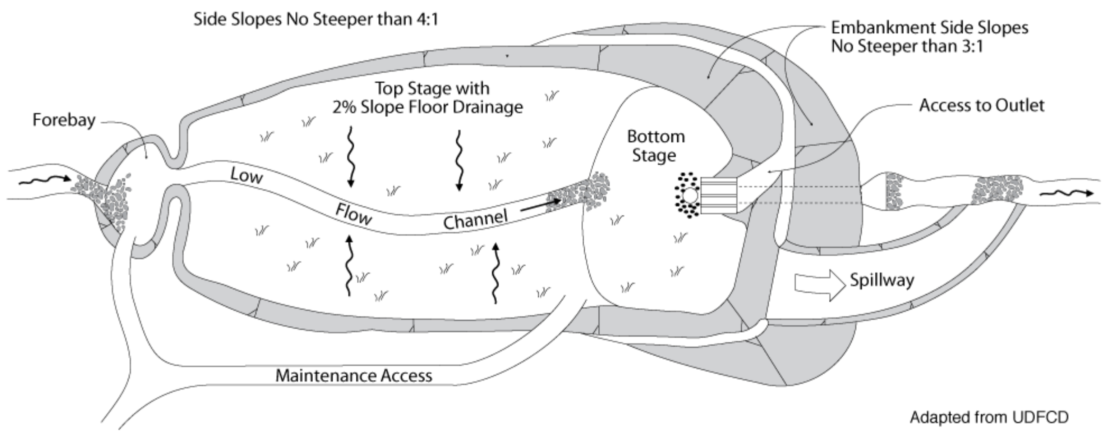
Limitations

- Discharge from Extended Detention Basins may pose a risk to cold-water receiving waters because water retained in the permanent pool is typically heated over time.
- Although wet Extended Detention Basins can increase property values, dry Extended Detention Basins can adversely affect the value of nearby properties due to the adverse aesthetics of dry, bare areas and inlet and outlet structures. Appropriate vegetation selection and maintenance can help to mitigate these adverse effects.

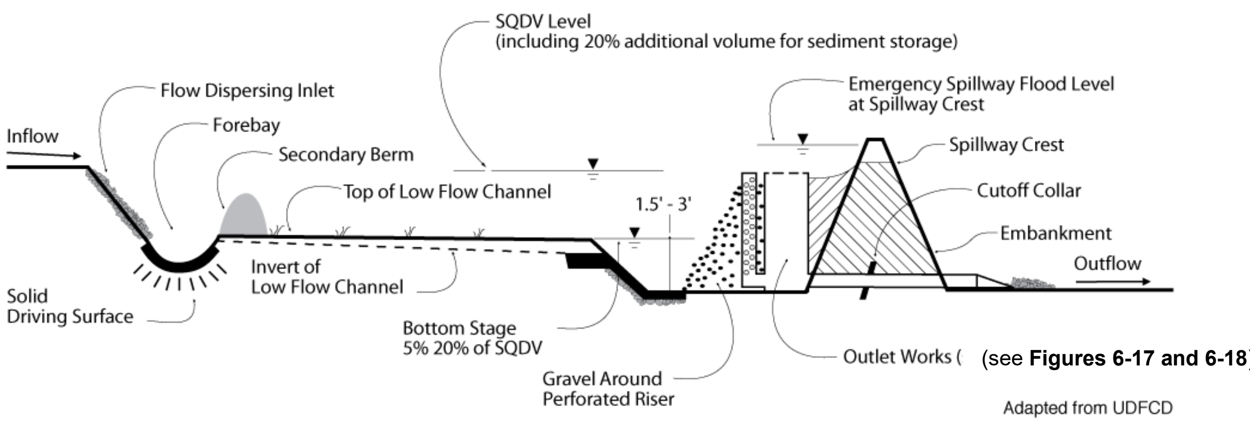
Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in ***Table 6-3****.*

Planning and Siting Considerations

- If constructed early in the land development cycle, it can serve as sediment trap during construction within the tributary area.
- Surface basins are typical, but underground vaults may be appropriate in a small commercial development.
- Tributary Drainage Area: Small to medium-sized regional tributary areas with available open space and drainage areas greater than about five (5) acres;
- Land area requirements: Approximately 0.5 to 2 percent of the tributary development area.
- Soil Type: Can be used with almost all soils and geology, with minor adjustments for regions with rapidly percolating soils. In these areas, impermeable liners can be installed to prevent groundwater contamination. The base of the basin should not intersect the groundwater table because a permanently wet bottom can become a vector breeding ground.



Plan View



Section View

Figure 6-16 Extended Detention Basin Conceptual Layout. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Design Criteria

Principal design criteria for Extended Detention Basins are listed in **Table 6-36**. A Design Data Summary Sheet is provided at the end of this fact sheet.

Table 6-36. Extended Detention Basin Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	80% annual capture. Use Figure 6-1 @ 48-hr drawdown
Maximum drawdown time for SQDV	48 h 12 h	Based on SQDV Minimum time for release of 50% SQDV
Basin design volume	120%	Percentage of SQDV. Provide 20% sediment storage volume.
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay **a. Volume** **b. Drain time**	5-10% < 45 min	Percentage of SQDV
Low-flow channel **a. Depth** **b. Flow capacity**	9 in. 200%	Percentage of forebay outlet release capacity
Upper stage **a. Bottom slope** **b. Depth** **c. Width**	2% 2 ft 30 ft	Minimum Minimum
Length to width ratio	2:1	Minimum (larger preferred)
Bottom stage **a. Volume** **b. Depth**	5-20% 1.5-3 ft	Percentage of SQDV Deeper than Upper Stage
Freeboard	1 ft	Minimum
Embankment side slope (H:V)	≥ 4:1 ≥ 3:1	Inside Outside (without retaining walls)
Maintenance access ramp slope (H:V)	10:1	or flatter
Maintenance access ramp width	16 ft	Minimum – approach paved with asphalt concrete

Design Procedure (for Trash Control see below)

Step 1 – Calculate Water Quality Volume (SQDV)

Using *Fact SheetT-0*, determine the tributary drainage area and SQDV for 48-hour drawdown.

Step 2 – Determine Minimum Basin Storage Design Volume

The volume of the basin (V_{BS}) shall be not less than 120% of the SQDV. The additional 20 percent provides an allowance for sediment accumulation.

$V_{BS} = 1.2 \times SQDV$

Step 3 – Design Outlet Works

The outlet works are to be designed to release the SQDV over a 48-hour period, with no more than 50% released in 12 hours. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. Refer to **Figures 6-17** and **6-18** for schematics pertaining to structure geometry, grates, trash racks, and screens; outlet type: perforated riser pipe or orifice plate.

a. For single orifice outlet control or a single row of orifices at the basin bottom surface elevation (see **Figure 6-18**), use the orifice equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

Orifice Equation

$$Q = C \times A \times \sqrt{2gD}$$

where

Q = Flow rate

C = Orifice coefficient (use 0.61)

A = Area of orifice

g = Acceleration due to gravity (32.2 ft/sec^2)

D = Depth of water above orifice centerline (D_{SQDV})

The equation can be solved for A based on the SQDV and design drawdown time (t) using the following conversion of the orifice equation

$$A = \frac{SQDV}{60.19 \times D^{0.5} \times t}$$

where

t = drawdown period (hrs) = 48 hrs

b. For perforated pipe outlets or vertical plates with multiple orifices (see **Figure 6-17),** use the following equation to determine the required area per row of perforations based on the SQDV (acre-ft) and depth of water above the centerline of the bottom perforation D (ft).

Area/row (in^2) = SQDV/K_{48}

where

$K_{48} = 0.013D^2 + 0.22D – 0.10$

Select appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches in the center from the bottom perforation. Thus, there will be 3 rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

nr = 1 + (D x 3)

Calculate the total outlet area by multiplying the area per row by the number of rows.

Total Orifice Area = area/row x nr

Step 4 – Provide Trash Rack/Gravel Pack

A trash rack or gravel pack around perforated risers shall be provided to protect outlet orifices from clogging. Trash racks are better suited for use with perforated vertical plates for outlet control and allow easier access to outlet orifices for purposes of inspection and cleaning. The trash rack shall be sized to prevent clogging of the primary water quality outlet without restricting the hydraulic capacity of the outlet control orifices.

Step 5 – Design Basin Shape

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction from the middle toward the outlet. The length-to-width ratio should be a minimum of 2:1. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

Step 6 – Two-Stage Design

A two-stage design, including a pool that often fills with frequently occurring runoff, minimizes standing water and sediment deposition in the remainder of the basin.

a. Upper Stage: The upper stage should be a minimum of 2 feet deep, with the bottom sloped at 2 percent toward the low flow channel. The minimum width of the upper stage should be 30 feet.

b. Bottom Stage: The active storage basin of the bottom stage should be 1.5 to 3 feet deeper than the upper stage and store 5 to 20 percent of the SQDV. A micro-pool below the active storage volume of the bottom stage, if provided, should be one-half the depth of the top stage or two (2) feet, whichever is greater.

Step 7 – Design Pond Forebay

The forebay provides a location for the sedimentation of larger particles and has a solid bottom surface to facilitate the mechanical removal of accumulated sediment. The forebay has a volume comprising 5 to 10% of the SQDV. Provide the forebay inlet with an energy dissipation structure and/or erosion protection. A berm should separate the forebay from the upper stage of the basin. The outlet pipe from the forebay to the low-flow channel should be sized to drain the forebay volume in 45 minutes. The outlet pipe entrance should be offset from the forebay inlet to prevent short-circuiting.

Step 8 – Low-Flow Channel

The low-flow channel conveys flow from the forebay to the bottom stage. Erosion protection should be provided where the low-flow channel enters the bottom stage. The lining of the low-flow channel with concrete is recommended. The depth of the channel should be at least 9 inches. The flow capacity of the channel should be twice the release capacity of the forebay outlet.

Step 9 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix G**. Bottom vegetation provides erosion protection and sediment entrapment. Basin bottoms, berms, and side slopes may be planted with native grasses or with irrigated turf.

Step 10 – Design Embankment Side Slopes

Design embankments to conform to State of California Division of Safety of Dams requirements if the basin dimensions cause it to fall under that agency's jurisdiction. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

Step 11 – Inlet/Outlet Design

Basin inlet and outlet points should be provided with an energy dissipation structure and/or erosion protection.

Step 12 – Design Maintenance Access

Provide for all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be 10 percent and the minimum width should be 16 feet. Ramps should be paved with concrete.

Step 13 – Provide Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with the applicable standards of the City.

Step 14 – Geotextile Fabric

Non-woven geotextile fabric used in conjunction with gravel packs around perforated risers shall conform to the specifications listed in **Table 6-37**.

Table 6-37. Non-woven Geotextile Fabric Specifications

Property	Test Reference	Minimum Specification
Grab Strength	ASTM D4632	90 lbs
Elongation at peak load	ASTM D4632	50%
Puncture Strength	ASTM D3787	45 lbs
Permittivity	ASTM D4491	0.7 sec^{-1}
Burst Strength	ASTM D3786	180 psi
Toughness	% Elongation x Grab Strength	5,500 lbs
Ultraviolet Resistance (Percent strength retained at 500 Weatherometer hours)	ASTM D4355	70%

Adapted from SSPWC, 1997.

Step 15 – Design Security Fencing

Provide aesthetic security fencing around basin to protect habitat except when specifically waived by the City of Stockton Municipal Utilities Department, Stormwater Division or the San Joaquin County Department of Public Works. The fencing design shall be approved by the City or County.

Design Procedure – Trash Control

The design of detention basins can be enhanced to comply with the Statewide Trash Amendments. To meet these requirements, the basin must:

1. Trap trash particles that are 5 mm or greater and include a screen[15]
2. at the BMP inlet, overflow, or bypass outlet to trap these particles from either of the following BMP designs:
   a. A flow-based design for:
      i. the peak flow rates generated by the one-year, one-hour storm event (0.345 inches/hour) from the applicable subdrainage area; or
      ii. the trash treatment capacity equal to or greater than the corresponding storm drain's design flow rate; or

[15] Upon approval by the Regional Water Quality Control Board Executive Officer, a 5mm screen will not be required if there is an external design feature or up-gradient structure designed to bypass flows exceeding the region specific one-year, one-hour storm event; or when the BMP's capacity to trap particles exceeds flows generated by the one-year, one-hour storm event.

b. A volume-based design that includes a trash treatment capacity that is equal to or greater than the volume generated from a one-year, one-hour storm event (0.345 inches).

   A screen is not required if the infiltration trench has capacity to treat either of these flows through media filtration or infiltration into native or amended soils.

3. Have a minimum treatment capacity for either of the flow rates described in 1.a. or b. above. The Rational Equation method may be used to calculate the peak flow rate for runoff from a small subdrainage area that is approximately 50 acres or less. The Rational Equation is expressed as Q = CiA, where:

   Q = design peak runoff rate, cfs,

   C = runoff coefficient, dimensionless,

   i = rainfall intensity 0.345 inches/hour, and

   A = subdrainage area, acres.

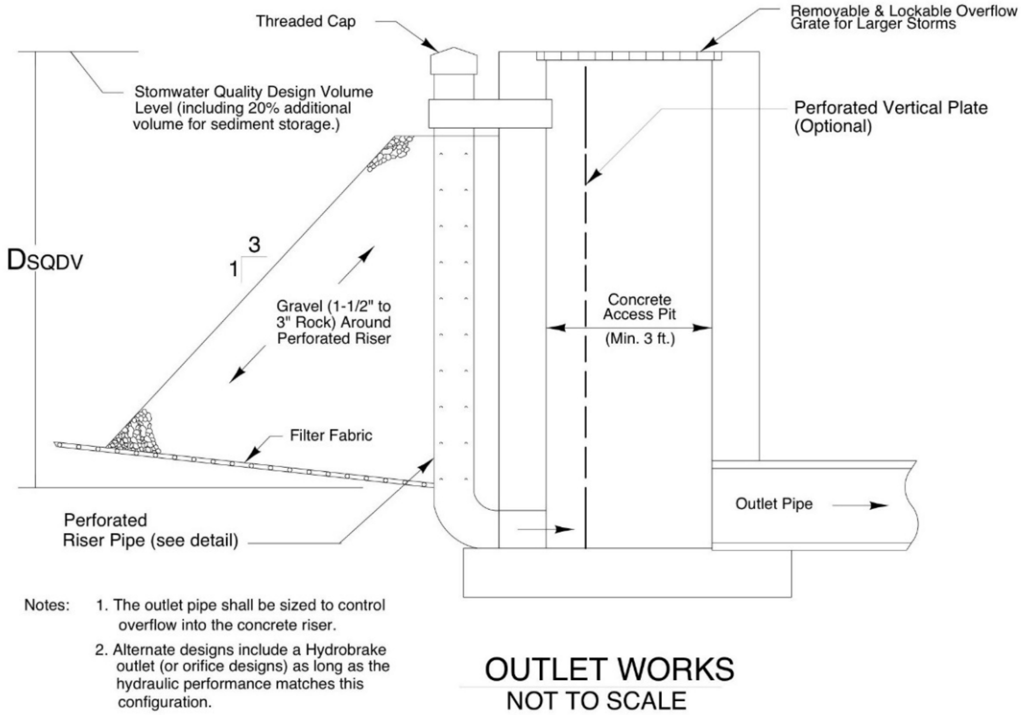
   Other calculation methods for drainage areas greater than 50 acres are allowed, provided a registered California-licensed professional engineer documents the calculations within the design plans.

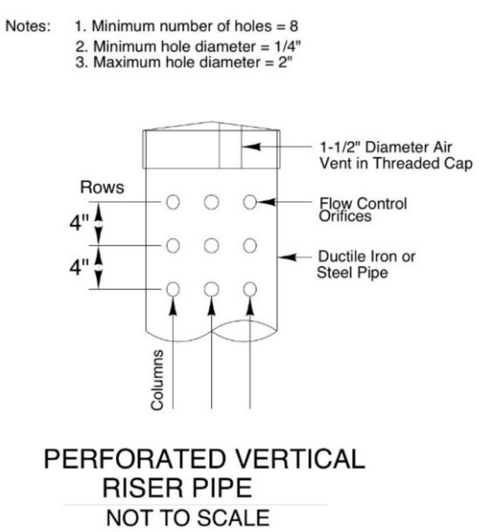
4. The detention BMP design plans must be stamped and signed by a registered California licensed professional civil engineer (see Bus. & Prof. Code Section 6702, et seq.).

The basin must meet State-sanctioned requirements detailed in the *Certified Multi-Benefit Treatment Systems Complying With Trash Full Capture System Requirements*, authorized March 9, 2018, and any subsequent revisions. Requirements can be accessed at https://www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html.

Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects.

Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets that are located within the boundaries of the parcel and that are operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City or County has agreed to enter into a maintenance agreement with the property owner (**Appendix D**).





Maximum Number of Perforated Columns				
Riser Diameter (in.)	Hole Diameter, in.			
	1/4"	1/2"	3/4"	1"
4	8	8	--	--
6	12	12	9	--
8	16	16	12	8
10	20	20	14	10
12	24	24	18	12

Hole Diameter, in.	Area of Hole (in.)[2]
1/8	0.013
1/4	0.049
3/8	0.110
1/2	0.196
5/8	0.307
3/4	0.442
7/8	0.601
1	0.785

ADAPTED FROM UDFCD, 1999

OUTLET CONFIGURATIONS USING MULTIPLE ORIFICE FLOW CONTROL

Figure 6-17. Perforated Pipe Outlet Structure. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

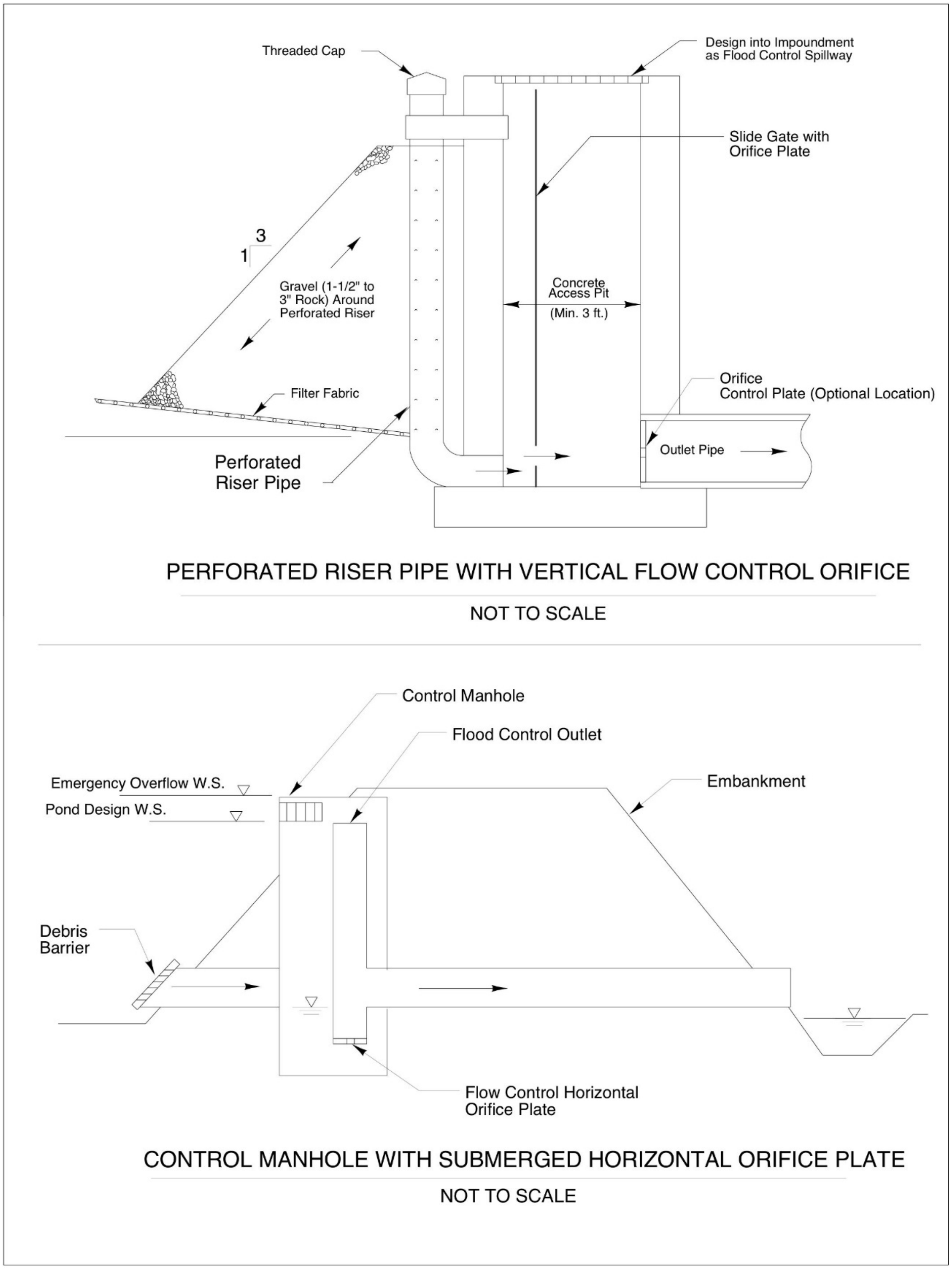


Figure 6-18 Orifice Plate Outlet Configuration. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Construction Considerations

- Install seepage collars on outlet piping to prevent seepage through embankments.
- Clearly mark areas to be used for extended detention basins before site work begins to avoid soil disturbance and compaction during construction.

Maintenance Requirements

The City or County requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Extended Detention Basins. Such agreements will typically include requirements such as those outlined in **Table 6-38**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-38. Inspection and Maintenance Requirements for Extended Detention Basins

Activity	Schedule
Remove litter and debris from the banks and basin bottom.	As required
Inspect Extended Detention Basin for the following items: clogging of outlet; differential settlement; cracking; erosion; leakage; tree growth on the embankment; the condition of riprap in the inlet, outlet, and pilot channels; sediment accumulation in the basin; trash and debris accumulation; damage from burrowing animals; and the health and density of grass turf on the basin side slopes and floor. Correct observed problems as necessary.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If permitted by the Department of Fish and Wildlife or other agency regulations, stock basin with mosquito fish to enhance natural mosquito and midge control.	As required
Remove sediment when accumulation reaches 25 percent of original design depth or if resuspension is observed. (Note: Sediment removal may not be required in the main basin for as long as 20 years.)	Clean in early spring so vegetation damaged during cleaning has time to reestablish.
Clean forebay to minimize frequency of main basin cleaning.	As required
Trim vegetation and inspect monthly to prevent the establishment of woody vegetation and for aesthetic and vector reasons.	At beginning and end of the wet season.
Control mosquitoes.	As necessary

For trash control, regular maintenance is required to maintain adequate trash capture capacity and ensure that trapped trash does not migrate offsite. The owner should establish a maintenance schedule based on site-specific factors, including the size of the detention BMP, storm frequency, and estimated or measured trash loading area.

Description

Image 6-15. Charles River Watershed Association
Source: Low Impact Best Management Practice (BMP) Information Sheet. www.charlesriver.org

Wet Ponds are open earthen basins that feature a permanent pool of water that is displaced by stormwater flow, in part or in total, during storm runoff events. Like Extended Detention Basins, Wet Ponds are designed to temporarily retain the SQDV of stormwater runoff and to slowly release this volume over a specified period (12 hours). Wet Ponds differ from Extended Detention Basins in that the influent runoff flow water mixes with and displaces the permanent pool as it enters the basin. The design drawdown time for Wet Ponds (12 hours) is shorter than for Extended Detention Basins (48 hours), because enhanced treatment is provided in the permanent pool. Wet Ponds differ from constructed wetlands in having a greater average depth. A dry-weather base flow is required to maintain a permanent pool. The primary removal mechanism is settling as stormwater resides in this pool, but pollutant removal, particularly nutrients, also occur through biological activity in the pond. The basic elements of a Wet Pond are shown in **Figure 6-19**.

Advantages

- Wet ponds can be designed to provide other benefits such as recreation, wildlife habitat, and open space.
- Ponds are often viewed as a public amenity when integrated into a park or open-space setting.
- The permanent pool can provide significant water quality improvement across a relatively broad spectrum of constituents including dissolved nutrients.
- Can serve essentially any size tributary area.

Limitations

- Public safety must be considered with respect to access and use.
- Potential for mosquito and midge breeding exists due to permanent water pool.
- Discharge from Wet Ponds may pose a risk to cold-water receiving waters because water retained in the permanent pool is typically heated over time.
- Base flow or supplemental water is required if water level is to be maintained, although ponds may be allowed to dry out during the dry season if non-stormwater flows are negligible.
- Algae growth may be a potential issue if the permanent water pool is maintained during the summer dry season.
- Ponds require a relatively large footprint.

- Depending on volume and depth, pond designs may require approval from the State Division of Safety of Dams.

Note: Various factors must be considered when selecting a treatment control. In addition to reducing target pollutants of concern, site considerations such as the size of the drainage area, depth between the water table and the treatment control, soil type and permeability, slope, hydraulic head, size of the treatment control, and need for vegetation irrigation are important factors in selecting the proper treatment control. Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects. The site constraints that are considered in selection of treatment controls are presented in ***Table 6-3****.*

Planning and Siting Considerations

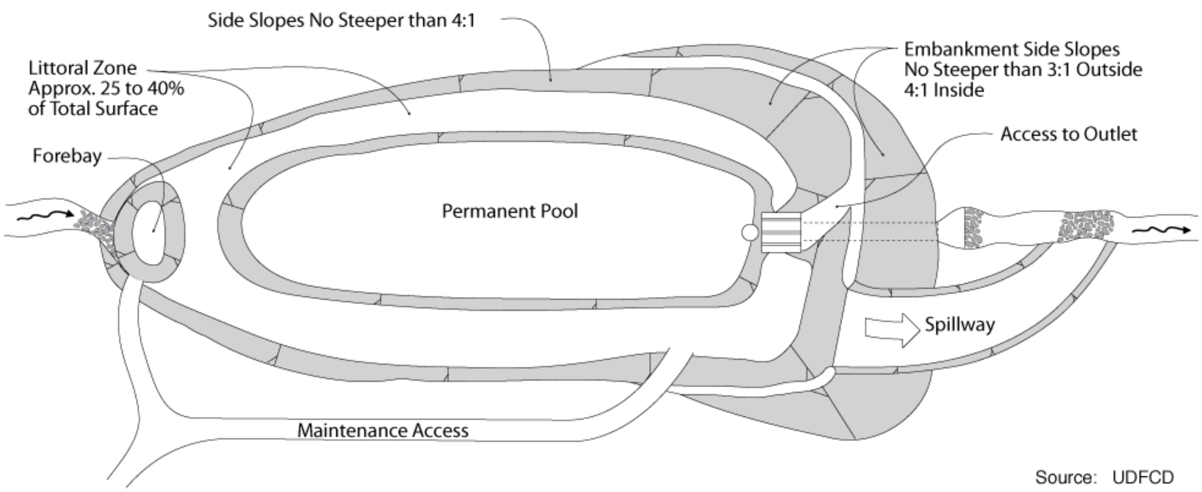
- Wet Ponds are appropriate for use in the following settings:
  - Where there is a need to achieve a reasonably high level of dissolved contaminant removal and/or sediment capture;
  - Where base flow rates or other channel flow sources are relatively consistent year-round; or
  - In residential settings where aesthetic and wildlife habitat benefits can be appreciated and maintenance activities are likely to be consistently undertaken.
- Not suitable for:
  - Dense urban areas;
  - Sites with steep, unstable slopes; or
  - Areas with long dry periods and high evaporation rates without a perennial groundwater base flow or supplemental water supply to maintain the permanent pool.
- Tributary drainage areas are typically small to medium-sized regional areas greater than approximately 10 acres with available open space.
- Land area requirements are approximately two to three percent of the tributary development area.
- Most appropriate for sites with low-permeability soils (types C or D).

Design Criteria

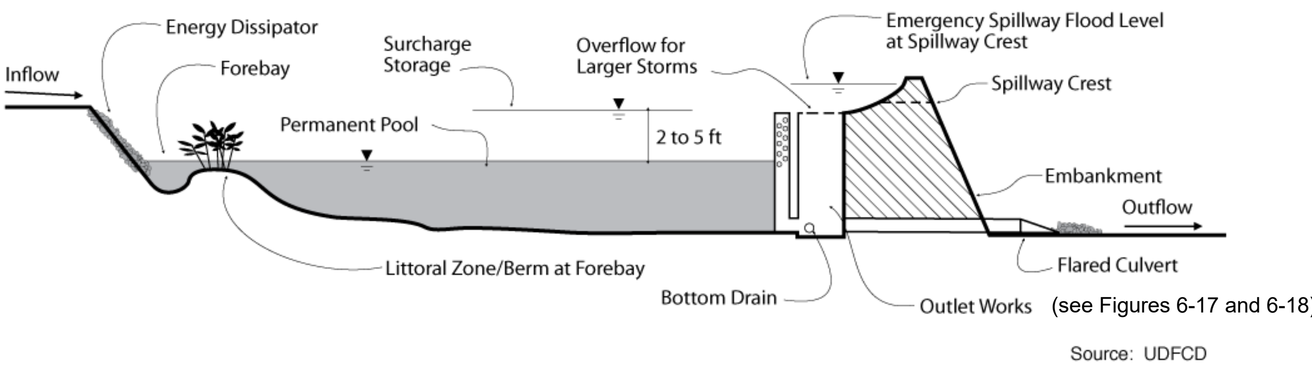
The principal design criteria for Wet Ponds are listed in **Table 6-39**.

Table 6-39. Wet Pond Design Criteria

Design Parameter	Criteria	Notes
Design volume	SQDV	80% annual capture. Use Figure 6-1 @ 12-hr drawdown
Maximum drawdown time for SQDV	12 h	Based on SQDV
Minimum permanent pool volume	100-150%	Percentage of SQDV
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity
Forebay **a. Volume** **b. Drain time** **c. Depth**	 5-10% < 45 min 2 to 4 ft	Percentage of SQDV
Littoral Zone **a. Area** **b. Depth**	 25-40% 6-18 in	Percentage of permanent pool surface area
Deeper Zone **a. Area (including forebay)** **b. Depth** **c. Maximum depth**	 55-65% 4-8 ft 12 ft	 Percentage of permanent pool surface area Average depth
Pond length to width ratio	2:1	Minimum (larger preferred)
Bottom width	30 ft	Minimum
Pond freeboard	1 ft	Minimum
Embankment side slope (H:V)	≥ 4:1 ≥ 3:1	Inside Outside (without retaining walls)
Maintenance access ramp slope (H:V)	10:1	or flatter
Maintenance access ramp width	16 ft	Minimum – approach paved with asphalt concrete



Plan View



Section View

Figure 6-19. Conceptual Layout of Wet Pond. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Design Procedure

Step 1 – Calculate Water Quality Design Volume (SQDV)

Using the *Calculation of Stormwater Quality Design Flow and Volume Fact Sheet*, determine the tributary drainage area and SQDV for 12-hour drawdown.

Step 2 – Determine Minimum Volume for Permanent Pool

The volume of the permanent pool (V_{pp}) shall be not less than 100% and up to 150% of the SQDV.

$$V_{pp} = 1.0 \text{ to } 1.5 \times SQDV$$

Step 3 – Determine Depth Zones

Distribution of the permanent pool area is needed to achieve the desired biodiversity. In addition to the forebay, two depth zones are required (see **Figure 6-19**). The Littoral Zone provides for aquatic plant growth along the perimeter of the pool. The Deeper Zone covers the remaining pond area and promotes sedimentation and nutrient uptake by phytoplankton. Distribute component areas as follows:

Components	Percent of Permanent Pool Surface Area	Design Water Depth
Forebay	5-10%	2 to 4 feet
Littoral Zone	25-40%	6 to 18 inches
Deeper Zone	55-65%	4 to 8 feet average; 12 foot max

a. Estimate average depth of permanent pool (D_{avg}) including all zones

b. Estimate the water surface area of the permanent pool (A_{pp}) based on actual V_{pp}

$A_{pp} = V_{pp} / D_{avg}$

c. Estimate water surface elevation of the permanent pool ($WS\ Elev_{pp}$) based on site elevations.

Step 4 – Determine inflow requirement

A net inflow of water must be available through a perennial base flow or supplemental water source. Use the following equation and parameters to estimate the quantity of monthly inflow required at various times of the year. The maximum monthly requirement will govern the design requirement.

$$Q_{inflow} = Q_{E-P} + Q_{seepage} + Q_{ET}$$

where

Q_{E-P} = Loss due to evaporation minus the gain due to precipitation (acre-ft/mo.)

$Q_{seepage}$ = Loss or gain due to seepage to groundwater (acre-ft/mo.)

Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface) (acre-ft/mo.)

Step 5 – Design Pond Forebay

The forebay provides a location for the sedimentation of larger particles and has a solid bottom surface to facilitate the mechanical removal of accumulated sediment. The forebay is part of the permanent pool and has a volume comprising 5 to 10% of the SQDV. The depth of the permanent pool in the forebay should be 2 to 4 feet. Provide the forebay inlet with an energy dissipation structure and/or erosion protection. A berm consisting of rock and topsoil mixture should be part of the littoral bench to create the forebay and have a minimum top width of 8 feet and side slopes no steeper than 4:1. Trash screens at the inlet are recommended to reduce the dispersion of large trash articles throughout the basin.

Step 6 – Design Outlet Works

The outlet works are to be designed to release the SQDV over a 12-hour period. Protect the outlet from clogging with a trash rack and a skimmer shield that extends below the outlet and above the maximum SQDV depth. An outlet works for a Wet Pond, is depicted in **Figure 6-21**.

a. For single orifice outlet control or a single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) (see **Figure 6-18**), use the orifice equation based on the SQDV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (in^2):

Orifice Equation

$$Q = C \times A \times \sqrt{2gD}$$

where

Q = Flow rate

C = Orifice coefficient (use 0.61)

A = Area of orifice

g = Acceleration due to gravity (32.2 ft/sec^2)

D = Depth of water above orifice centerline (D_{SQDV})

The equation can be solved for A based on the SQDV and design drawdown time (t) using the following conversion of the orifice equation

$$A = \frac{SQDV}{61.19 \times D^{0.5} \times t}$$

where

t = drawdown period (hrs) = 12 hrs

b. For perforated pipe outlets or vertical plates with multiple orifices (see **Figure 6-17**), use the following equation to determine required area per row of perforations, based on the SQDV (acre-ft) and depth of water above centerline of the bottom perforation D (ft).

Area/row (in^2) = SQDV/K_{12}

where

$K_{12} = 0.008D^2 + 0.056D – 0.012$

Select the appropriate perforation diameter and number of perforations per row (columns) with the objective of minimizing the number of columns and using a maximum perforation diameter of 2 inches. Rows are spaced at 4 inches in center from the bottom perforation. Thus, there will be three rows for each foot of depth plus the top row. The number of rows (nr) may be determined as follows:

nr = 1 + (D x 3)

Calculate the total outlet area by multiplying the area per row by the number of rows.

Total Orifice Area = area/row x nr

Step 7 – Design Basin Shape

Whenever possible, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The length-to-width ratio should be between 2:1 to 4:1, with 3:1 recommended. Internal baffling with berms or modification of inlet and outlet points may be necessary to achieve this ratio.

Step 8 – Design Embankment Side Slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Interior slopes should be no steeper than 4:1 and exterior slopes no steeper than 3:1. Flatter slopes are preferable.

Side slopes above the permanent pool should be no steeper than 4:1, preferably 5:1 or flatter.

The littoral zone should be very flat (40:1 or flatter), with the depth ranging from 6 inches near the shore and extending to no more than 12 inches at the furthest point from the shore.

The side slope below the littoral zone shall be 3:1 or flatter.

Step 9 – Inlet/Outlet Design

Basin inlet and outlet points should be provided with an energy dissipation structure and/or erosion protection.

Step 10 – Design Maintenance Access

Provide for all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be 10 percent and minimum width should be 16 feet. Ramps should be paved with concrete.

Step 11 – Provide Bypass

Provide for bypass or overflow of runoff volumes in excess of the SQDV. Spillway and overflow structures should be designed in accordance with the applicable standards of the City.

Step 12 – Provide Underdrains

Provide underdrain trenches near the edge of the pond. The trenches should be no less than 12 inches wide, filled with ASTM C-33 sand to within 2 feet of the pond's permanent pool water surface, and with an underdrain pipe connected through a valve to the outlet. These underdrains will permit the drying out of the pond when it has to be "mucked out" to restore the volume lost due to sediment deposition.

Step 13 – Select Vegetation

Select vegetation from the list of approved plants – **Appendix G.** Bottom vegetation provides erosion protection and sediment entrapment. Berms and side slopes may be planted with native grasses or with irrigated turf. The shallow littoral bench should have a 4 to 6-inch thick organic topsoil layer and be vegetated with aquatic species.

Step 14 – Design Security Fencing

Provide aesthetic security fencing around the basin to protect habitat except when specifically waived by the City of Stockton Municipal Utilities Department, Stormwater Division or the San Joaquin County Department of Public Works. The fencing design shall be approved by the City or County.

Construction Considerations

- An impermeable liner may be required to prevent infiltration and maintain permanent pool levels in areas with porous soils.
- Install seepage collars on outlet piping to prevent seepage through embankments.

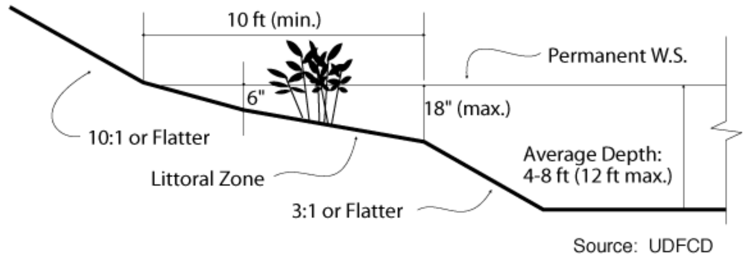


Figure 6-20. Depth Zones for Wet Pond. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November)*

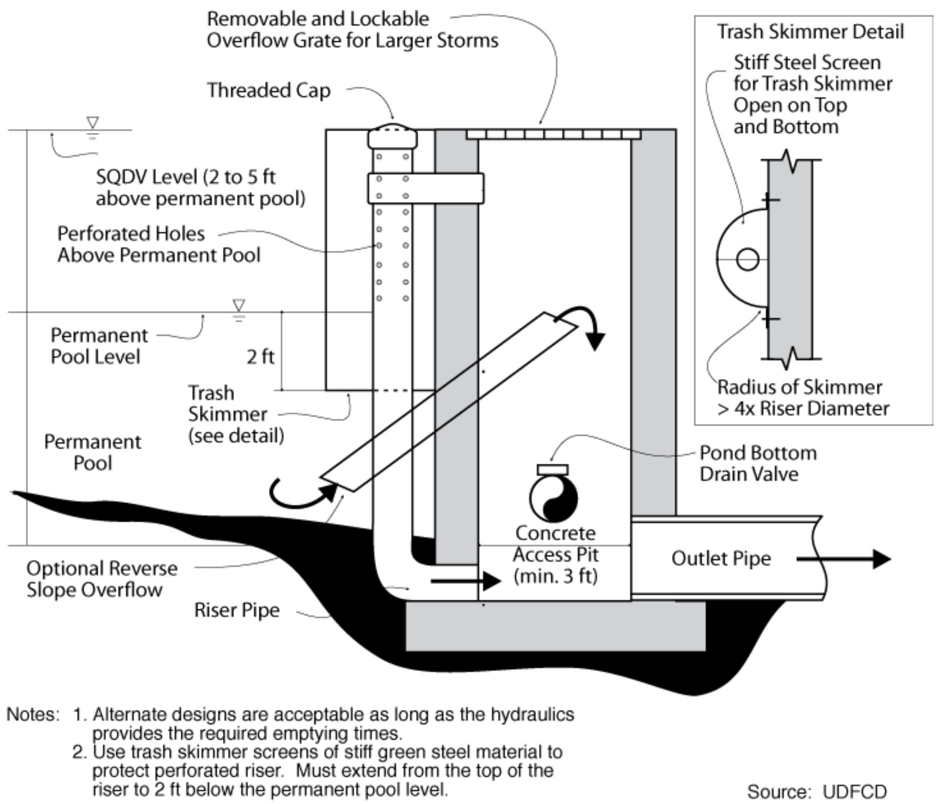


Figure 6-21. Outlet Works for Wet Pond. *Source: Adapted from Urban Storm Drain Criteria Manual Vol 3. – Best Management Practices, Urban Drainage and Flood Control District. (1999, November).*

Maintenance Requirements

The City or County requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Extended Detention Basins. Such agreements will typically include requirements such as those outlined in **Table 6-40**. The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-40. Inspection and Maintenance Requirements for Wet Ponds

Activity	Schedule
Remove litter and debris from the banks and pond bottom.	As required
Inspect Wet Pond for the following items: clogging of outlet; differential settlement; cracking; erosion; leakage; tree growth on the embankment; the condition of riprap in the inlet, outlet, and pilot channels; sediment accumulation in the basin; trash and debris accumulation; damage from burrowing animals; and the health and density of grass turf on the basin side slopes and floor. Correct observed problems as necessary.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If permitted by the Department of Fish and Wildlife or other agency regulations, stock basin with mosquito fish to enhance natural mosquito and midge control.	As required
Harvest vegetation for vector control and to maintain effective permanent pool volume.	Annually or more frequently if required
Remove sediment when accumulation reaches 25 percent of original design depth or if resuspension is observed. (Note: Sediment removal may not be required in the main pool area for as long as 20 years.)	Clean in early spring so vegetation damaged during cleaning has time to reestablish.
Clean forebay to minimize frequency of permanent pool cleaning.	As required

The 2020 SWQCCP provides guidance for the selection and design of some of the common on-site stormwater treatment controls for new development. The standard treatment controls (L-1 through L-9 and C-1 through C-3) included in this Section are non-proprietary (public domain) designs that have been reviewed and determined to be generally acceptable. Because the performance of these measures has already been demonstrated and reviewed by the City and the County, the plan check review and approval process will be routine for development projects that have selected one or more of these control measures from the SWQCCP.

The City and the County recognize, however, that these non-proprietary treatment controls may not be appropriate for all projects due to physical site constraints. Thus, if the VRR has been met through the use of VRMs (**Section 5**), the City or the County will allow the use of proprietary control measures that have been approved for general use by the City and County in those projects where the use of non-proprietary treatment controls (L-1 through L-9 and C-1 through C-3) have been demonstrated by the applicant to the satisfaction of the City or County to be infeasible or impractical. Proprietary devices that are approved by the City for general use are listed in **Appendix I** along with the sizing criteria and criteria used for approval (Note: **Appendix I** does not include devices approved for trash control. For a list of certified and/or agency-approved devices contact the City or County). This list will be updated periodically when additional proprietary devices are added to the approved list.

In general, any proprietary device must be designed to treat the SQDV or the SQDF. However, use of alternative sizing criteria is allowed for certain devices as indicated in **Appendix I**. Procedures to calculate the SQDV and SQDF are provided in Fact Sheet T-0. Site runoff in excess of the design capacity may be diverted around or through the treatment device. Any proposed device must include all maintenance, operation, and construction requirements, as indicated in **Appendix E** and as recommended by the manufacturer.

The City and the County also recognize that in special cases, typically small in-fill projects, the use of City and the County approved general treatment controls, either non-proprietary or proprietary, may not be feasible due to physical site constraints. In these special cases, the City or County will consider the use of substitute proprietary devices in lieu of approved general use control measures. Such substitute devices typically provide a lower level of treatment than the approved general-use treatment controls. In such cases where substitute devices are proposed, the applicant must demonstrate to the satisfaction of the City and the County by means of a thorough engineering analysis that the use of approved general use control measures is not feasible. Proprietary devices that are approved by the City and the County as substitute devices are listed in **Appendix I** along with the sizing criteria and criteria used for approval. This list will be updated periodically when additional proprietary devices are added to the approved list.

The City and the County encourage the development of innovative stormwater control measures and may consider a limited number of promising alternative control measures that are not on the approved list in **Appendix I**, including proprietary devices, on a 'pilot basis.' In order for a pilot project to be considered for proprietary devices, the manufacturer and/or property owner must commit to participating and fund a monitoring program to verify the device's performance. Site designers should anticipate additional review time and contact the

City or County stormwater staff early in the process to request consideration of pilot installation projects. If unsuccessful, the property owner may be required to install additional stormwater control measures.

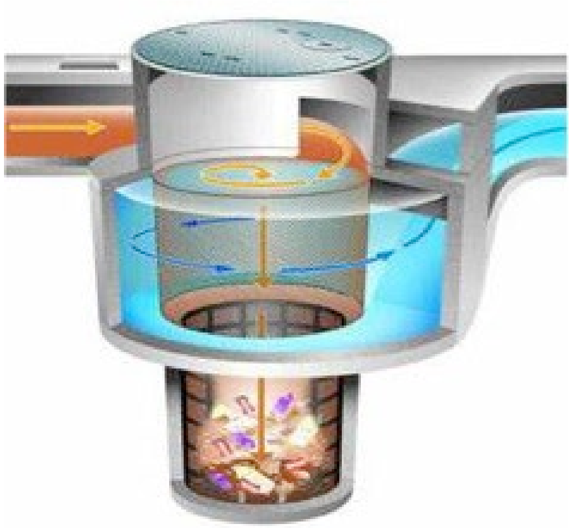


Image 6-16. Diagram of a Hydrodynamic Trash Separator. *Source: Environmental Protection Agency. (n.d.). Trash Capture Technologies. EPA. Retrieved October 7, 2021, from https://www.epa.gov/trash-free-waters/trash-capture-technologies.*

Description

A Trash Capture Device is a type of treatment control that either (a) removes pollutants and/or solids from stormwater runoff or (b) captures, infiltrates, and/or reuses stormwater runoff. A Trash Capture Device can include Full Capture Systems (FCS) or Low Impact Development (LID) controls.

For the purposes of this fact sheet and the use of these controls within the City of Stockton (City) or County of San Joaquin (County), C-5 Trash Capture Devices must be FCS (see below) [note: multi-benefit, LID, or public domain projects are defined in Factsheets L-1, L-4, L-5, and C-2].

A Trash Capture Device that is an FCS is a treatment control, or series of treatment controls, including but not limited to, a multi-benefit project (e.g., a bioretention facility that meets volume reduction and trash control requirements, see L-1) or an LID control measure 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.

Trash Capture Devices are typically proprietary-based controls that meet the design and maintenance criteria of the Statewide Trash Amendments.[16]

Only those devices that have been approved by the State Water Resources Control Board may be implemented to meet the Statewide Trash Amendment requirements and within the City and County. For a current list of certified and/or agency-approved devices, contact the City or County (depending on the location of the project).

Advantages

- Prevents trash from being transported into and through the storm drain system (for trash particles >5 mm) into the receiving waters.
- A wide range of proprietary devices provides options and flexibility to allow for site-specific conditions.
- Devices may be sized and custom-fit to existing stormwater infrastructure.

[16] https://www.waterboards.ca.gov/water_issues/programs/trash_control/documentation.html

- Some devices may be selected or configured to provide additional benefits, such as metal sorption or sediment capture.

Limitations

- Existing storm drain infrastructure may limit the types, size, and/or treatment capacity of some trash capture devices.
- Optimal device performance requires routine maintenance consistent with the manufacturer's specifications.
- Some devices have not been widely used or tested in the field, which could increase the risk for flooding or infrastructure issues.

Planning and Siting Considerations

- Land area and size of the upstream catchment area draining to the trash capture device.
- Dimensions and/or condition of the catch basin/vault where the device will be installed.
- The degree to which the proposed catch basin is connected to other catch basins.
- Other requirements such as permitting, construction, and utility clearance (especially for retrofits).
- Cost of construction and long-term maintenance.

Design Criteria

Principal design criteria for Trash Capture Devices are defined by the manufacturer. Refer to the list of certified and/or agency-approved devices that can be provided by the City or County and consult with the applicable manufacturer. In order for the Trash Capture Device to meet the requirements of the Statewide Trash Amendments (and thus, the City or County), the design of the device must conform with the following:

1. Trap trash particles that are 5 mm or greater and include a screen[17]
2. at the BMP inlet, overflow, or bypass outlet to trap these particles from either of the following BMP designs:
    a. A flow-based design for:
        i. the peak flow rates generated by the one-year, one-hour storm event (0.345 inches/hour) from the applicable subdrainage area; or
        ii. the trash treatment capacity equal to or greater than the corresponding storm drain's design flow rate; or
    b. A volume-based design that includes a trash treatment capacity that is equal to or greater than the volume generated from a one-year, one-hour storm event (0.345 inches).

[17] Upon approval by the Regional Water Quality Control Board Executive Officer, a 5mm screen will not be required if a) there is an external design feature or up-gradient structure designed to bypass flows exceeding the one-year, one-hour storm event (0.345 inch); or b) when the BMP's capacity exceeds flows generated by the one-year, one-hour storm event (0.345 inch).

3. Have a minimum treatment capacity for either of the flow rates described in 1.a. or b. above. The Rational Equation method may be used to calculate the peak flow rate for runoff from a small subdrainage area that is approximately 50 acres or less. The Rational Equation is expressed as Q = CiA, where:

   Q = design peak runoff rate, cfs,

   C = runoff coefficient, dimensionless,

   i = rainfall intensity 0.345 inches/hour, and

   A = subdrainage area, acres.

   Other calculation methods for drainage areas greater than 50 acres are allowed, provided a registered California-licensed professional engineer documents the calculations within the design plans.

4. The BMPs design plans must be stamped and signed by a registered California licensed professional civil engineer (see Bus. & Prof. Code Section 6702, et seq.).

   Vector breeding considerations must also be addressed in determining treatment controls because of the potential nuisance and human health effects.

   Trash controls shall be installed and maintained by the property owner for all storm drains, catch basins, or inlets that are located within the boundaries of the parcel and that are operated and maintained by the property owner. Trash controls shall only be installed in storm drains, catch basins, or inlets within the Public RoW if the City or County has agreed to enter into a maintenance agreement with the property owner (**Appendix D**).

Design Procedure

While the design procedure for a given project may vary, a general process for the design of Trash Capture Devices has been outlined below.

Step 1 – Evaluate maps and site location.

Evaluate the site location for stormwater infrastructure connectivity (i.e., storm drain lines, inlets, outfalls, and catchments) and identify the potential locations for the installation of a Trash Capture Device.

Step 2 – Delineate catchment drainage areas.

Conduct a GIS Desktop analysis or field visit to define the boundary of each stormwater catchment associated with a potential Trash Capture Device.

Step 3 – Identify appropriate Trash Capture Devices for catchment drainage areas.

Obtain the list of certified and/or agency-approved Trash Capture Devices from the City or County and identify the number and type of devices needed to treat the catchment drainage areas.

Step 4 – Conduct field evaluations/surveys to further identify site constraints and design criteria required by the manufacturer of the selected Trash Capture Device.

Using design criteria and specifications for the selected Trash Capture Devices, conduct a field evaluation to identify any potential site constraints and to obtain the design criteria specified.

Construction Considerations

- If a site is deemed to be technically infeasible for installation, the relocation of a Trash Capture Device upstream may be able to account for site-specific constraints.
- Trash Capture Devices shall be installed within the boundary of the project site location and not within the public right-of-way unless a prior agreement with the City or County has been reached.

Long-Term Maintenance

The City requires the execution of a maintenance agreement with the property owner prior to the final acceptance of a private development project, which includes treatment controls such as Trash Capture Devices. Such agreements will typically include requirements such as those outlined in **Table 6-41;** however, the requirements are expected to be specific to each device and based on the manufacturer’s recommendations.

The property owner or his/her designee is responsible for compliance with the agreement. The maintenance agreement and plan will provide the City or County designee with complete access to the device and its immediate vicinity at any time. Maintenance of the device is the sole responsibility of the owner. Sample agreements are presented in **Appendix D**. See **Appendix E** for additional Maintenance Plan requirements and suggested template.

Table 6-41. Example Inspection and Maintenance Requirements for Trash Capture Devices

Activity	Schedule
Cleaning devices	A minimum of once per seasonal cycle. Additional inspections after periods of heavy runoff are desirable.
Cleaning of inlet filters	A minimum of three times per seasonal cycle. Additional inspections after periods of heavy runoff are desirable.
Inspection and cleaning (applicable to all devices)	Follow manufacturers’ recommendations to ensure devices operate at desired effectiveness. Make necessary repairs in a timely manner.

7. CONTROL MEASURE MAINTENANCE

The continued effectiveness of control measures specified in this SWQCCP depends on diligent ongoing inspection and maintenance. To ensure that such maintenance is provided, the City and County require the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater control measures prior to final acceptance of a private development project, which may include one or more of the control measures detailed in **Sections 3,4, 5**, and **6**. The property owner or his/her designee is responsible for compliance with the agreement. Requirements for the maintenance plan and agreement are presented and discussed in this section. Sample agreements are presented in **Appendix D**.

7.1 MAINTENANCE PLAN

A post-construction Maintenance Plan shall be prepared and submitted to the City or County as part of the Project SWQCP submittal. The Maintenance Plan should include:

- Operation plan and schedule;
- Site map;
- Operations, maintenance and cleaning activities, including;
    a. A schedule;
    b. Equipment and resources required; and
    c. Responsible party(ies).

This section identifies the basic information that shall be included in a maintenance plan. Refer to Fact Sheets for individual control measures regarding device-specific maintenance requirements.

A. Site Map:

1. Provide a site map showing the boundaries of the site, acreage, and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.
2. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems, and grade breaks for purposes of pollution prevention.
3. With legend, show locations of expected sources of pollution generation (e.g., outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, and wash-racks). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
4. With legend, indicate types and locations of stormwater controls that will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

B. Baseline Descriptions:

1. List the property owners and persons responsible for the operation and maintenance of the stormwater control measures on-site. Include phone numbers and addresses.

2. Identify the intended method of providing financing for operation, inspection, routine maintenance, and upkeep of stormwater control measures.
3. List all permanent stormwater control measures. Provide a brief description of stormwater control measures selected and, if appropriate, facts sheets or additional information.
4. As appropriate for each stormwater control measure, provide:
   a. A written description and checklist of all maintenance and waste disposal activities that will be performed. Distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance. For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan shall address maintenance needs (e.g., pruning, irrigation, weeding) for a larger, more stable system. Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal/replacement, landscape features, or constructed wetland maintenance. These procedures shall provide enough detail for a person unfamiliar with maintenance to perform the activity or identify the specific skills or knowledge necessary to perform and document the maintenance.
   b. A description of site inspection procedures and documentation system, including record-keeping and retention requirements.
   c. An inspection and maintenance schedule, preferably in the form of a table or matrix, for each activity for all facility components. The schedule shall demonstrate how it will satisfy the specified level of performance and how the maintenance/inspection activities relate to storm events and seasonal issues.
   d. Identification of the equipment and materials required to perform the maintenance.

8. As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of treatment control measures.

C. Spill Plan (not required for PLU Only Projects):

1. Provide emergency notification procedures (phone and agency/persons to contact).
2. As appropriate for the site, provide emergency containment and cleaning procedures.
3. Note downstream receiving water bodies or wetlands which may be affected by spills or chronic untreated discharges.
4. As appropriate, create an emergency sampling procedure for spills. Emergency sampling can protect the property owner from erroneous liability for downstream receiving area clean-ups.

D. Facility Changes:

Operational or facility conditions or changes that significantly affect the character or quantity of pollutants discharging into the stormwater control measures may require modifications to the Maintenance Plan and/or additional stormwater controls.

E. Training:

1. Identify appropriate persons to be properly trained and ensure documentation of training.
2. Training to include:
   a. Good housekeeping procedures defined in the plan
   b. Proper maintenance of all pollution mitigation devices
   c. Identification and cleanup procedures for spills and overflows
   d. Large-scale spill or hazardous material response
   e. Safety concerns when maintaining devices and cleaning spills

F. Basic Inspection and Maintenance Activities:

1. Create and maintain an on-site log for inspector names, dates, and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.
2. Perform and document annual testing of any mechanical or electrical devices prior to wet weather.
3. Report any significant changes in stormwater controls to the site management. As appropriate, ensure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
4. Note any significant maintenance requirements due to spills or unexpected discharges.
5. As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to ensure stormwater controls are performing as designed and approved.
6. Assure *unauthorized* low-flow discharges from the property do not bypass stormwater controls (see the current municipal stormwater permit for a definition of Authorized Non-Stormwater Discharges).
7. Perform an annual assessment of each pollution-generating operation and its associated stormwater controls to determine if any part of the pollution reduction train can be improved.

G. **Revisions to Pollution Mitigation Measures:**

1. If future correction or modification of past stormwater controls or procedures is required, the owner shall obtain approval from the City or County prior to

commencing any work. Corrective measures or modifications shall not cause discharges to bypass or otherwise impede existing stormwater controls.

H. **Monitoring & Reporting Program**

1. The City or County may require a Monitoring & Reporting Program to ensure the stormwater controls approved for the site are performing according to design.
2. If required by the City or County, the Maintenance Plan shall include performance testing and reporting protocols specified by the City or County.

7.2 MAINTENANCE AGREEMENT

Verification of maintenance provisions is required for all structural controls specified in this Plan, whether Site Design Controls (see **Section 3**), Source Controls (see **Section 4**), VRMs (see **Section 5**), or Treatment Controls (see **Section 6**). Verification, at a minimum, shall include:

1. The owner/developer's signed statement accepts responsibility for inspection and maintenance until the responsibility is legally transferred. A sample Owners Certification statement is provided in **Appendix D**, <u>and</u> either
2. A signed statement from the public entity assuming responsibility for structural control measure inspection and maintenance and certifying that it meets all City or County design standards; <u>or</u>
3. Written conditions in the sales or lease agreement that require the recipient to assume responsibility for inspection and maintenance activities and to conduct a maintenance inspection at least once a year; <u>or</u>
4. Written text in project conditions, covenants, and restrictions for residential properties that assign maintenance responsibilities to the Homeowners Association for the inspection and maintenance of the structural controls; <u>or</u>
5. A legally enforceable maintenance agreement that assigns responsibility for the inspection and maintenance of post-construction structural controls to the owner/operator. A Maintenance Agreement with the City or County must be executed by the owner/operator before occupancy of the project is approved. Sample Maintenance Agreement forms are provided in **Appendix D**.

Appendices

A: Glossary of Key Terms and List of Acronyms

B: Volume Reduction Requirement Summary Worksheet

C: Volume Reduction Requirement Waiver Application

D: Maintenance Agreements and Forms

D-1: City of Stockton Stormwater Treatment Device Access and Maintenance Agreement Template

D-2 : Placeholder [Not Currently In Use]

D-3: SWQCP Owner's Certification Statement

D-4: County of San Joaquin Stormwater Treatment Device Access and Maintenance Agreement Template

E: SWQCP Submittal Guidance

E-1: Stormwater Quality Control Plan Guidance

E-2: Stormwater Quality Control Plan Template

E-3: Placeholder [Not in Use]

E-4: Placeholder [Not in Use

E-5: Placeholder [Not in Use]

E-6: Stormwater Maintenance Plan Guidance

E-7: Stormwater Maintenance Plan Template

E-8: Placeholder [Not in Use]

F: Hydrologic Soil Groups

G: Plants Suitable for Vegetative Control Measures

H: Standard Calculations for Diversion Structure Design

I: Approved Proprietary Control Measures

J: Example Calculation

K: References

APPENDIX A. GLOSSARY OF KEY TERMS AND LIST OF ACRONYMS

GLOSSARY OF TERMS

Automotive Repair Shop: a facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 5511, 7532-7534, or 7536- 7539.

Backfill: Earth or engineered material used to refill a trench or an excavation.

Berm: An earthen mound used to direct the flow of runoff around or through a structure.

Best Management Practices (BMPs): methods, measures, or practices designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and nonpoint source discharges including storm water. BMPs include structural and nonstructural controls, and operation and maintenance procedures, which can be applied before, during, and/or after pollution producing activities.

Buffer Strip or Zone: Strip of erosion-resistant vegetation over which stormwater runoff is directed.

Catch Basin (also known as Inlet or Drain Inlet): Box-like underground concrete structure with openings in curbs and gutters designed to collect runoff from streets and pavements.

Clean Water Act (CWA): (33 U.S.C. 1251 et seq.) requirement of the NPDES program are defined under Sections 301, 307, 402, 318 and 405 of the CWA.

Commercial Development: Any development on private land that is not heavy industrial or residential. The category includes, but is not limited to hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, car wash facilities, mini-malls, business complexes, shopping malls, hotels, office buildings, public warehouses, and light industrial complexes.

Conduit: Any channel or pipe for directing the flow of water.

Construction Activity: Includes clearing, grading, excavation, and contractor activities that result in soil disturbance.

Construction General Permit: A NPDES permit issued by the SWRCB for the discharge of stormwater associated with construction activity from soil disturbance of five (5) acres or more. Threshold lowered to one acre beginning October 10, 2003 (Construction General Permit No. CAS000002).

Conventional Treatment Controls: A subset of Treatment Controls that can be designed to treat the SQDV/SQDF. These controls typically do not reduce runoff volumes and cannot be used to help meet the Volume Reduction Requirement.

Conveyance System: Any channel or pipe for collecting and directing the stormwater.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Dead-end Sump: A below surface collection chamber for small drainage areas that is not connected to the public storm drainage system. Accumulated water in the chamber must be pumped and disposed in accordance with all applicable laws.

Denuded: Land stripped of vegetation or land that has had its vegetation worn down due to the impacts from the elements or humans.

Designated Public Access Points: Any pedestrian, bicycle, equestrian, or vehicular point of access to jurisdictional channels in the area subject to permit requirements.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of runoff at reduced peak flow rates. The capture and subsequent release of stormwater runoff from the site at a slower rate than it is collected the difference being held in temporary storage.

Development: Any construction, rehabilitation, redevelopment or reconstruction of any public or private residential project (whether single-family, multi-unit or planned unit development); industrial, commercial, retail and other non-residential projects, including public agency projects; or mass grading for future construction. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety.

Directly Adjacent: Situated within 200 feet of the contiguous zone required for the continued maintenance, function, and structural stability of an environmentally sensitive area.

Directly Connected Impervious Area (DCIA): The area covered by a building, impermeable pavement, and/or other impervious surfaces, which drains directly into the storm drain without first flowing across permeable land area (e.g. turf buffers, grass-lined channels).

Directly Discharging: Outflow from a drainage conveyance system that is composed entirely or predominantly of flows from the subject, property, development, subdivision, or industrial facility, and not commingled with the flows from adjacent lands.

Discharge of a Pollutant: any addition of any pollutant or combination of pollutants to waters of the United States from any point source or, any addition of any pollutant or combination of pollutants to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft which is being used as a means of transportation. The term discharge includes additions of pollutants into waters of the United States from: surface runoff which is collected or channeled by man; discharges through pipes, sewers, or other conveyances owned by a State, municipality, or other person which do not lead to a treatment works; and discharges through pipes, sewers, or other conveyances, leading into privately owned treatment works.

Disturbed Area: Area that is altered as a result of clearing, grading, and/or excavation.

Effluent Limits: Limitations on amounts of pollutants that may be contained in a discharge. Can be expressed in a number of ways including as a concentration, as a concentration over a time period (e.g., 30-day average must be less than 20 mg/L), or as a total mass per time unit, or as a narrative limit.

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 relating to farming, residential or industrial development, road building, or timber cutting.

Excavation: The process of removing earth, stone, or other materials, usually by digging.

Filter Fabric: Geotextile of relatively small mesh or pore size that is used to: (a) allow water to pass through while keeping sediment out (permeable); or (b) prevent both runoff and sediment from passing through (impermeable).

Full Capture System (FCS): A treatment control, or series of treatment controls, including but not limited to, a Multi-Benefit projects 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.

Grading: The cutting and/or filling of the land surface to a desired shape or elevation.

Hazardous Substance: (1) Any material that poses a threat to human health and/or the environment. Typical hazardous substances are toxic, corrosive, ignitable, explosive, or chemically reactive; (2) Any substance named by EPA to be reported if a designated quantity of the substance is spilled in the waters of the United States or if otherwise emitted into the environment.

Hazardous Waste: A waste or combination of wastes that, because of its quantity, concentration, or physical chemical, or infectious characteristics, may either cause or significantly contribute to an increase in mortality or an increase in serious irreversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. Possesses at least one of four characteristics (ignitability, corrosivity, reactivity, or toxicity) or appears on special EPA or state lists. Regulated under the federal Resource Conservation and Recovery Act and the California Health and Safety Code.

Hydromodification: The change in the natural watershed hydrologic processes and runoff characteristics (i.e., interception, infiltration, overland flow, interflow and groundwater flow) caused by urbanization or other land use changes that result in increased stream flows and sediment transport. In addition, alteration of stream and river channels, installation of dams and water impoundments, and excessive stream bank and shoreline erosion are also considered hydromodification, due to their disruption of natural watershed hydrologic processes.

Illicit Connection: Any man-made conveyance that is connected to the storm drain system without a permit, excluding roof drains and other similar type connections. Examples include channels, pipelines, conduits, inlets, or outlets that are connected directly to the storm drain system.

Illicit Discharge: Any discharge to the storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term “illicit discharge” includes all non storm-water discharges except discharges pursuant to a NPDES permit, discharges that are identified in Discharge Prohibitions of this Order, and discharges authorized by the Regional Board.

Impervious Surface/ Cover: A hard surface area that impede the natural infiltration of stormwater and causes water to runoff the surface in greater quantities or at an increased rate of flow from the flow present under pre-project conditions. Impervious surfaces include, but are not limited to, rooftops, walkways, patios, driveways, parking lots, roads or concrete and asphalt paving.

Industrial General Permit: A NPDES Permit (No. CAS000001) issued by the SWRCB for the discharge of Stormwater associated with industrial activity. Board Order 97-03-DWQ.

Infiltration: The downward entry of water into the surface of the soil.

Inlet: An entrance into a ditch, storm sewer, or other waterway.

Integrated Pest Management (IPM): An ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism.

Low Impact Development (LID): A stormwater management and land development strategy that emphasizes conservation and the use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely reflect pre-development hydrologic functions.

LID Treatment Controls: A subset of Treatment Controls that can be designed to treat the SQDV/SQDF and reduce runoff volumes. The runoff reduction achieved by these controls can be used to help meet the Volume Reduction Requirement.

Material Storage Areas: On site locations where raw materials, products, final products, by-products, or waste materials are stored.

Multi-Benefit Project: A treatment control project designed to achieve any of the benefits set forth in section 10562, subdivision (d) of the Water Code. Examples include projects designed to: infiltrate, recharge or store stormwater for beneficial reuse; develop or enhance habitat and open space through stormwater and non-stormwater management; and/or reduce stormwater and non-stormwater runoff volume.

Municipal Separate Storm Sewer System (MS4): a conveyance or system of conveyances (including roads with drainage systems, municipal streets, alleys, catch basins, curbs, gutters, ditches, manmade channels, or storm drains) owned by a State, city, county, town or other public body, that is designed or used for collecting or conveying storm water, which is not a combined sewer, and which is not part of a publicly owned treatment works, and which discharges to Waters of the United States.

National Pollutant Discharge Elimination System (NPDES): The national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under CWA §307, 402, 318, and 405.

New Development: Land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision.

Non-Stormwater Discharge: Any discharge to municipal separate storm drain that is not composed entirely of stormwater. Discharges containing process wastewater, non-contact cooling water, or sanitary wastewater are non-stormwater discharges.

Nonpoint Source Pollution: Pollution that does not come from a point source. Nonpoint source pollution originates from diffuse sources that are mostly related to land use.

Non-Structural Best Management Practice (BMP): Low technology procedures or management practices designed to prevent pollutants associated with site functions and activities from being discharged with stormwater runoff. Examples include reducing impervious cover, rain barrels, good housekeeping practices, employee training, standard operating practices, inventory control measures, etc.

Notice of Intent (NOI): A formal notice to SWRCB submitted by the owner/developer of an industrial or construction site that said owner seeks coverage under a General Permit for discharges associated with industrial and construction activities. The NOI provides information on the owner, location, type of project, and certifies that the owner will comply with the conditions of the construction General Permit.

Notice of Termination (NOT): Formal notice to the SWRCB submitted by owner/developer that a construction project is complete.

Outfall: The point where stormwater discharges from a pipe, channel, ditch, or other conveyance to a waterway. The end point where storm drains discharge water into a waterway.

Parking Lot: Land area or facility for the temporary parking or storage of motor vehicles used personally, for business or for commerce with an impervious surface area of 5,000 square feet or more, or with 25 or more parking spaces.

Permeability: A property of soil that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Point Source: Any discernible, confined, and discrete conveyance from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural stormwater runoff.

Pollutant: A substance introduced into the environment that adversely affects the usefulness of a resource.

Pollution Prevention (P2): Practices and actions that reduce or eliminate the generation of pollutants.

Post-project: The land use condition as a result of the proposed development activity.

Precipitation: Any form of rain or snow.

Pre-project: The existing land use condition prior to the proposed development activity.

Priority Land Uses (PLU): Those developed sites, facilities, or land uses (i.e., not simply zoned land uses) within the MS4 permittee's jurisdiction from which discharges of trash are regulated

1. High-density residential: all land uses with at least ten (10) developed dwelling units/acre.
2. Industrial: land uses where the primary activities on the developed parcels involve product manufacture, storage, or distribution (e.g., manufacturing businesses, warehouses, equipment storage lots, junkyards, wholesale businesses, distribution centers, or building material sales yards).
3. Commercial: land uses where the primary activities on the developed parcels involve the sale or transfer of goods or services to consumers (e.g., business or professional buildings, shops, restaurants, theaters, vehicle repair shops, etc.)
4. Mixed urban: land uses where high-density residential, industrial, and/or commercial land uses predominate collectively (i.e., are intermixed).
5. Public transportation stations: facilities or sites where public transit agencies' vehicles load or unload passengers or goods (e.g., bus stations and stops).

Receiving Stream: (for purposes of this Manual only) any natural or man-made surface water body that receives and conveys stormwater runoff.

Reclamation or Recycling (water reclamation or recycling): Planned use of treated effluent that would otherwise be discharged without being put to direct use.

Redevelopment (Significant): Significant redevelopment is defined as the *creation or addition of at least 5,000 square feet of impervious surfaces* on an already developed site. Significant redevelopment includes, but is not limited to, expansion of a building footprint or addition or replacement of a structure; structural development including an increase in gross floor area and/or exterior construction or remodeling; replacement of impervious surface that is not part of a routine maintenance activity; and land disturbing activities related with structural or impervious surfaces. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or emergency construction activities required to immediately protect public health and safety

Regional stormwater management facilities: A regional stormwater management facility is defined as a facility that provides detention of stormwater runoff typically for the entire upstream watershed.

Restaurant: means a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC Code 5812).

Retail Gasoline Outlet: Any facility engaged in selling gasoline and lubricating oils.

Retention: The storage of stormwater to prevent it from leaving the development site; may be temporary or permanent.

Runoff: Water originating from rainfall, melted snow, and other sources (e.g., sprinkler irrigation) that flows over the land surface to drainage facilities, rivers, streams, springs, seeps, ponds, lakes, wetlands, and shallow groundwater.

Run-on: Stormwater surface flow or another surface flow which enters property or area other than that where it originated. Off site stormwater surface flow or another surface flow which enters the site.

Scour: The erosive and digging action in a watercourse caused by flowing water.

Secondary Containment: Structures, usually dikes or berms, surrounding tanks or other storage containers and designed to catch spilled material from the storage containers.

Sedimentation: The process of depositing soil particles, clays, sands, or other sediments that were picked up by runoff.

Sediments: Soil, sand, and minerals washed from land into water, usually after rain, that accumulate in reservoirs, rivers, and harbors, destroying aquatic animal habitat and clouding the water such that adequate sunlight might not reach aquatic plants. Farming, mining, and building activities without proper implementation of BMPs will expose sediment materials, allowing them to be washed off the land after rainfalls.

Significant Materials: Includes, but not limited to, raw materials; fuels; materials such as solvents, detergents, and plastic pellets; finished materials such as metallic products; raw materials used in food processing or production; hazardous substances designed under Section 101(14) of CERCLA; any chemical the facility is required to report pursuant of Section 313 of Title III of SARA; fertilizers; pesticides; and waste products such as ashes, slag, and sludge that have the potential to be released with stormwater discharges.

Significant Quantities: The volume, concentrations, or mass of a pollutant in stormwater discharge that can cause or threaten to cause pollution, contamination, or nuisance that adversely impact human health or the environment and cause or contribute to a violation of any applicable water quality standards for receiving water.

Source Control BMPs: 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 contamination at the source of pollution.

Source Reduction (also Source Control): The technique of stopping and/or reducing pollutants at their point of generation so that they do not come into contact with stormwater.

Spill Guard: A device used to prevent spills of liquid materials from storage containers.

Spill Prevention Control and Countermeasures Plan (SPCC): Plan consisting of structures, such as curbing, and action plans to prevent and respond to spills of hazardous substances as defined in the CWA.

Storm Drains: Above- and below-ground structures for transporting stormwater to streams or outfalls for flood control purposes.

Storm Drain System: Network of above and below-ground structures for transporting stormwater to streams or outfalls.

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. Urban runoff and snowmelt runoff consisting only of those discharges, which originate from precipitation events. Stormwater is that portion of precipitation that flows across a surface to the storm drain system or receiving waters.

Stormwater Discharge Associated with Industrial Activity: Discharge from any conveyance which is used for collecting and conveying stormwater which is related to manufacturing processing or raw materials storage areas at an industrial plant [see 40 CFR 122.26(b)(14)].

Stormwater Pollution Prevention Plan (SWPPP): A written plant that documents the series of phases and activities that, first, characterizes your site, and then prompts you to select and carry out actions which prevent the pollution of stormwater discharges.

Structural BMP: Any structural facility designed and constructed to mitigate the adverse impacts of stormwater and urban runoff pollution (e.g. canopy, structural enclosure). The category may include both Treatment Control BMPs and Source Control BMPs.

Trash: All improperly discarded solid material from any production, manufacturing, or processing operation including, but not limited to, products, product packaging, or containers constructed of plastic, steel, aluminum, glass, paper, or other synthetic or natural materials.

Trash Amendments: *Amendment to the Water Quality Control Plan for Ocean Waters of California to Control Trash* and *Part 1 Trash Provision of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries* they are collectively referred to as "the Trash Amendments". The State Water Quality Control Board adopted these on April 7, 2015.

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 settling, media adsorption, biodegradation, biological uptake, chemical oxidation and ultraviolet radiation.

Treatment Controls: Any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process. Treatment Controls, for the purposes of this Plan have been divided into two types: LID Treatment Controls and Conventional Treatment Controls.

Treatment Controls (Trash Amendments): Structural best management practices to either

a) remove pollutants and/or solids from STORM WATER runoff, wastewater, or effluent, or

b) capture, infiltrate or reuse stormwater runoff, wastewater, or effluent.

Treatment controls include full capture systems and low impact development controls.

Toxicity: Adverse responses of organisms to chemicals or physical agents ranging from mortality to physiological responses such as impaired reproduction or growth anomalies.

Turbidity: Describes the ability of light to pass through water. The cloudy appearance of water caused by suspended and colloidal matter (particles).

Volume Reduction Measures: BMPs that can be used to direct, retain, reuse and/or infiltrate stormwater runoff (e.g., rain gardens and rain barrels**).**

Volume Reduction Requirement: New Development Priority Projects must reduce post-project runoff volume to pre-project runoff volumes for the 0.51” rainfall event (~85th percentile) using a combination of Volume Reduction Measures and LID Treatment Controls.

LIST OF ACRONYMS

ASTM	American Society for Testing Materials
BMPs	Best Management Practices
CASQA	California Stormwater Quality Association
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act (Federal Water Pollution Control Act of 1972 as amended in 1987)
DOE	Department of Ecology
ESC	Erosion and Sediment Control
FAR	Floor to Area Ratio
FCS	Trash Full Capture System
IPM	Integrated Pest Management
LID	Low Impact Development
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
O&G	Oil and Grease
O&M	Operations and Maintenance
ODS	Owners, developers, and/or successors-in-interest
PCC	Portland Cement Concrete
PLU	Priority Land Use
PPF	Porous Pavement Filter
SIC	Standard Industrial Classification
SQDF	Stormwater Quality Design Flow
SQDV	Stormwater Quality Design Volume
SUA	Stockton Urbanized Area
SWPPP	Stormwater Pollution Prevention Plan
SWQCCP	Stormwater Quality Control Criteria Plan
SWQCP	Stormwater Quality Control Plan
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
VRM	Volume Reduction Measures
VRR	Volume Reduction Requirement

APPENDIX B. VOLUME REDUCTION REQUIREMENT SUMMARY WORKSHEET

Project: ______________________________ **Detail:** ______________________________ **Design by:** ______________________________ **Date:** ______________________________	
1. Project Drainage Area Characteristics: Pre-project a. Weighted Runoff Coefficient (C_{rPRE}) b. Total Drainage Area (A_{PRE}) c. Pre-project Runoff Volume (Vol_{PRE})* $Vol_{PRE} = (0.51/12) \times A_{PRE} \times C_{rPRE}$	C_{rPRE} = ____________ A_{PRE} = _____________ ft^2 Vol_{PRE}= ____________ ft^3
2. Project Drainage Area Characteristics: Post-project a. Weighted Runoff Coefficient (C_{ra}) b. Total Drainage Area (A_{POST}) c. Post-project Runoff Volume (Vol_{POST}) $Vol_{POST} = (0.51/12) \times A_{POST} \times C_{ra}$ d. Volume Reduction Requirement* **VRR = Vol_{POST} – Vol_{PRE}**	C_{ra} = _____________ A_{POST} = ___________ ft^2 Vol_{POST}= __________ ft^3 **VRR = ____________ ft^3**
3. Volume Reduction Measures: Total number of VRMs in project Total Volume Reduction Credits from VRMs ($\sum Vol_{VRM}$) Total Tributary Impervious Area Reduction Credits for application to effective area calculation ($\sum Area_{credit}$) Remaining Volume Reduction required from LID Treatment Controls (VRR_{TREAT}) $VRR_{TREAT} = VRR - \sum Vol_{VRM}$	No. VRMs = __________ $\sum Vol_{VRM}$ = ___________ ft^3 $\sum Area_{credit}$ = _________ ft^2 **VRR_{TREAT} = ___________ ft^3**
4. LID Treatment Controls – Volume Reduction Credits Total Volume Reduction Credits from LID Treatment Controls ($\sum Vol_{TREAT}$) Total Volume Reduction Provided ($VRR_{PROVIDED}$) $VRR_{PROVIDED} = \sum Vol_{VRM}$ (line 3b) + $\sum Vol_{TREAT}$ (line 4a) Volume Reduction remaining (VRR_{REMAIN}) $VRR_{REMAIN} = VRR - VRR_{PROVIDED}$	$\sum Vol_{TREAT}$ = __________ ft^3 $VRR_{PROVIDED}$ = _________ ft^3 **VRR_{REMAIN} = _________ ft^3**

*Apply reductions to VRR as appropriate for Significant Redevelopment in Section 5

APPENDIX C. VOLUME REDUCTION REQUIREMENT WAIVER APPLICATION

A waiver may be granted if the VRR cannot be met due to site constraints, as described in **Section 5.2**. However, even if the project cannot meet the full VRR, the project must still reduce volume to the MEP. The burden of proof is on the project applicant to demonstrate that it is technically infeasible to meet the VRR. Economic hardship is not an acceptable reason for noncompliance. In general, the City and County do not expect to grant waivers for the VRR.

Meeting the VRR is an iterative process. Designers should return to prior steps to explore alternative combinations of VRM and LID Treatment Controls. Projects that cannot fully meet the VRR must select Treatment Controls with a medium to high removal efficiency for the pollutant of concern (see **Tables 2-1 and 6-2**).

The final determination will be made by City of Stockton Municipal Utilities Department, Stormwater Division or the San Joaquin County Department of Public Works. The City and County have the authority to reject a VRR Waiver request if VRM and/or LID Treatment Controls are considered feasible at the project site.

Consideration of a waiver request requires applicants to:

- Reduce volume to the MEP, even if the full VRR cannot be met.
- Consider all of the VRM and LID Treatment Controls. Applicants must show why certain VRM and/or LID Treatment Controls are not feasible at the development site.
- Demonstrate that site conditions warrant technical infeasibility, as described in **Section 5**.
- Submit this application with or prior to preliminary site plan submission.
- Obtain the signature and stamp of the project engineer registered in California.
- Submit the Volume Reduction Design Summary Worksheet (**Appendix B**) along with this application.

An example application that may be used for projects within the City is provided below. For projects within the County, the same information must be provided as a part of the application package.

Volume Reduction Requirement Waiver Application

Property Owner/Developer Information:

Name of Business:______________________________

Contact Person:______________________________

Street: ______________________________

City:______________State:_______Zip:_________

Phone Number:______________________________

Email Address:______________________________

Mailing Address: ____________________________

City:______________ State:_______Zip:___________

Plan Preparer Information:

Name of Business: ____________________________

Contact Person:______________________________

Street: ______________________________

City:______________State:_______Zip:_________

Phone Number:______________________________

Email Address:______________________________

Mailing Address: ____________________________

City:______________________________

State:_________Zip:____________

Project Name:____

Project Category (**check all that apply** – see Section 2.1 of the Stormwater Quality Control Criteria Plan for project definitions):

A) **Priority Land Use Projects -** ☐ **High Density Residential** ☐ **Industrial** ☐ **Commercial** ☐ **Mixed Urban** ☐ **Public Transportation Station**

B) **Priority Projects -** ☐ **Residential Subdivision** ☐ **Commercial/Industrial** ☐ **Parking Lot** ☐ **Significant Redevelopment**

Property Description (include location, size, land uses, etc.):

____

____

Volume Reduction Requirement ________ *(Volume Reduction Summary Worksheet, line 2e)*

Volume Reduction Provided ________ *(Volume Reduction Summary Worksheet, line 4b)*

Volume Reduction Remaining ________ *(Volume Reduction Summary Worksheet, line 4c)*

Type and Number of LID Treatments Proposed:	
☐ *Bioretention (L-1)*	☐ *Porous Pavement Filter (L-6)*
☐ *Stormwater Planter (L-2)*	☐ *Vegetated (Dry) Swale (L-7))*
☐ *Tree-well Filter (L-3)*	☐ *Grassy Swale (L-8)*
☐ *Infiltration Basin (L-4)*	☐ *Grassy Filter Strip (L-9)*
☐ *Infiltration Trench (L-5)*	

Type and Number of Volume Reduction Proposed:	
☐ *Rain Garden (V-1)*	☐ *Grassy Channel (V-4)*
☐ *Rain Barrel/Cistern (V-2)*	☐ *Vegetated Buffer Strip (V-5)*
☐ *Interception Trees (V-3)*	

Describe Why a Volume Reduction Requirement Waiver is Needed
*(please include specifics on site conditions that warrant technical infeasibility, see **Section 5 of SWQCCP**) attach any supporting documentation:*

____
____
____
____

Describe Alternative Compliance Design

Under all such designs, the portion of the volume that cannot be reliably retained on-site (Volume Reduction Summary Worksheet, line 4c) must be treated and temporarily held on site and released into the City or County stormwater network once the storm event passed: see ***Section 5 of SWQCCP.*** *Attach any supporting documentation:*

____
____
____
____

APPLICATION FEE PER CURRENT CITY OF STOCKTON FEE STRUCTURE

CERTIFICATION

I hereby certify that the information provided in this Application is correct

Application Prepared By: ____

Print Name and Firm

Signed: ____

Signature of Project Engineer in the Firm Named Above

Title: ____

Affix professional registration stamp of the person named above with signature and expiration date

APPENDIX D. MAINTENANCE AGREEMENTS AND FORMS

This appendix includes the following maintenance agreements and forms:

D-1: City of Stockton Stormwater Treatment Device Access and Maintenance Agreement Template

D-2: Placeholder [Not currently in use]

D-3: SWQCP Owner's Certification Statement

D-4: County of San Joaquin Stormwater Treatment Device Access and Maintenance Agreement

Appendix D-1: City Of Stockton Stormwater Treatment Device Access And Maintenance Agreement Template

INSTRUCTIONS TO COMPLETE

STORMWATER TREATMENT DEVICE ACCESS

AND MAINTENANCE AGREEMENT

Please complete the following:

1. Complete the Stormwater Treatment Device Access and Maintenance Agreement (Agreement) with the owner(s) name, mailing address, contact person and phone, property address, and assessor parcel number. Enter the date and owner(s) names in the first paragraph. A copy of the Deed must be attached as the last page to verify the ownership and legal description. Complete the **Owner Acknowledgment** on and have it notarized.

2. Return one original signed copy of the Agreement to the Municipal Utilities Department, 2500 Navy Drive, Stockton, CA 95206. A recording fee check payable to the San Joaquin County Recorder must be submitted with signed agreement upon filing with the City. Check with City staff on the current fee schedule. City staff will record the executed Agreement at the office of the San Joaquin County Recorder.

3. The City will provide one fully executed copy of Agreement to the Owner for his/her record.

Should you have questions or require other assistance regarding this matter, please contact the Permit Center at (209) 937-8704.

STORMWATER TREATMENT DEVICE
ACCESS AND MAINTENANCE AGREEMENT

After recorded, return to:
Stormwater Division
Municipal Utilities
Department City of Stockton
2500 Navy Drive
Stockton, CA 95206

MUNICIPAL UTILITIES DEPARTMENT
After Recording Transmit Copy to:

___ Owner of Record
___ Municipal Utilities Department
____City Clerk (Original)

OWNER NAME (S) ______________________________
(as shown on deed) &
MAILING ADDRESS ______________________________

O&M CONTACT ______________________________
PERSON & PHONE #
____

FACILITY NAME ______________________________
AND ADDRESS
____

ASSESSOR PARCEL NO. ______________________________

THIS AGREEMENT is made and entered into in Stockton, California, this ______________ day of ___________________, by and between _____________________________________.hereinafter referred to as "Owner" and the CITY OF STOCKTON, a municipal corporation, located in the County of San Joaquin, State of California hereinafter referred to as "CITY,"

WHEREAS, the Owner owns real property ("Property") in the City of Stockton, County of San Joaquin, State of California, depicted in Exhibit “A” and intends to install a pollution control system described in Exhibit “B”, both of which are attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of development project known as ____ within the Property described herein, the City required the project to employ on-site control measures to minimize pollutants in urban runoff;

WHEREAS, the Owner has chosen to install a___________________________________, hereinafter referred to as "Device," as the onsite control measure to minimize pollutants in urban runoff;

WHEREAS, said Device has been installed in accordance with the requirements of the City of Stockton Stormwater Quality Control Criteria Plan and the Owner's plans and specifications accepted by the City;

WHEREAS, said Device, with installation on private property and draining only private property, is a private facility with all operation, maintenance and replacement; therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the Owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1. Owner hereby provides the City or City's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City's Director of Municipal Utilities with no advance notice, for the purpose of inspection, sampling, testing of the Device, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. The Owner/Operator shall retain all operation and maintenance records at the facility for City inspection, and a copy shall be provided to the City if requested. City shall make every effort at all times to minimize or avoid interference with Owner's use of the Property.

2. Owner shall use its best efforts to diligently maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. When requested from time to time by the City, the Owner shall provide the City with documentation identifying the material(s) removed, the quantity, and disposal destination.

3. In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City, the City is hereby authorized to cause any maintenance necessary to be done and charge the

entire cost and expense to the Owner or Owner's successors or assigns, including administrative costs, attorney's fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full, and Owner hereby agrees to pay such charge within 30 days of receipt of City's written demand for payment.

4. The City may require the owner to post security in form and for a time period satisfactory to the City of guarantee the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respects to the property on which a Device has been installed until such time as Owner repays to City its reasonable costs incurred in accordance with paragraph 3 above.

5. This agreement shall be recorded in the Office of the Recorder of San Joaquin County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City, including interest as herein above set forth, subject to foreclosure in event of default in payment.

6. In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

8. The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City at the same time such notice is provided to the successor.

9. Time is of the essence in the performance of this Agreement.

10. Any notice or demand for payment to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to addresses listed on Page 1 of this agreement either for the Owner or City. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

CITY OF STOCKTON, a
Municipal Corporation

ATTEST: APPROVED AS TO FORM:

By ____
HARRY BLACK
CITY MANAGER

OFFICE OF THE CITY ATTORNEY

By__________________________________
Deputy City Attorney

____
NAME OF PROPERTY OWNER

By ____
PROPERTY OWNER

Name ______________________________________

Title _______________________________________

CITY ACKNOWLEDGMENT

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

STATE OF CALIFORNIA
COUNTY OF SAN JOAQUIN _____________________________

On ____________________________before me, ____
(Insert Name and Title of Officer)

personally appeared ____,
who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

____________________________________ **(Seal)**
Signature of Notary

OWNER ACKNOWLEDGMENT

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

STATE OF CALIFORNIA
COUNTY OF ________________________________)

On __________________________before me, ____
(Insert Name and Title of Officer)

personally appeared ____,
who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

________________________________ **(Seal)**
Signature of Notary

OWNER ACKNOWLEDGMENT

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

STATE OF CALIFORNIA
COUNTY OF ________________________________)

On __________________________before me, ____
(Insert Name and Title of Officer)

personally appeared ____,
who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

________________________________ **(Seal)**
Signature of Notary

EXHIBIT A

(Deed Copy)

<u>EXHIBIT B</u>

(Operation & Maintenance Plan)

Appendix D-2: [Not in Use]

Appendix D-3: SWQCP Owner's Certification Statement

OWNER'S CERTIFICATION

STOMWATER QUALITY CONTROL PLAN

for

(PROJECT NAME)

This Project Stormwater Quality Control Plan (Plan) was prepared for ____(Project Owner / Developer)_ by __________(Name of Preparing Firm/Individual)_______. This Plan is intended to comply with all requirements specified in the City of Stockton and County of San Joaquin Stormwater Quality Control Criteria Plan (SWQCCP) for new development and redevelopment projects.

The undersigned understands that stormwater pollution control measures are enforceable requirements under the SWQCCP. The undersigned, while owning the property on which such control measures are to be implemented, is responsible for the implementation of the provisions of this Plan and for the maintenance of all structural stormwater pollution control measures and agrees to ensure that the conditions on the project site conform to the requirements specified in the SWQCCP.

Once the undersigned transfers its interest in the project property, its successors-in-interest shall bear the aforementioned responsibility to maintain structural stormwater pollution control measures and to implement and amend this Plan.

Name of Owner ____

Address of Owner____

____

Phone Number of Owner____

Signature ____________________________________

Print Name ____________________________________

Title ____________________________________

Date ____________________________________

Appendix D-4: County of San Joaquin Stormwater Treatment Device Access and Maintenance Agreement Template

INSTRUCTIONS TO COMPLETE

STORMWATER TREATMENT DEVICE ACCESS
AND MAINTENANCE AGREEMENT

Please complete the following:

1. Complete the Stormwater Treatment Device Access and Maintenance Agreement (Agreement) with the owner(s) name, mailing address, property address, and assessor parcel number. Enter the date and owners names in the first paragraph. A copy of the Deed must be attached as the last page to verify the ownership and legal description. Complete the **owner acknowledgment** on page 5, and have it notarized.

2. Return one original signed copy of the Agreement to the Public Works Department, 1810 E. Hazelton Avenue, Stockton, CA 95201. A recording fee check payable to the San Joaquin County Recorder must be submitted with signed agreement upon filing with the County. County staff will record the executed Agreement at the office of the San Joaquin County Recorder.

3. The County will provide one fully-executed copy of Agreement to the Owner for his/her record.

Stormwater Treatment Device
Access and Maintenance
Agreement

After recorded, return to:
San Joaquin County
Public Works Department
1810 E. Hazelton Avenue
Stockton, CA 95201

PUBLIC WORKS DEPARTMENT

After Recording Transmit Copy to:

___ Owner of Record
___ Public Works Department
____City Clerk (Original)

OWNER NAME (S) ______________________________
(as shown on deed)
____

MAILING ADDRESS ______________________________
____

FACILITY NAME ______________________________
AND ADDRESS
____

ASSESSOR PARCEL NO. ______________________________

THIS AGREEMENT is made and entered into in ____________________________________, California,

this ____ day of __________________, by and between____

hereinafter referred to as "Owner" and COUNTY OF SAN JOAQUIN, a political subdivision of the State of California, located in the County of San Joaquin, State of California hereinafter referred to as "COUNTY";

WHEREAS, the Owner owns real property ("Property") in San Joaquin County, State of California, depicted in Exhibits A and B, which are attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of development project known as

____

____ within the Property described herein, the County required the project to employ on-site control measures to minimize pollutants in urban runoff;

WHEREAS, the Owner has chosen to install a , hereinafter referred to as "Device", as the on-site control measure to minimize pollutants in urban runoff;

WHEREAS, said Device has been installed in accordance with the requirements of the San Joaquin County Stormwater Quality Control Criteria Plan and the Owner's plans and specifications accepted by the County;

WHEREAS, said Device, with installation on private property and draining only private property, is a private facility with all operation, maintenance and replacement, therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the Owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1. Owner hereby provides the County or County's designee complete access, of any duration, to the Device and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by County's Director of Public Works with no advance notice, for the purpose of inspection, sampling, testing of the Device, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner's expense as provided in paragraph 3 below. The Owner/Operator shall retain all operation and maintenance records at the facility for County inspection and a copy shall be provided to the County if requested. County shall make every effort at all times to minimize or avoid interference with Owner's use of the Property.

2. Owner shall use its best efforts to diligently maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's

representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. When requested from time to time by the County, the Owner shall provide the County with documentation identifying the material(s) removed, the quantity, and disposal destination.

3. Owner is solely responsible for the initial and continued performance of said Device as approved by the County, including but not limited to, continued operation, maintenance, repair and replacement of said Device in accordance with the terms of this Agreement.

4. In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the County, the County is hereby authorized to cause any maintenance necessary to be done and charge the entire cost and expense to the Owner or Owner's successors or assigns, including administrative costs, attorneys fees and interest thereon at the maximum rate authorized by the Civil Code from the date of the notice of expense until paid in full, and Owner hereby agrees to pay such charge within 30 days of receipt of County’s written demand for payment.

5. The County may require the owner to post security in form and for a time period satisfactory to the County of guarantee the performance of the obligations stated herein. Should the Owner fail to perform the obligations under the Agreement, the County may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, and require the sureties to perform the obligations of the Agreement. As an additional remedy, the Director may withdraw any previous stormwater related approval with respects to the property on which a Device has been installed until such time as Owner repays to County its reasonable costs incurred in accordance with paragraph 3 above.

6. This agreement shall be recorded in the Office of the Recorder of San Joaquin County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the County, including interest as herein above set forth, subject to foreclosure in event of default in payment.

7. In event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the County in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

8. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien there against.

9. The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the County at the same time such notice is provided to the successor.

10. Time is of the essence in the performance of this Agreement.

11. Any notice or demand for payment to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to addresses listed on Page 1 of this agreement either for the Owner or County. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

SAN JOAQUIN COUNTY:

____
Name:
Title: Director of Public Works

Attest:

____
Date

OWNER:

Name: ________________________________

Title: ________________________________

OWNER:

Name: ________________________________

Title: ________________________________

OWNER:

Name: ________________________________

Title: ________________________________

OWNER:

Name: ________________________________

Title: ________________________________

APPROVED AS TO FORM:

____
Name:

Deputy County Counsel

<u>EXHIBIT A</u>

(Operation & Maintenance Plan)

<u>EXHIBIT B</u>

(Deed Copy)

APPENDIX E. SWQCP SUBMITTAL GUIDANCE

This appendix includes the following templates and forms:

E-1: Stormwater Quality Control Plan Guidance

E-2: Stormwater Quality Control Plan Template

E-3: Placeholder [Not in Use]

E-4: Placeholder [Not in Use]

E-6: Stormwater Maintenance Plan Guidance

E-7: Stormwater Maintenance Plan Template

E-8: Placeholder [Not in Use]

APPENDIX E-1: STORMWATER QUALITY CONTROL PLAN GUIDANCE

This appendix identifies the information that shall be included in a Project Stormwater Quality Control Plan (SWQCP) (the Template provided in Appendix E-2 shall be used for this submittal).

I. Cover Page

- Project Name, address, and Assessor's Parcel Number (APN)
- Property Owner/Developer's name and contact information
- Plan Preparer's name and contact information
- Dates submitted and revised (first and subsequent submittals, as needed)
- Date completed

II. Owner's Certification

III. Project Description

1. Project Category – type of project (Priority Land Use Project and/or Priority Project) and associated pollutant categories of concern (select all that apply see **Section 2.1**)
2. Project Information – location (lattitude, longitude), project and drainage area, receiving water(s), topography, depth to groundwater, etc.
3. Project Narrative – narrative description about the proposed project including the size, location, land uses, expected pollutant-generating activities, and any other pertinent information
4. Site maps
    a. Provide a vicinity map showing the location of the project relative to principal landmarks.

    b. Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site.

    c. Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.

    d. With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.

    e. With legend, indicate types and locations of structural stormwater control measures that will be built to permanently control stormwater pollution.

IV. Stormwater Pollution Control Measures

1. Summary matrix of each type of control measure provided.
2. Site Design Controls
    a. Describe each Site Design Control (G-1 through G-4) that will be utilized and how each conforms to design criteria.
    b. If a Site Design Control is not applicable to the project, provide a statement of justification describing why the control measure is not applicable.
    c. If implementation of an applicable Site Design Control is not feasible due to project site conditions, provide a statement of justification describing why implementation is not feasible.
3. Source Controls
    a. Describe each Source Control (S-1 thorugh S-7) that will be utilized (Note: Source Control S-1 is required for all projects) and how each conforms to the design criteria.
4. Volume Reduction Measures
    a. Describe each Volume Reduction Measure (VRM) that will be utilized.
    b. Use the summary sheet in **Appendix B** to track conformance with the VRR.
    c. If implementation of VRMs is not feasible and/or the VRR cannot be met, use the Waiver Application in **Appendix C** to justify why implementation is not feasible. All VRMs must be taken into consideration.
5. Treatment Controls
    a. Describe each Treatment Control measure to be provided, include trash control measures, where applicable.
    b. If the VRR was not fully met through the use of VRMs, LID Treatment Controls must be used. The summary sheet in Appendix B should be used to continue tracking conformance with the VRR. If implementation of VRMs is not feasible and/or the VRR cannot be met, use the Waiver Application in Appendix C to justify why implementation is not feasible. All VRMs must be taken into consideration.
    c. Summarize design data for treatment control measures on appropriate design procedure forms (see **Appendix I** for forms). Provide detailed supporting calculations for design data values in a clear and organized manner.

V. Maintenance Plan and Responsibility

1. Provide a summary of the structural control measures to be provided and responsible parties responsible for maintenance of each control.
2. Provide complete contact information for each identified responsible party.

3. Indicate any anticipated transfer of responsibility due to future transfer of ownership or annexation.
4. Provide a statement that a detailed Maintenance Plan will be prepared in accordance with SWQCCP requirements (see **Appendix E-6** for guidance).

APPENDIX E-2: STORMWATER QUALITY CONTROL PLAN TEMPLATE

The worksheets are available on the City and County websites and are required for submittal as part of the *2020 Stormwater Quality Control Criteria Plan* (SWQCCP).

APPENDIX E-3: PLACEHOLDER [NOT IN USE]

APPENDIX E-4: PLACEHOLDER [NOT IN USE]

APPENDIX E-5: PLACEHOLDER [NOT IN USE]

APPENDIX E-6: STORMWATER MAINTENANCE PLAN GUIDANCE

This appendix identifies the information that shall be included in a maintenance plan (the Template provided in Appendix E-7 shall be used for this submittal). Refer to the Fact Sheets for individual control measure and device-specific maintenance requirements.

I. Cover Page

- Project Name, address, and Assessor's Parcel Number (APN)
- Property Owner/Developer's name and contact information
- Operations and Maintenance name and contact information

II. Baseline Descriptions (as applicable)

- List responsible parties for operation and maintenance of the stormwater control measures on site and associated contact information.
- Identify the intended method of providing financing for operation, inspection, routine maintenance, and upkeep of stormwater control measures.
- Provide a description of the types of activities that will take place at this site.
- List all permanent stormwater control measures.

III. Routine Maintenance - As appropriate for each stormwater control measure provide the following:

- List and describe all maintenance and waste disposal activities that will be performed and distinguish between the maintenance appropriate for a 2-year establishment period and expected long-term maintenance.

For example, maintenance requirements for vegetation in a constructed wetland may be more intensive during the first few years until the vegetation is established. The post-establishment maintenance plan shall address maintenance needs (e.g. pruning, irrigation, weeding) for a larger, more stable system.

Include maintenance performance procedures for facility components that require relatively unique maintenance knowledge, such as specific plant removal/replacement, landscape features, or constructed wetland maintenance. These procedures shall provide enough detail for a person unfamiliar with maintenance to perform the activity or identify the specific skills or knowledge necessary to perform and document the maintenance.

- Identification of the equipment and materials required to perform the maintenance.
- Parties responsible for the O&M plan and number of years for which records will be retained.

As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain. Identify housekeeping BMPs that reduce maintenance of treatment control measures.

IV. Training

- Identify persons to be trained and ensure that the training occurs.

- Training shall include:
    d. Good housekeeping procedures defined in the plan.
    e. Proper maintenance of all pollution mitigation devices.
    f. Identification and cleanup procedures for spills and overflows.
    g. Large-scale spill or hazardous material response.
    h. Safety concerns when maintaining devices and cleaning spills.

V. Inspections - Use the maintenance log provided in Appendix E-7 to record the various maintenance activities that are conducted onsite.

- Perform annual testing of any mechanical or electrical devices prior to wet weather.
- Report any significant changes in stormwater control measures to the site management. As appropriate, assure mechanical devices are working properly and/or landscaped BMP plantings are irrigated and nurtured to promote thick growth.
- Note any significant maintenance requirements due to spills or unexpected discharges.
- As appropriate, perform maintenance and replacement as scheduled and as needed in a timely manner to assure stormwater control measures are performing as designed and approved.
- Assure *unauthorized* low-flow discharges from the property do not by-pass stormwater control measures.
- Perform an annual assessment of each pollution generation operation and its associated stormwater control measures to determine if any part of the pollution reduction train can be improved.
- For trash controls, regular maintenance is required to maintain adequate trash capture capacity and ensure that trapped trash does not migrate offsite. The owner should establish a maintenance schedule based on site-specific factors, including the size of the detention BMP, storm frequency, and estimated or measured trash loading area.

VI. Additional Information

Spill Plan

- Provide a spill plan and include spill plan documents as an appendix, if applicable.
    i. Provide emergency notification procedures (phone and agency/persons to contact).
    j. As appropriate for site, provide emergency containment and cleaning procedures.

Facility Changes

- Operational or facility changes which significantly affect the character or quantity of pollutants discharging into the stormwater control measures will require modifications to the Maintenance Plan and/or additional stormwater control measures.

Revisions to Pollution Mitigation Measures

- If future correction or modification of pass stormwater control measures or procedures is required, the owner shall obtain approval from the governing stormwater agency prior to commencing any work. Corrective measures or modifications shall not cause discharges to by-pass or otherwise impede existing stormwater control measures.

Monitoring & Reporting Program

- The governing stormwater agency may require a Monitoring & Reporting Program to assure the stormwater control measures approved for the site are performing according to design.
- If required by local agency, the Maintenance Plan shall include performance testing and reporting protocols.

Site Map

- Provide a site map showing boundaries of the site, acreage and drainage patterns/contour lines. Show each discharge location from the site and any drainage flowing onto the site. Distinguish between soft and hard surfaces on the map.
- Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems and grade-breaks for purposes of pollution prevention.
- With legend, show locations of expected sources of pollution generation (outdoor work and storage areas, heavy traffic areas, delivery areas, trash enclosures, fueling areas, industrial clarifiers, wash-racks, etc.). Identify any areas having contaminated soil or where toxins are stored or have been stored/disposed of in the past.
- With legend, indicate types and locations of stormwater control measures that will be built to permanently control stormwater pollution. Distinguish between pollution prevention, treatment, sewer diversion, and containment devices.

APPENDIX E-7: STORMWATER MAINTENANCE PLAN TEMPLATE

The worksheets are available on the City and County websites and are required for submittal as part of the *2020 Stormwater Quality Control Criteria Plan* (SWQCCP).

APPENDIX E-8: PLACEHOLDER [NOT IN USE]

APPENDIX F. HYDROLOGIC SOIL GROUPS

This appendix includes information on the Hydrologic Soil Groups in San Joaquin County to use in designing various stormwater control measures:

Relevance of Hydrologic Soil Groups Information

The hydrologic soil groups of a development area are pertinent to design of controls that involve infiltration and for identifying sites appropriate for detention basins. The predominant soil group will control the effectiveness of infiltration facilities or the suitability of an area for impounding water. Hydrologic soil group information should be used for preliminary siting studies only. Actual design should be based on in-situ soil investigations and testing by a qualified engineer or geologist.

Table F-1. Typical Infiltration Rates

Soil Type (Hydrologic Soil Group)	Infiltration Rate *(in/hr)*
A	1.00 – 8.3
B	0.5 – 1.00
C	0.17 – 0.27
D	0.02 – 0.10

Infiltration rates shown represent the range covered by multiple sources, e.g. ASCE, BASMAA, etc.

Hydrologic Soil Groups

The hydrologic soil groups are classified by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service. There are four hydrologic soil groups: A, B, C and D. Soils may be classified by two groups. Soil groups A and B have the highest infiltration rates, unless the soils under consideration have been compacted during construction. Soil groups A and B are typically the best candidate soils for construction of infiltration facilities. Sites with soil groups C and D are usually more appropriate for detention basins.

Soils in group A have a low runoff potential and high infiltration rate, as the soils typically are sands and gravel. Soil group B includes soils with moderate infiltration rates when completely wetted. Group B soils are sandy loam soils with moderately fine to moderately coarse textures. Soils in group C have slow infiltration rates when thoroughly wetted and these soils typically are silty-loam soils with an impeding layer or soils with moderately fine to fine texture. Group D soils have a high runoff potential and very slow infiltration rate when thoroughly wetted. Group D soils include clay soils with high swelling potential, soils in a permanently high water table and shallow soils over nearly impervious material.

The hydrologic soil information presented here should be used as a general overview. For more specific information, consult the *San Joaquin County Soil Survey* (USDA, NRCS) or contact the NRCS at (530) 662-3986.

APPENDIX G. PLANTS SUITABLE FOR VEGETATIVE CONTROL MEASURES

Vegetation serves primarily to maintain soil porosity and prevent erosion. The effectiveness and aesthetic appeal of control measures are enhanced by selection of appropriate vegetative cover. Turf grass is preferred, and some other ground covers also may be appropriate. An important maintenance consideration in the selection of appropriate vegetation is whether irrigation is planned for the site. Consult with City stormwater staff regarding selection of appropriate vegetation.

Table G-1 provides a sample list of appropriate vegetative covers. Additional suggested vegetative species are listed in **Table G-2 and G-3.**[18]

The tables are intended as guides in selecting vegetative covers. For specific species suitability and care information, refer to the sources listed for these tables.

Table G-1. Sample List of Appropriate Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Maintenance and Usage Notes*
Bermuda Grass (Cynodon)	Santa Ana hybrid Common	Moderate maintenance. Dormant (brown) in winter. Heat tolerant. Erosion control, swales.
Fescue (Festuca)	Red fescue (F. rubra)	Low to moderate maintenance. Tolerates some shade and poor soil. Lawns, swales, erosion control.
	"Kentucky 31" Tall Fescue (F. elatior)	Low maintenance. Tolerate shade and compacted soils. Rapid germination. Lawns, swales, erosion control. Useful as overseed for Bermuda grass during dormant (winter) season.
Ryegrass (Lolium)	Perennial (L. perenne)	Moderate maintenance. Heat intolerant. Fast sprouting. Useful as overseed for Bermuda grass during dormant (winter) season. Swales.
	Annual (L. multiflorum)	Annual (may live several seasons in mild climate). Moderate maintenance. Heat intolerant. Fast growing. Useful as overseed for winter-dormant species. Swales.

*Generally, these species will require supplemental irrigation.
Sources: ASCE, MWCG, Sunset

[18] California Native Plant Society https://calscape.org/loc-37.9176,-121.171%20(san%20joaquin%20county)/cat-all-plants/ord-popular

Table G-2. Additional Suggested Vegetative Covers

Plant Name Common (Latin)	Appropriate Species	Usage Notes
Orchard grass (Dactylis)	"Akaroa" or "Berber" (D. glomerata)	Irrigated and Non-irrigated Sites
Wheatgrass (Agropyron)	"Luna" or "Topar" pubescent (A. intermedium trichophorum)	Irrigated and Non-irrigated Sites
Zorro Fescue (Vulpia)	(V. myuros)	Irrigated and Non-irrigated Sites
Creeping wild Rye (Leymus)	(L. triticoides)	Nonirrigated Sites
Brome (Bromus)	Blando (B. mollis)	Nonirrigated Sites
	California or "Cucamonga" (B. carinatus)	Nonirrigated Sites

Sources: NRCS-FOTG. Manual of Standards for Erosion and Sediment Control Measures, Association of Bay Area Governments, 1995.

Table G-3. San Joaquin County Native Plant List (obtained from the California Native Plant Society)

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Ferns										
Azolla filiculoides	Mosquito Fern	2.4 in					X			
Marsilea vestita	Hairy Waterclover	1.1 ft					X			
Marsilea vestita ssp. vestita	Hairy Waterclover	1.1 ft					X			
Pilularia americana	American Pillwort									
Grasses										
Agrostis exarata	Spike Bentgrass	1 - 3.3 ft					X	X		
Alopecurus saccatus	Pacific Foxtail	1.5 ft								
Bolboschoenus maritimus	Alkali Bulrush	3 ft				X	X			E
Carex barbarae	Valley Sedge	1.6 - 3.3 ft			X	X		X		E
Cyperus eragrostis	Tall Flatsedge	3 ft				X	X			E
Cyperus erythrorhizos	Red Rooted Cyperus	2.5 - 3.3 ft					X			
Deschampsia danthonioides	Annual Hair Grass	1.3 - 2 ft								
Distichlis spicata	Saltgrass	1.1 - 1.6 ft				X	X			
Echinochloa muricata	Rough Barnyard Grass	2.5 - 5 ft								
Eleocharis macrostachya	Common Spikerush	1.6 - 3.3 ft				X	X			E
Elymus multisetus	Big Squirreltail	2 ft		X			X			
Eragrostis hypnoides	Creeping Love Grass	4 in								
Eragrostis mexicana	Mexican Lovegrass									
Eragrostis mexicana ssp. virescens	Chilean Love Grass									
Eragrostis pectinacea	Tufted Lovegrass	0.33 - 2.6 ft								
Eragrostis pectinacea var. pectinacea	Carolina Love Grass									
Eriochloa acuminata	Tapertip Cupgrass									
Festuca microstachys	Pacific Fescue	2.5 ft		X			X			
Hordeum brachyantherum	Meadow Barley	2 - 3.3 ft			X	X	X			D
Hordeum brachyantherum ssp. brachyantherum	Meadow Barley	3 ft			X	X		X		
Hordeum depressum	Low Barley	1.8 ft				X	X			
Juncus acuminatus	Taper Tip Rush	1.5 - 3 ft					X			
Juncus balticus	Baltic Rush	3 ft				X		X		E
Juncus bufonius	Toad Rush	1 ft				X	X			
Juncus effusus	Soft Rush	4.9 - 6.6 ft				X		X		E

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Juncus oxymeris	Pointed Rush	2 ft				X	X	X		
Juncus xiphioides	Irisleaf Rush	1 - 3 ft				X		X		E
Leersia oryzoides	Rice Cutgrass	3.3 - 5 ft					X			
Melica californica	California Melicgrass	1 - 4.3 ft		X			X	X		
Panicum capillare	Witch Grass	3.3 ft								
Paspalum distichum	Knotgrass	0.9 - 2 ft					X			
Grasses (continued)										
Phalaris lemmonii	Lemmon's Canary Grass	2.5 - 4.9 ft								
Phragmites australis	Common Reed	6.6 - 19.7 ft					X			
Poa secunda	One Sided Blue Grass	1.4 - 3.3 ft			X					
Poa secunda ssp. secunda	Pine Bluegrass	3.3 ft						X		
Schoenoplectus acutus	Hardstem Bulrush	3 - 10 ft				X	X			E
Schoenoplectus acutus var. occidentalis	Tule	13 ft					X			
Perennial Herbs										
Alisma triviale	Water Plantain	1 ft					X	X		
Allium serra	Jeweled Onion			X			X			
Anemopsis californica	Yerba Mansa	0.33 - 1 ft				X	X	X		D
Apocynum cannabinum	Indianhemp Dogbane	3.3 - 6.6 ft				X		X		
Artemisia douglasiana	Douglas' Sagewort	8 ft			X	X	X	X	X	D
Asclepias fascicularis	Narrow Leaf Milkweed	1.7 - 3.3 ft			X	X	X			D
Asclepias vestita	Woolly Milkweed									
Astragalus asymmetricus	San Joaquin Milk Vetch	1.6 - 3.9 ft					X	X		
Astragalus douglasii	Douglas' Milkvetch	0.7 - 3.3 ft								
Baccharis glutinosa	Saltmarsh Baccharis	3.3 - 7 ft				X		X		
Bacopa eisenii	Gila River Water Hyssop									
Brodiaea terrestris	Dwarf Brodiaea	8.4 in					X	X		
Brodiaea terrestris ssp. terrestris	Dwarf Brodiaea	8.4 in					X	X		
Callitriche marginata [a]	Winged Water Starwort									
Ceratophyllum demersum	Hornwort	3.3 - 9.8 ft								
Chenopodium californicum	California Goosefoot	0.7 - 3.3 ft								
Clematis ligusticifolia [h]	Virgin's Bower	1 - 30 ft			X			X	X	D
Cressa truxillensis	Alkali Weed	9.8 in			X		X			

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Cucurbita foetidissima [a]	Missouri Gourd	1 ft		X	X		X			
Damasonium californicum	Fringed Water-plantain	1.5 ft								
Datura wrightii	Toluaca	1 - 5 ft			X		X	X		
Delphinium hesperium	Western Larkspur	1.6 - 3.3 ft					X	X		
Delphinium parryi	San Bernardino Larkspur	2 - 4 ft					X	X		
Delphinium parryi ssp. parryi	Parry's Larkspur	0.5 - 3.5 ft					X	X		
Delphinium recurvatum	Byron Larkspur	1.6 - 2.8 ft					X			
Dipterostemon capitatus	Blue Dicks	1.5 - 2 ft			X		X			D
Epilobium ciliatum	Northern Willow Herb	1.6 - 6 ft			X	X	X			
Epilobium ciliatum ssp. ciliatum	Fringed Willowherb	6 ft					X			
Erigeron foliosus	Leafy Fleabane	0.7 - 3.3 ft						X		
Erigeron foliosus var. foliosus [e]	Leafy Fleabane									
Eryngium castrense	Great Valley Coyote-thistle	1.6 ft								
Eryngium racemosum [a]	Delta Button-celery									
Eryngium vaseyi	Coyotethistle									
Erysimum capitatum [a]	Sanddune Wallflower							X		
Erythranthe guttata [a]	Seep Monkey Flower	2 - 5 ft				X	X	X		D
Eschscholzia californica [a]	California Poppy	0.16 - 2 ft		X	X		X			D
Euthamia occidentalis	Western Goldentop	3.5 - 7 ft				X	X			
Frankenia salina	Alkali Heath	1 ft				X	X			D
Glycyrrhiza lepidota	Wild Licorice	1.3 - 4 ft				X	X			
Grindelia camporum	Great Valley Gumweed	2 - 6.6 ft		X			X			D
Gutierrezia californica [b]	California Matchweed	1 - 2 ft		X			X			D
Helenium puberulum	Sneezeweed	5 ft				X	X			
Heliotropium curassavicum	Seaside Heliotrope	1.2 - 1.6 ft				X	X			
Heliotropium curassavicum var. oculatum	Seaside Heliotrope	0.33 - 2 ft								
Heterotheca sessiliflora [a]	False Goldenaster	2 - 4 ft		X			X	X		
Heterotheca sessiliflora ssp. echioides	Bristly Goldenaster	4 ft					X	X		
Lasthenia fremontii [a]	Fremont's Goldfields	1.2 ft								
Lathyrus jepsonii	Jepson's Pea	6.6 ft					X	X	X	
Lathyrus jepsonii var. californicus	California Pea	8.2 ft					X	X		

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Lemna minor	Duckweed						X			
Lepidium acutidens [a]	Alkali Pepperwort									
Lomatium utriculatum	Common Lomatium	1.6 ft					X	X		
Lupinus bicolor [a]	Miniature Lupine	0.26 - 1.3 ft			X		X			
Lupinus formosus	Summer Lupine	0.7 - 2.6 ft		X			X			
Lycopus americanus	American Water Horehound	0.7 - 1.8 ft						X		
Lythrum californicum	Common Loosestrife	0.7 - 2 ft						X		
Malvella leprosa	Alkali Mallow	0.33 - 1.3 ft			X		X			
Mentha canadensis	American Cornmint	0.33 - 1.5 ft					X			
Nitrophila occidentalis	Boraxweed	1 ft								
Oenanthe sarmentosa	Pacific Oenanthe	5 ft					X			
Oenothera deltoides [a]	Dune Primrose	0.33 - 3.3 ft	X	X			X			
Oenothera deltoides ssp. Cognata [a]	Birdcage Evening Primrose									
Oenothera elata	Hooker's Evening Primrose	5 ft			X		X	X		
Oenothera elata ssp. hirsutissima	Hairy Evening Primrose					X	X			
Persicaria amphibia	Swamp Knotweed	7.9 - 1.2 in						X		D
Persicaria hydropiperoides	Water Pepper	1 - 3.3 ft					X			D
Persicaria punctata	Water Smartweed	0.49 - 3.3 ft					X			D
Phyla lanceolata	Lanceleaf Fogfruit	1.2 in								
Phyla nodiflora	Common Lippia	2.4 - 6 in					X			
Pluchea odorata [a]	Marsh Fleabane	2 - 4 ft				X	X			
Pluchea odorata var. odorata [a]	Saltmarsh-fleabane	4.9 ft								
Potamogeton foliosus	Leafy Pondweed	2.5 ft								
Potamogeton illinoensis	Shining Pondweed									
Primula clevelandii	Padre's Shootingstar	0.5 - 1 ft			X		X	X		D
Primula clevelandii var. patula	Shooting Star						X			
Pseudognaphalium stramineum	Chilean Cudweed	2.3 ft						X		
Ranunculus californicus	California Buttercup	0.6 - 2.3 ft			X	X	X	X		D
Rorippa curvisiliqua [a]	Curvepod Yellowcress	1 ft								
Rorippa palustris [a]	Bog Yellowcress	3.3 ft								
Rumex salicifolius	Willow Dock	1 - 3 ft				X	X	X		
Sagittaria latifolia	Wappato	0.7 - 4.9 ft					X			

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Sagittaria montevidensis										
Sagittaria montevidensis ssp. calycina										
Sagittaria sanfordii	Sanford's Arrowhead	4.3 ft								
Sesuvium verrucosum	Western Sea-purslane									
Solanum americanum [b]	American Black Nightshade	2.6 - 4.9 ft				X	X			
Spergularia macrotheca	Large Flowered Sand Spurry						X			
Spergularia macrotheca var. leucantha										
Stachys ajugoides	Ajuga Hedge Nettle	0.33 - 1 ft					X			
Stachys albens	White Hedge Nettle	1.6 - 8 ft				X		X	X	E
Suaeda nigra	Bush Seepweed	3 - 4.9 ft				X	X			E
Symphyotrichum lentum	Suisun Marsh Aster	1.3 - 4.9 ft								
Symphyotrichum spathulatum	Western Mountain Aster	1.5 ft					X			
Symphyotrichum subulatum var. parviflorum										
Triteleia hyacinthina	White Brodiaea	1.3 - 2 ft				X	X			D
Triteleia laxa	Ithuriel's Spear	2 ft			X		X	X	X	D
Typha angustifolia	Narrowleaf Cattail	5 ft					X			D
Typha domingensis	Southern Cattail	13 ft				X	X			
Typha latifolia	Broadleaf Cattail	1 - 5 ft				X	X			D
Urtica dioica	Common Nettle									
Urtica dioica ssp. holosericea	Hoary Nettle									
Utricularia gibba	Humped Bladderwort									
Utricularia macrorhiza	Common Bladderwort						X			
Shrubs										
Allenrolfea occidentalis	Iodine Bush	1 - 7 ft					X			
Atriplex lentiformis	Big Saltbush	3.3 - 10 ft			X		X			E
Baccharis pilularis	Coyote Bush	1.5 - 10 ft		X	X		X	X		E
Baccharis salicifolia	Mulefat	6 - 12 ft			X		X			E/D
Cephalanthus occidentalis	California Buttonbush	3 - 20 ft				X	X			D
Ericameria linearifolia	Linear Leaved Goldenbush	5 ft		X			X			
Erigeron foliosus var. foliosus [e]	Leafy Fleabane									
Eriodictyon californicum	California Yerba Santa	3.3 - 9.8 ft		X			X	X		E

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Eriogonum nudum	Nude Buckwheat	0.5 - 1 ft	X	X			X			D
Gutierrezia californica [b]	California Matchweed	1 - 2 ft		X			X			D
Lupinus albifrons	Silver Lupine	3.2 - 5 ft		X			X			E
Quercus wislizeni [f]	Interior Live Oak	15 - 50 ft		X	X		X	X		E
Rosa californica	California Wildrose	8 - 10 ft			X	X	X	X	X	D
Rubus ursinus [g]	Pacific Blackberry	2 - 6 ft				X	X	X	X	D
Salix exigua [f]	Sandbar Willow	10 - 23 ft				X	X			D
Salix exigua var. hindsiana [f]	Sandbar Willow	16.4 ft						X		D
Salix lasiandra [f]	Shining Willow	3 - 30 ft				X		X		D
Salix lasiandra var. lasiandra [f]	Yellow Willow	33 - 53 ft						X		D
Salix lasiolepis [f]	Arroyo Willow	7 - 35 ft				X	X			D
Sambucus nigra [f]	Black Elderberry	13.1 - 30 ft			X					D
Sambucus nigra ssp. Caerulea [f]	Blue Elderberry	20 - 30 ft			X		X	X	X	D
Solanum americanum [b]	American Black Nightshade	2.6 - 4.9 ft				X	X			
Solanum umbelliferum	Bluewitch Nightshade	3.3 ft		X			X	X		D
Toxicodendron diversilobum [g]	Poisonoak	1.6 - 13 ft			X		X	X		D
Vitis californica [g]	California Grape	10 - 40 ft			X	X	X	X		D
Succulents										
Crassula aquatica [c]	Water Pygmyweed									
Crassula connata [c]	Pygmy-weed	0.8 - 4 in								
Leptosyne stillmanii [c]	Stillman's Coreopsis	0.16 - 1 ft					X			
Acer negundo	Box Elder	35 - 66 ft				X	X	X		D
Aesculus californica	California Buckeye	13.1 - 39.4 ft		X	X		X	X		D
Alnus rhombifolia	White Alder	49.2 - 82 ft				X	X	X		D
Fraxinus latifolia	Oregon Ash	35 - 82 ft			X	X	X	X		D
Juglans hindsii	Northern California Black Walnut	60 ft			X	X	X			
Populus fremontii	Fremont Cottonwood	39.4 - 114.8 ft				X	X			D
Populus fremontii ssp. fremontii	Fremont Cottonwood	66 ft					X			
Quercus lobata	Valley Oak	60 - 100 ft			X		X			D
Sambucus nigra [f]	Black Elderberry	13.1 - 30 ft			X					D
Sambucus nigra ssp. Caerulea [f]	Blue Elderberry	20 - 30 ft			X		X	X	X	D
Salix exigua [f]	Sandbar Willow	10 - 23 ft				X	X			D

Botanical Name	Common Name	Height	Water Requirement				Sun Requirement			Deciduous/ Evergreen
			Extremely Low	Very Low	Low	Moderate - High	Full Sun	Part Shade	Shade	
Salix exigua var. hindsiana [f]	Sandbar Willow	16.4 ft						X		D
Salix gooddingii	Gooding's Black Willow	15 - 40 ft				X	X			D
Salix laevigata	Red Willow	30 - 50 ft				X	X	X		D
Salix lasiandra [f]	Shining Willow	3 - 30 ft				X		X		D
Salix lasiandra var. lasiandra [f]	Yellow Willow	33 - 53 ft						X		D
Salix lasiolepis [f]	Arroyo Willow	7 - 35 ft				X	X			D
Quercus wislizeni [f]	Interior Live Oak	15 - 50 ft		X	X		X	X		E
Vines										
Clematis ligusticifolia [h]	Virgin's Bower	1 - 30 ft			X			X	X	D
Cuscuta californica [d]	Chaparral Dodder									
Cuscuta campestris [d]	Field Dodder									
Cuscuta subinclusa [d]	Canyon Dodder									
Rubus ursinus [g]	Pacific Blackberry	2 - 6 ft				X	X	X	X	D
Toxicodendron diversilobum [g]	Poisonoak	1.6 - 13 ft			X		X	X		D
Vicia hassei [d]	Slender Vetch	0.7 - 2.3 ft								
Vitis californica [g]	California Grape	10 - 40 ft			X	X	X	X		D

Reference: California Native Plant Society website https://calscape.org/loc-37.9176,-121.171%20(san%20joaquin%20county)/cat-all-plants/ord-popular

Annual herb, Perennial herb

Annual herb, Perennial herb, Shrub

Annual herb, Succulent

Annual herb, Vine

Perennial herb, Shrub

Shrub, Tree

Shrub, Vine

Vine, Perennial herb

APPENDIX H. STANDARD CALCULATIONS FOR DIVERSION STRUCTURE DESIGN

Introduction

Stormwater runoff in excess of the water quality flow or volume is to be diverted around or through the treatment control measure. The following paragraphs provide equations and design criteria necessary to design diversion structures to divert runoff in excess of the SQDV or SDQF around or through the treatment control measures.

Diversion Structure Design

Capture or isolation of the SQDV is typically achieved by employing one of the following techniques:

- Divert the SQDV into the treatment control measure from the on-site storm drain system using weirs or orifices at or upstream of the point of entrance to the treatment control measure.
- Bypassing flows in excess of the SQDV within the treatment control measure using weirs and pipes for channel or pipe storm drain systems or routing excessive flows through a vegetated swale.

By employing diversion techniques, the water quality flow or volume is treated and discharged to the storm drain system and runoff that exceeds the water quality flow or volume is diverted or bypassed, untreated, directly to the downstream storm drain system.

Equations and criteria to design a diversion structure are provided below. Alternative designs may be considered subject to approval.

All diversion structures are designed using the on-site storm design event. The drainage design storm is established by the governing agency and is not the same as the SQDF or SQDV. The drainage design storm is used to design the conveyance system, i.e. pipes, swales, etc. of the site without regard for treatment. The design engineer must ensure sufficient head room in the on-site system above the diversion to accommodate overflows.

Diverting Flows at the Inlet or Upstream of the Treatment Control Device

Diverting flow at the inlet to the treatment control is the more common approach to divert excess runoff. **Figure H-1** illustrates the more commonly used diversion structures. The height of the weir to divert the flow is determined as follows:

<u>Treatment Control Measures Designed Based on the SQDV</u>

1. Determine the SQDV (see **Section 6**)

2. Utilizing design techniques provided in the treatment control measure fact sheets, determine the maximum height of the water level in the treatment control measure when the entire SQDV is being held,

3. Set the height of the diversion weir to the maximum height of the water level.

4. Determine weir dimensions needed to divert peak flows of the drainage design storm using the following equation for a rectangular sharp-crested weir

Q_d = C xL x $h^{1.5}$ *eqn H-1*

Where: Q_d = Peak flow rate for drainage design storm, cfs

L = Effective length of weir, ft

C = Weir discharge coefficient

h = Depth of the flow above the crest of the weir, ft

The discharge coefficient "C" accounts for many factors, such as velocity of approach, in the weir equation. The height of the weir (H) and the height of the flow over the weir (h) are two characteristics of the sharp-crested weir that affect the value of C. **Table H-1** can be used to approximate C for rectangular sharp-crested weirs without end contractions.

5. Provide sufficient head room in the treatment control to accommodate depth of flow over the weir.

Table H-1. Weir Discharge Coefficient (C) for Rectangular Sharp-crested Weirs Without End Contractions[1]

H/h	Head (h) over weir, ft						
	0.2	**0.4**	**0.6**	**0.8**	**1.0**	**2.0**	**5.0**
0.5	4.18	4.13	4.12	4.11	4.11	4.10	4.10
1.0	3.75	3.71	3.69	3.68	3.68	3.67	3.67
2.0	3.53	3.49	3.48	3.47	3.46	3.46	3.45
10.0	3.36	3.32	3.30	3.30	3.29	3.29	3.28
∞	3.32	3.28	3.26	3.26	3.25	3.25	3.24

1. From Lindsay and Franzini (1979)

<u>Treatment Control Measures Designed Based on the SQDF</u>

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm

2. Determine the SQDF (see **Section 6**)

3. Determine the depth of flow in the on-site drainage system when carrying the SQDF using Manning's equation (eqn H-2)

eqn H-2

Where: SQDF = Water Quality Flow, cfs

n = Manning's roughness coefficient

A = Cross sectional area of drainage pipe or channel, ft^2

R = Hydraulic radius, ft

S = Slope of pipe or channel, ft/ft

4. Using nomographs or computer programs, determine the depth of flow at SQDF. Set the weir height at this depth.

5. Using Equation H-1, establish weir dimensions. Provide sufficient head room in treatment control to accommodate flows over the weir.

Bypassing Excess Flows within the Treatment Control Measure

For certain site conditions, bypassing runoff in excess of the SQDV must be achieved in the treatment control measure. When this occurs, the control measure must be designed to ensure the bypass system can be accommodated in the unit, i.e. sufficient depth, width and length to accommodate pipes, length of weirs, etc. The following discusses design considerations for the different treatment control measures.

Bypassing Flows through Infiltration and Sedimentation/Filtration Treatment Control Measures

Weirs, orifices or pipes in treatment control measures are used to bypass runoff in excessive of the SQDV and SQDF. Design of these measures is similar to the approach described above under diverting flows at the inlet to the treatment control measure. Bypass for filtration devices occurs in the sedimentation chamber.

Weirs

Weirs are commonly used to bypass excess storm events. Determining the height of the weir is based on the maximum water elevation in a treatment control device when holding the entire SQDV. To design the weir, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV.

Orifices

Orifices can be considered in place of weirs or pipes. To avoid drawing floatables into the bypass, a hooded orifice (see **Figure H-2**) should be designed using the equation H-3:

$Q_d = C \times A \times (2gh)^{0.5}$ *eqn H-3*

Where:

Q_d	=	Peak flow rate for drainage design storm, cfs
C	=	Orifice discharge coefficient, (use 0.6)
A	=	Area of orifice, ft^2
h	=	Depth of the water above midpoint of orifice, ft
g	=	32.2 ft/sec^2

Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

Determining the elevation of the orifice is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. Use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to establish the elevation of the mid-point of the orifice opening.

The size of the orifice is determined by using Equation H-3 for the orifice to bypass the peak flow of the on-site storm.

Ensure sufficient head room in the treatment unit to accommodate flows through orifice.

Pipes

Pipes can also be employed to bypass excess runoff. Determining the invert elevation of the bypass inlet is based on determining the maximum water elevation in a treatment control device when holding the entire SQDV. To do this, use the procedures established under Diversion Structures for Treatment Control Measures Designed Using the SQDV to design a diversion weir.

For filtration control measures, a hooded inlet using a 90° elbow should be considered at the inlet to the bypass pipe to prevent drawing floatables into the bypass (see **Figure H-2**). Hoods should extend into one-third of the permanent pool depth or one-foot whichever is greater. Commercial catch basin traps can be used in lieu of a hood.

For infiltration control measures (see **Figure H-3**) bypass pipes are perforated and wrapped with filter fabric to avoid drawing sediment and small particles into the bypass pipe. Hoods are not necessary for these overflow pipes.

Bypass pipes are sized using the Manning's equation (eqn H-4) using the peak flow of the drainage design storm and assuming they are flowing full. Under these conditions, Manning's equation reduces to:

eqn H-4

Where: D = Diameter of pipe, ft

Q_d = Peak flow rate for drainage design storm, cfs

n = Manning's coefficient for pipe material

s = Slope of pipe, ft/ft (0.5% minimum required)

Provide sufficient head room in the treatment control to accommodate flows.

<u>Routing Excess Runoff Through a Vegetated Swale</u>

The depth of flow in a Vegetated Swale at SQDF is determined using a roughness coefficient of 0.2. If additional flows beyond the SQDF are to be directed to the vegetated swale, the roughness coefficient for these flows will be lower (approximately 0.03), because the flows exceeding the SQDF do not flow through the swale and are only influenced by surface friction/roughness. Swales with distinctly different roughness coefficients can be designed using an equivalent roughness coefficient that is determined based on the roughness associated with the wetted perimeters (P). For most on-site Vegetated Swale designs, there will be two different "n" values. An equivalent "n_e" value can be determined using equation H-5:

eqn H-5

An iterative approach is used to develop an equivalent "n_e", that can be calculated with most computer hydraulic program applications:

1. Estimate an equivalent roughness coefficient (estimated “n_e”);

2. Use the estimated roughness coefficient to determine the depth of flow using trial and error solution of Equation H-2 substituting the peak flow of the drainage design storm for the SQDF;

3. Use the calculated depth to determine the wetted perimeter for the drainage system;

4. Use the wetted perimeter associated with each “n” for the drainage system and using Equation H-5 to calculate the equivalent roughness coefficient (calculated “n_e”), and compare to the estimated “n_e”; and

5. Continue the process until the calculated “n_e” equals the estimated “n_e”. This value is the equivalent roughness coefficient and used to design the Vegetated Swale according to recommendations provided in Fact Sheet L-7.

Note - This approach results in conservative n values. High flows in the swale may cause some vegetation to bend resulting in a lower n_1 and lower equivalent “n_e”.

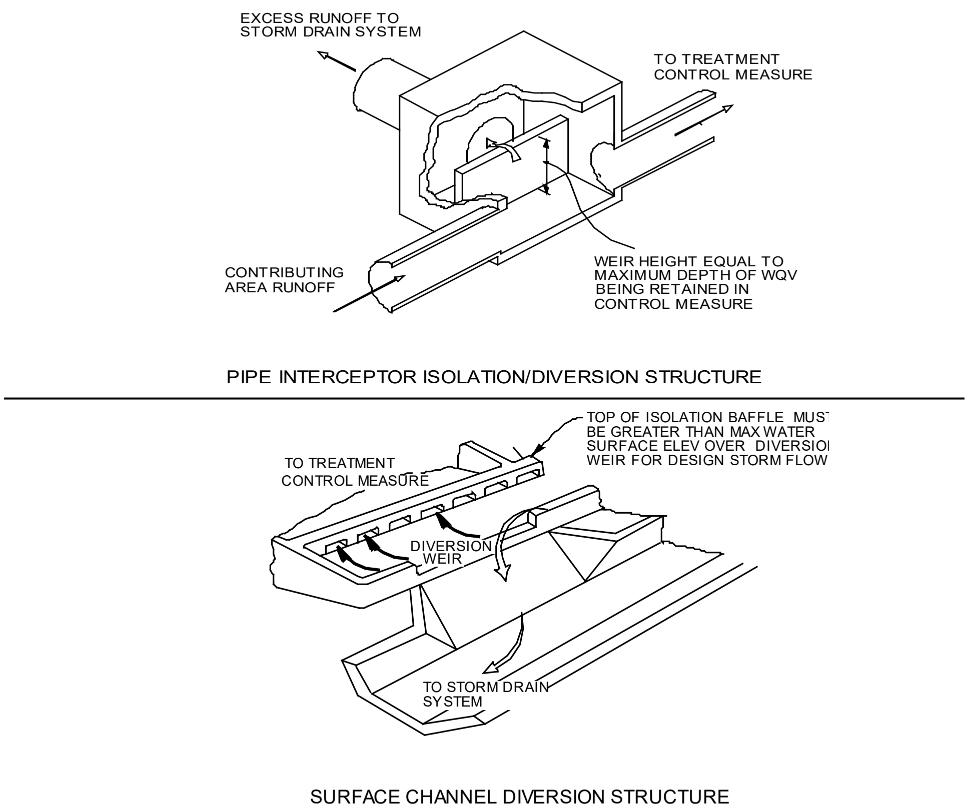


Figure H-1. Common Diversion Structures at Inlets
North Tennessee Water Quality BMP Manual Design and Maintenance of Structural BMPs. (2008). (tech.).

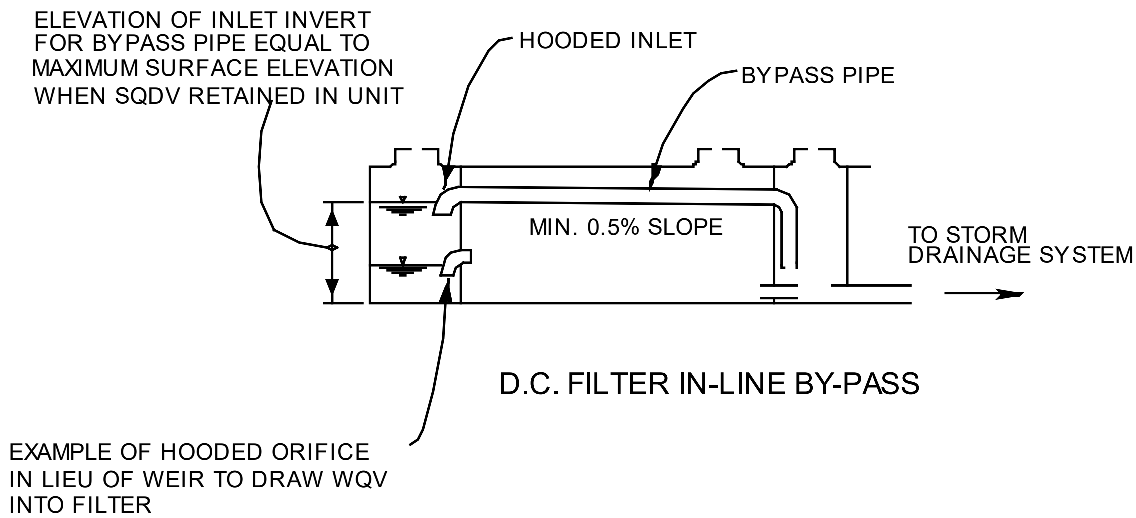


Figure H-2. Illustration of Pipe Bypass in Infiltration Trench

North Tennessee Water Quality BMP Manual Design and Maintenance of Structural BMPs. (2008). (tech).

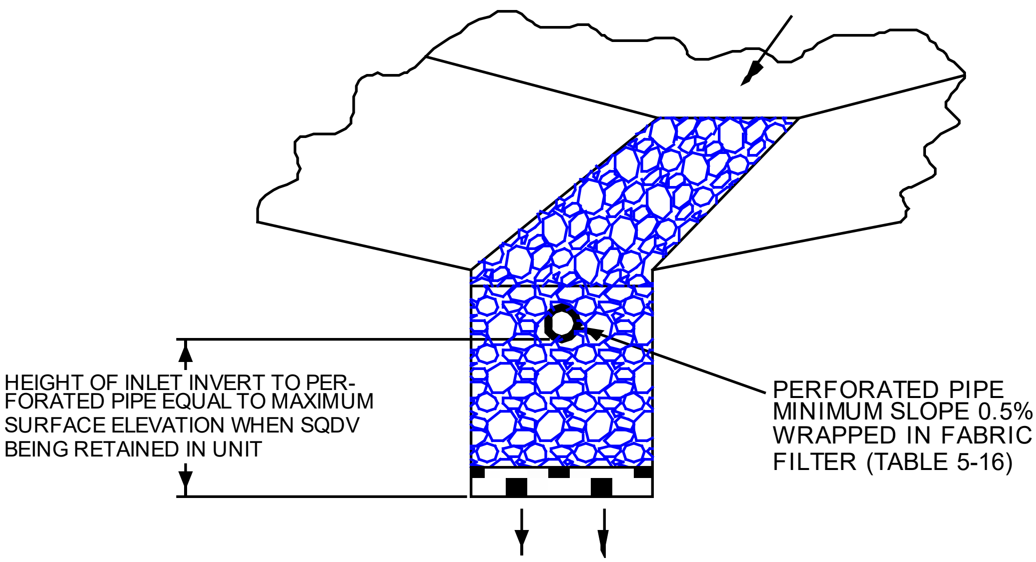


Figure H-3. Ilustration of Pipe Bypass in a Filtration Device

North Tennessee Water Quality BMP Manual Design and Maintenance of Structural BMPs. (2008). (tech.).

APPENDIX I. APPROVED PROPRIETARY CONTROL MEASURES

This Appendix lists proprietary stormwater treatment devices that have been approved by the City and the County for general use in new development and significant redevelopment projects within the SUA. In order to use Proprietary Control Measures, projects must first show that the VRR is met through the use of VRMs (**Section 5**).

*It should be noted that **Appendix I** does not include devices approved for trash control. For a list of certified and/or agency-approved devices contact the City or County. In addition, vector breeding considerations must be addressed when considering what types of trash treatment controls to implement due to the potential nuisance and human health effects. Those devices that have been reviewed and approved by Vector Control are identified within the State's certified list of trash treatment control devices and should be confirmed with the City or County.*

To provide a rational basis for approval of proprietary devices, the City and County has elected to recognize as approved for general and pilot use those proprietary devices that have been approved for general, conditional, or pilot use by other selected major stormwater programs that have established and are actively conducting a comprehensive testing protocol and approval process. Currently, the City and County recognizes the lists of proprietary devices approved for general, conditional, and pilot use as well as trash capture systems from the following stormwater programs:

- Sacramento Stormwater Quality Partnership (website: http://www.sacstormwater.org/)
- State of Washington Department of Ecology (DOE) Stormwater Program (website: http://www.ecy.wa.gov/programs/wq/stormwater/newtech/index.html)
- State Water Board Certified Full Capture System List of Trash Treatment Control Devices (website: www.waterboards.ca.gov/water_issues/programs/stormwater/trash_implementation.html)

The City and County may recognize lists from other programs in the future and will update **Appendix I** accordingly.

APPENDIX J. EXAMPLE CALCULATION

This Appendix provides an example calculation to illustrate the application of the VRR, VRMs, tributary impervious area credit and LID Treatment Controls. The calculation begins at Step 5, Apply VRMs. Real world development applications should also adhere to Steps 1 – 4 as described in **Section 2**.

SITE CONDITIONS

A commercial site design (**Figure J-1**), is used for the example calculation. This is a new development scenario and it is assumed that the pre-project conditions primarily consisted of disturbed soils with some undisturbed open space and no impervious cover elements.

STEP 5: APPLY Volume Reduction Measures

The sub steps for Step 5 as described in **Section 5** are as follows:

- Calculate the VRR (post - pre)
- Select VRMs
- Determine volume reduction
- Determine remaining VRR
- Determine tributary impervious area credits

Calculate Volume Reduction Requirement

Pre-Project Volume

Site Element	Element Area ft^2	Fraction of Total Area	Runoff Coefficient	Weighted Runoff Coefficient (Fraction of Total Area * Runoff Coefficient)	0.51-inch Storm Volume, ft^3 (Total Project Area * Total Weighted Runoff Coefficient *(0.51/12))
Disturbed soils	76,750	0.91	0.25	0.228	
Undisturbed open space /trees	7,250	0.09	0.05	0.004	
Total	**84,000**			**0.233**	**831**

Post-Project Volume

Site Element	Element Area ft^2	Fraction of Total Area	Runoff Coefficient	Weighted Runoff Coefficient (Fraction of Total Area * Runoff Coefficient)	0.51-inch Storm Volume, ft^3 (Total Project Area * Total Weighted Runoff Coefficient * (0.51/12))
Permeable pavers	2,410	0.03	0.60	0.02	
Roofs	15,200	0.18	0.95	0.17	
Parking lot	22,961	0.27	0.95	0.26	
Driveway	14,531	0.17	0.95	0.16	
Plaza	4,755	0.06	0.95	0.05	
Walkways	5,607	0.07	0.95	0.06	
Amended soils	11,286	0.13	0.05	0.01	
Undisturbed open space /trees	7,250	0.09	0.05	0.00	
Total	84,000			0.74	**2,647**
Pre-project Volume					831
VRR (post – pre)					**1,816**

Select Volume Reduction Measures & Determine Volume Reduction

Thirty-four evergreen, interception trees were selected as the VRMs for this site. Additional details on interception trees can be found in Fact Sheet V-4.

Parameter	Unit	Value
No. of trees	ea	34
Avg. canopy diameter	ft	20
Unit projected canopy area (area of tree projected over impervious area)	ft^2	314
Total canopy area (unit projected canopy area * no. of trees)	ft^2	10,676
Percent interception	%	40%
Volume reduction (0.51” * Total canopy area * Percent interception / 12 in/ft)	ft^3	**181**

Determine Remaining Volume Reduction Requirement

Remaining VRR (VRR – Interception Tree Volume Reduction):

$1{,}816\ ft^3 – 181\ ft^3 = 1{,}635\ ft^3$

Determine Tributary Impervious Area Credits

Each Volume Reduction Measure fact sheet describes how impervious area credits are calculated. See Fact Sheet V-4 for details on calculating the credits associated with interception trees.

Site Element	Area of Canopy Coverage ft^2	Impervious Area Credit ft^2 (Area of Canopy Coverage * Percent Interception)
Parking lot	5,018	2,007
Plazas	3,737	1,495
Walkways	1,921	768
Total	10,676	4,270

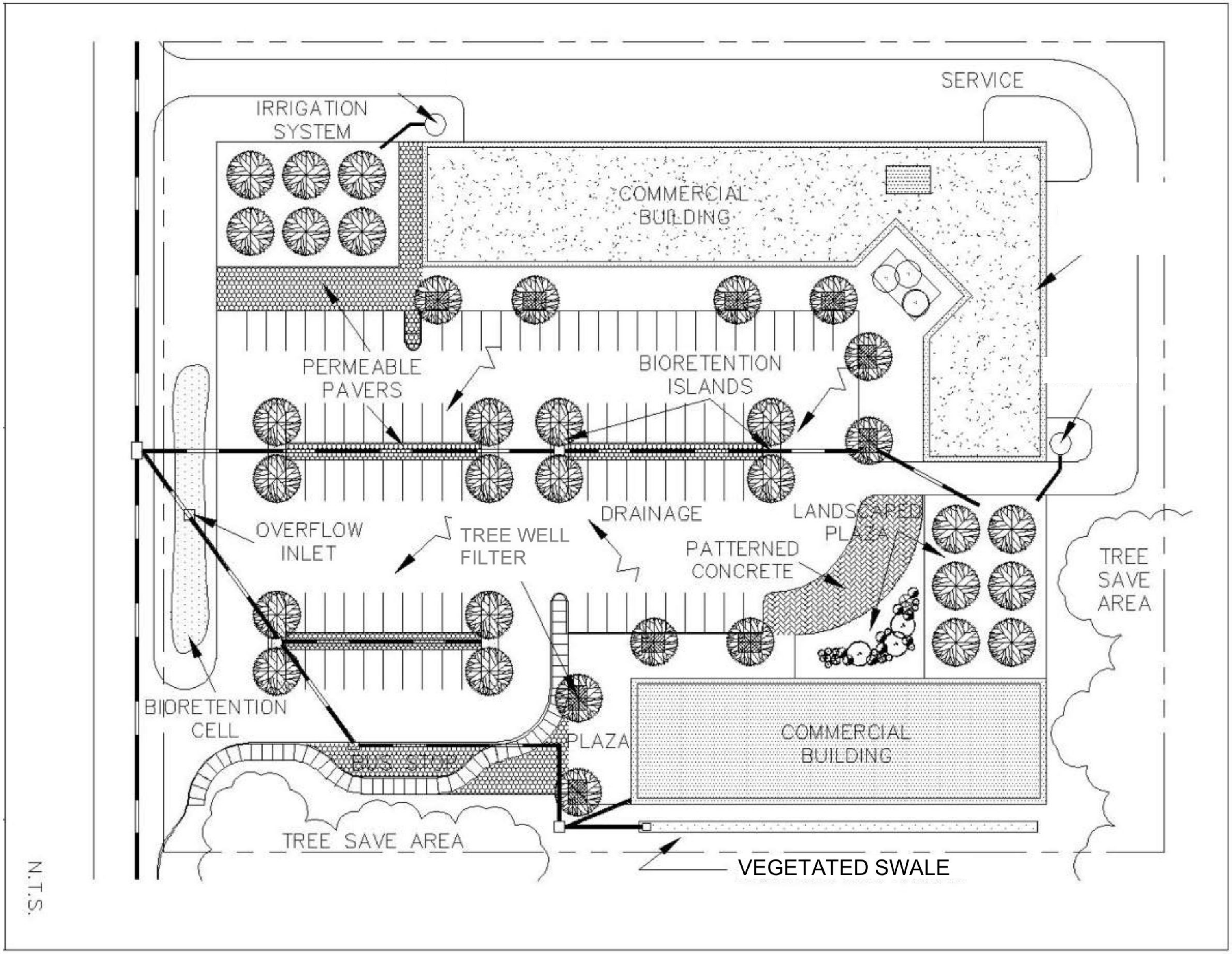


Figure J-1. Example Commercial Site Design. Modified from LID Center. *Source: Guillette, A. (n.d.). Anne Guillette, LEED Accredited Professional Low Impact Design Studio (formerly with the Low Impact Development Center). Low Impact Development: An Alternative Site Design Strategy. https://doi.org/2016*

STEP 6: APPLY LID TREATMENT CONTROLS

If VRR was not met through use of VRMs (Step 5), LID Treatment Controls must be used to further reduce volume. Treatment controls must be designed to treat the SQDF or SQDV.

In this example calculation, the VRR was not fully met through the use of Interception Trees as a result, the development will also apply the following LID Treatment Controls:

- Parking Lot Bioretention
- Vegetated Swale
- Bioretention Cell
- Tree-well Filter

Calculations for each of the LID Treatment Controls are provided in the tables below.

Parking Lot Bioretention	Unit	Value
Tributary area (Area draining to parking lot bioretention)	ft^2	22,961
Tributary impervious area credit (see Tributary Impervious Area Credits in Step 5)	ft^2	2,007
Effective tributary area (Tributary area – Tributary impervious area credit)	ft^2	20,954
SQDV[1] (Unit Basin Storage Volume[2] * Effective tributary area * 1ft/12in)	ft^3	559
Bioretention area	ft^2	1,563
Depth of ponding zone	ft	0.50
Depth of planting zone	ft	1.50
Treatment volume provided[1] (Bioretention area * Depth of ponding zone)	ft^3	782
Volume reduction (Depth of ponding zone * Bioretention area * 0.25) + (Depth of planting zone * Bioretention area * 0.1)	ft^3	430

1: SQDV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by parking lot bioretention
2: See Figure 6-1

Vegetated Swale	Unit	Value
Tributary area (Area draining to vegetated swale)	ft^2	5,188
Tributary impervious area credit (see Tributary Impervious Area Credits in Step 5)	ft^2	-
Effective tributary area (Tributary area – Tributary impervious area credit)	ft^2	5,188
SQDV[1] (Unit Basin Storage Volume[2] * Effective tributary area * 1ft/12in)	ft^3	138
Swale area	ft^2	798
Depth of ponding zone	ft	0.67
Depth of planting zone	ft	1.50
Treatment volume provided[1] (Swale area * Depth of ponding zone)	ft^3	535
Volume reduction (Depth of ponding zone * Swale area * 0.25) + (Depth of planting zone * Swale area * 0.1)	ft^3	253

1: SQDV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by vegetated swale
2: See **Figure 6-1**

Tree-well Filters	Unit	Value
Tributary area (Area draining to tree-well filter)	ft^2	4,755
Tributary impervious area credit (see Tributary Impervious Area Credits in Step 5)	ft^2	1,495
Effective tributary area (Tributary area – Tributary impervious area credit)	ft^2	3,260
SQDV[1] (Unit Basin Storage Volume[2] * Effective tributary area * 1ft/12in)	ft^3	87
No. of filters	ea	12
Unit filter area	ft^2	16
Total filter area (No. of filters * Unit filter area)	ft^2	192
Depth of ponding zone	ft	0.75
Depth of planting zone	ft	1.50
Treatment volume provided[1] (Total filter area * Depth of ponding zone)	ft^3	144
Volume reduction (Depth of ponding zone * Total filter area * 0.25) + (Depth of planting zone * Total filter area * 0.1)	ft^3	65

1: SQDV is treatment volume required; Treatment volume provided is the amount of treatment actually provided by bioretention cell
2: See **Figure 6-1**

SUMMARY OF VOLUME REDUCTION

Control Measure	Units	Volume Reduction
Tree Interception	ft^3	181
Parking Lot Bioretention	ft^3	430
Vegetated Swale	ft^3	253
Bioretention Cell	ft^3	909
Tree-well Filters	ft^3	65
Total Volume Reduction	ft^3	**1,838**
VRR	ft^3	1,816

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