CITY OF MODESTO
STORMWATER MANAGEMENT PROGRAM

2011 Revised Guidance Manual for Development Stormwater Quality Control Measures

Prepared for
NPDES Permit No. CAS083526; Order R5-2008-0092
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SECTION 1. INTRODUCTION

1.1. Purpose and Goals


The 2011 Revised Guidance Manual has been prepared to accomplish the following objectives and goals:

- Protect receiving water, groundwater, and irrigation canals from adverse impacts of urban runoff from the City;
- Implement design standards consistent with the City’s municipal stormwater permit and other State requirements;
- Provide development standards for developers, engineers, and planners;
- Integrate LID strategies;
- Outline maintenance protocols for long-term, effective pollution control; and
- Identify the differences between flood control and water quality standards.

1.2. Background

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

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

As part of the City’s Phase I municipal stormwater permit (Order No. 94-163), which was issued by the Central Valley Regional Water Quality Control Board (Regional Water Board) on June 24, 1994, the City was required to develop and implement Development
Standards that require source and treatment control Best Management Practices (BMPs) to reduce pollutants from new development and redevelopment areas. To address this requirement, the City developed the Guidance Manual for New Development Stormwater Quality Control Measures in January 2001.

1.3. 2008 Municipal Stormwater Permit Requirements

In June 2008, the Regional Water Board re-issued the City’s municipal stormwater NPDES permit (Order No. R5-2008-0092) (2008 Municipal Stormwater Permit), which required the submittal of a revised/functionally-updated Guidance Manual to the Regional Water Board. The 2008 Municipal Stormwater Permit requires that new development and significant redevelopment integrate LID strategies and use a combination of stormwater control measures.

As a result, the 2011 Revised Guidance Manual identifies how new development and significant redevelopment can meet these requirements by using a volume retention requirement. The volume retention requirement must be met through implementation of a combination of LID and treatment control measures to retain the design water quality volume on-site. The design water quality volume is different from the City’s flood control retention volume.

1.4. Low Impact Development Strategies

Historically, stormwater management has consisted of a network of impervious surfaces (rooftops, driveways, roads, etc.) connected to a storm drain system that was designed to quickly convey stormwater off-site. Dozens of studies have documented the impacts of connected impervious cover on the natural hydrologic cycle (Center for Watershed Protection, 2003). In a natural setting, the majority of precipitation is either infiltrated into the soil or is lost to evapotranspiration. However, with urbanization, pervious surfaces (such as forests and meadows) are converted into impervious cover and precipitation is converted into stormwater runoff. This leads to an increase in the volume and flow rate of stormwater runoff to water bodies (Figure 1-1). This increased stormwater runoff, if not managed correctly, may adversely affect local water bodies.

Figure 1-1. Pre- vs. Post-Project Hydrograph (Modified from Haltiner, 2006)
To mitigate these impacts, conventional BMPs such as detention basins were implemented to temporarily detain stormwater runoff by releasing the volume over a period of time. However, detention basins have limited pollutant removal and groundwater recharge benefits (Figure 1-2).

Figure 1-2. Hydrograph with Conventional Best Management Practices (Modified from Haltiner, 2006)

To enhance pollutant removal and groundwater recharge benefits, improvements are being made beyond the conventional BMPs through use of LID strategies. LID, as required in the 2008 Municipal Stormwater Permit, is defined as “a stormwater management and land development strategy that emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic controls to more closely reflect predevelopment hydrologic functions”.

LID is a decentralized approach to stormwater management that works to mimic the natural hydrology of the site by retaining precipitation on-site. The goal is to reduce and/or eliminate the shaded areas, as shown in Figure 1-3, by reducing the peak volume and duration of flow through the use of site design and LID control measures. The benefits of reduced stormwater volume include reduced pollutant loadings and increased groundwater recharge and evapotranspiration rates.

Figure 1-3. Goal of Low Impact Development is to Mimic the Pre-Project Hydrograph through Reduction in Peak Runoff Volume and Flow (Modified from Haltiner, 2006)
1.5. Updates to the Guidance Manual: Key Concepts

The primary difference between the 2011 Revised Guidance Manual and the 2001 Guidance Manual is the increased emphasis on LID strategies and a volume retention requirement. The volume retention requirement allows developers and plan reviewers to determine when LID has been achieved and what constitutes adequate implementation of a combination of stormwater control measures. Key concepts associated with the volume retention requirement include:

- All Priority New Development and Significant Redevelopment Projects (Priority Projects) must apply four categories of stormwater runoff control measures: Site Design Control Measures (Section 4), Source Control Measures (Section 5), Low Impact Development (Section 7), and Treatment (Section 8).
- New Development Priority Projects must comply with the volume retention requirement. The volume retention requirement can be met through the application of LID control measures (BMPs that reduce stormwater runoff volume as outlined in Section 7) and some treatment control measures (BMPs that provide treatment and reduce stormwater runoff volume as outlined in Section 8).
- The volume retention requirement is determined by calculating the stormwater runoff volume based on a 0.50-inch storm depth, which is the average 85th percentile, 24-hour storm depth estimated for the Modesto area by the California Department of Transportation (Caltrans).
- Significant redevelopment projects must also comply with the volume retention requirement. Credits of 0.05 inches from the 0.50-inch volume retention requirement may be applied to specific types of redevelopment. The credits are additive such that a maximum credit of 0.25 inches is possible for a project that meets all five criteria:
  - Significant redevelopment (as defined in Section 2.2);
  - Brownfield redevelopment;
  - High density (22 or more units per acre);
  - Vertical density (two or more stories); or
  - Mixed use and transit-oriented development (within ½ miles of public transit).
- The stormwater runoff coefficients used to calculate the volume retention requirement should be based on site-specific land use elements at the development site (e.g., as opposed to a blanket stormwater runoff coefficient for all medium density residential). The goal is to reduce or minimize impervious areas, and thus stormwater runoff coefficients, through site design strategies such as using a minimum allowable roadway width. Lower stormwater runoff coefficients will result in a smaller volume retention requirement.
- To meet the volume retention requirement, projects must first apply LID control measures, which are presented in Section 7.
LID control measures also provide treatment benefits, which are recognized through effective tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate the water quality flow (WQF) or water quality volume (WQV). Implementing LID control measures will reduce effective impervious area, and thereby the volume of water required to be treated. Tributary area credits for design of treatment control measures are discussed in Section 7.

If a project does not fully meet the volume retention requirement after applying LID control measures, the project must use treatment control measures to further retain stormwater runoff and treat the WQF or WQV. Procedures for calculating the volume retention of treatment control measures are provided in fact sheets in Section 8.

Treatment control measures are categorized into three groups: Infiltration (BMPs that retain stormwater runoff), Evapotranspiration and Biofiltration (BMPs that retain some stormwater runoff), and other public domain treatment control measures (BMPs that typically do not retain stormwater runoff).

Selection of treatment control measures should be based on their ability to retain stormwater runoff and remove pollutants of concern.

If the volume retention requirement is not entirely achieved through the combination of LID and/or treatment control measures, the project must submit a Volume Retention Requirement Waiver as described in Section 6.

1.6. Stormwater Quality Requirements vs. Flood Control Requirements

On October 8, 2008, the City of Modesto Community and Economic Development Department and Public Works Department implemented the Storm Drainage Design Interim Policy for Infill/Redevelopment Pending the Adoption & Implementation of the New Storm Water Master Plan (Interim Policy). The purpose of the Interim Policy was to provide clarification for storm drain system design in the 2006 City of Modesto Public Works Department Standard Specifications (2006 Standard Specifications). The 2006 Standard Specifications were updated by Modesto City Council Resolution in 2014 (2014 Standard Specifications). The Interim Policy separates storm drain system requirements for infill and redevelopment for commercial properties less than or equal to three (3) acres and for new development properties less than or equal to three (3) acres.

The Interim Policy defines infill and redevelopment properties as:

- Not being in a specific plan area;
- One legal lot surrounded by urban development on at least three sides (does not have to be directly adjacent to);
- Served by existing underground utilities (sewer and water); and
- Infill and redevelopment sites with existing development (site does not necessarily have to coincide within the City’s Redevelopment Area).
For infill and redevelopment commercial projects of three (3) acres or less that drain to the storm drain system, the Interim Policy requires on-site storage of approximately one (1)-inch of stormwater runoff, which must percolate within 48 hours. For infill and redevelopment commercial projects of three (3) acres or less that do not drain to the storm drain system, the Interim Policy requires on-site storage of approximately 2.88 inches of stormwater runoff, which must percolate within 48 hours.

For all new development projects that are less than three (3) acres, the Interim Policy requires on-site storage of approximately 5.6-inches of stormwater runoff that must be percolated within six (6) days.

Larger projects are not subject to the Interim Policy. The 2014 Standard Specifications state that “all development connecting to a pipe network discharging directly to a creek, river, or stream shall not exceed the predevelopment storm release rates and no development shall discharge at a rate, which exceeds the capacity of any portion of the existing downstream system.”

The Interim Policy was designed for the purpose of flood control and handling stormwater runoff volume. While the 2011 Revised Guidance Manual addresses some part of the stormwater runoff volume (0.50 inches of storm event depth), the primary objective of the 2011 Revised Guidance Manual is to address stormwater runoff quality. Control measure design standards in the 2011 Revised Guidance Manual only address the first 0.50 inches of stormwater runoff for water quality purposes. Developers are still required to meet any applicable City flood control measures.

1.7. Organization of the 2011 Revised Guidance Manual

The 2011 Revised Guidance Manual is organized as follows:

Section 1  Presents an overview of the 2011 Revised Guidance Manual, applicable regulations, and an introduction to LID.

Section 2  Outlines a step-by-step process for meeting the standards outlined within the 2011 Revised Guidance Manual.

Section 3  Contains information on site assessment.

Section 4  Provides fact sheets on site design control measures.

Section 5  Provides fact sheets on source control measures.

Section 6  Provides procedures for calculating retention volume and WQF and WQV.

Section 7  Provides fact sheets on LID control measures.

Section 8  Provides fact sheets on treatment control measures.

Section 9  Details maintenance requirements for control measures.
SECTION 2. GUIDANCE MANUAL OVERVIEW AND USE

This section provides an overview of the stormwater management standards for new development and significant redevelopment projects. This section contains information regarding development projects that are subject to the 2011 Revised Guidance Manual and outlines the process that must be used to effectively incorporate stormwater control measures and satisfy the requirements of the permitting agencies in the City.

The control measures, often termed Best Management Practices (BMPs), described in the 2011 Revised Guidance Manual were selected to optimize post-construction, on-site stormwater pollution control. All Priority Projects must apply all four categories of stormwater pollution control measures:

- Site Design Control Measures (Section 4);
- Source Control Measures (Section 5);
- Low Impact Development Control Measures (Section 7); and
- Treatment Control Measures (Section 8).

2.1. Implementation Schedule

The 2008 Municipal Stormwater Permit outlines the implementation schedule for the 2011 Revised Guidance Manual. Upon adoption, the 2011 Revised Guidance Manual is applicable to all Priority Projects or phases of Priority Projects, which do not have one of the following:

- Approval of a tentative map within two years prior to approval of the 2011 Revised Guidance Manual;
- Approval of improvement plans by City engineers; or
- A permit for development or construction.

Any extension of a tentative map after adoption of the 2011 Revised Guidance Manual requires compliance with the 2011 Revised Guidance Manual. Also, infill projects that require only a Use Permit from the City for Priority Projects are subject to the requirements of the 2011 Revised Guidance Manual.

2.2. Process to Comply with City Standards

A step-by-step process for incorporating these control measures is illustrated in Figure 2-1. The applicability of specific control measures outlined in Steps 3-6 should be confirmed with the City.

In addition to the requirements prescribed within the 2011 Revised Guidance Manual, development projects also adhere to applicable drainage standards as specified in the 2014 Standard Specifications or most current City of Modesto Standard Specifications. In the event that requirements prescribed within the 2011 Revised Guidance Manual
conflict with requirements within the City of Modesto Standard Specifications, the purpose of the control measure should be identified. If the purpose of the control measure is for water quality, then the 2011 Revised Guidance Manual requirements should apply. If the purpose of the control measure is not for water quality, then the City of Modesto Standard Specifications should apply.

Step 1: Determine if the Project is Subject to the 2011 Revised Guidance Manual

The first step is to identify whether the project is considered a Priority Project. Priority Projects must implement the control measures and meet the volume retention requirement identified in the 2011 Revised Guidance Manual.

Projects that are not Priority Projects are still subject to City stormwater staff review. Stormwater control measures may be required by the City for Non-Priority Projects, depending on the potential discharge of pollutants in stormwater runoff.

Priority Projects are defined as the following:

- Home subdivisions of 10 housing units or more – This category includes single-family homes, multi-family homes, condominiums, and apartments. A housing unit is also defined as a dwelling unit.

- Commercial development greater than 10,000 square feet of impervious area – This category is defined as any development on private land that is not for heavy industrial or residential uses, where the land area for development is greater than 10,000 square feet of impervious area. The category includes, but is not limited to, hospitals, laboratories, and other medical facilities, educational institutions, recreational facilities, commercial retail nurseries, car wash facilities, mini-malls, and other business complexes, shopping malls, hotels, office buildings, public warehouses, and other industrial facilities.

- Automotive repair shops – This category is defined as a facility that is categorized in any of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.

- Restaurants – This category is defined as a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling foods and drinks for immediate consumption (SIC code 5812), where total impervious area for development is greater than or equal to 5,000 square feet. For restaurants less than 5,000 square feet, the development must meet all development standards except for treatment control measures and numeric sizing criteria.

- Parking lots 5,000 square feet or more or 25 or more parking spaces and potentially exposed to urban runoff – This category defines a parking lot as a land area or facility for the temporary parking or storage of motor vehicles used personally, for business, or for commerce.

- Streets and roads – This category includes any paved surface used for the transportation of automobiles, trucks, motorcycles, and other vehicles.
• Retail Gasoline Outlets (RGOs) – An RGO is defined as any facility engaged in selling gasoline.

• Significant Redevelopment – Significant redevelopment is defined as the creation or addition of at least 5,000 square feet of impervious area 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 activity¹, and land disturbing activities related with structural or impervious surfaces. Where significant redevelopment results in an increase of less than fifty percent of the impervious surfaces to a previously existing development, and the existing development was not subject to the 2001 Guidance Manual, the numeric sizing criteria (WQV or WQF) applies only to the addition, and not the entire development.²

The standards set forth in the 2011 Revised Guidance Manual shall apply to all new development and significant redevelopment projects falling under the Priority Project categories as specified above. Compliance with the 2011 Revised Guidance Manual should be discussed as early as possible in the site design process. The project engineer and other design professionals (including landscape designers and architects) should be involved during the City’s Tentative Map stage.

In addition to the City requirements, owners/developers of some sites may also be subject to the State of California’s general permit for stormwater discharges from industrial activities (Industrial General Permit) and general permit for stormwater discharges from construction and land disturbance activities (Construction General Permit). The control measures provided in the 2011 Revised Guidance Manual may assist the owner/developer in meeting the requirements for the State’s permits (http://www.waterboards.ca.gov/water_issues/programs/stormwater). City stormwater staff are available to provide assistance regarding State permit requirements.

¹ Routine maintenance includes activities that maintain original line and grade, hydraulic capacity, or original purpose of facility. Exchanging one type of impervious area for a different type of impervious area is considered significant redevelopment if it is at least 5,000 square feet, and would be subject to the 2011 Revised Guidance Manual. Changing the drainage pattern for the site would also subject the project to the 2011 Revised Guidance Manual.

² Example: If an existing development currently has 10,000 square feet of impervious area and a significant redevelopment project intends to add 4,999 square feet of impervious area (< 50% of existing development impervious area), the 2011 Revised Guidance Manual will only apply to the additional 4,999 square feet of impervious area being added. If the significant redevelopment project intends to add 5,000 square feet of impervious area (≥ 50% of existing development impervious area), then the 2011 Revised Guidance Manual must be applied to the entire site, including the existing development (10,000 square feet of impervious area).
Figure 2-1. Process for Meeting New Development and Significant Redevelopment Stormwater Standards

Step 1
Does 2011 Revised Guidance Manual apply to project?

Yes
Step 2
Conduct Site Assessment

No
City Stormwater Staff Review

Step 3
Apply Site Design Control Measures

Step 4
Apply Source Control Measures

Step 5
Calculate Volume Retention Requirement

Step 6
Apply Low Impact Development Measures

Step 7
Apply Treatment Control Measures

Step 8
Volume Retention Requirement Met?

Yes
Step 9
Submit Project Stormwater Quality Control Measures Plan & Maintenance Plan

No

Step 1
Stormwater Control Measures Required?

Yes
Retain to MEP and Apply for Technical Infeasibility Waiver

Is it technically feasible to meet Volume Retention Requirement?

No

Continue Project Design Process

Yes
Step 2. Conduct Site Assessment

After determining if a project is a Priority Project, the next step is to collect site information that is critical for selecting the appropriate stormwater control measures. (See Section 3 for more information.) The following information should be collected:

- Priority Project category (Step 1);
- Gross project area (acres);
- Drainage areas (acreage and location via site map);
- Impervious area (acreage and location via site map);
- Location(s) of discharge point(s) to the storm drain system or local receiving water;
- Land use type and 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;
- Activities expected to be on-site;
- Site conditions;
- Soil type and geology;
- Geotechnical considerations;
- Topography;
- Hydraulic head; and
- Groundwater and soils.
Table 2-1. New Development/Significant Redevelopment Priority Project Categories and Associated Pollutants of Concern

<table>
<thead>
<tr>
<th>Priority Project Category</th>
<th>Pollutants of Concern Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sediment</td>
</tr>
<tr>
<td>Home subdivisions (≥ 10 units)</td>
<td>X</td>
</tr>
<tr>
<td>Commercial developments (&gt; 10,000 ft²)</td>
<td>●</td>
</tr>
<tr>
<td>Automotive repair shops</td>
<td>X</td>
</tr>
<tr>
<td>Restaurants</td>
<td>●</td>
</tr>
<tr>
<td>Parking lots (≥ 5,000 ft² or ≥ 25 spaces)</td>
<td>●</td>
</tr>
<tr>
<td>Streets/roads</td>
<td>X</td>
</tr>
<tr>
<td>Retail gasoline outlets</td>
<td>X</td>
</tr>
</tbody>
</table>

X = Pollutant likely to be present in stormwater runoff from project area
● = Pollutant may be present, but is dependent on activities (e.g., landscaping) occurring at an individual development

Step 3: Apply Site Design Control Measures

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 areas of the project site that are less environmentally-sensitive. Additionally, the project should minimize impervious area and soil compaction in areas to remain pervious. These control measures will help to reduce stormwater runoff volume and is the first step (and possibly the most inexpensive control measure) in meeting the volume retention requirement. Additional guidance on site design control measures is presented in Section 4. Minimizing or eliminating the use of curb and gutter so that road/street runoff drains to swales and other volume retention measures or LID treatment controls is strongly encouraged where slope and density permit.

Step 4: Apply Source Control Measures

All Priority Projects must implement applicable source control measures. Source control measures are operational practices that prevent pollution by reducing potential pollutants at the source and/or preventing pollutants from coming into contact with stormwater runoff. Source control measures typically do not require significant maintenance or significant construction. Any Priority Project that has one or more of the following activities on-site must implement source control measures as specified in Table 2-2. Additional guidance on source control measures is presented in Section 5.
Step 5: Calculate Volume Retention Requirement

All Priority Projects must retain and treat the first 0.50 inch of stormwater runoff volume. The volume retention requirement, which is calculated using the Rational Method, is a product of the design rainfall depth (0.50 inch), site-specific stormwater runoff coefficient, and drainage area size.

Priority Projects must also comply with the volume retention requirement. Because redevelopment projects usually occur in areas where space may be limited for stormwater control measures, credits reducing retention volume may be applied depending on the type of redevelopment. A credit of 0.05 inch may be applied for each of the following types of redevelopment:

- Significant redevelopment (as defined in Section 2.1);
- Brownfield redevelopment;
- High density (22 or more units per acre);
- Vertical density (two or more stories); or
- Mixed use and transit-oriented development (within ½ miles of public transit).

Credits are additive such that a maximum credit of 0.25 inches is possible for a project that meet all five types of redevelopment. Procedures for calculating the volume retention requirement and credits are provided in Section 6.

Step 6: Apply Low Impact Development Control Measures

All Priority Projects must apply LID control measures (Table 2-2). LID control measures are BMPs that can direct, retain, reuse, and/or infiltrate stormwater runoff (e.g., rain gardens, rain barrels). Additional guidance on LID control measures is provided in Section 7.

The application of LID control measures is driven by the volume retention requirement. The volume retention requirement is a new requirement developed in response to the 2008 Municipal Stormwater Permit requirements specifying the explicit use of LID strategies and a combination of stormwater control measures.

LID control measures 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 WQF or WQV, which are the primary design criteria used to size treatment control measures. LID control measures reduce the effective impervious area, and thereby, the volume of water to be treated. Procedures for calculating volume retention and tributary impervious area credit are presented in each LID control measure fact sheet (See Section 7). Credits may be applied in calculations of the effective impervious area for design of treatment control measures in Section 8.
<table>
<thead>
<tr>
<th>Project Category</th>
<th>Site Design</th>
<th>Source</th>
<th>Low Impact Development (L-1 to L-6)</th>
<th>Treatment (R-1 to R-14, C-1 to C-4, P-1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site Planning (G-1)</td>
<td>Protect and Restore Natural Areas (G-2)</td>
<td>Minimize Land Disturbance (G-3)</td>
<td>Minimize Impervious Areas (G-4)</td>
</tr>
<tr>
<td>Significant redevelopment</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Home subdivisions (≥10 units)</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Commercial developments (≥5,000 ft²)</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Automotive repair shops</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Restaurants</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Parking lots (≥5,000 ft² or 25 spaces)</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Streets/roads (≥1 acre paved surface)</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Retail gasoline outlets</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
</tbody>
</table>

R = required; R₁ = required if outdoor activity area is included in project; R² = required for multi-family dwellings; S = select one or more applicable control measures.

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Step 7: Apply Treatment Control Measures

If the volume retention and/or treatment requirement is not entirely achieved using LID control measures, treatment control measures must be applied to meet the requirements. Guidance on selecting and designing treatment control measures is provided in Section 8.

Step 8: Determine Additional Retention Volume, if necessary

If LID and treatment control measures are unable to meet the volume retention requirement, alternate combination and sizing of LID and treatment control measures should be evaluated. If it is technically infeasible to meet the volume retention requirement, stormwater runoff must be retained and treated to the maximum extent practicable. For the remaining volume, a Volume Retention Technical Infeasibility Waiver must be obtained.

Step 9: Submit Project Stormwater Quality Control Measures Plan and Maintenance Plan

Priority Projects are required to submit a Project Stormwater Quality Control Measures Plan that adequately demonstrates that the proposed development project will conform to all requirements of the 2011 Revised Guidance Manual.

The Project Stormwater Quality Control Measures Plan must be approved by City stormwater staff before building or use permits will be issued for the project. The Project Stormwater Quality Control Measures Plan must be submitted in addition to the Stormwater Pollution Prevention Plan (SWPPP) required for all construction projects. Project Stormwater Quality Control Measures Plans should conform to the content and format requirements indicated in Appendix E of the 2011 Revised Guidance Manual. The City’s Stormwater Quality Control Measures Plan review and approval process are as follows:

- Receive Project Stormwater Quality Control Measures Plan from applicant.
- Send Project Stormwater Quality Control Measures Plan to inspector.
- Send comment letter to applicant outlining steps needed to be taken to obtain plan approval.
- Receive requested item(s) from applicant.
- Check resubmittal.
- Send second comment letter to applicant, if necessary.
- Approve Project Stormwater Quality Control Measures Plan through the City’s Tidemark database.
- Send approved Project Stormwater Quality Control Measures Plan to the City of Modesto Environmental Compliance Section for use by inspectors.

The City also requires 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 project using any LID and/or treatment control measures that require maintenance. Maintenance Plans must include guidelines for how and when inspection and maintenance will occur for each control measure. Additional information and guidance on compliance with maintenance requirements is presented in Section 9 and Appendix D.
SECTION 3. SITE ASSESSMENT

This section discusses the steps for assessing sites during the planning phase of a project to determine the existing site conditions and what control measures are feasible for the site. This step in the planning and design process is important for identifying site constraints that may limit or reduce the ability of a site to meet volume retention or treatment requirements. Conducting this step early in the planning process reduces the chance of having to re-design the site if proposed control measures are not technically feasible at the site.

3.1. Assessing Site Conditions and Other Constraints

Assessing a site’s potential for implementation of LID and treatment control measures requires both the review of existing information and the collection of site-specific measurements. Available information regarding site layout and slope, soil type, geotechnical conditions, and local groundwater conditions should be reviewed as discussed below. In addition, soil and infiltration testing must be conducted to determine if stormwater runoff infiltration is feasible, and to determine the appropriate design infiltration rates for infiltration-based treatment control measures.

Project Location

If a project is defined as a Priority Project, as described in Section 2.1, then the 2011 Revised Guidance Manual is applicable. The City may also identify other projects that are required to use the 2011 Revised Guidance Manual, as appropriate.3 Once the project location has been identified, it is necessary to conduct initial field investigations of the project site to determine site conditions and other constraints that may limit the ability to apply stormwater quality control measures.

As part of this initial assessment, the developer must identify the following:

- Project area size;
- Drainage area;
- Location of point(s) of stormwater runoff discharge; and
- Activities expected on-site.

The project area size and drainage area are important factors in determining the sizing and placement of stormwater runoff control measures. Identifying the point(s) of

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3 The City may opt to require use of the 2011 Revised Guidance Manual for non-Priority Projects on a case-by-case basis. Examples of non-Priority Projects may include, but are not limited to, specific commercial development that has less than 10,000 square feet of impervious area or development near or that discharge to Environmentally-Sensitive Areas (ESAs).
discharge of stormwater runoff off the project site is necessary to determine where stormwater runoff conveyance and/or control measures need to be located. Determining the activities expected to be conducted on-site before, during, and after construction is important in assessing what potential pollutants may be present in stormwater runoff.

Site Conditions

Topography

Assess site topography to evaluate surface drainage, identify topographic high and low points, and locate the presence of steep slopes. Each of these site characteristics can impact the type of LID or treatment control measure that will be most beneficial for a given project site. For example, stormwater runoff infiltration is more effective on level or gently sloping sites than steeply-sloped sites. Flows applied to slopes steeper than 15% may runoff as surface flows rather than infiltrate.

Soil Type and Geology

Identify site soil types and geologic conditions to evaluate the infiltration capacity at the site to determine the areas where infiltration is suitable as well as unsuitable for the purpose of locating infiltration-based control measures. Modesto area soil types are:

- Type A Soil – typically sands, loamy sands, or sandy loams. Type A soils have low stormwater runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep and well to excessively drained sands or gravels, and have a high rate of water transmission.
- Type B Soil – typically silt loams or loams. They have moderate infiltration rate when thoroughly wetted and consist chiefly of moderately-deep to deep and moderately-well- to well-drained soils with moderately fine to moderately coarse texture.
- Type C Soil – typically sandy clay loams. They have low infiltration rates when thoroughly wetted, consist chiefly of soils with a layer that impedes downward movement of water, and/or have moderately-fine to fine soil structure.
- Type D Soil – typically clay loams, silty clay loams, sandy clays, silty clays, or clays. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with high swelling potential, permanent high water table, claypan or clay layer at or near the surface, and/or shallow soils over nearly impervious material.

If site-specific data are available, soils with infiltration rates of 0.5 in/hr or greater are considered feasible for infiltration-based control measures. Early identification of soil types throughout the project footprint can reduce the number of test pit investigations and infiltration tests needed by narrowing potential test sites to locations with those that are most likely to be amenable to infiltration.
Available geologic or geotechnical reports on local geology should be reviewed to identify relevant features such as depth to bedrock, rock type, lithology, faults, or hydrostratigraphic or confining units. These geologic investigations, which may also identify shallow water tables and past groundwater issues, provide important information for control measure design.

**Groundwater Considerations**

Site groundwater conditions must be considered prior to LID or treatment control measure siting, selection, sizing, and design. The depth to groundwater beneath the project during the wet season may preclude infiltration because ten (10) feet of separation to the seasonal high groundwater level is required. In areas with known groundwater pollution, infiltration should be avoided because it may potentially contribute to the movement or dispersion of groundwater contamination.

Where soils have very high infiltration rates, groundwater quality may be impacted by infiltration-based control measures. Prior to use of infiltration-based control measures, consult with the City to identify if unconfined aquifers are located beneath the project site to determine the appropriateness of infiltration-based control measures.

**Geotechnical Considerations**

Water infiltration can cause geotechnical issues, including settlement through collapsible soil, expansive soil movement, and slope instability. Stormwater infiltration temporarily increases the groundwater level near the infiltration control measure, such that the potential geotechnical conditions are likely to be of greatest significance near the infiltration area and diminish with distance. A geotechnical investigation must be performed for the infiltration-based control measure to identify potential geotechnical issues.

Increased water pressure in soil pores reduces soil strength. Decreased soil strength can make foundations more susceptible to settlement and slopes more susceptible to failure. In general, control measures must be set back from building foundations or steep slopes. Recommendations for each site must be determined by a licensed geotechnical engineer based on soils boring data, drainage patterns, and current requirements for stormwater treatment.

**Managing Off-Site Drainage**

Locations and sources of off-site run-on onto the project site must be identified early in the design process. Off-site drainage must be considered when determining appropriate control measures for the site so that the drainage can be managed. Concentrated flows from off-site drainage may cause extensive erosion if not properly conveyed through or around the project site or otherwise managed. By identifying the locations and sources of off-site drainage, the volume of run-on may be estimated and factored into the siting and sizing of on-site control measures. Vegetated swales or
storm drains may be used to intercept, divert, and convey off-site drainage through or around the project site to prevent flooding or erosion that might otherwise occur.

**Existing Utilities**

Existing utility lines that are on-site will limit the possible locations of certain control measures. For example, infiltration-based control measures should not be located near utility lines where the increased amount of water could damage utilities. Stormwater runoff should be directed away from existing underground utilities and project designs that require relocation of existing utilities should be avoided, if possible.

**Environmentally-Sensitive Areas**

The presence of Environmentally Sensitive Areas (ESAs) may limit the siting of certain control measures. ESAs typically are delineated by, and fall under the regulatory oversight of state and federal agencies such as the United States Army Corps of Engineers, California Department of Fish and Game or United States Fish and Wildlife Service, or California Environmental Protection Agency. ESAs are identified in the City’s October 2008 *Final Master Environmental Impact Report for the Urban Area General Plan Update* (MEIR).

### 3.2. Pollutants of Concern

The CWA requires that states adopt water quality standards for receiving waters, and to have those standards approved by the United States Environmental Protection Agency (USEPA). Water quality standards consist of designated beneficial uses for a particular receiving water (e.g., wildlife habitat, agricultural supply), along with water quality criteria necessary to support those beneficial uses. Water quality criteria are prescribed concentrations or levels of constituents — such as lead, suspended solids, or bacteria — or narrative statements that represent the quality of water that supports a particular use. Applicable water quality standards for surface and groundwater in the Modesto area are outlined in the *Water Quality Control Plan for the Sacramento and San Joaquin River Basins* (Basin Plan), which was most recently adopted in October 1998 by the Regional Water Board as the fourth edition. Numeric water quality criteria for surface waters are also promulgated in the California Toxics Rule, which was adopted in May 2000 by USEPA. Additional drinking water standards may also apply.

The pollutants of concern for a project site depend on the following factors:

- Project location;
- Land use and activities that have occurred on the project site in the past;
- Land use and activities that are likely to occur in the future; and
- Receiving water impairments
In the Modesto area, the Tuolumne River is listed as impaired for diazinon, Group A Pesticides\(^4\), and unknown toxicity on the *2006 CWA Section 303(d) List of Water Quality Limited Segments Requiring TMDLs* (2006 303(d) List). The San Joaquin River, which ultimately drains the Tuolumne River, Dry Creek, and irrigation canals in Modesto, is listed as impaired for DDT, Group A Pesticides, mercury, and unknown toxicity.

Monitoring data collected between 2002 and 2007 identified the following pollutants of concern in City’s stormwater runoff:

- Aluminum, total recoverable;
- Copper, total recoverable;
- Lead, total recoverable;
- Iron, total recoverable;
- Total dissolved solids;
- Diazinon;
- Escherichia coli;
- Fecal Coliform;
- pH; and
- Turbidity.

In addition to pollutants of concern identified above, other common post-development pollutants of concern based on typical land use activities are presented in Table 3-1.

\(^4\) Group A Pesticides are aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane (including Lindane), endosulfan, and toxaphene.
Table 3-1. Typical Pollutants of Concern and Sources for Post-Development Areas

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Potential Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sediment (total suspended solids and turbidity), trash and debris</td>
<td>Streets, landscaped areas, driveways, roads, construction activities, atmospheric deposition, soil erosion (channels and slopes)</td>
</tr>
<tr>
<td>(gross solids and floatables)</td>
<td></td>
</tr>
<tr>
<td>Pesticides and herbicides</td>
<td>Residential lawns and gardens, roadsides, utility right-of-ways, commercial and industrial landscaped areas, soil wash-off</td>
</tr>
<tr>
<td>Organic materials/oxygen demanding substances</td>
<td>Residential lawns and gardens, commercial landscaping, animal waste</td>
</tr>
<tr>
<td>Metals</td>
<td>Automobiles, bridges, atmospheric deposition, industrial areas, soil erosion, metal surfaces, combustion processes</td>
</tr>
<tr>
<td>Oil and grease, organics associated with petroleum</td>
<td>Roads, driveways, parking lots, vehicle maintenance areas, gas stations, illicit dumping to storm drains, automobile emissions, and fats, oils, and grease from restaurants</td>
</tr>
<tr>
<td>Bacteria and viruses</td>
<td>Lawns, roads, leaking sanitary sewer lines, sanitary sewer cross-connections, animal waste (domestic and wild), septic systems, homeless encampments, sediments/biofilms in storm drain system</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Landscape fertilizers, atmospheric deposition, automobile exhaust, soil erosion, animal waste, detergents</td>
</tr>
</tbody>
</table>

Source: Adapted from USEPA, 1999 (Preliminary Data Summary of Urban Storm Water BMPs)

While there is some uncertainty in identifying pollutants of concern for a project, as land use activities and site design practices evolve, particularly with increased incorporation of LID control measures, characteristic stormwater runoff concentrations and pollutants of concern from various land use types are also likely to change. Nevertheless, identifying potential pollutants of concern is a necessary ongoing step in handling stormwater runoff.
SECTION 4. SITE DESIGN CONTROL MEASURES

4.1. Introduction

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

- Reduction in size of downstream treatment control measures and conveyance systems;
- Reduction in pollutant loading to treatment control measures; and
- Reduction in hydraulic impact on receiving waters.

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

- G-1: Site Planning
- G-2: Protect and Restore Natural Areas
- G-3: Minimize Land Disturbance
- G-4: Minimize Impervious Area

Site design control measures described in this section are required for all Priority Projects unless the project applicant demonstrates to the satisfaction of the City that particular control measures are not applicable to the proposed project, or the project site conditions make it infeasible to implement the site design control measure in question. Site design control measures such as minimizing of impervious cover can reduce the volume retention requirement and possibly decrease the cost of implementing other control measures.

4.2. Description

Detailed descriptions and design criteria for each site design control measure are presented in the following fact sheets.
G-1: Site Planning

Purpose

Planners, developers, architects, and engineers must reconsider conventional approaches to stormwater management in order to incorporate aspects of LID. Prior to starting a project, the project site should be evaluated in order to generate a more hydrologically functional site that maximizes LID and integrates stormwater management throughout the site. Early site planning can identify physical site constraints, reduce costs of downstream control measures, and prevent potential site re-design.

Design Criteria

The following criteria shall be considered during the early site planning stages:

- LID control measures shall be considered as early as possible in the site planning process. Hydrology shall be an organizing principle that is integrated into the initial site assessment planning phases.
- During the initial phases of the project, utilize a multidisciplinary approach that includes planners, engineers, landscape architects, and architects.
- Individual LID control measures should be distributed throughout the project site, and may influence configuration of roads, buildings, and other infrastructure.
- Consider flood control early in the design stages. Even sites with LID control measures will still have stormwater runoff that occurs during large storm events. Look for opportunities to simultaneously address flood control requirements.
G-2: Protect and Restore 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 less sensitive areas of a project 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 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:

- Preserve riparian areas and wetlands.
- Concentrate or cluster development on less sensitive areas of a site, while leaving the remaining land in a natural, undisturbed state. Less sensitive areas may include, but are not limited to, areas that are not adjacent to receiving waters or areas where erosion may be an issue.
- Identify and avoid areas susceptible to erosion and sediment loss.
- 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.
- Maintain existing topography and existing drainage divides to encourage dispersed flow.
- Maximize trees and other vegetation at each site by planting additional vegetation, clustering tree areas, and promoting the use of native and/or drought-tolerant plants.
- Promote natural vegetation by using parking lot islands and other landscaped areas.
G-3: Minimize Land Disturbance

Purpose

Slope and channel erosion can be a major source of sediment and associated pollutants, such as nutrients, if not properly protected and stabilized.

This control measure works to protect water quality by preserving some of the natural hydrologic function of the site. Existing soils may contain organic material and soil biota that are ideal for storing and infiltrating stormwater runoff. Clearing, grading, and using equipment removes and compacts existing soils, which reduces soil infiltration capacity. The design criteria presented below are not intended to supersede compaction requirements associated with building codes.

Design Criteria

Slope Protection

Slope protection practices must conform to design requirements or standards set forth in the most recent City of Modesto Standard Specifications. The design criteria described in this fact sheet are intended to enhance and be consistent with these standards.

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

Channel Protection

The following measures should be implemented to provide erosion protection of un-lined receiving waters. Activities and structures must conform to applicable standards and specifications of agencies with jurisdiction (e.g., U.S. Army Corps of Engineers, California Department of Fish and Game).

- Utilize natural drainage systems where feasible, but minimize stormwater runoff discharge rate and volume to avoid erosive flows.
- Stabilize permanent channel crossings.
- Provide special stabilization in cases where beds and/or banks of receiving waters are fragile and particularly susceptible to erosion.
- Reduce channel slope with a small grade control structure (e.g., drop structure).
- Protect severe bends or cut banks with biotechnical engineered practices.
- Protect fragile beds with rock-lined, low-flow channels if appropriate.
- Install energy dissipaters, such as rock riprap, at outlets of storm drains, culverts, conduits, or channels that discharge into un-lined channels to lessen erosion potential.

**Soil Compaction**

- Delineate and mark development envelope for the site (e.g., identify minimum area needed to build lots, allow access, and provide fire protection).
- Restrict equipment access and construction equipment storage to the development envelope.
- Avoid removal of existing trees and valuable vegetation, as feasible.
- It may be difficult for infill and redevelopment projects to avoid soil compaction or may start with compacted soils. In these cases, the project should consider soil amendments to restore permeability and organic content.
G-4: Minimize Impervious Area

Purpose

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

Minimizing impervious area will also reduce the stormwater runoff coefficient, which is directly proportional to the volume retention requirement. Therefore, lowering the stormwater runoff coefficient will lower the amount of stormwater runoff that must be retained on-site and treated.

Design Criteria

Some aspects of site design are directed by City building and fire codes and ordinances. The design criteria recommended in this fact sheet are intended to enhance and be consistent with these codes and ordinances. Minimizing impervious area at every possible opportunity requires integration of many small strategies. Suggested strategies for minimizing impervious areas through site design include the following:

- Use minimum allowable roadway and sidewalk cross sections, driveway lengths, and parking stall widths (refer to the most recent City of Modesto Standard Specifications).
- Minimize or eliminate the use of curb and gutter is strongly encouraged where slope and density permit so that street/road stormwater runoff drains to swales and other LID or treatment control measures.
- Use two-track/ribbon driveways or shared driveways.
- Include landscape islands in cul-de-sacs (where approved).
• Reduce building and parking lot footprints.
• Cluster buildings and paved areas to maximize pervious area.
• Maximize tree preservation or tree planting.
• Avoid compacting or paving over soils with high infiltration rates (see G-3).
• Use pervious pavement material where appropriate, such as modular paving blocks, turf blocks, porous concrete and asphalt, brick, and gravel or cobble (Ref. BASMAA, 1999 for description of pervious pavement options).
• Use grass-lined channels or surface swales to convey stormwater runoff instead of paved gutters.
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SECTION 5. SOURCE CONTROL MEASURES

5.1. Introduction

Source control measures are BMPs designed to prevent pollutants from contacting stormwater runoff or to prevent discharge of contaminated stormwater runoff to the storm drain system and/or receiving water. This section describes source control measures for activities that are potentially significant pollutant sources in stormwater runoff. Each source control measure specified in this section should be implemented in conjunction with appropriate non-structural source control measures, such as good housekeeping and employee training, to optimize pollution prevention. Non-structural source control measures are not discussed in the 2011 Revised Guidance Manual. The California Stormwater Best Management Practices Handbooks may be consulted for information on non-structural control measures (California Stormwater Quality Association, 2009). City stormwater staff may require additional source control measures not included in the 2011 Revised Guidance Manual for specific pollutants, activities, or land uses.

The source control measures addressed in this section apply to both stormwater and non-stormwater discharges. Non-stormwater discharges are the discharge of any substance, such as excess irrigation, cooling water, process wastewater, etc., to the storm drain system or receiving water that is not comprised of entirely stormwater. Stormwater that is mixed or comingled with other non-stormwater flows is considered non-stormwater. Stormwater and non-stormwater discharges to the storm drain system or receiving water may be subject to local, state, or federal permitting prior to starting any discharge. The appropriate agency should be contacted prior to any discharge. Discuss the matter with City staff if you are uncertain as to which agency should be contacted.

Some source control measures presented in this section require 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 (209-577-6300) to obtain information regarding obtaining sanitary sewer permits from the City. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive. The designer is urged to contact the City prior to completing site and equipment design of the facility.

5.2. Description

Source control measures and associated design features specified for various sites and activities are summarized in Table 5-1. Fact sheets are presented in this section for each source control measure. These fact sheets include design criteria established by the City to ensure effective implementation of the required source control measures.
Table 5-1. Summary of Source Control Measure Design Features

<table>
<thead>
<tr>
<th>Source Control Measure</th>
<th>Design Feature or Element</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Signs, placards, stencils, stamps</td>
</tr>
<tr>
<td>Storm Drain Message and Signage (S-1)</td>
<td>X</td>
</tr>
<tr>
<td>Outdoor Material Storage Area (S-2)</td>
<td>X</td>
</tr>
<tr>
<td>Outdoor Trash Storage and Waste Handling Area (S-3)</td>
<td>X</td>
</tr>
<tr>
<td>Outdoor Loading/Unloading Dock Area (S-4)</td>
<td>X</td>
</tr>
<tr>
<td>Outdoor Vehicle/Equipment Repair/Maintenance Area (S-5)</td>
<td>X</td>
</tr>
<tr>
<td>Outdoor Vehicle/Equipment/Accessory Washing Area (S-6)</td>
<td>X</td>
</tr>
<tr>
<td>Fuel and Maintenance Area (S-7)</td>
<td>X</td>
</tr>
<tr>
<td>Building Materials (S-8)</td>
<td>X</td>
</tr>
</tbody>
</table>
S-1: Storm Drain Message and Signage

Purpose

Waste material 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 for installing storm drain messages at storm drain inlets located project sites.

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 of wastes into storm drain inlets is prohibited and/or the drain that discharges to a receiving water.

Design Criteria

Signs with language and/or graphical icons, which prohibit illegal dumping, shall be posted at designated public access points along channels, and streams within the project area. Consult with City staff to determine specific signage requirements.

Storm drain message markers, placards, or concrete stamps are required at all storm drain inlets within the boundary of the development project. The marker should be placed in clear sight adjacent to the inlet (see Figure 5-1). All storm drain inlet locations must be identified on the development site map.

Maintenance Requirements

Legibility of markers and signs shall be maintained.
Figure 5-1. Storm Drain Message Location

NOTES:
1. STORM DRAIN MESSAGE SHALL BE APPLIED IN SUCH A WAY AS TO PROVIDE A CLEAR, LEGIBLE IMAGE.
2. STORM DRAIN MESSAGE SHALL BE PERMANENTLY APPLIED DURING THE CONSTRUCTION OF THE CURB AND GUTTER USING A METHOD APPROVED BY THE LOCAL AGENCY.
S-2: Outdoor Material Storage Area

Purpose

Materials (i.e., raw, finished, waste products) stored outdoors can become pollutant sources in stormwater runoff if not handled or stored properly. The type of pollutants associated with the materials will vary depending on the type of commercial or industrial activity present. Some materials are of more concern than others. While toxic or hazardous materials must be prevented from coming into contact with stormwater runoff, non-toxic or non-hazardous materials, such as debris and sediment, can also have significant impacts on receiving waters.

Applicability

Materials are classified into three categories based on the potential risk of pollutant release associated with stormwater runoff contact – high risk, medium risk, and low risk. General types of materials under each category are presented in Table 5-2. The City will make final determinations regarding category listing, if necessary.

Table 5-2. Classification of Materials for Potential Pollutant Risk

<table>
<thead>
<tr>
<th>High Risk Materials</th>
<th>Medium Risk Materials</th>
<th>Low Risk Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycled materials with discharge potential</td>
<td>Clean recycled materials without discharge potential</td>
<td>Washed gravel/rock</td>
</tr>
<tr>
<td>Corrosives</td>
<td>Metal (excluding lead and copper, and any metals with oil/grease coating)</td>
<td>Finished lumber (non-pressure treated)</td>
</tr>
<tr>
<td>Food items</td>
<td>Sawdust/bark chips</td>
<td>Rubber or plastic products (excluding small pieces)</td>
</tr>
<tr>
<td>Chalk/gypsum products</td>
<td>Sand/soil</td>
<td>Clean, precast concrete products</td>
</tr>
<tr>
<td>Scrap or salvage goods</td>
<td>Unwashed gravel/rock</td>
<td>Glass products (new)</td>
</tr>
<tr>
<td>Feedstock/grain</td>
<td></td>
<td>Inert products</td>
</tr>
<tr>
<td>Fertilizers</td>
<td></td>
<td>Gaseous products</td>
</tr>
<tr>
<td>Pesticides</td>
<td></td>
<td>Products in containers that prevent contact with stormwater (fertilizers and pesticides excluded)</td>
</tr>
<tr>
<td>Compost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime/lye/soda ash</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal/human wastes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubber and plastic pellets or other small pieces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncured concrete/cement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead and copper, and any metals with oil/grease coating</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Design Criteria

Design requirements for material storage areas are regulated by current City building and fire codes, ordinances, and zoning requirements. Source control measures described in this fact sheet are intended to enhance and be consistent with code and ordinance requirements. The design features presented in Table 5-3 should be incorporated into the design of outdoor material storage areas when stored materials could potentially contribute significant pollutants to the storm drain system. The level of controls required varies relative to the risk category of the material stored.

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 regulations, and cannot be discharged directly to the storm drain or sanitary sewer system without appropriate permission. Contact the City (209-577-6300) regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by the City’s Municipal Code. Failure to properly maintain building and property may subject the property owner to citation.
<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfacing</td>
<td>High-Risk Materials:</td>
</tr>
<tr>
<td></td>
<td>- Construct/pave storage area with a material that is chemically resistant to the materials being stored and impervious to leaks and spills.</td>
</tr>
<tr>
<td></td>
<td>Medium-Risk Materials:</td>
</tr>
<tr>
<td></td>
<td>- Pave storage area with impervious surfaces.</td>
</tr>
<tr>
<td></td>
<td>Low-Risk Materials:</td>
</tr>
<tr>
<td></td>
<td>- No requirement for surfacing.</td>
</tr>
<tr>
<td>Covers</td>
<td>High-Risk Materials:</td>
</tr>
<tr>
<td></td>
<td>- Cover storage area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the storage area. Direct stormwater runoff from the cover away from the storage area to a stormwater disposal point that meets all applicable code requirements and applicable requirements of the 2011 Revised Guidance Manual.</td>
</tr>
<tr>
<td></td>
<td>- Covers ten (10) feet high or less shall have a minimum overhang of three (3) feet measured from the perimeter of the hydraulically-isolated storage area.</td>
</tr>
<tr>
<td></td>
<td>- Cover higher than ten (10) feet shall have a minimum overhang of five (5) feet measured from the perimeter of the hydraulically-isolated storage area.</td>
</tr>
<tr>
<td></td>
<td>Medium-Risk Materials:</td>
</tr>
<tr>
<td></td>
<td>- At a minimum, completely cover material with temporary plastic sheeting during storm events.</td>
</tr>
<tr>
<td>Hydraulic Isolation and Drainage</td>
<td>High-Risk Materials:</td>
</tr>
<tr>
<td></td>
<td>- Hydraulically-isolate storage area by means of grading, berms, or drains to prevent stormwater run-on from surrounding areas or roof drains.</td>
</tr>
<tr>
<td></td>
<td>- Direct stormwater runoff from surrounding areas away from the hydraulically-isolated storage area to a stormwater disposal point that meets all applicable requirements of the 2011 Revised Guidance Manual and City codes.</td>
</tr>
<tr>
<td></td>
<td>- 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 sanitary sewer or collection point.</td>
</tr>
<tr>
<td></td>
<td>Medium-Risk Materials:</td>
</tr>
<tr>
<td></td>
<td>- Drainage from storage area may be allowed to an approved treatment control measure or possibly to an approved standard storm drain(s).</td>
</tr>
<tr>
<td></td>
<td>- For erodible material, provide grading and a structural containment barrier on at least three sides of each stockpile to prevent stormwater run-on from surrounding areas and migration of material due to wind erosion.</td>
</tr>
</tbody>
</table>
S-3: Outdoor Trash Storage and Waste Handling Area

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 to nearby storm drain inlets, channels, and/or receiving water. Waste handling operations that may be pollutant sources include dumpsters, litter control, and waste piles. This fact sheet contains details on specific control measures required to reduce and/or prevent pollutants in stormwater runoff associated with trash storage and waste handling.

Design Criteria

Design requirements for waste handling areas are regulated by Building and Fire Codes and by current City ordinances and zoning requirements. The design criteria described in this fact sheet are meant to enhance and be consistent with code and ordinance requirements. Any hazardous waste must be handled in accordance with legal requirements established in Title 22 of the California Code of Regulations.

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 trash storage area design features presented in Table 5-4 were developed to enhance City codes and ordinances and should be implemented depending on the type of waste or the type of containment. The design criteria 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 trash storage and collection areas. Conflicts or issues should be discussed with City staff.

Table 5-4. Design Criteria for Outdoor Trash Storage and Waste Handling Area

<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfacing</td>
<td>Construct storage area with a material impervious to leaks and spills.</td>
</tr>
<tr>
<td>Screens/Covers</td>
<td>Install a screen or wall around trash storage area to prevent off-site transport of loose trash.</td>
</tr>
<tr>
<td></td>
<td>Use lined bins or dumpsters to reduce leaking of liquid wastes.</td>
</tr>
<tr>
<td></td>
<td>Use waterproof lids on bins/dumpsters or provide a roof to cover enclosure (City discretion) to prevent precipitation from entering containers.</td>
</tr>
<tr>
<td>Grading/Drainage</td>
<td>Berm/grade waste handling area to prevent stormwater run-on.</td>
</tr>
<tr>
<td></td>
<td>Locate waste handling area at least 35 feet from storm drains.</td>
</tr>
<tr>
<td>Signs</td>
<td>Post signs inside enclosures and/or on all dumpsters prohibiting disposal of liquids and hazardous materials.</td>
</tr>
</tbody>
</table>
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 regulations, and cannot be discharged directly to the storm drain or sanitary sewer system without appropriate permission. Contact the City (209-577-6300) regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by the City’s Municipal Code. Failure to properly maintain building and property may subject the property owner to citation.
S-4: Outdoor Loading/Unloading Dock Area

Purpose

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

Design Criteria

Design requirements for outdoor loading/unloading of materials are governed by Building and Fire Codes and by current City ordinances and zoning requirements. Source control measures described in this fact sheet are intended to enhance and be consistent with these codes and access requirements for loading docks. The design criteria presented in Table 5-5 should be followed when developing construction plans for outdoor material loading/unloading areas. The design criteria listed in Table 5-5 are not intended to be in conflict with requirements established by individual companies. Conflicts or issues should be discussed with City staff.

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 appropriate permission. Contact the City (209-577-6300) regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., covers, signs) must be maintained by the owner/operator as required by the City’s Municipal Code. Failure to properly maintain building and property may subject the property owner to citation.
### Table 5-5. Design Criteria for Outdoor Loading/Unloading Dock Area

<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfacing</td>
<td>Construct floor surfaces with paving material that is impervious and chemically resistant to materials being handled in the loading/unloading area.</td>
</tr>
<tr>
<td>Covers</td>
<td>Cover outdoor loading/unloading areas to a distance of at least ten (10) feet beyond the loading dock or building face if there is no raised dock. For interior transfer bays, provide a minimum ten (10) foot minimum “No Obstruction Zone” to allow trucks or trailers to extend at least five (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 cover to shield all material transfers between trailers and building.</td>
</tr>
<tr>
<td>Hydraulic Isolation/Drainage</td>
<td>For outdoor loading/unloading areas, hydraulically isolate the first six (6) feet of paved area measured from the building or dock face by means of grading, berms, or drains to prevent stormwater run-on from surrounding areas or roof drains. Direct stormwater runoff and drainage from surrounding areas away from hydraulically-isolated areas to a stormwater discharge point that meets all applicable requirements of the 2011 Revised Guidance 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 hydraulically-isolated loading/unloading area to approved sediment/oil/water separator system connected to an approved City sanitary sewer or other approved collection point. Provide a manual emergency spill diversion valve upstream of 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.</td>
</tr>
</tbody>
</table>
S-5: Outdoor Vehicle/Equipment Repair/Maintenance Area

Purpose

Activities at vehicle/equipment repair/maintenance facilities that can contaminate stormwater include engine repair, service, and parking (e.g., leaking engine or parts). Oil and grease, solvents, car battery acid, coolant, and gasoline from repair/maintenance facilities can adversely impact stormwater runoff. This fact sheet contains details on the specific control measures required to reduce and/or prevent pollutants in stormwater runoff from vehicle/equipment repair/maintenance areas.

Design Criteria

Design requirements for vehicle/equipment repair/maintenance areas are governed by Building and Fire Codes and by City ordinances and zoning requirements. These design criteria described in the fact sheet are intended to enhance and be consistent with these code requirements. The design criteria required for vehicle/equipment repair/maintenance are presented in Table 5-6. All hazardous and toxic wastes must be prevented from entering the storm drain system. Conflicts or issues should be discussed with City staff.

Table 5-6. Design Criteria for Outdoor Vehicle/Equipment Repair/Maintenance Areas

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

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 appropriate permissions. Contact the City (209-577-6300) regarding permits for discharge of contaminated accumulated water.

**Maintenance Requirements**

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by the City’s Municipal Code. Failure to properly maintain building and property may subject the property owner to citation.
S-6: Outdoor Vehicle/Equipment/Accessory Washing Area

Purpose

Washing vehicles/equipment/accessories in areas where wash water flows onto the ground can adversely impact receiving waters. Wash water can contain high concentrations of oil and grease, metals, solvents, phosphates, and high suspended solids loads that can be transported to the storm drain system or receiving water. This fact sheet contains details on the specific control measures required to reduce and/or prevent pollutants in stormwater runoff from vehicle/equipment/accessory washing areas.

Design Criteria

Design requirements for vehicle/equipment/accessory washing areas are governed by Building and Fire Codes and City ordinances and zoning requirements. The design criteria presented in Table 5-7 are intended to enhance and be consistent with these requirements. Hazardous and toxic wastes cannot enter the storm drain system. Conflicts or issues should be discussed with City staff.

Table 5-7. Design Criteria for Outdoor Vehicle/Equipment/Accessory Washing Areas

<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfacing</td>
<td>Construct the vehicle/equipment/accessory washing area floors with Portland cement concrete.</td>
</tr>
<tr>
<td>Covers</td>
<td>Provide a cover that extends at least three (3) feet beyond the hydraulically-isolated area for cover heights less than or equal to ten (10) feet.</td>
</tr>
<tr>
<td></td>
<td>Provide a cover that extends at least five (5) feet beyond the hydraulically-isolated area for cover heights greater than ten (10) feet.</td>
</tr>
<tr>
<td>Grading/Drainage</td>
<td>Hydraulically isolate vehicle/equipment/accessory washing area using berms or grading to prevent stormwater run-on or runoff.</td>
</tr>
<tr>
<td></td>
<td>Grade/berm washing area to contain wash water within the covered area.</td>
</tr>
<tr>
<td></td>
<td>Direct wash water to treatment and recycle or pretreatment and proper connection to the sanitary sewer system. Obtain approval from the City</td>
</tr>
<tr>
<td></td>
<td>before discharging to the sanitary sewer system.</td>
</tr>
<tr>
<td></td>
<td>Direct stormwater runoff from downspouts/roofs away from washing areas.</td>
</tr>
<tr>
<td></td>
<td>Do not locate storm drains in the immediate vicinity of washing area.</td>
</tr>
<tr>
<td>Emergency Storm Drain</td>
<td>Provide means, such as isolation valves, drain plugs, or drain covers, to prevent spills or contaminated stormwater from entering the storm drain</td>
</tr>
<tr>
<td>Seal</td>
<td>system.</td>
</tr>
</tbody>
</table>
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 appropriate permissions. Contact the City (209-577-6300) regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by the City’s Municipal Code. Failure to properly maintain building and property may subject the property owner to citation.
S-7: Fuel and Maintenance Area

Purpose

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

Design Criteria

Design requirements for fuel and maintenance areas are regulated by Building and Fire Codes and current City ordinances and zoning requirements. The design criteria presented in Table 5-8 are intended to enhance and be consistent with these code and ordinance requirements. Conflicts or issues should be discussed with City staff.

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 appropriate permission. Contact the City (209-577-6300) regarding permits for discharge of contaminated accumulated water.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., screens, covers, signs) must be maintained by the owner/operator as required by the City’s Municipal Code. Failure to properly maintain building and property may subject the property owner to citation.
### Table 5-8. Design Criteria for Fuel and Maintenance Areas

<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surfacing</strong></td>
<td>Pave fuel dispensing/maintenance area with Portland cement concrete. The fuel dispensing/maintenance area is defined as extending 6.5 feet from the corner of each fuel dispenser or the length at which the hose and nozzle assembly may be operated plus one (1) foot, whichever is greater. Paving around the fuel dispensing/maintenance area may exceed the minimum dimensions of the “fuel dispensing/maintenance area” stated above. Use asphalt sealant to protect asphalt-paved areas surrounding the fuel dispensing/maintenance area.</td>
</tr>
</tbody>
</table>
| **Covers**                            | Cover fuel dispensing/maintenance area with a permanent canopy, roof, or awning to prevent precipitation from directly contacting the fuel dispensing/maintenance area. Direct stormwater runoff from the cover away from the area to a stormwater runoff disposal point that meets all applicable code requirements and applicable requirements of the 2011 Revised Guidance Manual.  
  o Covers ten (10) feet high or less shall have a minimum overhang of three (3) feet measured from the perimeter of the hydraulically-isolated fuel dispensing/maintenance area.  
  o Covers higher than ten (10) feet shall have a minimum overhang of five (5) feet measured from the hydraulically-isolated fuel dispensing/maintenance area.  
  For facilities designed to accommodate very large vehicles or equipment that would prohibit the use of covers, hydraulically-isolate the uncovered fuel dispensing/maintenance area and direct stormwater runoff from the area through upstream controls to the sanitary sewer system as described below. |
| **Hydraulic Isolation/Drainage**      | Design the fuel dispensing/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 paved fuel dispensing/maintenance area to prevent stormwater run-on from surrounding areas or roof drains by one of the following methods. Design should conform to applicable American Disabilities Act requirements for disabled access:  
  o Berms: Design the berm height four (4) inches above the surface of the fuel dispensing/maintenance area pad such that the pad will serve as a spill containment area.  
  o Perimeter trench drains: Locate trench drains around the pad perimeter. Direct stormwater runoff from the perimeter drains to one of the following:  
    ▪ Sanitary sewer system, upon City approval. Provide an automatic shut-off valve installed upstream of the sanitary sewer system connection and below grade in a manhole or similar concrete containment structure. The valve shall be designed to close automatically when the maximum oil/fuel storage capacity of the structure is reached.  
    ▪ An approved below-grade containment vault with at least 60 ft³ of storage capacity. The vault must be emptied, as required, |
<table>
<thead>
<tr>
<th>Design Feature</th>
<th>Design Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>and contents disposed of in accordance with applicable laws.</td>
</tr>
<tr>
<td></td>
<td>o Elevated fueling pad: Elevate the grade of the fueling pad such that it is high enough to prevent run-on from surrounding areas. The fueling pad should be flat in order to contain small spills and prevent stormwater runoff.</td>
</tr>
<tr>
<td></td>
<td>Direct stormwater runoff from surrounding areas away from hydraulically-isolated areas to a stormwater discharge point that meets all applicable requirements of the 2011 Revised Guidance Manual. Locate stormwater drains for surrounding areas at least ten (10) feet from the hydraulically-isolated fuel dispensing/maintenance area.</td>
</tr>
</tbody>
</table>
S-8: Building Materials

Purpose

The use of alternative building materials can reduce potential pollutant sources in stormwater runoff by eliminating compounds that can leach into stormwater runoff. Metal buildings, roofing, and fencing materials may be significant sources of metals in stormwater runoff. This fact sheet outlines concerns and alternatives to using metal products at a project site.

Design Criteria

Minimizing the use of copper and galvanized (zinc-coated) metals on buildings and fencing can help reduce leaching of these constituents into storm water runoff. The following building materials are conventionally made of galvanized metals:

- Metal roofs;
- Chain-link fencing; and
- Metal downspouts and vents on roofs.

Architectural use of copper for roofs and gutters should be avoided. As an alternative to copper and galvanized materials, coated metal products are available for both roofing and gutter application. Vinyl-coated fencing is an alternative to traditional galvanized chain-link fences. These products eliminate contact of bare metal with precipitation. There are also roofing materials made of recycled rubber and plastic. Vegetated roofs may also be an option.

Maintenance Requirements

The integrity of structural elements that are subject to damage (e.g., signs) must be maintained by the owner/operator as required by the City’s Municipal Code. Failure to properly maintain building and property may subject the property owner to citation.
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SECTION 6.  VOLUME RETENTION REQUIREMENT AND WATER QUALITY VOLUME/WATER QUALITY FLOW

6.1. Introduction

The City’s approach to minimize potential water quality impacts from stormwater runoff is implementing a volume retention requirement. By retaining a portion of stormwater runoff, the City expects to reduce and/or eliminate the pollutant loads, which are typically higher during the beginning of storm events, from reaching the receiving waters. Volume retention at a site depends on a number of factors including: type of potential pollutants in stormwater runoff, quantity of stormwater runoff, project site conditions, and receiving water conditions. Land area requirements and costs to design, construct, and maintain facilities to retain the design stormwater runoff volume will vary.

6.2. Volume Retention Requirement

The volume retention requirement is a new requirement developed in response to 2008 Municipal Stormwater Permit requirements specifying the use of LID and a combination of non-structural and structural control measures. The volume retention requirement specifies that the first 0.50 inch, which is the average 85th percentile, 24-hour storm depth for the Modesto area estimated by Caltrans, of a storm event must be retained and treated on-site. This calculated stormwater runoff volume for retention and treatment is different from the flood control retention requirements. The retention and treatment requirements are for water quality purposes, while the flood control retention requirements are for flood control purposes. The procedures for calculating the volume of stormwater runoff that must be retained on-site is presented in Fact Sheet C-1.
C-1: Volume Retention Requirement Calculation

Purpose

The purpose of this fact sheet is to provide details for calculating the volume of stormwater runoff that must be retained on-site at a project location. Effective tributary area credits are available depending on the types of LID control measures selected to reduce the volume of stormwater runoff that must be retained on-site.

Calculating the Retention Volume

The volume of stormwater runoff that must be retained at a project site is calculated using the following equation:

\[ V_{ret} = C \times R \times A \]

Where:

- \( V_{ret} \) = stormwater runoff volume to be retained (ft\(^3\));
- \( C \) = site-specific stormwater runoff coefficient (see Fact Sheet C-2 for calculation procedures);
- \( R \) = design rainfall depth (in) = 0.50 in = 0.042 ft; and
- \( A \) = effective site area (ft\(^2\)).

Priority significant redevelopment/infill projects must also comply with the volume retention requirement, but incentives in the form of credits may be applied based on the type of redevelopment. A credit of 0.05 inch from the 0.50 inch volume retention requirement may be applied to any of the following types of redevelopment/infill projects:

- Significant redevelopment (as defined in Section 2.1)
- Brownfield redevelopment
- High density (22 or more units per acre)
- Vertical density (two or more stories)
- Mixed use and transit-oriented development (within ½ mile of public transit)

Example Calculation

For a new development or redevelopment (that does not meet the type of redevelopment/infill project that qualifies for a credit) the volume retention is calculated by the equation \( V_{ret} = C \times R \times A \). For a priority project with an area of 75,000 ft\(^2\), a site specific stormwater runoff coefficient of 0.90, and a rainfall depth of 0.50 in = 0.042 ft, the volume retention requirement is calculated as:

\[ V_{ret} = 0.90 \times 0.042 \text{ ft} \times 75,000 \text{ ft}^2 = 2,835 \text{ ft}^3 \]
Example Calculation

For a priority redevelopment project that meets the vertical density and mixed use and transit-oriented development credits with the proposed site conditions listed above, the volume retention requirement is calculated by multiplying the number of credits times the credit as detailed in the example below:

\[ V_{\text{ret}} = C \times \{R - \left( \#\text{credits} \times \text{credit} \right) \div 12 \} \times A \]

Using the example above, a facility with two credits for vertical density and mixed use at a factor of 0.05/credit, a total project area of 75,000 ft², a site specific stormwater runoff coefficient of 0.90, and a rainfall depth of 0.50 inches the volume retention requirement is calculated as:

\[ V_{\text{ret}} = 0.90 \times \{0.5 - (2 \times 0.05) \div 12\} \times 75,000 \text{ ft}^2 = 2,250 \text{ ft}^3 \]
C-2: Water Quality Flow /Water Quality Volume Calculation

Purpose

The primary stormwater runoff control strategy for all treatment control measures specified in Section 8 is to treat the water quality flow (WQF) or water quality volume (WQV). This fact sheet presents calculation procedures and design criteria necessary to calculate the WQF and WQV, which are distinct parameters from the volume retention requirement that is discussed in Fact Sheet C-1. The WQF and WQV are required design parameters used to size treatment control measures. The volume retention requirement is a separate and independent requirement that must be met by application of a combination of LID and treatment control measures.

The treatment control measures specified in the 2011 Revised Guidance Manual are listed in Table 6-1 along with the basis of design, WQF or WQV, to be used and the respective design drawdown periods. It should be noted that treatment control measures designated as R may be used solely or in combination to meet the volume retention requirement, while treatment control measures designated as C or P do not assist in meeting the volume retention requirement.
Table 6-1. Sizing Criteria for Treatment Control Measures

<table>
<thead>
<tr>
<th>Treatment Control Measure</th>
<th>Design Basis</th>
<th>Design Drawdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infiltration Control Measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infiltration Well (R-1)</td>
<td>WQV</td>
<td>48 hr</td>
</tr>
<tr>
<td>Water Quality Infiltration Basin (R-2)</td>
<td>WQV</td>
<td>48 hr</td>
</tr>
<tr>
<td>Water Quality Infiltration Trench (R-3)</td>
<td>WQV</td>
<td>48 hr</td>
</tr>
<tr>
<td>Bioretention without Underdrain (R-4)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Dry Well (R-5)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>French Drain (R-6)</td>
<td>WQV</td>
<td>48 hr</td>
</tr>
<tr>
<td>Permeable Paving without an Underdrain (R-7)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Evapotranspiration and Biofiltration Control Measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioretention with Underdrain (R-8)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Permeable Paving with Underdrain (R-9)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Stormwater Planter (R-10)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Tree-well Filter (R-11)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Vegetated Swale (R-12)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Grassy Swale (R-13)</td>
<td>WQF</td>
<td>N/A</td>
</tr>
<tr>
<td>Vegetated Filter Strip (R-14)</td>
<td>WQF</td>
<td>N/A</td>
</tr>
<tr>
<td>Other Public Domain Treatment Control Measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Media Sand Filters (C-1)</td>
<td>WQV</td>
<td>40-48 hr</td>
</tr>
<tr>
<td>Constructed Wetland (C-2)</td>
<td>WQV</td>
<td>24 hr</td>
</tr>
<tr>
<td>Extended Detention Basin (C-3)</td>
<td>WQV</td>
<td>48 hr</td>
</tr>
<tr>
<td>Wet Pond (C-4)</td>
<td>WQV</td>
<td>12 hr</td>
</tr>
<tr>
<td>Proprietary Treatment Control Measures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proprietary Treatment Controls (P-1)</td>
<td>WQF or WQV</td>
<td>48 hr</td>
</tr>
</tbody>
</table>

Determining Design Imperviousness, Runoff Coefficient, and Effective Area

WQF and WQV calculations require following parameters associated with the drainage area tributary to the treatment control under design:

- Weighted stormwater runoff coefficient \( (C_r) \) (without application of impervious area credits); and
- Effective tributary area following application of impervious area credits \( (A_{\text{eff}}) \).
**Weighted Imperviousness and Stormwater Runoff Coefficient Calculations**

Projects typically comprise a variety of site elements that have variable values of imperviousness and associated stormwater runoff coefficients. The stormwater runoff coefficient is a function of imperviousness and permeability of the soil, if the stormwater runoff contacts the soil. Values of imperviousness and stormwater runoff coefficients that will be used for calculating WQF and WQV in the 2011 Revised Guidance Manual are listed in Table 6-2 for typical site elements. The weighted stormwater runoff coefficient value for a particular drainage area is determined as follows:

- Determine area associated with each site element \(A_{element}\).
- Determine sum of site element areas \(A_{site}\).
- Determine fraction of total area associated with each site element \(A_{element}/A_{site}\).
- Determine the stormwater runoff coefficient \(C_{r}\) associated with each site element from Table 6-2.
- Calculate weighted imperviousness \(I_{a}\) or stormwater runoff coefficient \(C_{ra}\):

\[
I_{a} = \sum_{i=1}^{n} \left( \frac{I_{i} \times A_{element,i}}{A_{site}} \right)
\]

\[
C_{ra} = \sum_{i=1}^{n} \left( \frac{C_{r} \times A_{element,i}}{A_{site}} \right)
\]

**Table 6-2. Stormwater Runoff Coefficients for Typical Site Elements**

<table>
<thead>
<tr>
<th>Site Element</th>
<th>Stormwater Runoff Coefficient (C_{r}) (^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type A and B Soils</td>
</tr>
<tr>
<td>Asphalt/concrete pavement</td>
<td>0.95</td>
</tr>
<tr>
<td>Roofs</td>
<td>0.95</td>
</tr>
<tr>
<td>Gravel pavement</td>
<td>0.35</td>
</tr>
<tr>
<td>Permeable pavement</td>
<td>Variable (^{(2)})</td>
</tr>
<tr>
<td>Managed turf</td>
<td>0.18</td>
</tr>
<tr>
<td>Disturbed soils</td>
<td>0.18</td>
</tr>
<tr>
<td>Vegetated areas with amended Type A soil</td>
<td>0.03</td>
</tr>
<tr>
<td>Forest/undisturbed open space</td>
<td>0.03</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Adapted from Center for Watershed Protection, Ellicott City, MD.

\(^{(2)}\) Variable with product type. Consult manufacturer for appropriate design values.

Example calculations for weighted stormwater runoff coefficients for a site with Type D soil are presented in Table 6-3.
Table 6-3. Example Calculation Table for Weighted Stormwater Runoff Coefficient

<table>
<thead>
<tr>
<th>Site Element</th>
<th>Element Area ($A_{element}$, ft$^2$)</th>
<th>Fraction of Total Area ($A_{element}/A_{site}$)</th>
<th>Element Stormwater Runoff Coefficient ($C_e$)</th>
<th>Weighted Stormwater Runoff Coefficient ($C_{eff}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt/concrete pavement</td>
<td>40,000</td>
<td>0.40</td>
<td>0.95</td>
<td>0.38</td>
</tr>
<tr>
<td>Roofs</td>
<td>30,000</td>
<td>0.30</td>
<td>0.95</td>
<td>0.29</td>
</tr>
<tr>
<td>Permeable pavement</td>
<td>5,000</td>
<td>0.05</td>
<td>0.35</td>
<td>0.17</td>
</tr>
<tr>
<td>Managed turf</td>
<td>20,000</td>
<td>0.20</td>
<td>0.25</td>
<td>0.05</td>
</tr>
<tr>
<td>Forest/undisturbed open space</td>
<td>5,000</td>
<td>0.05</td>
<td>0.03</td>
<td>0.01</td>
</tr>
<tr>
<td>Total Site ($A_{site}$)</td>
<td>100,000</td>
<td></td>
<td></td>
<td>0.90</td>
</tr>
</tbody>
</table>

(1) Actual area without adjustment for tributary impervious area credits from LID control measures.

**Effective Tributary Area Calculations**

The effective tributary area is defined as the effective area being used in WQF and WQV calculations for specific treatment control measures, and is determined by subtracting the tributary impervious area credits earned for LID control measures from the actual tributary drainage area served by the treatment control measure.

\[
A_{eff} = A_{tributary} - A_{credit}
\]

Note that a tributary impervious area credit for an LID control measure must be applied to a treatment control measure that serves the same tributary drainage area as the LID control measure for which the credit is earned. The credits cannot be greater than the total tributary drainage area of the treatment control measure to which they are applied. Example calculations for effective area are presented in Table 6-4.

Table 6-4. Example Calculation Table for Effective Tributary Area

<table>
<thead>
<tr>
<th>Site Element</th>
<th>Element Area (ft$^2$)</th>
<th>Area Credit ($A_{credit}$, ft$^2$)</th>
<th>Effective Area ($A_{eff}$, ft$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt/concrete pavement</td>
<td>40,000</td>
<td>10,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Roofs</td>
<td>30,000</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Permeable pavement (2)</td>
<td>5,000</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td>Managed turf</td>
<td>20,000</td>
<td>0</td>
<td>20,000</td>
</tr>
<tr>
<td>Forest/undisturbed open space</td>
<td>5,000</td>
<td>0</td>
<td>5,000</td>
</tr>
</tbody>
</table>

(1) Area credit from low impact development control measures.

(2) Credit for permeable pavement has already been provided in the form of a reduced stormwater runoff coefficient (see Table 6-2 and Table 6-3).
Water Quality Flow (WQF) Calculation

Hydrologic calculations for design of flow-based treatment control measures in Modesto shall be in accordance with the most current City of Modesto Standard Specifications. The WQF is defined to be equal to the maximum flow rate of stormwater 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 in the Modesto area is estimated to be approximately 0.10 in/hr, based on California State University, Sacramento Office of Water Programs’ Basin Sizer, Version 1.45 (2007).

Calculation Procedure

The following procedure is used to calculate the WQF:

- Determine the 85th percentile hourly rainfall intensity for the Modesto area. Use 0.10 in/hr.
- Multiply the 85th percentile hourly rainfall intensity by a factor of two to obtain the design rainfall intensity (i). Use $i = 0.10 \times 2 = 0.20$ in/hr.
- Determine the weighted stormwater runoff coefficient for the project area using the procedure illustrated in Table 6-3.
- Determine the effective area ($A_{eff}$) of the drainage area using the procedure illustrated in Table 6-4.
- Calculate WQF using the following equation:

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

Where:

- $WQF = \text{Water quality flow (cfs)}$;
- $i = \text{Design rainfall intensity (0.20 in/hr)}$;
- $C_{ra} = \text{Weighted stormwater runoff coefficient for project area}$; and
- $A_{eff} = \text{Effective project drainage area (acres)}$ (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$^2$; $C_{ra} = 0.90$

$$WQF = 0.20 \times 0.90 \times \frac{75,000}{43,560} = 0.31 \text{ cfs}$$
Water Quality Volume (WQV) Calculation

Hydrologic calculations for design of volume-based treatment control measures in Modesto shall be in accordance with the procedures set forth herein.

The WQV is defined as the volume necessary to capture and treat 80 percent or more of the annual stormwater runoff volume from the site at the design drawdown period specified for each treatment control measure. The WQV should not be confused with the volume retention requirement, which is a separate requirement as defined previously.

Calculation Procedure

The following procedures are used to calculate the WQV:

- Review drainage area of the proposed treatment control measure. Determine the weighted stormwater runoff coefficient \( C_{ra} \) of the drainage area using the procedure presented in Table 6-3.
- A direct reading of the Unit Basin Storage Volumes (Figure 6-1) is required for 80% annual capture of stormwater runoff for values of \( C_{ra} \) determined in the previous step.
- Determine the effective area of the drainage area using the procedure outlined in Table 6-4.
- The WQV for the proposed treatment control measure is calculated by multiplying the Unit Basin Storage Volume by the effective drainage area. Due to the mixed units that result (e.g., acre-feet, acre-inches), it is recommended that the resulting volume be converted to cubic feet (\( \text{ft}^3 \)) for use during design.

\[
WQV = V_u \times A_{eff}
\]

Where:

\( V_u = \) Unit basin storage volume (ft); and
\( A_{eff} = \) Effective drainage area (acres).

Example Calculation

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

- Determine design drawdown period for proposed control measure (see Table 6-1)
  Example: Water Quality Infiltration Basin \( \rightarrow \) drawdown period = 48 hours
- Determine Unit Basin Storage Volume for 80% annual capture, \( V_u \), using Figure 6-1:
  For \( C_{ra} = 0.90 \) and drawdown time = 48 hours \( \rightarrow V_u = 0.42 \text{ in} \)
• Calculate WQV for basin:

\[ WQV = V_u \times A_{eff} = (0.42 \text{ in}) \times (75,000 \text{ ft}^2) \times \left( \frac{1 \text{ ft}}{12 \text{ in}} \right) = 2,625 \text{ ft}^3 \]

Figure 6-1. Unit Basin Storage Volume vs. Weighted Stormwater Runoff Coefficient
SECTION 7.  LOW IMPACT DEVELOPMENT CONTROL MEASURES

7.1.  Introduction

LID control measures are required to minimize potential water quality impacts from stormwater runoff. LID control measures are BMPs that can be used to direct, retain, reuse, and/or infiltrate stormwater runoff. The type of LID control measure to be implemented at a project site depends on a number of factors including, but not limited to the following:

- Type of potential pollutants in stormwater runoff;
- Quantity of stormwater runoff to be treated;
- Size of the drainage area;
- Site slope and need for vegetation irrigation;
- Project site conditions (e.g., soil type, soil permeability, groundwater levels); and
- Receiving water conditions.

Vector breeding considerations must also be addressed because of nuisance and potential human health effects. Land area requirements and costs to design, construct, and maintain LID control measures vary. The site constraints used to select LID control measures is presented in Table 7-1.
### Table 7-1. Site Constraints for Low Impact Development Control Measures

<table>
<thead>
<tr>
<th>Low Impact Development Control Measure</th>
<th>Drainage Area (acres)</th>
<th>Depth to Water Table (feet)</th>
<th>Soil Type (1,2)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Slope (%)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Irrigation Required? (3)</th>
<th>Vector Control Frequency (4)</th>
<th>Maintenance Frequency (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain Garden (L-1)</td>
<td>&lt;0.05</td>
<td>10&lt;sup&gt;(5)&lt;/sup&gt;</td>
<td>X</td>
<td>X</td>
<td>Y</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Rain Barrel/Cistern (L-2)</td>
<td>&lt;0.25</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>N</td>
<td>H&lt;sup&gt;(6)&lt;/sup&gt;</td>
<td>L</td>
</tr>
<tr>
<td>Vegetated Roof (L-3)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>Y</td>
<td>L</td>
<td>M&lt;sup&gt;(6)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Interception Trees (L-4)</td>
<td>n/a</td>
<td>n/a</td>
<td>X</td>
<td>X</td>
<td>Y</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Grassy Channels (L-5)</td>
<td>&lt;1</td>
<td>n/a</td>
<td>X</td>
<td>X</td>
<td>≤ 4</td>
<td>Y</td>
<td>L</td>
</tr>
<tr>
<td>Vegetated Buffer Strips (L-6)</td>
<td>&lt;1</td>
<td>n/a</td>
<td>X</td>
<td>X</td>
<td>&lt; 5</td>
<td>Y</td>
<td>L</td>
</tr>
</tbody>
</table>

(1) X = control measure is suitable for listed site condition.
(2) Type A soils are sands and gravels and 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) Y = Yes; N = No.
(4) H = High; M = Medium; L = Low.
(5) Applies if rain garden is allowed to infiltrate.
(6) Concerns may be mitigated through design features (see corresponding fact sheets).
(7) Once vegetation is established, maintenance requirements are low.

### 7.2. Description of Low Impact Development Control Measures

This section provides fact sheets for design and implementation of LID control measures. The fact sheets include planning and site considerations, design criteria, and maintenance requirements to ensure optimal performance of the control measures.
L-1: Rain Garden

Description

A rain garden is a planted depression that is designed to receive, retain, and infiltrate stormwater runoff from impervious areas, such as rooftops and pavement. Stormwater runoff is initially captured in a ponding zone above the vegetated surface. Captured stormwater runoff infiltrates the surface layer of the garden and filters through a planting soil layer before entering the groundwater or being collected by an underdrain system. The garden may include a gravel retention zone below the planting soil layer to facilitate infiltration. Stormwater runoff treatment occurs as it filters through the root zone of the vegetation. A portion of the water held in the root zone of the garden is returned to the atmosphere through transpiration by the 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 design may also include an underdrain pipe. However, underdrain pipes will reduce the retention capabilities of the rain garden.

Other names

Micro-bioretention, biofiltration

Advantages

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

Disadvantages

- Volume retention may be limited by space available.
- May not be suitable for low permeability soils.
- Requires individual owners/tenants to perform maintenance.
• Not suitable for industrial sites or sites where spills may occur unless infiltration is prevented by an impermeable liner.

Planning and Site Considerations

• Locate rain gardens at least ten (10) feet from building foundations.
• Maintain a slope of at least one (1) percent from impervious surfaces 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.
• For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the rain garden, and cars are allowed to overhang the rain garden.
• Irrigation is typically required to maintain viability of the rain garden vegetation. Coordinate design of general landscape irrigation system with that of the rain garden, as applicable.

Design Criteria

Design criteria for rain gardens are presented in Table 7-2. A schematic showing the basic elements of a typical rain garden is presented in Figure 7-1.

Table 7-2. Rain Garden Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface area of ponding zone</td>
<td>20-30%</td>
<td>Typical percentage of impervious area draining to rain garden. Smaller percentages are acceptable with overflow drainage provided.</td>
</tr>
<tr>
<td>Maximum depth of ponding zone (D_{\text{RG}})</td>
<td>6 in</td>
<td>Depth above top of mulch layer.</td>
</tr>
<tr>
<td>Depth to top mulch layer</td>
<td>2-3 in</td>
<td>Shredded hardwood or softwood or compost.</td>
</tr>
<tr>
<td>Depth of planting media</td>
<td>12-18 in</td>
<td>Mix: 60-65% loamy sand + 35-40% compost; or 30% loamy sand + 30% course sand + 40% compost</td>
</tr>
<tr>
<td>Depth of retention zone (optional)</td>
<td>9-12 in</td>
<td>Washed drain rock (0.5-1.5 inch diameter). Use with under drain.</td>
</tr>
<tr>
<td>Underdrain pipe (optional)</td>
<td>4-in</td>
<td>Perforated PVC or HDPE. Use with Type C and D soils.</td>
</tr>
<tr>
<td>Excavation side slope (H:V)</td>
<td>3:1</td>
<td>Maximum steepness.</td>
</tr>
</tbody>
</table>
Volume Retention and Tributary Impervious Area Credit Calculation

Rain gardens provide volume retention by capturing water in pore spaces of the planting soil layer (detention/filtration zone) and infiltrating it into the underlying soil. Rain gardens may be used to help meet the volume retention requirement, and can be used to reduce the size of required downstream treatment control measures (see Section 8). The volume retention credit calculation for rain gardens is presented in Table 7-3. Additional information on calculating and meeting the volume retention requirement is provided in Appendix B.

Rain gardens can be used to reduce the size of required treatment control measures through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate WQF or WQV, which are used to size treatment control measures. Implementation of rain gardens reduces effective impervious area and thereby the volume of water that needs to be treated. The credit is based on the ratio of volume retention to the WQV for the rain garden drainage area. Note that these credits must be applied to treatment control measures that are 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 area of the rain garden.
The tributary impervious area credit calculation for rain gardens is presented in Table 7-3.

Table 7-3. Rain Garden Volume Retention and Tributary Impervious Area Credit Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rain Garden without Subsurface Drain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Volume Retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ponding zone depth</td>
<td>( D_{pz} = ) ft</td>
</tr>
<tr>
<td></td>
<td>Ponding zone area</td>
<td>( A_{pz} = ) ft²</td>
</tr>
<tr>
<td></td>
<td>Detention zone depth</td>
<td>( D_{dz} = ) ft</td>
</tr>
<tr>
<td></td>
<td>Detention zone area</td>
<td>( A_{dz} = ) ft²</td>
</tr>
<tr>
<td></td>
<td>Volume retention</td>
<td>( V_{rel} = ) ft³</td>
</tr>
<tr>
<td>Rain Garden with Subsurface Drain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Volume Retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ponding zone depth</td>
<td>( D_{pz} = ) ft</td>
</tr>
<tr>
<td></td>
<td>Ponding zone area</td>
<td>( A_{pz} = ) ft²</td>
</tr>
<tr>
<td></td>
<td>Detention zone depth</td>
<td>( D_{dz} = ) ft</td>
</tr>
<tr>
<td></td>
<td>Detention zone area</td>
<td>( A_{dz} = ) ft²</td>
</tr>
<tr>
<td></td>
<td>Retention zone depth</td>
<td>( D_{rz} = ) ft</td>
</tr>
<tr>
<td></td>
<td>Retention zone area</td>
<td>( A_{rz} = ) ft²</td>
</tr>
<tr>
<td></td>
<td>Volume retention</td>
<td>( V_{rel} = ) ft³</td>
</tr>
<tr>
<td>2. Impervious area tributary to rain garden</td>
<td>( A_{imp} = ) ft²</td>
<td>Unit Basin Storage Volume for 12-hour drawdown at 100% imperviousness (0.95 stormwater runoff coefficient) = 0.32 inches (see Figure 6-1). Adjust value for ( A_{imp} &lt; 100% ) impervious. ( WQV = 0.32 \text{ in} \times \frac{A_{imp}}{12 \text{ in/ft}} )</td>
</tr>
<tr>
<td>3. WQV for ( A_{imp} ) (12-hour drawdown)</td>
<td>( WQV = ) ft³</td>
<td></td>
</tr>
<tr>
<td>4. Tributary Impervious Area Credit</td>
<td>( A_{c} = ) ft²</td>
<td>( A_{imp} \times V_{rel} \div WQV )</td>
</tr>
</tbody>
</table>

Construction Considerations

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
• Install sediment controls, such as silt fences, around the rain garden to prevent high sediment loads from entering the area during ongoing construction activities.
• Avoid compaction of native soils below planting media layer or gravel zone.
• Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes LID control measures such as rain gardens. Such agreements typically include requirements such as those outlined in Table 7-4. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the LID control measure and its immediate vicinity at any time. LID control measure maintenance is the responsibility of the owner. A sample maintenance agreement is presented in Appendix D.

Table 7-4. Inspection and Maintenance Requirements for Rain Gardens

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remulch void areas.</td>
<td>As needed</td>
</tr>
<tr>
<td>Treat diseased trees and shrubs.</td>
<td>As needed</td>
</tr>
<tr>
<td>Use Integrated Pest Management Practices.</td>
<td>As needed</td>
</tr>
<tr>
<td>Water plants daily for two weeks.</td>
<td>At project completion</td>
</tr>
<tr>
<td>Inspect soil and repair eroded areas.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Remove litter and debris.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Remove and replace dead and diseased vegetation.</td>
<td>Twice per year</td>
</tr>
<tr>
<td>Add additional mulch.</td>
<td>Once per year</td>
</tr>
<tr>
<td>Replace tree stakes and wire.</td>
<td>Once per year</td>
</tr>
</tbody>
</table>
**L-2: Rain Barrel/Cistern**

**Description**

Rain barrels and cisterns are containers that collect and store stormwater runoff from rooftop drainage systems that would otherwise be lost to runoff and diverted to the storm drain system. 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 7-2). Stored stormwater 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.

**Limitations**

- Storage volume may be limited.
- Stored water is not suitable for human or pet consumption.
- Contact of stored water with fruits/vegetables should be avoided due to unknown risks.
- 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 Site Considerations

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

Volume Retention and Tributary Impervious Area Credit Calculation

Rain barrels and cisterns provide volume retention by storing water in the container. Rain barrels and cisterns may be used to help meet the volume retention requirement, and can be used to reduce the size of required downstream treatment control measures (see Section 8). The volume retention credit calculation for rain barrels and cisterns is presented in Table 7-5. Additional information on calculating and meeting the volume retention requirement is provided in Appendix B.

Rain barrels and cisterns can be used to reduce the size of required treatment control measures through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate WQF or WQV, which are used to size treatment control measures. Implementation of rain barrels and
cisterns reduces effective impervious area and thereby the volume of water that needs to be treated. The credit is based on the ratio of volume retention to the WQV for the rain barrel or cistern drainage area. Note that these credits must be applied to treatment control measures that are in the same tributary drainage area as the rain barrel or cistern for which the credits are determined, and the credits cannot be greater than the tributary drainage area of the rain barrel or cistern. The tributary impervious area credit calculation for rain barrels and cisterns is presented in Table 7-5.

Table 7-5. Rain Barrel/Cistern Volume Retention and Tributary Impervious Area Credit Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Volume Retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total storage volume of rain barrel/cistern</td>
<td>$V_s = \text{___________}$ ft$^3$</td>
<td></td>
</tr>
<tr>
<td>Effectiveness factor</td>
<td>$\text{Eff} = 75%$</td>
<td>Effectiveness factor considers container may not be emptied between each storm event.</td>
</tr>
<tr>
<td>Volume retention</td>
<td>$V_{\text{ret}} = \text{___________}$ ft$^3$</td>
<td>$V_s \times \text{Eff}$</td>
</tr>
<tr>
<td>2. Total roof area</td>
<td>$A_{\text{roof}} = \text{___________}$ ft$^2$</td>
<td></td>
</tr>
<tr>
<td>3. WQV for $A_{\text{roof}}$ (12-hour drawdown)</td>
<td>$\text{WQV} = \text{___________}$ ft$^3$</td>
<td>Unit Basin Storage Volume for 12-hour drawdown at 100% imperviousness (0.95 stormwater runoff coefficient) = 0.32 inches (see Figure 6-1). [ \text{WQV} = 0.32 \text{ in} \times A_{\text{roof}} \div 12 \text{ in/ft} ]</td>
</tr>
<tr>
<td>4. Tributary Impervious Area Credit</td>
<td>$A_c = \text{___________}$ ft$^2$</td>
<td>$A_{\text{roof}} \times V_{\text{ret}} \div \text{WQV}$</td>
</tr>
</tbody>
</table>

Construction Considerations

- Stormwater runoff should not be diverted to a rain barrel or cistern until the overflow discharge area has been stabilized.
- A designated use for the stormwater runoff must be identified. Rain barrels or cisterns must be emptied between storm events to prevent overflow.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes LID control measures such as rain barrels and cisterns. Such agreements typically include requirements such as those outlined in Table 7-6. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the LID control measure and its immediate vicinity at any time. LID control measure maintenance is the responsibility of the owner. A sample maintenance agreement is presented in Appendix D.
Table 7-6. Inspection and Maintenance Requirements for Rain Barrels and Cisterns

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspect roof connection, gutter, downspout, rain barrel/cistern,</td>
<td>Twice per year. Repair as required.</td>
</tr>
<tr>
<td>mosquito screen, and overflow pipes for leaks and obstructions.</td>
<td></td>
</tr>
<tr>
<td>Inspect insect and debris screens. Clean as required.</td>
<td>Following significant storm events.</td>
</tr>
<tr>
<td>Prevent vector breeding by removing standing water.</td>
<td>Following storm events.</td>
</tr>
</tbody>
</table>
L-3: Vegetated Roof

Description

A vegetated roof is a multi-layered rooftop system designed for filtering, absorbing, and retaining stormwater runoff. Vegetated roofs are comprised of light-weight growth media and a specialized mix of vegetation underlain by a root barrier, a drainage layer, and a waterproofing membrane that protects the building structure. A vegetated roof retains precipitation within the pore space of the growing medium and releases that volume slowly via evaporation from soil and transpiration by plants.

Vegetated roofs reduce stormwater runoff volume and peak discharge flow rates by retaining and slowly releasing the water that would otherwise flow quickly into the storm drain system. Vegetated roofs improve stormwater runoff quality through biological, physical, and chemical processes that occur within the plants and growth media to prevent airborne pollutants from entering the storm drain system.

There are two types of vegetated roofs: intensive and extensive. Intensive vegetated roofs are characterized by thick soil depths, heavy weights, and elaborate plantings that include shrubs and trees. Extensive vegetated roofs consist of a thin soil layer and a cover of grass, sedums, or moss.

Other names

Ecoroof, green roof, green rooftop, nature roof, vegetated roof cover, living roof

Advantages

- Allows for reduction in drainage capacity requirements at both roof and ground levels.
- Provides thermal insulation, which reduces energy costs.
- Extends roof life by protecting underlying roof material from climatic extremes, ultraviolet light, and damage.
- Reduces amount of airborne pollutants entering the storm drain system.
- Reduces volume and peaks of stormwater runoff.
• Absorbs air pollution, collects airborne particulate matter, and negates acid rain effects.
• Provides “islands” or “stepping stone” habitat for wildlife, particularly avian species.
• Reduces urban heat island effect.
• Provides sound insulation to reduce noise transfer (e.g., air traffic).

**Limitations**

• Vegetated roofs are best incorporated into plans for new buildings that provide adequate structural support; however, they can be retrofitted for existing buildings.
• Special structural design requirements increase building costs.
• Vegetation maintenance – appropriate plant selection is necessary to ensure plant survival. Irrigation during the first year may be necessary to establish vegetation. Plants should be selected that are drought-tolerant and require little maintenance.

**Planning and Site Considerations**

• Climate, especially temperature and rainfall patterns.
• Size, slope, height, and directional orientation of the roof. Vegetated roofs are typically installed on flat roofs, but may be installed on roofs with slopes up to 10%.
• Roof must be capable of handling vegetated roof load.
• Accessibility and intended use. Safe access must be available for workers and materials during both construction and maintenance.
• Visibility, architectural fit, and aesthetic preferences.
• Compatibility with other systems (e.g., solar panels).
• Irrigation is typically required to maintain viability of vegetated roofs. Coordinate design of general irrigation system with that of vegetated roof, as applicable.
• Appropriate vegetation selection (drought-tolerant and requires little maintenance) is extremely important to the success of this LID control measure.

**Design Criteria**

Design criteria for vegetated roofs are listed in Table 7-7. A typical vegetated roof configuration is provided in Figure 7-3.
Table 7-7. Vegetated Roof Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Extensive Vegetated Roof</th>
<th>Intensive Vegetated Roof</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth media</td>
<td>Typical depth: 1-5 inches&lt;br&gt;Mix should have high mineral content</td>
<td>Typical depth: 6-24 inches&lt;br&gt;Mix should have high mineral content</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Variety of vegetated ground cover and grasses. Select vegetation that is drought tolerant and requires little maintenance</td>
<td>Large trees, shrubs, and complex gardens. Select vegetation that is drought tolerant and requires little maintenance</td>
</tr>
<tr>
<td>Waterproofing membrane</td>
<td>Resistant to biological and root attack</td>
<td>Resistant to biological and root attack</td>
</tr>
<tr>
<td>Load</td>
<td>12-50 pounds per square foot</td>
<td>80-150 pounds per square foot</td>
</tr>
<tr>
<td>Public access</td>
<td>Usually not designed for public access</td>
<td>Accommodated and encouraged</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Annual maintenance walks should be performed until plants are established</td>
<td>Significant maintenance required</td>
</tr>
<tr>
<td>Drainage</td>
<td>Simple irrigation and drainage system</td>
<td>Complex irrigation and drainage system</td>
</tr>
</tbody>
</table>

Figure 7-3. Vegetated Roof Schematic

- Vegetation
- Growing Medium
- Drainage, Aeration, Water Storage and Root Barrier
- Insulation
- Membrane Protection and Root Barrier
- Roofing Membrane
- Structural Support
Volume Retention and Tributary Impervious Area Credit

Vegetated roofs provide volume retention by storing water in the pore space of the planting/growing medium. Vegetated roofs may be used to help meet the volume retention requirement, and can be used to reduce the size of required downstream treatment control measures (see Section 8). The volume retention credit calculation for vegetated roofs is presented in Table 7-8. Additional information on calculating and meeting the volume retention requirement is provided in Appendix B.

Vegetated roofs can be used to reduce the size of required treatment control measures through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate WQF or WQV, which are used to size treatment control measures. Implementation of vegetated roofs reduces effective impervious area and thereby the volume of water that needs to be treated. The credit is based on the ratio of volume retention to the WQV for the vegetated roof drainage area. Note that these credits must be applied to treatment control measures that are in the same tributary drainage area as the vegetated roof for which the credits are determined, and the credits cannot be greater than the tributary drainage area of the vegetated roof. The tributary impervious area credit calculation for vegetated roofs is presented in Table 7-8.

Table 7-8. Vegetated Roof Volume Retention and Tributary Impervious Area Credit Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Volume Retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume of growth medium</td>
<td>$V_{gm} =$</td>
<td>ft$^3$</td>
</tr>
<tr>
<td>AWHC of growth medium</td>
<td>$W_{gm} =$</td>
<td></td>
</tr>
<tr>
<td>Volume retention</td>
<td>$V_{ret} =$</td>
<td>ft$^3$</td>
</tr>
<tr>
<td>2. Total roof area</td>
<td>$A_{roof} =$</td>
<td>ft$^2$</td>
</tr>
<tr>
<td>3. WQV for $A_{roof}$ (12-hour drawdown)</td>
<td>$WQV =$</td>
<td>ft$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unit Basin Storage Volume for 12-hour drawdown at 100% imperviousness (0.95 stormwater runoff coefficient) = 0.32 inches (see Figure 6-1).</td>
</tr>
<tr>
<td>4. Tributary Impervious Area Credit</td>
<td>$A_c =$</td>
<td>ft$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$A_{roof} x V_{ret}$ x WQV</td>
</tr>
</tbody>
</table>

Construction Considerations

- Vegetation selection and planting is critical to the success of this control measure. Plants should be selected, installed, and maintained by experienced
horticulturists or landscaping contractors who understand the City’s local environment and climate.

- Vegetated roof components, particularly the vegetation, must be protected until established.
- Load bearing capacity of the roof must be adequate to support soils, plants, and rain.
- Appropriate safety measures for working on industrial/commercial rooftops should be followed.
- The vegetated roof should be constructed in sections for easier inspection and maintenance access to the membrane and roof drains.

**Long-Term Maintenance**

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes LID control measures such as vegetated roofs. Such agreements typically include requirements such as those outlined in Table 7-9. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the LID control measure and its immediate vicinity at any time. LID control measure maintenance is the responsibility of the owner. A sample maintenance agreement is presented in Appendix D.

Once a properly-installed vegetated roof is established, its maintenance requirements are usually minimal. Intensive vegetated roofs tend to have higher maintenance requirements compared to extensive vegetated roofs due to its increased weight and more concentrated plantings.

**Table 7-9. Inspection and Maintenance Requirements for Vegetated Roofs**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation: Extensive vegetated roof.</td>
<td>Establishment of vegetation during periods of drought</td>
</tr>
<tr>
<td>Irrigation: Intensive vegetated roof.</td>
<td>Year-round, except during storm events</td>
</tr>
<tr>
<td>Weeding.</td>
<td>Establishment of vegetation; thereafter, as needed</td>
</tr>
<tr>
<td>Repair/replace vegetation to maintain desired cover.</td>
<td>As needed (2-3 times per year)</td>
</tr>
<tr>
<td>Inspection and maintenance of waterproof membrane.</td>
<td>2-3 times per year</td>
</tr>
<tr>
<td>Inspection and maintenance of drainage layer flow paths.</td>
<td>As needed</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As needed</td>
</tr>
<tr>
<td>Fertilization: To achieve water quality benefits, vegetated roofs should generally not be fertilized.</td>
<td>None</td>
</tr>
</tbody>
</table>
L-4: Interception Trees

Description

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 retention benefit. The rainfall interception and evaporation benefits received through a tree’s hydrologic cycle are presented in Figure 7-4.

Advantages

- Reduces stormwater runoff volume and pollutant discharge.
- Enhances site aesthetics.
  Increases property values.
- Provides shading and cooling.
- Improves air quality.
- Can be used to also meet landscaping requirements.

Limitations

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

Planning and Site Considerations

- Trees should be selected that maximize tree canopy, are low maintenance, drought-tolerant, and are appropriate for local soil conditions. A list of recommended trees are presented in Appendix H.
- Locate trees appropriate distances from buildings and infrastructure to avoid damage by roots and interference by branches.

(Source: FISRWG, 1998)
Figure 7-4. Tree's Hydrologic Cycle Schematic
• Locate trees such that canopies cover impervious areas to maximum extent practicable.
• Irrigation is typically required to maintain viability of interception trees. Coordinate design of general landscape irrigation system with that of interception trees, as applicable.

Volume Retention and Tributary Impervious Area Credit Calculation

Interception trees provide volume retention by storing water in leave branches and the tree stem. Interception trees may be used to help meet the volume retention requirement, and can be used to reduce the size of required downstream treatment control measures (see Section 8). The volume retention credit calculation for interception trees is presented in Table 7-10. Additional information on calculating and meeting the volume retention requirement is provided in Appendix B.

Interception trees can be used to reduce the size of required treatment control measures through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate WQF or WQV, which are used to size treatment control measures. Implementation of interception trees reduces effective impervious area and thereby the volume of water that needs to be treated. The credit is based on area of canopy projection over impervious areas and the percentage of rainfall interception allowed for the type of tree selected. The tributary impervious area credit calculation for interception trees is presented in Table 7-10.

Table 7-10. Interception Tree Volume Retention and Impervious Area Credit Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Percent of rainfall interception by tree</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evergreen tree</td>
<td>Int = 40%</td>
<td>Provide separate total for each type of tree</td>
</tr>
<tr>
<td>Deciduous tree</td>
<td>Int = 20%</td>
<td></td>
</tr>
<tr>
<td>2. Number of trees</td>
<td>N = ____________</td>
<td></td>
</tr>
<tr>
<td>3. Canopy projected over impervious area per tree</td>
<td>( A_p = ) __________</td>
<td>( \text{ft}^2 )</td>
</tr>
<tr>
<td>4. Design storm depth</td>
<td>( d = ) __________</td>
<td>( \text{in} )</td>
</tr>
</tbody>
</table>
| 5. Volume retention                                    | \( V_{\text{rel}} = \) __________ | \( \text{ft}^3 \) | Provide separate calculation for each type of tree with different canopy and Int value. \( d \times A_p \times \text{Int} \times N \div 12 \text{ inch/foot} \)
| 6. Tributary Impervious Area Credit                    | \( A_c = \) __________ | \( \text{ft}^2 \) | \( A_p \times \text{Int} \) |
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 root spaces.
- Provide at least 400 (optimally 1,000) square feet of soil for large trees (Urban Forestry, 1999).
- Limit 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-tolerate tree species.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes LID control measures such as interception trees. Such agreements typically include requirements such as those outlined in Table 7-11. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the LID control measure and its immediate vicinity at any time. Maintenance of the LID control measure is the sole responsibility of the owner. A sample maintenance agreement is presented in Appendix D.

Table 7-11. Inspection and Maintenance Requirements for Interception Trees

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove and replace any diseased or dying trees.</td>
<td>Annually</td>
</tr>
<tr>
<td>Maintain trees (watering, pruning).</td>
<td>As needed</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As needed</td>
</tr>
</tbody>
</table>
L-5: Grassy Channel

Description

Grassy channels are densely vegetated drainage ways with gentle side slopes and gradual longitudinal slopes in the direction of flow that receives stormwater runoff from impervious areas and slowly convey the water to downstream points of treatment or discharge. Grassy channels provide an opportunity for infiltration, reduce peak flows from impervious areas, and provide some pollutant removal. Where development
density, topography, and soils permit, grassy channels are a preferable alternative to curb and gutter and storm drains as stormwater conveyance systems. The features and function of grassy channels are similar to the full treatment grassy swale discussed in Fact Sheet R-13 (Section 8), but grassy channels are less engineered to meet treatment criteria.

Grassy channels are appropriate for use in residential, commercial, industrial, and institutional settings for drainage areas typically less than five (5) acres. They can be used in conjunction with vegetated filter strips, and are located adjacent to impervious areas to be mitigated. Several grassy channels may be used on a site, each designed to receive stormwater runoff from different impervious areas. Grassy channels can also provide pretreatment for other treatment control measures, such as bioretention areas. Irrigation and regular mowing are required to maintain the grass cover.

**Other names**
- Grassy swale, Bioswale

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

**Limitations**
- 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.

**Planning and Site Considerations**
- Select location where site topography allows for design of a grassy channel with sufficiently mild slopes and enough surface area to maintain non-erosive velocities in the channel.
- Integrate grassy channels into open space buffers and other landscape areas when possible.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the grassy channel, and cars are allowed to overhang the channel.
- Irrigation is typically required to maintain viability of grassy channel vegetation. Coordinate design of general landscape irrigation system with that of the grassy channel, as applicable.
- The potential for mosquitoes due to standing water will be greatly reduced or eliminated if the grassy channel is properly designed, constructed, and operated.
Design Criteria

Design elements, construction considerations, and maintenance requirements of grassy channels are similar to those of full treatment grassy swales presented in Fact Sheet R-13 (Section 8). Grassy channels typically differ in terms of the values used for the three parameters that govern treatment performance:

- Contact time, which is a function of length;
- Flow depth; and
- Flow velocity.

Key design criteria and reference values for grassy channels are listed in Table 7-12 along with reference values for use in calculation of credits for reducing effective impervious areas. The ratios of design values and reference values are used in the credit calculations for reducing effective impervious area.
Table 7-12. Grassy Channel Design Criteria and Reference Values

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal slope (flow direction)</td>
<td>0.5-4.0%</td>
<td></td>
</tr>
<tr>
<td>Maximum bottom width</td>
<td>6 ft</td>
<td></td>
</tr>
<tr>
<td>Maximum side slopes (H:V)</td>
<td>4:1</td>
<td>Side slopes to allow for ease of mowing</td>
</tr>
<tr>
<td>Roughness coefficient (n) for treatment design</td>
<td>0.2</td>
<td>Reflects roughness of swale when depth of flow is above the height of grass.</td>
</tr>
<tr>
<td>Roughness coefficient (n) for conveyance design</td>
<td>0.1</td>
<td>Reflects roughness of swale when depth of flow is above the height of grass. Used to determine capacity of swale to convey peak hydraulic flows.</td>
</tr>
<tr>
<td>Vegetation</td>
<td>–</td>
<td>Turf grass (irrigated)</td>
</tr>
<tr>
<td>Vegetation height (typical)</td>
<td>4-6 in</td>
<td>Vegetation should be maintained at a height greater than flow depth at design flow rate but sufficiently low to prevent lodging or shading of vegetation</td>
</tr>
</tbody>
</table>

Reference Values for Credit Calculation

<table>
<thead>
<tr>
<th>Reference Values for Credit Calculation</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference design flow (WQF&lt;sub&gt;rel&lt;/sub&gt;)</td>
<td>WQF</td>
<td>0.20 in/hr x C x A</td>
</tr>
<tr>
<td>Reference contact time (t&lt;sub&gt;rel&lt;/sub&gt;)</td>
<td>7 min</td>
<td></td>
</tr>
<tr>
<td>Reference flow depth (d&lt;sub&gt;rel&lt;/sub&gt;)</td>
<td>3 in</td>
<td>In flow direction</td>
</tr>
<tr>
<td>Reference flow velocity (V&lt;sub&gt;rel&lt;/sub&gt;)</td>
<td>1 ft/s</td>
<td>In flow direction</td>
</tr>
</tbody>
</table>

Volume Retention and Tributary Impervious Area Credit Calculation

Grassy channels provide volume retention by infiltrating water during conveyance and retention of water in the vegetative layer. Grassy channels may be used to help meet the volume retention requirement, and can be used to reduce the size of required downstream treatment control measures (see Section 8). Volume retention achieved with Type C or D soils is less than that achieved with Type A or B soils because less infiltration will occur with Type C or D soils. The volume retention credit calculation for grassy channels is presented in Table 7-13. Additional information on calculating and meeting the volume retention requirement is provided in Appendix B.

Grassy channels can be used to reduce the size of required treatment control measures through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate WQF or WQV, which are used to size treatment control measures. Implementation of grassy channels reduces effective impervious area and thereby the volume of water that needs to be treated. The credit is based on the ratio of volume retention to the WQV for the grassy channel drainage area. Note that these credits must be applied to treatment control measures 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 area of the
grassy channel. The tributary impervious area credit calculation for grassy channels is presented in Table 7-13.

Table 7-13. Grassy Channels Volume Retention and Tributary Impervious Area Credit Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reference WQF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impervious tributary area</td>
<td>(A_{\text{imp}} = ) ft(^2)</td>
<td></td>
</tr>
<tr>
<td>Impervious area stormwater runoff coefficient</td>
<td>(C_{\text{imp}} = )</td>
<td>(C_{\text{imp}} = 0.95)</td>
</tr>
<tr>
<td>Reference WQF</td>
<td>(WQF_{\text{ref}} = ) ft(^3)</td>
<td>(0.2 \times A_{\text{imp}} \times C_{\text{imp}} \div 43,560) ft(^2)/acre</td>
</tr>
<tr>
<td>2. Design grassy channel bottom width</td>
<td>(w_{\text{gc}} = ) ft</td>
<td></td>
</tr>
<tr>
<td>3. Design longitudinal slope</td>
<td>(s_{\text{gc}} = ) ft/ft</td>
<td></td>
</tr>
<tr>
<td>4. Design grassy channel length</td>
<td>(L_{\text{gc}} = ) ft</td>
<td></td>
</tr>
<tr>
<td>5. Flow geometry at WQF from Manning’s equation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design flow depth</td>
<td>(d_{\text{gc}} = ) ft</td>
<td></td>
</tr>
<tr>
<td>Design flow area</td>
<td>(A_{\text{gc}} = ) ft(^2)</td>
<td></td>
</tr>
<tr>
<td>Design flow velocity</td>
<td>(v_{\text{gc}} = ) ft/s</td>
<td></td>
</tr>
<tr>
<td>6. Contact time at WQF</td>
<td>(t_{\text{gc}} = ) min</td>
<td>(L_{\text{gc}} \div v_{\text{gc}} \div 60 ) seconds</td>
</tr>
<tr>
<td>7. Impervious area credit</td>
<td>(A_{\text{c}} = ) ft(^2)</td>
<td>If ((d_{\text{ref}}/d_{\text{gc}}) \times (v_{\text{ref}}/v_{\text{gc}}) \times (t_{\text{gc}}/t_{\text{ref}}) &gt; 1.0), then (A_{\text{c}} = 1.0).</td>
</tr>
<tr>
<td>Type A or B soils, (V_{\text{soil}} = 0.50)</td>
<td>(V_{\text{soil}} = ) ft(^3)</td>
<td>(V_{\text{soil}}) is the volume retention factor allowed for infiltration, which varies with soil permeability</td>
</tr>
<tr>
<td>Type C or D soils, (V_{\text{soil}} = 0.25)</td>
<td>(V_{\text{soil}} = ) ft(^3)</td>
<td></td>
</tr>
<tr>
<td>Volume retention</td>
<td>(V_{\text{rel}} = ) ft(^3)</td>
<td>(A_{\text{c}} \times V_{\text{soil}} \times (0.5/12))</td>
</tr>
</tbody>
</table>

Credit Calculation Example

Examples for volume retention and tributary impervious area credit calculations are presented below.
Step 1 – Calculate WQF for Impervious Area Tributary to Grassy Channel

Using procedures described in Fact Sheet C-2, determine WQF for area tributary to grassy channel.

\[ WQF_{ref} = i \times C \times A \]

Where:

- \( WQF_{ref} \) = water quality flow (cfs);
- \( i \) = design storm intensity (0.20 inches/hour);
- \( C_{imp} \) = stormwater runoff coefficient for impervious area tributary to grassy channel; and
- \( A_{imp} \) = impervious area tributary to grassy channel (acres).

Example:

\[
\begin{align*}
C_{imp} &= 0.95 \\
A_{imp} &= 4,000 \text{ ft}^2
\end{align*}
\]

\[
WQF_{ref} = i \times C_{imp} \times A_{imp} = \frac{0.20 \text{ in/hr} \times 0.95 \times 4,000 \text{ ft}^2}{43,560 \text{ ft}^2/\text{acre}} = 0.017 \text{ cfs}
\]

Step 2 – Determine Design Grassy Channel Bottom Width (\( w_{gc} \))

Note: Design of grassy channel bottom width is not restricted to any value, but ease of mowing and maintenance should be considered.

Example:

\[
w_{gc} = 0.5 \text{ ft}
\]

Step 3 – Determine Design Grassy Channel Longitudinal Slope and Side Slope

\[
\begin{align*}
s_{gc} &= 0.5\text{-}4.0\% \\
H:V &= 4:1
\end{align*}
\]

Example:

\[
s_{gc} = 1\% = 0.01 \text{ ft/ft}
\]

Step 4 – Determine Design Grassy Channel Length (\( L_{gc} \))

Note: Design of grassy channel length is not restricted to any minimum value.

Example:

\[
L_{gc} = 20 \text{ ft}
\]
**Step 5 – Calculate Design Flow Depth and Flow Velocity at WQF**

Use Manning’s Equation:

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

Where:

- \( Q = \) WQF \(_\text{ref} \) (cfs);
- \( A \) = cross-sectional area of flow (\( \text{ft}^2 \));
- \( P \) = wetted perimeter of flow (ft);
- \( s \) = bottom slope in flow direction (ft/ft); and
- \( n \) = Manning’s \( n \) (roughness coefficient) = 0.2 for depth less than six (6 inches).

Solve Manning’s equation by trial and error to determine flow depth, area, and velocity at the WQF and the design channel geometry.

**Example:**

- \( d_{gc} = 1.5 \text{ in} \)
- \( A_{gc} = 0.0625 \text{ ft}^2 \)
- \( v_{gc} = \frac{\text{WQF}}{A_{gc}} = 0.02 \text{ cfs}/0.0625 \text{ ft}^2 = 0.28 \text{ ft/s} \)

**Step 6 – Calculate Contact Time for Grassy Channel (t\(_{gc}\))**

\[ t_{gc} = \frac{L_{gc}}{v_{gc}} = \frac{20 \text{ ft}}{0.28 \frac{\text{ft}}{\text{s}} \times 60 \text{ s}} = 1.2 \text{ min} \]

**Step 7 – Calculate Impervious Area Credit for Grassy Channel (A\(_c\))**

\[ A_c = \left( \frac{d_{rel}}{d_{gc}} \right)^2 \times \left( \frac{v_{rel}}{v_{gc}} \right)^2 \times \left( \frac{t_{gc}}{t_{rel}} \right) \times A_{imp} \]

Note: The ratios, \( (d_{rel}/d_{gc}) \) and \( (v_{rel}/v_{gc}) \), are squared to account for reduced efficiency of full treatment systems at higher hydraulic loading rates. If calculated values of \( (d_{rel}/d_{gc}) \), \( (v_{rel}/v_{gc}) \), or \( (t_{gc}/t_{rel}) \) are greater than 1.0, then the value is set to 1.0. The maximum allowable value of \( A_c \) is \( A_{imp} \).

**Example:**
\[ A_c = \left( \frac{d_{ref}}{d_{gc}} \right)^2 \times \left( \frac{v_{ref}}{v_{gc}} \right)^2 \times \left( \frac{t_{gc}}{t_{ref}} \right) \times A_{imp} \]
\[ = \left( \frac{3 \text{ ft}}{1.5 \text{ ft}} \right)^2 \times \left( \frac{1 \text{ ft/s}}{0.28 \text{ ft/s}} \right)^2 \times \left( \frac{1.2 \text{ min}}{7 \text{ min}} \right) \times 4,000 \text{ ft}^2 \]
\[ = (1.0)^2 \times (1.0)^2 \times (0.17) \times 4,000 \text{ ft}^2 = 680 \text{ ft}^2 \]

**Step 8 – Calculate Volume Retention Credit for Design Storm Depth (V_{ret})**

\[ V_{ret} = A_c \times V_{soil} \times \frac{0.50 \text{ in}}{12 \text{ in/ft}} \]

Example:

\[ V_{soil} = 0.25 \text{ for Type C or D soil} \]

\[ V_{ret} = A_c \times V_{soil} \times \frac{0.50 \text{ in}}{12 \text{ in/ft}} = 680 \text{ ft}^2 \times 0.25 \times \frac{0.50 \text{ in}}{12 \text{ in/ft}} = 7.2 \text{ ft}^3 \]

**Construction Considerations**

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the grassy channel to prevent high sediment loads from entering the grassy channel 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 requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes LID control measures such as grassy channels. Such agreements typically include requirements such as those outlined in Table 7-14. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the LID control measure and its immediate vicinity at any time. LID control measure maintenance is the responsibility of the owner. A sample maintenance agreement is presented in Appendix D.
Table 7-14. Inspection and Maintenance Requirements for Grassy Channels

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mow grass to maintain height of 4-6 inches or above flow depth at WQF.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove grass clippings.</td>
<td>As required</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove trash and debris from grassy channel.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect grassy channel for signs of erosion, vegetation damage/coverage, channelization problems, debris build-up, and excess sedimentation in bottom of channel. Correct problems or remove debris and sediment as soon as possible.</td>
<td>At least twice annually. Schedule one inspection at the end of wet season so that summer maintenance can be scheduled to prepare grassy channel for wet season. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the grassy channel is retarded or blocked.</td>
<td>As required</td>
</tr>
<tr>
<td>Repair ruts or holes in the grassy channel by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect grassy channel 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.</td>
<td>At least twice during wet season after significant storm events. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
</tbody>
</table>
L-6: Vegetated Buffer Strips

**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. A portion of stormwater runoff can be retained in the surface soil and thatch layer of the strip as well as through infiltration. Some pollutant removal is achieved as stormwater runoff flows through the vegetation and over the soil surface at a shallow depth by a variety of physical, chemical, and biological mechanisms.

For rooftop drainage disconnection, direct stormwater runoff away from the building foundation and disperse flow to the strip. Buried extensions with pop-up outlets, as shown in the figure below, can be used for the same purpose. To increase the effectiveness of a vegetated buffer 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 the slope of the strip exceeds four (4) percent.

**Other names**

Vegetated filter strips, Grassy buffer strips, Grassy filter strips

**Advantages**

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

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

Planning and Site Considerations

- Select location where site topography allows for design of vegetated buffer strips with proper slopes in 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 viability of buffer strip vegetation. Coordinate design of general landscape irrigation system with that of the vegetated buffer strip, as applicable.

Design Criteria

Design elements, construction considerations, and maintenance requirements of vegetated buffer strips are similar in most aspects to those of full treatment vegetated filter strips presented in Fact Sheet R-14 (Section 8). Vegetated buffer strips typically differ in terms of the values used for the two principal design parameters that govern treatment performance:

- Length of vegetated buffer strip in direction of flow; and
- Application rate across top of strip.

Key design criteria and reference values for vegetated buffer strips are listed in Table 7-15 along with reference values for use to calculate credits for reducing effective impervious area. The ratio of design values and reference values are used for credit calculation for volume retention and effective impervious area reduction.
Table 7-15. Vegetated Buffer Strips Design Criteria and Reference Values

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum design length (L_VBS)</td>
<td>3 ft</td>
<td>In flow direction</td>
</tr>
<tr>
<td>Slope (flow direction)</td>
<td>0.5-4.0%</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>–</td>
<td>Turf grass or dense ground cover (irrigated)</td>
</tr>
<tr>
<td>Vegetation height (typical)</td>
<td>1-3 in</td>
<td></td>
</tr>
</tbody>
</table>

Reference Values for Credit Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference design flow (WQF_ref)</td>
<td>WQF</td>
<td>0.20 in/hr x C x A</td>
</tr>
<tr>
<td>Reference linear application rate (q_rel)</td>
<td>0.005 cfs/ft width</td>
<td></td>
</tr>
<tr>
<td>Width for normal to flow (default value)</td>
<td>3 ft</td>
<td>Greater flow widths will increase credit values and can be achieved with flow spreader devices.</td>
</tr>
<tr>
<td>Reference length (L_ref)</td>
<td>20 ft</td>
<td>In flow direction. Maximum length for credit. Longer lengths receive no additional credit.</td>
</tr>
<tr>
<td>Stormwater runoff coefficient</td>
<td>0.18</td>
<td>Type A or B soil</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>Type C or D soil</td>
</tr>
</tbody>
</table>

Volume Retention and Tributary Impervious Area Credit Calculation

Vegetated buffer strips provide volume retention by infiltrating stormwater runoff during conveyance into the vegetative layer. Vegetated buffer strips may be used to help meet the volume retention requirement, and can be used to reduce the size of required downstream treatment control measures (see Section 8). The volume retention credit calculation for vegetated buffer strips is presented in Table 7-16. Additional information on calculating and meeting the volume retention requirement is provided in Appendix B.

Vegetated buffer strips can be used to reduce the size of required treatment control measures through application of tributary impervious area credits. These credits can be applied to reduce the effective design area used to calculate WQF or WQV, which are used to size treatment control measures. Implementation of vegetated buffer strips reduces effective impervious area and thereby the volume of water that needs to be treated. The credit is based on the ratio of volume retention for the vegetated buffer strip in question to the volume retention estimated for a reference vegetated buffer strip that would provide full treatment for the drainage area. Note that these credits must be applied to treatment control measures that are 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 area of the vegetated buffer strip. The tributary impervious area credit calculation for vegetated buffer strip is presented in Table 7-16.
Table 7-16. Vegetated Buffer Strip Volume Retention and Impervious Area Credit Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Reference WQF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impervious tributary area</td>
<td>( A_{\text{imp}} = ) _______ ft(^2)</td>
<td></td>
</tr>
<tr>
<td>Impervious area stormwater runoff coefficient</td>
<td>( C_{\text{imp}} = ) _______</td>
<td>( C_{\text{imp}} = 0.95 )</td>
</tr>
<tr>
<td>Reference WQF</td>
<td>( \text{WQF}_{\text{ref}} = ) _______ cfs</td>
<td>( 0.2 \times A_{\text{imp}} \times C_{\text{imp}} \div 43,560 )</td>
</tr>
<tr>
<td>2. Design width</td>
<td>( W_{\text{vbs}} ) _______ ft</td>
<td>Minimum default width = 3.0 ft</td>
</tr>
<tr>
<td>3. Design linear application rate</td>
<td>( q_a ) _______ cfs/ft</td>
<td>Reference ( q_a = 0.005 ) cfs/ft</td>
</tr>
<tr>
<td>4. Design length</td>
<td>( L_{\text{vbs}} ) _______ ft</td>
<td>Reference ( L_{\text{vbs}} = 20 ) ft, which is maximum length allowed for credit</td>
</tr>
<tr>
<td>5. Impervious area credit</td>
<td>( A_c ) _______ ft(^2)</td>
<td>If ((q_{\text{aref}}/q_a)) or ((L_{\text{vbs}}/L_{\text{ref}}) &gt; 1.0), then (A_c = 1.0). Maximum allowable credit = (A_{\text{imp}} \times (q_{\text{aref}}/q_a)^2 \times (L_{\text{vbs}}/L_{\text{ref}}) \times A_{\text{imp}})</td>
</tr>
<tr>
<td>6. Volume retention</td>
<td>( V_{\text{ref}} ) _______ ft(^3)</td>
<td>( A_c \times (C_{\text{imp}} - C_{\text{vbs}}) \times (0.5/12) )</td>
</tr>
</tbody>
</table>

Credit Calculation Example

Examples for volume retention and tributary impervious area credit calculations are presented below.

Step 1 – Calculate WQF for Impervious Area Tributary to Vegetated Buffer Strip

Using procedures described in Fact Sheet C-2, determine WQF for area tributary to vegetated buffer strip.

\[
WQF_{\text{ref}} = i \times C \times A
\]

Where:

- \( WQF \) = water quality flow (cfs);
- \( i \) = design storm intensity (0.20 inches/hour);
- \( C_{\text{imp}} \) = stormwater runoff coefficient for impervious area tributary to vegetated buffer strip; and

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impervious area tributary to vegetated buffer strip (acres).

Example:

\[ C_{\text{imp}} = 0.95 \]
\[ A_{\text{imp}} = 3,600 \text{ ft}^2 \]
\[ WQF_{\text{ref}} = i \times C_{\text{imp}} \times A_{\text{imp}} = \frac{0.20 \text{ in/hr} \times 0.95 \times 3,600 \text{ ft}^2}{43,560 \text{ ft}^2/\text{acre}} = 0.016 \text{ cfs} \]

**Step 2 – Determine Design Vegetated Buffer Strip Width \( (w_{\text{vbs}}) \)**

Note: Design of vegetated buffer strip width is not restricted to any value, but stormwater runoff flow must be distributed uniformly across the width of the strip. The minimum default width is three (3) feet. Wider values can be used if flow is dispersed with a spreader device.

Example:

\[ w_{\text{vbs}} = 3.0 \text{ ft} \]

**Step 3 – Calculate Design Linear Application Rate \( (q_a) \)**

\[ q_a = \frac{WQF_{\text{ref}}}{w_{\text{vbs}}} \]

Where:

\[ q_a = \text{linear application rate (cfs/ft)} \]
\[ WQF_{\text{ref}} = \text{water quality flow (cfs); and} \]
\[ w_{\text{vbs}} = \text{vegetated buffer strip width (ft).} \]

Example:

\[ q_a = 0.016 \text{ cfs/3.0 ft} = 0.005 \text{ cfs/ft} \]

**Step 4 – Determine Design Vegetated Buffer Strip Length \( (L_{\text{vbs}}) \)**

Note: Design of vegetated buffer strip length is not restricted to any maximum value, but twenty (20) feet is the maximum length for credit calculation.

Example:

\[ L_{\text{vbs}} = 12 \text{ ft} \]

**Step 5 – Calculate Impervious Area Credit for Vegetated Buffer Strip \( (A_c) \)**

\[ A_c = \left( \frac{q_{\text{a ref}}}{q_a} \right)^2 \times \left( \frac{L_{\text{vbs}}}{L_{\text{ref}}} \right) \times A_{\text{imp}} \]
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 greater than 1.0, then the value is set to 1.0. The maximum allowable value of \(A_c\) is \(A_{imp}\).

Example:

\[
A_c = \left(\frac{q_{aref}}{q_a}\right)^2 \times \left(\frac{L_{vbs}}{L_{ref}}\right) \times A_{imp} = \left(\frac{0.005 \text{ cfs/ft}}{0.005 \text{ cfs/ft}}\right)^2 \times \left(\frac{12 \text{ ft}}{20 \text{ ft}}\right) \times 3,600 \text{ ft}^2 \\
= (1.0)^2 \times (0.60) \times 3,600 \text{ ft}^2 = 2,160 \text{ ft}^2
\]

Step 6 – Calculate Volume Retention Credit for Design Storm Depth \((V_{ret})\)

\[
V_{ret} = A_c \times (C_{imp} - C_{vbs}) \times \frac{0.50 \text{ in}}{12 \text{ in/ft}}
\]

Example:

\[
V_{soil} = 0.25 \text{ for Type C or D soil}
\]

\[
V_{ret} = A_c \times (C_{imp} - C_{vbs}) \times \frac{0.50 \text{ in}}{12 \text{ in/ft}} = 2,160 \text{ ft}^2 \times (0.95 - 0.25) \times \frac{0.50 \text{ in}}{12 \text{ in/ft}} = 64 \text{ ft}^3
\]

Construction Considerations

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the vegetated buffer strip to prevent high sediment loads from entering the vegetated buffer strip during ongoing upstream construction activities.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes LID control measures such as vegetated buffer strips. Such agreements typically include requirements such as those outlined in Table 7-17. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the LID control measure and its immediate vicinity at any time. LID control measure maintenance is the responsibility of the owner. A sample maintenance agreement is presented in Appendix D.
Table 7-17. Inspection and Maintenance Requirements for Vegetated Buffer Strips

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mow grass to maintain height of 2-4 inches (typical).</td>
<td>As required</td>
</tr>
<tr>
<td>Remove grass clippings.</td>
<td>As required</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove trash and debris from vegetated buffer strip.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect vegetated buffer strip for signs of erosion, vegetation</td>
<td>At least twice annually. Schedule one inspection at the end of wet season so that summer</td>
</tr>
<tr>
<td>damage/coverage, channelization problems, debris build-up, and excess</td>
<td>maintenance can be scheduled to prepare vegetated filter strip for wet season. Additional</td>
</tr>
<tr>
<td>sedimentation on surface of vegetated buffer strip. Correct problems or</td>
<td>inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>remove debris and sediment as soon as possible.</td>
<td></td>
</tr>
<tr>
<td>Remove sediment in inlet areas, the channel, culverts, and outlets</td>
<td>As required</td>
</tr>
<tr>
<td>whenever flow into the vegetated buffer strip is retarded or blocked.</td>
<td></td>
</tr>
<tr>
<td>Repair ruts or holes in the vegetated buffer strip by removing vegetation,</td>
<td>As required</td>
</tr>
<tr>
<td>adding and tamping suitable soil, and reseeding. Replace damaged</td>
<td></td>
</tr>
<tr>
<td>vegetation.</td>
<td></td>
</tr>
<tr>
<td>Inspect vegetated buffer strip for obstructions (e.g., debris</td>
<td>At least twice during wet season after significant storm events.</td>
</tr>
<tr>
<td>accumulation, invasive vegetation) and pools of standing water that</td>
<td>Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>can provide mosquito-breeding habitat. Correct observed problems as</td>
<td></td>
</tr>
<tr>
<td>soon as possible.</td>
<td></td>
</tr>
</tbody>
</table>
SECTION 8. TREATMENT CONTROL MEASURES

8.1. Introduction

Treatment control measures are required in addition to site design control measures, source control measures, and LID control measures to reduce pollutants in stormwater runoff to the maximum extent practicable. Treatment control measures are engineered technologies designed to remove pollutants from stormwater runoff. The type of treatment control(s) to be implemented at a site depends on a number of factors including the following:

- Type of pollutants in stormwater runoff;
- Quantity of stormwater runoff to be treated;
- Project site conditions (e.g., soil type, soil permeability, slope); and
- Receiving water conditions.

Land requirements and costs to design, construct, and maintain treatment control measure will vary.

Unlike flood control measures that are designed to handle peak flows, stormwater treatment control measures are designed to treat the more frequent, lower-flow storm events, or the first flush portions of stormwater runoff from larger storm events (typically referred to as first-flush events). Small, frequent storm events represent most of the total average annual rainfall for the area. The flow and volume of such small events, referred to as the WQF and WQV, respectively, are targets for treatment. There is marginal water quality benefit gained by sizing treatment facilities to treat flows or volumes larger than WQF or WQV.

Treatment control measures presented in the 2011 Revised Guidance Manual are based on flow rates or volume of stormwater runoff. Treatment control measures designed based on flow are to be designed for the WQF, and those designed based on volume are to be designed based for the WQV. Definitions and calculation procedures to determine WQF and WQV are presented in Section 6. Stormwater runoff in excess of the WQF or WQV must be diverted around the treatment control measure to prevent overloading or may be diverted through the treatment control measure if it will not cause overloading.

Treatment control measures are categorized according to the following types:

- Infiltration control measures;
- Evapotranspiration and biofiltration control measures;
- Other public domain control measures; and
- Proprietary control measures.

Infiltration, evapotranspiration, and biofiltration treatment control measures have the ability to retain stormwater runoff and may be used in combination with LID control
measures to meet the volume retention requirement. In the 2011 Revised Guidance Manual, fact sheets for infiltration, evapotranspiration, and biofiltration treatment control measures are designated R-1 to R-14. Other public domain and proprietary treatment control measures typically do not retain stormwater runoff volumes. These treatment control measures may be used to meet water quality treatment requirements only after the volume retention requirements have been met. In the 2011 Revised Guidance Manual, other public domain and proprietary treatment control measures are designated C-1 to C-4 and P-1, respectively.

The stormwater treatment control measures specified in this section are more common non-proprietary control measures being implemented nationwide. Studies have shown these treatment control measures to be reasonably effective if properly installed and maintained. Consequently, application of these control measures is considered to achieve compliance with the objective of controlling pollutants to the maximum extent practicable and working towards attaining and/or maintaining water quality standards in the receiving water. The relative effectiveness of the treatment control measures specified in this section for reducing pollutants of concern is presented in Table 8-1. Pollutants of concern are those that have been identified as causing or contributing to impairment of beneficial uses of water bodies in California.

Treatment control measure selection should be based on its ability both to retain stormwater runoff and remove pollutants of concern. Priority Projects that cannot fully meet the volume retention requirement must select treatment control measures with medium to high removal efficiency for pollutants of concern.
### Table 8-1. Treatment Control Measures Efficiency for Reducing Concentrations of Pollutants of Concern

<table>
<thead>
<tr>
<th>Treatment Control Measures</th>
<th>Pollutants of Concern&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>Bacteria</th>
<th>Pesticides</th>
<th>Metals</th>
<th>Sediments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infiltration Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infiltration well (R-1)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Water quality infiltration basin (R-2)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Water quality infiltration trench (R-3)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Bioretention without an underdrain (R-4)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Dry well (R-5)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>French drain (R-6)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Permeable paving without an underdrain (R-7)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td><strong>Evapotranspiration and Bioretention Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioretention with underdrain (R-8)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Permeable paving with an underdrain (R-9)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Stormwater planter (R-10)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Tree-well filter (R-11)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Vegetated swales (R-12)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td>Grassy swale (R-13)</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td></td>
</tr>
<tr>
<td>Vegetated filter strip (R-14)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>H</td>
</tr>
<tr>
<td><strong>Other Public Domain Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Media filters (C-1)</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Constructed wetland (C-2)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Extended detention basin (C-3)</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Wet pond (C-4)</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td><strong>Proprietary Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proprietary treatment controls (P-1)</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

<sup>(1)</sup> H ≥ 75% expected removal efficiency for typical urban stormwater runoff; M = 25-75% expected removal efficiency for typical urban stormwater runoff; L < 25% expected removal efficiency for typical urban stormwater runoff.

<sup>(2)</sup> Effectiveness of proprietary devices varies depending on the manufacturer and type of device. Limited performance data are available.
8.2. Selection of Treatment Controls

Various factors must be considered when selecting a treatment control measure. In addition to reducing target pollutants of concern, site considerations such as size of the drainage area, depth between the water table and treatment control measure, soil type and permeability, site slope, hydraulic head, size of treatment control measure, and need for vegetation irrigation are important factors in selecting the proper treatment control measure. Vector breeding considerations must also be addressed in determining treatment control measures because of the potential for nuisance and human health effects. The applicability of specific control measures outlined in this section should be confirmed with the City. The site constraints that are considered in the selection of treatment control measure are presented in Table 8-2.

Volume Retention Requirement

All new development priority projects must meet the volume retention requirement through a combination of LID control measures and treatment control measures. If project applicants do not fully meet the volume retention requirement through use of LID control measures, the project must use infiltration or evapotranspiration and bioretention treatment control measures to further reduce stormwater runoff volumes to treat the WQF or WQV. If the volume retention requirement is met through the use of LID control measures, then a treatment control measure may be chosen from the available treatment controls list. Procedures for calculating the volume retention for LID control measures are provided within each fact sheet.

Volume Retention Requirement Waiver

A Volume Retention Requirement Waiver may be granted if the volume retention requirement cannot be fully met due to technical infeasibility, such as site constraints. However, even if the project is unable to meet the full volume retention requirement, the project must still retain and treat the WQF or WQV volume to the maximum extent practicable. Meeting the volume retention requirement is an iterative process, and designers should return to prior steps to explore alternative combinations of LID and/or treatment control measures. The burden of proof is on the project applicant to show why the volume retention requirement cannot be met. Economic hardship is not an acceptable reason for technical infeasibility.

The Volume Retention Requirement Waiver is primarily available for priority redevelopment or infill projects where site constraints, such as available land, may limit the ability to implement LID and/or treatment control measures to retain and/or treat the WQF or WQV. In general, the City does not expect to grant Volume Retention Requirement Waiver for new development projects. The final determination will be made by the City. Priority Projects that are not able to fully meet the volume retention requirement must fill out and submit the Volume Retention Requirement Waiver (Appendix C). The City has the authority to reject a Volume Retention Requirement Waiver if a combination of LID and/or treatment control measures is considered feasible for the project site.
8.3. Description of Treatment Control Measures

This section provides fact sheets for design and implementation of treatment control measures. The fact sheets include site considerations, design criteria, and maintenance requirements to ensure optimal performance of the control measures. The 2011 Revised Guidance Manual also contains calculation fact sheets and worksheets to aid the design of treatment control measures.

It should be noted that treatment control measure fact sheets contain design criteria, which may differ from design criteria identified in the City of Modesto Standard Specifications. The purpose of design criteria for treatment control measures in the 2011 Revised Guidance Manual is to construct and implement treatment control measures that meet water quality requirements in terms of volume retention and pollutant removal. Other similar devices may be constructed on a project site for the purpose of flood control according to the City of Modesto Standard Specifications, but may not meet water quality requirements.
Table 8-2. Site Constraints for Treatment Control Measures

<table>
<thead>
<tr>
<th>Treatment Control Measure</th>
<th>Drainage Area</th>
<th>Soil Type</th>
<th>Maximum Slope</th>
<th>Hydraulic Head</th>
<th>Vegetation Irrigation</th>
<th>Vector Control Frequency</th>
<th>Maintenance Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 10 acres</td>
<td>≥ 10 acres</td>
<td>A or B only</td>
<td>A, B, C, or D</td>
<td>~ 0%</td>
<td>&lt; 15%</td>
<td></td>
</tr>
<tr>
<td><strong>Infiltration Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infiltration Well (R-1)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>N</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Water Quality Infiltration Basin (R-2)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>Y*</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Water Quality Infiltration Trench (R-3)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>N</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Bioretention without an Underdrain (R-4)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>M</td>
<td>Y</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Dry Well (R-5)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>N</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>French Drain (R-6)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>N</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td>Permeable Paving without an Underdrain (R-7)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>M</td>
<td>N</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td><strong>Evapotranspiration and Biofiltration Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bioretention with Underdrain (R-8)</td>
<td>X</td>
<td></td>
<td>X</td>
<td>M</td>
<td>Y</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Permeable Paving with an Underdrain (R-9)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>M</td>
<td>N</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Stormwater Planter (R-10)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>M</td>
<td>Y</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Tree-well Filter (R-11)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>M</td>
<td>Y</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Vegetated Swales (R-12)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>Y</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Grassy Swale (R-13)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>Y</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Vegetated Filter Strip R-14)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>Y</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td><strong>Other Public Domain Treatment Control Measures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Media Filters (C-1)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>N</td>
<td>L</td>
</tr>
</tbody>
</table>

City of Modesto
Stormwater Management Program

Revised February 2015
<table>
<thead>
<tr>
<th>Treatment Control Measure</th>
<th>Drainage Area</th>
<th>Soil Type</th>
<th>Maximum Slope</th>
<th>Hydraulic Head</th>
<th>Vegetation Irrigation</th>
<th>Vector Control Frequency</th>
<th>Maintenance Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 10 acres</td>
<td>≥ 10 acres</td>
<td>A or B only</td>
<td>A, B, C, or D</td>
<td>~ 0%</td>
<td>&lt; 15%</td>
<td></td>
</tr>
<tr>
<td>Constructed Wetlands (C-2)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>Y</td>
<td>H</td>
</tr>
<tr>
<td>Extended Detention Basin (C-3)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>Y*</td>
<td>M</td>
</tr>
<tr>
<td>Wet Pond (C-4)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>Y*</td>
<td>H</td>
</tr>
</tbody>
</table>

**Proprietary Treatment Control Measures**

| Proprietary Devices (P-5)       | X             | X         | X              | X              | H                      | N                        | L                      | H                      |

Key:  X = control measure suitable for site condition; H = high; M = medium; L = low; Y = yes; Y* = yes if vegetated; N = no

Proprietary devices were excluded from table because suitability depends on manufacturer and type of device.
R-1: Infiltration Well

Description

An infiltration well, which are classified as Class V underground injection wells by USEPA, is typically a vertical bore, which contains a perforated vertical pipe, filled with gravel. Stormwater runoff is typically conveyed to a covered concrete catch basin containing the infiltration well. An overflow pipe conveys water from the catch basin into the infiltration well. Water infiltrates through the gravel media and into the underlying soil over a design drawdown period. Infiltration wells are similar to the City’s rockwells, but differ in that they are designed for the purpose stormwater runoff treatment and retention as opposed to drainage.

Stormwater runoff treatment is primarily filtration as the stormwater runoff flows through the gravel media and into the underlying soil profile. To ensure adequate treatment and protect groundwater quality, the depth of the unsaturated soil between the infiltration well bottom and the maximum groundwater surface level should be a minimum of ten (10) feet. A schematic of an infiltration well configuration is presented in Figure 8-1.

Other Names

Injection well

Advantages

- Provides effective treatment through filtration while requiring a small space.
- Is placed below ground.
- Reduces peak stormwater runoff flows during small storm events.
- Can be incorporated into site landscape features

Disadvantages

- Not appropriate for areas with low permeability soils (Type C or D soil) or high groundwater.
- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Must be protected from high sediment loads. Once clogged with sediment, restoration of infiltration capacity may be difficult.
- Not appropriate on fill or steep slopes.
Planning and Site Considerations

- Soil permeability, depth to groundwater, and design safety factors should be determined by a qualified geotechnical engineer or geologists to ensure that conditions conform to Table 8-3.
- Pretreatment using grassy channels, vegetated buffer strips, vegetated swales, grassy swales, and/or vegetated filter strip is required to protect infiltration wells from high sediment loads.
- Plan for appropriate setback distances presented in Table 8-3.
Design Criteria

Principal design criteria for infiltration wells are listed in Table 8-3.

Table 8-3. Infiltration Well Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawdown time</td>
<td>48 hr (maximum)</td>
<td></td>
</tr>
<tr>
<td>Water Quality Volume</td>
<td>80% annual capture (acre-ft)</td>
<td></td>
</tr>
<tr>
<td>Tributary drainage area</td>
<td>10,000 ft² (maximum)</td>
<td>Per infiltration well</td>
</tr>
<tr>
<td>Bore diameter</td>
<td>36 in</td>
<td></td>
</tr>
<tr>
<td>Groundwater separation</td>
<td>10 ft (minimum)</td>
<td>Between infiltration well bottom and historical seasonally high groundwater table</td>
</tr>
<tr>
<td>Soil permeability range</td>
<td>0.6-2.0 in/hr</td>
<td>Saturated vertical permeability</td>
</tr>
<tr>
<td>Slope</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Core pipe diameter</td>
<td>8 in</td>
<td>Perforated PVC pipe with removable cap</td>
</tr>
<tr>
<td>Core pipe length</td>
<td>20 ft</td>
<td>Maximum length</td>
</tr>
<tr>
<td>Core pipe perforations</td>
<td>0.5 in</td>
<td>Every 90° around the pipe</td>
</tr>
<tr>
<td>(diameter)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core pipe perforations (number of rows)</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Gravel size (diameter)</td>
<td>1-2.5 in</td>
<td></td>
</tr>
<tr>
<td>Setbacks</td>
<td>150 ft (minimum)</td>
<td>From domestic water supply wells</td>
</tr>
<tr>
<td></td>
<td>20 ft (minimum)</td>
<td>Between all other vertical infiltration wells or rockwells</td>
</tr>
<tr>
<td></td>
<td>20 ft</td>
<td>Down slope from foundation</td>
</tr>
<tr>
<td></td>
<td>100 ft</td>
<td>Up slope from foundation</td>
</tr>
</tbody>
</table>
Design Procedure

*Step 1 – Calculate WQV*

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 48-hour drawdown period.

*Step 2 – Calculate Minimum Surface Area of Infiltration Well Bottom (A$_{min}$)*

\[
A_{min} = \frac{WQV \times s \times 12}{t_{max} \times I}
\]

Where:
- \(WQV\) = water quality volume (ft$^3$);
- \(t_{max}\) = maximum drawdown time = 48 hours;
- \(I\) = site infiltration rate (soil permeability, in/hr); and
- \(s\) = safety factor.

In the formula above, the safety factor accounts for possible inaccuracies in the infiltration rate measurement. A larger safety factor should be used when the infiltration rate is less certain. 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 project site. Multiple infiltration wells may be necessary at a site to achieve the required total infiltration bottom area.

*Step 3 – Design Overflow Pipe*

An overflow pipe connecting the infiltration well to the catch basin must be installed to convey stormwater runoff from the tributary drainage area to the infiltration well. The overflow pipe entering the infiltration well should be a minimum of 12 inches above the top of the gravel layer.

*Step 4 – Design Core Pipe*

The core pipe should be a perforated-C900, Class 200 PVC pipe with an eight- (8-) inch diameter and 20 feet maximum length.

*Step 5 – Design Gravel Layer*

The washed gravel layer should be composed of 1-2.5-inch diameter stone.

*Step 6 – Design Screen Cover*

A screen cover is required on top of the core pipe. See the applicable City of Modesto Standard Specifications for details.
Volume Retention Calculation

Infiltration wells may be used to achieve both the volume retention and treatment requirements. An infiltration well provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

Construction Considerations

- Once construction is complete, stabilize entire tributary area to the infiltration well before allowing stormwater runoff to enter the infiltration well.
- Store excavated material at least ten (10) feet from the infiltration well to avoid backsliding and cave-ins.
- Clean, washed gravel should be placed in the bore hole in lifts and lightly compacted. Use of unwashed gravel can result in clogging.
- Minimize compaction near the infiltration well to the maximum extent practicable during construction to prevent loss of infiltrative capacity.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as infiltration wells. Such agreements typically include requirements such as those outlined in Table 8-4. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-4. Inspection and Maintenance Requirements for Infiltration Wells

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor infiltration rate in infiltration well after storm events by</td>
<td>Several times during first year following installation. During subsequent seasons at beginning</td>
</tr>
<tr>
<td>recording the drop in water depth versus time using a calibrated</td>
<td>and end of wet season. Additional monitoring after periods of heavy stormwater runoff is desirable.</td>
</tr>
<tr>
<td>rod or staff gauge.</td>
<td>As required</td>
</tr>
<tr>
<td>If drawdown period is observed to have increased significantly over the</td>
<td>As required</td>
</tr>
<tr>
<td>design drawdown period, clean the drop inlet, wash the top 18 inches</td>
<td></td>
</tr>
<tr>
<td>of gravel, and clean the bore. This maintenance activity may be reduced</td>
<td></td>
</tr>
<tr>
<td>by minimizing upstream erosion.</td>
<td></td>
</tr>
<tr>
<td>Remove litter and debris from infiltration well area.</td>
<td>As required</td>
</tr>
<tr>
<td>Maintain pretreatment control measures in accordance to its</td>
<td>As required</td>
</tr>
<tr>
<td>respective “Long-Term Maintenance” section.</td>
<td></td>
</tr>
</tbody>
</table>
R-2: Water Quality Infiltration Basin

Description
A water quality infiltration basin is a shallow earthen basin constructed in naturally pervious soil (Type A or B soil) designed for infiltrating stormwater runoff. A water quality infiltration basin retains the WQV and allows the retained stormwater runoff to percolate into the underlying native soils and into the groundwater table over the drawdown period. Water quality infiltration basins are similar to the City’s infiltration basins, but differ in that they are designed for the purpose of stormwater runoff treatment and retention as opposed to drainage.

The bottoms of the basins are typically vegetated with dry-land grasses or irrigated turf grass. Stormwater runoff treatment occurs through a variety of natural mechanisms as water flows through the soil profile. To ensure adequate treatment, the depth of unsaturated soils between the water quality infiltration basin bottom and the seasonal maximum groundwater surface level should be a minimum of ten (10) feet. A typical water quality infiltration basin layout is presented in Figure 8-2.

Other names
Percolation basin

Advantages
- Reduces or eliminates stormwater runoff discharge to receiving water during most storm events.
- Reduces peak stormwater runoff flows during small storm events.
- Can be incorporated into site landscape features or multi-use facilities such as parks or athletic fields.

Disadvantages
- Not appropriate for areas with low permeability soils or high groundwater.
- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Must be protected from high sediment loads. Once clogged with sediment, restoration of infiltration capacity may be difficult.
- Potential for mosquito breeding due to standing water. This can be greatly reduced and/or eliminated if the water quality infiltration basin is properly designed, constructed, and operated to maintain its infiltration capacity.
- Not appropriate on fill or sites with steep slopes.
Figure 8-2. Water Quality Infiltration Basin Schematic

Source: Stormwater Manager's Resource Center
Planning and Site Considerations

- Soil permeability, depth to groundwater, and design safety factors should be determined by a qualified geotechnical engineer or geologist to ensure that conditions conform to the criteria listed in Table 8-5.
- Integrate water quality infiltration basins into open space buffers and other landscape areas when possible.
- If vegetation is included in the design, irrigation may be required to maintain vegetation viability. Coordinate design of general landscape irrigation system with that of the basin, as applicable.
- Pretreatment using grassy channels, vegetated buffer strips, vegetated swales, grassy swales, and/or vegetated filter strip is required to protect water quality infiltration basin from high sediment loads.
- Plan for setback requirements (see Table 8-5).

Design Criteria

Principal design criteria for water quality infiltration basins are listed in Table 8-5.
Table 8-5. Water Quality Infiltration Basin Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawdown time</td>
<td>48 hr (maximum)</td>
<td></td>
</tr>
<tr>
<td>Water Quality Volume</td>
<td>80% annual capture (acre-ft)</td>
<td>Use Figure 6-1 at 48-hr drawdown</td>
</tr>
<tr>
<td>Soil permeability range</td>
<td>0.6-2.0 in/hr</td>
<td>Saturated vertical permeability</td>
</tr>
<tr>
<td>Groundwater separation</td>
<td>10 ft (minimum)</td>
<td>Between water quality infiltration basin bottom and historical seasonally high groundwater table</td>
</tr>
<tr>
<td>Freeboard</td>
<td>1.0 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>Setbacks</td>
<td>100 ft</td>
<td>From wells, tanks, springs</td>
</tr>
<tr>
<td></td>
<td>20 ft</td>
<td>Down slope from building foundations</td>
</tr>
<tr>
<td></td>
<td>100 ft</td>
<td>Up slope from building foundations</td>
</tr>
<tr>
<td>Inlet/outlet erosion control</td>
<td>–</td>
<td>Energy dissipater to reduce inlet/outlet velocity</td>
</tr>
<tr>
<td>Embankment side slope (H:V)</td>
<td>≥ 4:1</td>
<td>Inside basin embankment</td>
</tr>
<tr>
<td></td>
<td>≥ 3:1</td>
<td>Outside basin embankment (without retaining wall)</td>
</tr>
<tr>
<td>Maintenance access ramp slope</td>
<td>10:1 or flatter</td>
<td></td>
</tr>
<tr>
<td>Maintenance access ramp width</td>
<td>10 ft</td>
<td>Approach paved with asphalt/concrete</td>
</tr>
<tr>
<td>Vegetation</td>
<td>–</td>
<td>Side slopes and bottom (may require irrigation during summer)</td>
</tr>
</tbody>
</table>

Design Procedure

**Step 1 – Calculate WQV**

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 48-hour drawdown period.

**Step 2 – Calculate Design Maximum Depth of Water Surcharge in Water Quality Infiltration Basin (D_max)**

\[
D_{\text{max}} = \frac{t_{\text{max}} \times I}{12 \times s}
\]

Where:

\[
t_{\text{max}} = \text{maximum drawdown time} = 48 \text{ hours};
\]

\[
I = \text{site infiltration rate} \text{ (soil permeability, in/hr); and}
\]

\[
s = \text{safety factor}.
\]
In the formula above, the safety factor accounts for possible inaccuracies in the infiltration rate measurement. A larger safety factor should be used when the infiltration rate is less certain. 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.

**Step 3 – Calculate Minimum Surface Area of Water Quality Infiltration Basin Bottom (A_{min})**

\[ A_{min} = \frac{WQV}{D_{max}} \]

Where:

- \( A_{min} \) = minimum area required (ft\(^2\)); and
- \( D_{max} \) = maximum allowable depth (ft)

**Step 4 – Design Forebay Settling Basin**

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

**Step 5 – Design Embankments**

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

**Step 7 – Design Security Fencing**

Provide aesthetic security fencing around the water quality infiltration basin to protect habitat except when specifically waived by the City. Fencing design shall adhere to the City of Modesto Standard Specifications, and be approved by the City.

**Step 8 – Design Diversion Structure**

Provide for bypass or overflow of stormwater runoff volumes in excess of the WQV. Provide spillway or overflow structures, as applicable (see Figure 8-2). See Appendix I for more information on diversion structure design.
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

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 irrigation system to maintain viability of vegetation, if applicable. The irrigation system must include a City-approved automatic timer.

Volume Retention Calculation

Water quality infiltration basins may be used to achieve both the volume retention and treatment requirements. A water quality infiltration basin provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

Construction Considerations

- If possible, stabilize the entire tributary area to the water quality infiltration basin before construction begins. If this is not possible, divert flow around the water quality infiltration basin to protect it from sediment loads during construction or remove the top two (2) inches of soil from the water quality infiltration basin floor after the entire area has been stabilized.
- Once construction is complete, stabilize entire tributary area to the water quality infiltration basin before allowing stormwater runoff to enter water quality infiltration basin.
- Divert stormwater runoff (other than necessary irrigation) during the period of vegetation establishment.
- Construct the water quality infiltration basin using equipment with extra wide, low-pressure tires. Prevent construction traffic from entering water quality infiltration basin to avoid soil compaction, which can reduce infiltration capacity.
- Final grading shall produce a level basin bottom without low spots or depressions.
- After final grading, deep till the water quality infiltration basin bottom.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control.
measures such as water quality infiltration basins. Such agreements typically include requirements such as those outlined in Table 8-6. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-6. Inspection and Maintenance Requirements for Water Quality Infiltration Basins

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>If erosion occurs within the water quality infiltration basin, re-</td>
<td>As required</td>
</tr>
<tr>
<td>vegetate immediately and stabilize erosion control mulch or mat until</td>
<td></td>
</tr>
<tr>
<td>vegetation cover is established.</td>
<td></td>
</tr>
<tr>
<td>Monitor infiltration rate in basin after storm events by recording the</td>
<td>Several times during first year following installation. During subsequent seasons at beginning</td>
</tr>
<tr>
<td>drop in water depth versus time using a calibrated rod or staff gauge.</td>
<td>and end of wet season. Additional monitoring after periods of heavy stormwater runoff is desirable.</td>
</tr>
<tr>
<td>If drawdown period is observed to have increased significantly over the</td>
<td>As required</td>
</tr>
<tr>
<td>design drawdown period, clean, re-grade, and till water quality</td>
<td></td>
</tr>
<tr>
<td>infiltration basin bottom to restore infiltrative capacity. This</td>
<td></td>
</tr>
<tr>
<td>maintenance activity is expensive and the need for it can be</td>
<td></td>
</tr>
<tr>
<td>minimized through prevention of upstream erosion.</td>
<td></td>
</tr>
<tr>
<td>Trim vegetation to prevent establishment of woody vegetation and for</td>
<td>At beginning and end of wet season</td>
</tr>
<tr>
<td>aesthetic and vector control reasons.</td>
<td></td>
</tr>
<tr>
<td>Monitor health of vegetation and replace.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from water quality infiltration basin area.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect water quality infiltration basin to identify potential problems</td>
<td>At beginning and end of wet season. Additional inspections after periods of heavy stormwater runoff</td>
</tr>
<tr>
<td>such as erosion of basin side slopes and invert, standing water, trash,</td>
<td>are desirable.</td>
</tr>
<tr>
<td>and debris, and sediment accumulation.</td>
<td></td>
</tr>
<tr>
<td>Remove accumulated sediment and re-grade when accumulated sediment</td>
<td>As required for both forebay settling basin and infiltration basin</td>
</tr>
<tr>
<td>volume exceeds ten (10) percent of the water quality infiltration basin</td>
<td></td>
</tr>
<tr>
<td>volume. Note: Scarification or other activities creating disturbance</td>
<td></td>
</tr>
<tr>
<td>should only be performed when there are actual signs of clogging, rather</td>
<td></td>
</tr>
<tr>
<td>than on a routine basis.</td>
<td></td>
</tr>
<tr>
<td>Maintain pretreatment control measures in accordance to its respective</td>
<td>As required</td>
</tr>
<tr>
<td>“Long-Term Maintenance” section.</td>
<td></td>
</tr>
</tbody>
</table>
R-3: Water Quality Infiltration Trench

Description

A water quality infiltration trench is a narrow trench constructed in naturally pervious soils (Type A or B soil) and filled with gravel and sand, although use of manufactured percolation tank modules may be considered in place of gravel fill. Stormwater runoff is stored in the water quality infiltration trench until it infiltrates into the soil profile over a specified drawdown period. Overflow drains are often provided to allow drainage if the water quality infiltration trench becomes clogged. Water quality infiltration trenches are similar to the City’s infiltration trenches, but differ in that they are designed for the purpose stormwater runoff treatment and retention as opposed to drainage.

Infiltration vaults and infiltration leach fields are subsurface variations of the water quality infiltration trench concept in which stormwater runoff is distributed to the upper zone of the subsurface gravel bed by means of perforated pipes.

Infiltrated water typically reaches the underlying groundwater. Stormwater runoff treatment occurs through a variety of natural mechanisms as 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 historical high groundwater surface level should be a minimum of ten (10) feet.

A typical water quality infiltration trench configuration is presented in Figure 8-3.

Other names

Percolation trench, dispersal trench, French drain

Advantages

- Provides effective treatment 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.
- Reduces peak flows during small storm events.
Disadvantages

- Potential for clogging of media. Upstream treatment control measures to remove large sediment may be required to prevent or minimize media clogging. The cost of restorative maintenance can be high if soil infiltration rates are significantly reduced due to sediment deposition.
- Not appropriate for areas with slow permeable soils (Type C or D soil) or high groundwater.
- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.

Planning and Site Considerations

- Integrate water quality infiltration trenches into open space buffers and other landscape areas when possible.
- Plan for setback requirements listed in Table 8-7.
- Do not locate water quality infiltration trenches under tree drip lines.
- Pretreatment using grassy channels, vegetated buffer strips, vegetated swales, grassy swales, and/or vegetated filter strip is required to protect water quality infiltration trenches from high sediment loads (see Figure 8-3).

Design Criteria

Principal design criteria for water quality infiltration trenches are listed in Table 8-7.

**Table 8-7. Water Quality Infiltration Trench Design Criteria**

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary drainage area</td>
<td>≤ 5 acres</td>
<td></td>
</tr>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>48 hr (maximum)</td>
<td></td>
</tr>
<tr>
<td>Soil permeability range</td>
<td>0.6-2.0 in/hr</td>
<td>Saturated vertical permeability</td>
</tr>
<tr>
<td>Groundwater separation</td>
<td>10 ft (minimum)</td>
<td>Between water quality infiltration trench bottom and historical seasonally high groundwater table</td>
</tr>
<tr>
<td>Trench surcharge depth (D&lt;sub&gt;max&lt;/sub&gt;)</td>
<td>10 ft (maximum)</td>
<td></td>
</tr>
<tr>
<td>Setbacks</td>
<td>100 ft</td>
<td>From wells, tanks, springs</td>
</tr>
<tr>
<td></td>
<td>20 ft</td>
<td>Down slope from foundation</td>
</tr>
<tr>
<td></td>
<td>100 ft</td>
<td>Up slope from foundation</td>
</tr>
<tr>
<td>Trench media material size/type</td>
<td>1-3 in</td>
<td>Washed gravel or manufactured percolation tank modules</td>
</tr>
<tr>
<td>Trench lining material</td>
<td>–</td>
<td>Geotextile fabric (see Table 8-8) prevents clogging</td>
</tr>
<tr>
<td>Observation well size</td>
<td>4-6 in</td>
<td>Perforated PVC pipe with removable cap</td>
</tr>
<tr>
<td>Pretreatment vegetated buffer strip length</td>
<td>10 ft (minimum)</td>
<td>Length in flow direction</td>
</tr>
<tr>
<td>Pretreatment vegetated buffer strip slope</td>
<td>5% (maximum)</td>
<td>Slope in flow direction</td>
</tr>
</tbody>
</table>
Table 8-8. Geotextile Fabric Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Method</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td></td>
<td>Nonwoven geotextile fabric</td>
</tr>
<tr>
<td>Unit weight</td>
<td></td>
<td>8 oz/yd² (minimum)</td>
</tr>
<tr>
<td>Filtration rate</td>
<td></td>
<td>0.08 in/sec (minimum)</td>
</tr>
<tr>
<td>Puncture strength</td>
<td>ASTM D-751 (Modified)</td>
<td>125 lbs (minimum)</td>
</tr>
<tr>
<td>Mullen burst strength</td>
<td>ASTM D-751</td>
<td>400 lb/in² (minimum)</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>AST D-1682</td>
<td>300 lbs (minimum)</td>
</tr>
<tr>
<td>Equiv. opening size</td>
<td>US Standard Sieve</td>
<td>No. 80 (minimum)</td>
</tr>
</tbody>
</table>

Design Procedure

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 48-hour drawdown period.

Step 2 – Calculate Minimum Surface Area of Water Quality Infiltration Trench Bottom (Amin)

\[ A_{min} = \frac{WQV \times s \times 12}{t_{max} \times I} \]

Where:

- WQV = water quality volume (ft³);
- \( t_{max} = \) maximum drawdown time = 48 hours;
- \( I = \) site infiltration rate (soil permeability, in/hr); and
- \( s = \) safety factor

In the formula above, the safety factor accounts for possible inaccuracies in the infiltration rate measurement. A larger safety factor should be used when the infiltration rate is less certain. 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.

Step 3 – Calculate Design Depth of Water Surcharge in Water Quality Infiltration Trench (Dmax)

\[ D_{max} = \frac{WQV}{P \times A_{min}} \]

Where:

- WQV = water quality volume (ft³);
- \( P = \) Porosity of infiltration gravel material (use 0.30). Note: Use of manufactured percolation tank modules can provide greater porosity than...
gravel.
\[ A_{\text{min}} = \text{Minimum area required (ft}^2\text{).} \]

Note: \( D_{\text{max}} \) should not exceed ten (10) feet. If necessary, increase \( A_{\text{min}} \) to keep \( D_{\text{max}} \leq 10 \) 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 water quality infiltration trench on a footplate and with a locking, removable cap. The observation well is needed to monitor the infiltration rate in water quality infiltration trench and is useful for marking the location of the water quality infiltration trench.

**Step 5 – Design Diversion Structure**

Provide bypass or overflow of stormwater runoff volumes in excess of the WQV by means of a screened overflow pipe connected to the downstream storm drain system or grated overflow outlet. See Appendix I for more information on diversion structure design.

**Volume Retention Calculation**

Water quality infiltration trenches may be used to achieve both the volume retention and treatment requirements. A water quality infiltration trench provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

**Construction Considerations**

- If possible, stabilize the entire tributary area to the water quality infiltration trench before construction begins. If this is not possible, divert flow around the water quality infiltration trench site to protect it from sediment loads during construction.
- Once construction is complete, stabilize the entire tributary area to the water quality infiltration trench before allowing stormwater runoff to enter the water quality infiltration trench.
- Install geotextile fabric on sides, bottom, and one foot below the surface of the trench (see Table 8-8). Provide generous overlap at all seams.
- Store excavated material at least ten (10) feet from the water quality infiltration 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. Use of unwashed gravel can result in clogging.
Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as water quality infiltration trenches. Such agreements typically include requirements such as those outlined in Table 8-9. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-9. Inspection and Maintenance Requirements for Water Quality Infiltration Trenches

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>If erosion occurs within the tributary area, re-vegetate immediately and stabilize erosion control mulch or mat until vegetation cover is established.</td>
<td>As required</td>
</tr>
<tr>
<td>Monitor infiltration rate in water quality infiltration trench after storm events by recording the drop in water depth versus time using a calibrated rod or staff gauge.</td>
<td>Several times during first year following installation. During subsequent seasons at beginning and end of wet season. Additional monitoring after periods of heavy stormwater runoff is desirable.</td>
</tr>
<tr>
<td>Clean water quality infiltration 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 upper layer of filter fabric may be necessary. Clogging is most likely occurring near top foot of water quality infiltration trench between the upper gravel layer and protective layer of filter fabric. Cleaning can be accomplished by removing top layer of gravel and clogged filter fabric, installing a new layer of filter fabric, and replacing gravel layer with washed gravel. This maintenance activity is expensive, and the need for it can be minimized through prevention of upstream erosion.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove pioneer trees that sprout in the vicinity of water quality infiltration trench to prevent root puncture of filter fabric that could allow sediment to enter the water quality infiltration trench.</td>
<td>As required</td>
</tr>
<tr>
<td>Trim adjacent trees to prevent drip lines from extending over surface of water quality infiltration trench.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from the water quality infiltration trench area.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect water quality infiltration trench to identify potential problems such as standing water, trash, and debris, and sediment accumulation.</td>
<td>At beginning and end of wet season. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>Maintain pretreatment control measures in accordance to its respective “Long-Term Maintenance” section.</td>
<td>As required</td>
</tr>
</tbody>
</table>
R-4: Bioretention without an Underdrain

Description

A bioretention area without an underdrain is a vegetated shallow depression that is designed to receive, retain, and infiltrate stormwater 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 temporary storage of captured stormwater runoff. During storm events, stormwater runoff accumulates in the surcharge zone and gradually infiltrates and filters through the engineered soil matrix, filling the void spaces of the matrix before infiltrating the underlying soil.

Stormwater runoff treatment occurs through a variety of natural mechanisms as stormwater runoff filters through the vegetation root zone, and is detained in the pore spaces 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. If the underlying soil is permeable (typically Type A or B soil with permeability greater than the engineered soil layers), the bioretention area can be constructed without an underdrain pipe. When a bioretention area is constructed without an underdrain pipe, all captured stormwater runoff will infiltrate into the underlying soil profile. An impermeable liner cannot be used for a bioretention area without an underdrain system in order to receive a volume retention credit.

A schematic of a typical bioretention area without an underdrain is presented in Figure 8-4.

Advantages

- Low installation cost.
- Enhances site aesthetics.
- Retains stormwater runoff volume and eliminates pollutant discharge.
- Potential water conservation.
- Easy maintenance.
Disadvantages

- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Will not work if underlying soil profile is Type C or D soil. See Fact Sheet R-8
  - Bioretention with Underdrain.
- Will require individual owner/tenants to perform maintenance.

Planning and Site Considerations

- 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 one (1) percent from impervious surface to bioretention areas inlet.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the bioretention area, and cars are allowed to overhang the bioretention area.
• Irrigation is typically required to maintain viability of bioretention area vegetation. Coordinate design of general landscape irrigation system with that of the bioretention area, as applicable.
• Provide an overflow discharge that drains away from building foundations to the storm drain system or more suitable infiltration area.

Design Criteria

Principal design criteria for bioretention without an underdrain are listed in Table 8-10.

Table 8-10. Bioretention without an Underdrain Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ponding zone depth ($D_{pz}$)</td>
<td>12 in</td>
<td>Maximum depth above top mulch layer</td>
</tr>
<tr>
<td>Top mulch layer depth</td>
<td>2-3 in</td>
<td>Mulch, softwood, or shredded hardwood</td>
</tr>
<tr>
<td>Planting media depth</td>
<td>12-24 in</td>
<td>Mix 60-65% loamy sand + 35-40% compost; or 30% loamy sand + 30% course sand + 40% compost</td>
</tr>
<tr>
<td>Excavation side slope (H:V)</td>
<td>2:1</td>
<td>Maximum steepness</td>
</tr>
</tbody>
</table>

Design Procedure

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

Step 2 – Design Average Ponding Depth ($D_{pz}$)

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

Step 3 – Calculate Bioretention Planter Surface Area ($A_s$)

The design surface area of the bioretention planter is determined from the design WQV and $D_{pz}$ as follows:

$$A_s = \frac{WQV}{D_{pz}}$$

Where:

- $WQV$ = water quality volume ($ft^3$);
- $D_{pz}$ = average ponding depth ($ft$).
**Step 4 – Design 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 greater than or equal to one inch per hour (1 in/hr) at 80% 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.

**Step 5 – Select Vegetation**

Select vegetation that:

- 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 Integrated Pest Management practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Examples of appropriate vegetation for the Modesto area are presented in Appendix G.

**Step 6 – Design Irrigation System**

Provide irrigation system to maintain viability of vegetation, if applicable. The irrigation system must include a City-approved automatic timer.

**Step 7 – Design Overflow Device**

Provide an overflow device with an inlet to open conveyance or to the storm drain system. Set the overflow inlet elevation above the WQV surcharge water level. A drop inlet or an overflow standpipe with an inverted opening are an appropriate overflow devices. See Appendix I for more information on overflow device design.

**Volume Retention Calculation**

A bioretention area without an underdrain may be used to achieve both the volume retention and treatment requirements. A bioretention area without an underdrain provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

**Construction Considerations**

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
• Install sediment controls, such as silt fences, around the bioretention area to prevent high sediment loads from entering the area during ongoing construction activities.
• Avoid compaction of native soils below planting media layer or gravel zone.
• Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as bioretention areas without an underdrain. Such agreements typically include requirements such as those outlined in Table 8-11. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-11. Inspection and Maintenance Requirements for Bioretention Areas without an Underdrain

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remulch void areas.</td>
<td>As needed</td>
</tr>
<tr>
<td>Treat diseased trees and shrubs.</td>
<td>As needed</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices</td>
<td>As needed</td>
</tr>
<tr>
<td>Water plants daily for two weeks.</td>
<td>At project completion</td>
</tr>
<tr>
<td>Inspect soil and repair eroded areas.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Remove litter and debris.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Remove and replace dead and diseased vegetation.</td>
<td>Twice per year</td>
</tr>
<tr>
<td>Add additional mulch.</td>
<td>Once per year</td>
</tr>
<tr>
<td>Replace tree stakes and wire.</td>
<td>Once per year</td>
</tr>
</tbody>
</table>
R-5: Dry Well

Description
A dry well is a bored, drilled, or driven shaft or hole whose depth is greater than its width. A dry well is designed specifically for alleviation of flooding and the disposal of stormwater runoff. Dry wells design and function are similar to infiltration trenches in that they are designed to temporarily store and infiltrate stormwater runoff, primarily from rooftops and other impervious areas with low pollutant loadings. A dry well may either be a small excavated pit filled with aggregate or a prefabricated storage chamber or pipe segment.

Dry wells can be used to reduce the increased volume of stormwater runoff caused by building roofs. While generally not a significant source of stormwater runoff pollution, roofs are one of the most important sources of new or increased stormwater runoff volume from land development sites. Dry wells can be used to indirectly enhance water quality by reducing the amount of stormwater runoff volume to be treated by other downstream treatment control measures.

A dry well cross-section schematic is presented in Figure 8-5.

Advantages

- Can be placed below ground.
- Reduces peak stormwater runoff flows during small storm events.

Disadvantages

- Not appropriate for areas with low permeability soils (Type C or D soils) or high groundwater.
- Cannot receive untreated stormwater runoff, except from rooftops.
- Rehabilitation of failed dry wells requires complete reconstruction.
- Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.

Planning and Site Considerations

- Integrate dry wells into open space buffers and other landscape areas when possible.
- Plan for appropriate setback distances presented in Table 8-12.
- Pretreatment using grassy channels, vegetated buffer strips, vegetated swales, grassy swales, and/or vegetated filter strip is required to protect dry wells from high sediment loads.
- Install an observation well to check water levels, drawdown time, and evidence of clogging.

Figure 8-5. Dry Well Schematic

Design Criteria

Principal design criteria for dry wells are listed in Table 8-12.
Table 8-12. Dry Well Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary drainage area</td>
<td>≤ 10,000 ft²</td>
<td></td>
</tr>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>12 hr (maximum)</td>
<td></td>
</tr>
<tr>
<td>Soil permeability range</td>
<td>0.6-2.0 in/hr</td>
<td>Saturated vertical permeability</td>
</tr>
<tr>
<td>Groundwater separation</td>
<td>10 ft (minimum)</td>
<td>Between dry well bottom and historical seasonally high groundwater table</td>
</tr>
<tr>
<td>Trench surcharge depth (Dₘₐₓ)</td>
<td>10 ft (maximum)</td>
<td></td>
</tr>
<tr>
<td>Setbacks</td>
<td>100 ft</td>
<td>From wells, tanks, fields, springs</td>
</tr>
<tr>
<td></td>
<td>20 ft</td>
<td>Down slope from foundation</td>
</tr>
<tr>
<td></td>
<td>100 ft</td>
<td>Up slope from foundation</td>
</tr>
<tr>
<td>Filter media diameter</td>
<td>1.5-3 in</td>
<td>Gravel or prefabricated media</td>
</tr>
<tr>
<td>Observation well size</td>
<td>4-6 in</td>
<td>Perforated PVC pipe with removable cap</td>
</tr>
<tr>
<td>Pretreatment vegetated buffer strip length</td>
<td>10 ft (minimum)</td>
<td>Length in flow direction</td>
</tr>
<tr>
<td>Pretreatment vegetated buffer strip slope</td>
<td>5% (maximum)</td>
<td>Slope in flow direction</td>
</tr>
</tbody>
</table>

Design Procedure

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

Step 2 – Calculate Minimum Surface Area of Dry Well Bottom (Aₘᵢₙᵢₙ)

\[ A_{min} = \frac{WQV \times s \times 12}{t_{max} \times I} \]

Where:

- WQV = water quality volume (ft³);
- tₘᵢₙᵢₙ = maximum drawdown time = 12 hours;
- I = site infiltration rate (soil permeability, in/hr); and
- s = safety factor

In the formula above, the safety factor accounts for possible inaccuracies in the infiltration rate measurement. A larger safety factor should be used when the infiltration rate is less certain. 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.
Step 3 – Calculate Design Depth of Water Surcharge in Dry Well \((D_{\text{max}})\)

\[
D_{\text{max}} = \frac{WQV}{P \times A_{\text{min}}}
\]

Where:

- \(WQV\) = water quality volume \((\text{ft}^3)\);
- \(P\) = Porosity of dry well material (use 0.30). Note: Use of manufactured percolation tank modules can provide greater porosity than gravel.
- \(A_{\text{min}}\) = Minimum surface area for dry well bottom required \((\text{ft}^2)\).

Note: \(D_{\text{max}}\) should not exceed ten (10) feet. If necessary, increase \(A_{\text{min}}\) to keep \(D_{\text{max}} \leq 10\) 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 dry well on a footplate and with a locking, removable cap. The observation well is needed to monitor the infiltration rate in the dry well and is useful for marking the location of the dry well.

Step 5 – Design Diversion Structure

Provide bypass or overflow of stormwater runoff volumes in excess of the WQV by means of a screened overflow pipe connected to the downstream storm drain system or grated overflow outlet. See Appendix I for more information on diversion structure design.

Volume Retention Calculation

Dry wells may be used to achieve both the volume retention and treatment requirements. A dry well provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

Construction Considerations

- If possible, stabilize the entire tributary area to the dry well before construction begins. If this is not possible, divert flow around the dry well site to protect it from sediment loads during construction.
- Once construction is complete, stabilize the entire tributary area to the dry well before allowing stormwater runoff to enter the dry well.
- Store excavated material at least ten (10) feet from the dry well to avoid backsliding and cave-ins.
- Install geotextile fabric on sides, bottom, and one foot below the surface of the dry well (see Table 8-8). Provide generous overlap at all seams.
- Minimize compaction of the subgrade to the maximum extent practicable during construction to prevent loss of infiltrative capacity.
- Clean, washed gravel should be placed in the excavated dry well in lifts and lightly compacted with a plate compactor. Use of unwashed gravel can result in clogging.

**Long-Term Maintenance**

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as dry wells. Such agreements typically include requirements such as those outlined in Table 8-13. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

**Table 8-13. Inspection and Maintenance Requirements for Dry Wells**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor infiltration rate in well after storm events by recording the drop in water depth versus time using a calibrated rod or staff gauge.</td>
<td>Several times during first year following installation. During subsequent seasons at beginning and end of wet season. Additional monitoring after periods of heavy stormwater runoff is desirable. As required</td>
</tr>
<tr>
<td>Clean dry well when loss of infiltrative capacity is observed. If infiltration rate is observed to have decreased significantly over the design rate, remove sediment and/or gravel from the dry well, and replace with washed gravel if necessary. Clogging is most likely occurring at the top dry well. This maintenance activity is expensive, and the need for it can be minimized through prevention of upstream erosion.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from dry well area.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect dry well to identify potential problems such as standing water, trash, and debris, and sediment accumulation.</td>
<td>At beginning and end of wet season. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>Maintain pretreatment control measures in accordance to its respective “Long-Term Maintenance” section.</td>
<td>As required</td>
</tr>
</tbody>
</table>
R-6: French Drain

See R-3, on page 8-20 (Water Quality Infiltration Trench) for design specifications for a French drain.
R-7: Permeable Pavement without an Underdrain

Description

Permeable pavement include permeable interlocking concrete pavers, pervious concrete, or porous asphalt pavement that is flat in all directions, and is provided with a ponding zone to temporarily store stormwater runoff draining from an adjacent area. Stormwater runoff infiltrates into the porous pavement and sublayers of sand and gravel.

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 cement materials used to create a paste that forms a thick coat around aggregate particles. Unlike conventional concrete, the mixture contains little or no sand, which creates a substantial void content between 15% and 25%. Porous asphalt, or “open-graded” asphalt, pavement contains no fine aggregate particles. This creates 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 permeable pavement without an underdrain is presented in Figure 8-6.

Advantages

- Reduces stormwater runoff volume and peak flows during small storm events.
- Can serve functional and aesthetic purposes.
- Can reduce heat island effects if light color concrete pavements are used.
- Creates dual use for limited space (e.g., parking and stormwater management provided within same space) and can reduce the need and space required for separate stormwater treatment controls.

Disadvantages

- 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. These factors should be taken into consideration when selecting a permeable pavement type.
• Not appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.

Planning and Site Considerations

• Should only be installed on relatively flat surfaces.
• May be used in low vehicle-movement areas. Potential applications may include the following:
  o Low vehicle movement airport zones;
  o Parking aprons and maintenance roads;
  o Crossover/emergency stopping/parking lanes on divided highways;
  o Residential street parking lanes;
  o Residential driveways;
  o Overflow parking;
  o Maintenance roads and trails; and
  o Emergency vehicle and fire access lanes in apartment/multi-family/complex facilities.
• Additionally, permeable pavement may also be used for sidewalks, walkways, and patios.
• Vehicle movement lanes that lead up to permeable pavement parking pads should be solid asphalt or concrete pavement.
• Grass can be used in block voids, but it may require irrigation and lawn care.
• Should be located far enough from foundations in expansive soils so as to limit potential damage to structures.
Design Criteria

Principal design criteria for permeable pavement without an underdrain are summarized in Table 8-14.

Table 8-14. Permeable Pavement without an Underdrain Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQV</td>
<td>80% annual capture</td>
<td>Use Figure 6-1 at 12-hr drawdown</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>12 hr (minimum)</td>
<td></td>
</tr>
<tr>
<td>Surcharge storage volume above pavement</td>
<td>WQV</td>
<td></td>
</tr>
<tr>
<td>Surcharge zone depth</td>
<td>2 in</td>
<td>Maximum depth above pavement</td>
</tr>
<tr>
<td>Imperviousness</td>
<td>&lt;60%</td>
<td>Variable with pavement type</td>
</tr>
<tr>
<td>Permeable paver infill</td>
<td>ASTM No. 8 crushed aggregate</td>
<td></td>
</tr>
<tr>
<td>Base courses</td>
<td>1-in ASTM No. 8 over 9-in ASTM No. 57</td>
<td></td>
</tr>
</tbody>
</table>

Source: Cahill Associates
Design Procedure

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

Step 2 – Determine Ponding Zone Storage Volume (V_{pz})

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

\[ V_{pz} = 1.0 \times WQV \]

Where:

- WQV = water quality volume (ft^3).

Step 3 – Calculate Surface Area (A_s)

Calculate minimum required surface area based on ponding depth of two (2) inches above pavement as follows:

\[ A_s = \frac{WQV}{0.17} \]

Where:

- WQV = water quality volume (ft^3).

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 8-6.
Step 7 – Provide Perimeter Wall

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

Step 8 – Design Overflow Device

Provide an overflow device, possibly with an inlet to the storm drain system, set at a maximum of two (2) inches above the level of the permeable pavement surface. Make sure the two-(2) inch ponding depth is contained and does not flow out of the area at the ends or the sides. See Appendix I for more information on overflow device design.

Volume Retention Calculation

Permeable pavement without an underdrain may be used to achieve both the volume retention and treatment requirements. Permeable pavement without an underdrain provides volume retention for the entire WQV calculated in Step 1 of the Design Procedure.

Construction Considerations

- Before the entire site is graded, the area planned for permeable pavement should be cordoned off to prevent heavy equipment from compacting the underlying soil.
- Install geotextile fabric under the base course (see Table 8-8). Provide generous overlap at all seams.
- Both prior to and during construction, diversions should be installed around the perimeter of the permeable pavement as needed to prevent stormwater runoff and sediment from entering the site until the permeable pavement is in place.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as permeable pavement without an underdrain. Such agreements typically include requirements such as those outlined in Figure 8-19. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.
Table 8-15. Inspection and Maintenance Requirements for Permeable Pavement with an Underdrain

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspect pavements to determine if stormwater runoff is infiltrating properly. If infiltration is significantly reduced, remove surface aggregate by vacuuming. Dispose of and replace old aggregate with fresh aggregate.</td>
<td>At least twice during wet season after significant storm events. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>If stabilized grassy permeable pavement is used, trim vegetation and remove weeds to limit unwanted vegetation.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from the permeable pavement area.</td>
<td>As required</td>
</tr>
</tbody>
</table>
R-8: Bioretention with an Underdrain

Description

A bioretention area with an underdrain is a vegetated shallow depression that is designed to receive, retain, and infiltrate stormwater runoff from downspouts, piped inlets, or sheet flow from adjoining paved areas. A shallow ponding zone is provided above the vegetated surface for temporary storage of captured stormwater runoff. During storm events, stormwater runoff accumulates in the ponding zone and gradually infiltrates the surface and filters through the engineered soil matrix, filling the void spaces of the matrix before being collected by an underdrain system.

Stormwater runoff treatment occurs through a variety of natural mechanisms as stormwater runoff filters through the vegetation root zone, and is detained in the pore spaces 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. If the underlying soil is less permeable (typically Type C or D soil) or the slope is steep, an underdrain is required to prevent excessive ponding. If an underdrain is present, only a portion of the captured stormwater runoff will be retained on-site through vegetation uptake.

A schematic of a bioretention area with an underdrain is presented in Figure 8-7.

Advantages

- Low installation cost.
- Enhances site aesthetics.
- Retains some stormwater runoff, which reduces some pollutant discharge.
- Potential water conservation.
- Easy maintenance.

Disadvantages

- May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Not appropriate for areas with steep slopes or high groundwater unless infiltration is prevented by an impermeable liner.
- Will require individual owner/tenants to perform maintenance.

Figure 8-7. Bioretention Area with an Underdrain Schematic

Planning and Site Considerations

- 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 one (1) percent from impervious surface to bioretention areas inlet.
- Provide an overflow discharge that drains away from building foundations to the storm drain system or more suitable infiltration area.
- Provide impermeable liners in areas subject to spills or pollutant hot spots.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the bioretention area, and cars are allowed to overhang the bioretention area.
- Irrigation is typically required to maintain viability of bioretention vegetation. Coordinate design of general landscape irrigation system with that of the bioretention area, as applicable.
Design Criteria

Principal design criteria for bioretention without an underdrain are listed in Table 8-16.

Table 8-16. Bioretention with an Underdrain Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ponding zone depth ($D_{pz}$)</td>
<td>12 in</td>
<td>Maximum depth above top mulch layer</td>
</tr>
<tr>
<td>Top mulch layer depth</td>
<td>2-3 in</td>
<td>Mulch, softwood, or shredded hardwood</td>
</tr>
<tr>
<td>Planting media depth</td>
<td>12-24 in</td>
<td>Mix 60-65% loamy sand + 35-40% compost; or</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30% loamy sand + 30% course sand + 40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>compost</td>
</tr>
<tr>
<td>Aggregate filter blanket</td>
<td>9-12 in</td>
<td>For use with subsurface drain pipe</td>
</tr>
<tr>
<td>Subsurface drain pipe</td>
<td>4-8 in</td>
<td>Slotted PVC per ASTM D1785 Sch. 40 (Use with</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type C or D soil)</td>
</tr>
<tr>
<td>Excavation side slope (H:V)</td>
<td>2:1</td>
<td>Maximum steepness</td>
</tr>
</tbody>
</table>

Design Procedure

**Step 1 – Calculate WQV**

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

**Step 2 – Design Average Ponding Depth ($D_{pz}$)**

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

**Step 3 – Calculate Bioretention Planter Surface Area ($A_s$)**

The design surface area of the bioretention planter is determined from the design WQV and $D_{pz}$ as follows:

$$A_s = \frac{WQV}{D_{pz}}$$

Where:

- $WQV = \text{water quality volume (ft}^3\text{)}$; and
- $D_{pz} = \text{average ponding depth (ft)}$.

**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 greater than or equal to one inch per hour (1 in/hr) at 80%.
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 drain pipe) – Place drain pipe on a 3-foot wide, 6-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec. 68-1.025). Cover top and sides of pipe with gravel to a minimum depth of 12 inches. Do not wrap pipe or gravel envelope with filter fabric to prevent 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 an impermeable liner at the bottom of the bioretention facility. If an impermeable liner is used, no volume retention credit will be given.

**Step 6 – Design Subsurface Drain Pipe**

Provide a subsurface drain pipe with a diameter sized for required hydraulic capacity (4-inch minimum). Use heavy-walled, slotted PVC pipe (ASTM D1785 Sch. 40) to allow pressure water cleaning and root cutting, if necessary. Connect subsurface drain pipe to 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 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 Integrated Pest Management practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Examples of appropriate vegetation for the Modesto area are presented in Appendix G.

**Step 8 – Design Irrigation System**

Provide irrigation system to maintain viability of vegetation, if applicable. The irrigation system must include a City-approved automatic timer.

**Step 9 – Design Overflow Device**

Provide an overflow device with an inlet to open conveyance or to the storm drain system. Set the overflow inlet elevation above the WQV ponding water level. A drop
inlet or an overflow standpipe with an inverted opening are an appropriate overflow devices. See Appendix I for more information on overflow device design.

**Volume Retention Calculation**

Bioretention without an underdrain may be used to at least partly achieve the volume retention requirement in addition to the treatment control requirement. The presence of the underdrain reduces the volume retained because less infiltration occurs. If an impermeable liner is used, no volume retention credit is given. The calculation procedure for volume retention for biofiltration without an underdrain is presented in Table 8-17.

**Table 8-17. Bioretention with an Underdrain Volume Retention Calculation**

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ponding zone</td>
<td></td>
<td>Infiltration allowance for water in ponding zone water = 0.25</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pz} = )</td>
<td>ft</td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pz} = )</td>
<td>ft²</td>
</tr>
<tr>
<td>2. Planting media layer</td>
<td></td>
<td>Available water holding capacity of planting media layer = 0.1 x volume</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pm} = )</td>
<td>ft</td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pm} = )</td>
<td>ft²</td>
</tr>
<tr>
<td>3. Gravel zone</td>
<td></td>
<td>Porosity of gravel zone = 0.30</td>
</tr>
<tr>
<td>Depth below pipe</td>
<td>( D_{gz} = )</td>
<td>ft</td>
</tr>
<tr>
<td>Area below pipe</td>
<td>( A_{gz} = )</td>
<td>ft²</td>
</tr>
<tr>
<td>4. Volume retention</td>
<td></td>
<td>( V_{ret} = ) ( (D_{pz} \times A_{pz} \times 0.25) + (D_{pm} \times A_{pm} \times 0.10) + (D_{gz} \times A_{gz} \times 0.30) ) ft³</td>
</tr>
</tbody>
</table>

Note: Required for Type C or D soil.

**Construction Considerations**

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the bioretention area to prevent high sediment loads from entering the area during ongoing construction activities.
- Avoid compaction of native soils below planting media layer or gravel zone.
- Repair, seed, or re-plant damaged areas immediately.
**Long-Term Maintenance**

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as bioretention areas with an underdrain. Such agreements typically include requirements such as those outlined in Table 8-18. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

**Table 8-18. Inspection and Maintenance Requirements for Bioretention Areas with an Underdrain**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remulch void areas.</td>
<td>As needed</td>
</tr>
<tr>
<td>Treat diseased trees and shrubs.</td>
<td>As needed</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As needed</td>
</tr>
<tr>
<td>Water plants daily for two weeks.</td>
<td>At project completion</td>
</tr>
<tr>
<td>Inspect soil and repair eroded areas.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Remove litter and debris.</td>
<td>Monthly</td>
</tr>
<tr>
<td>Remove and replace dead and diseased vegetation.</td>
<td>Twice per year</td>
</tr>
<tr>
<td>Add additional mulch.</td>
<td>Once per year</td>
</tr>
<tr>
<td>Replace tree stakes and wire.</td>
<td>Once per year</td>
</tr>
</tbody>
</table>
R-9: Permeable Pavement with an Underdrain

Description

Permeable pavement include permeable interlocking concrete pavers, pervious concrete, or porous asphalt pavement that is flat in all directions, and is provided with a ponding zone to temporarily store stormwater runoff draining from an adjacent area. Stormwater runoff infiltrates into the porous pavement and 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 cement materials used to create a paste that forms a thick coat around aggregate particles. Unlike conventional concrete, the mixture contains little or no sand, which creates a substantial void content between 15% and 25%. Porous asphalt, or “open-graded” asphalt, pavement contains no fine aggregate particles. This creates 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 schematic of permeable pavement with an underdrain is presented in Figure 8-6.

Advantages

- Reduces stormwater runoff volume and peak flows during small storm events.
- Can serve functional and aesthetic purposes.
- Can reduce heat island effects if light color concrete pavements are used.
- Creates dual use for limited space (e.g., parking and stormwater management provided within same space) and can reduce the need and space required for separate stormwater treatment controls.

Disadvantages

- Cost of restorative maintenance can be somewhat high when the system seals with sediment and can no longer function properly as permeable pavement.
• May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination. An impermeable liner may be used, but the benefit of volume retention will be eliminated.

• Uneven driving surfaces and potential traps for high-heeled shoes are potential limitations. These factors should be taken into consideration when selecting a permeable pavement type.

Planning and Site Considerations

• Should only be installed on relatively flat surfaces.
• May be used in low vehicle-movement areas. Potential applications may include the following:
  o Low vehicle movement airport zones;
  o Parking aprons and maintenance roads;
  o Crossover/emergency stopping/parking lanes on divided highways;
  o Residential street parking lanes;
  o Residential driveways;
  o Overflow parking;
  o Maintenance roads and trails; and
  o Emergency vehicle and fire access lanes in apartment/multi-family/complex facilities.

• Additionally, permeable pavement may also be used for sidewalks, walkways, and patios.
• Vehicle movement lanes that lead up to permeable pavement parking pads should be solid asphalt or concrete pavement.
• Grass can be used in block voids, but it may require irrigation and lawn care.
• Should be located far enough from foundations in expansive soils so as to limit potential damage to 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. However, this will reduce the retained volume.
Design Criteria

Principal design criteria for permeable pavement with an underdrain are summarized in Table 8-14.

Table 8-19. Permeable Pavement with an Underdrain Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQV</td>
<td>80% annual capture</td>
<td>Use Figure 6-1 at 12-hr drawdown</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>12 hr (minimum)</td>
<td></td>
</tr>
<tr>
<td>Surcharge storage volume above pavement</td>
<td>WQV</td>
<td></td>
</tr>
<tr>
<td>Surcharge zone depth</td>
<td>2 in</td>
<td>Maximum depth above pavement</td>
</tr>
<tr>
<td>Imperviousness</td>
<td>&lt;60%</td>
<td>Variable with pavement type</td>
</tr>
<tr>
<td>Permeable paver infill</td>
<td>ASTM No. 8 crushed aggregate</td>
<td></td>
</tr>
<tr>
<td>Base courses</td>
<td>1-in ASTM No. 8 over 9-in ASTM No. 57</td>
<td></td>
</tr>
</tbody>
</table>
Design Procedure

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

Step 2 – Determine Ponding Zone Storage Volume (Vpx)

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

\[ V_{px} = 1.0 \times WQV \]

Where:

WQV = water quality volume (ft\(^3\)).

Step 3 – Calculate Surface Area (As)

Calculate minimum required surface area based on ponding depth of two (2) inches above pavement as follows:

\[ A_s = \frac{WQV}{0.17} \]

Where:

WQV = water quality volume (ft\(^3\)).

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 8-6.
Step 7 – Provide Perimeter Wall

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

Step 8 – Install Sub-base

If expansive soils or rock are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base course.

Step 9 – Design Overflow Device

Provide an overflow device, possibly with an inlet to the storm drain system, set at a maximum of two (2) inches above the level of the permeable pavement surface. Make sure the two-(2) inch ponding depth is contained and does not flow out of the area at the ends or the sides. See Appendix I for more information on overflow device design.

Volume Retention Calculation

Permeable pavement may be used to achieve the volume retention requirement in addition to the treatment control requirement. Stormwater runoff is only retained if it is ponded above the surface of the permeable pavement. The volume retention for permeable pavement is less if an underdrain pipe is provided because less infiltration will occur. If the permeable pavement is constructed with an impermeable liner, no volume retention credit is given. The calculation procedure for volume retention for permeable pavement is presented in Table 8-20.

Table 8-20. Permeable Pavement with an Underdrain Volume Retention Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Volume retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume retention for permeable pavement without impermeable liner</td>
<td>( V_{ret} ) ft(^3)</td>
<td>Infiltration allowance for water in ponding zone = 0.25 WQV x 0.25</td>
</tr>
<tr>
<td>Volume retention for permeable pavement with impermeable liner</td>
<td>( V_{ret} )</td>
<td>No volume retention credit is given for permeable pavement with impermeable liner</td>
</tr>
</tbody>
</table>

Construction Considerations

- Before the entire site is graded, the area planned for permeable pavement should be cordoned off to prevent heavy equipment from compacting the underlying soil.
• Install geotextile fabric under the base course (see Table 8-8). Provide generous overlap at all seams.
• Both prior to and during construction, diversions should be installed around the perimeter of the permeable pavement as needed to prevent stormwater runoff and sediment from entering the site until the permeable pavement is in place.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as permeable pavement with an underdrain. Such agreements typically include requirements such as those outlined in Table 8-21. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-21. Inspection and Maintenance Requirements for Permeable Pavement with an Underdrain

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspect pavements to determine if stormwater runoff is infiltrating properly. If infiltration is significantly reduced, remove surface aggregate by vacuuming. Dispose of and replace old aggregate with fresh aggregate.</td>
<td>At least twice during wet season after significant storm events. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>If stabilized grassy permeable pavement is used, trim vegetation and remove weeds to limit unwanted vegetation.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from the permeable pavement area.</td>
<td>As required</td>
</tr>
</tbody>
</table>
R-10: 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 that is designed to receive and capture stormwater runoff from downspouts or piped inlets or sheet flow from adjoining impervious areas. A shallow ponding zone is provided above the vegetated surface for temporary storage of captured stormwater runoff. During storm events, stormwater runoff accumulates in the ponding 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.

Stormwater runoff treatment occurs through a variety of natural mechanisms as stormwater runoff infiltrates through the root zone of the vegetation and during detention of stormwater 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 stormwater planters are used, the stormwater runoff volume can be retained through infiltration into underlying soils. For stormwater planters underlain with expansive soils or located next to buildings where infiltration of stormwater runoff is undesirable, a flow-through stormwater planter with an impermeable bottom liner should be employed. This type of stormwater planter features an impermeable bottom liner to prevent infiltration and a perforated underdrain pipe to collect treated stormwater runoff. The underdrain gradually dewatered the sand/peat bed over the drawdown period and discharges the stormwater runoff to downstream conveyance. However, a stormwater planter with an underdrain pipe reduces the amount of water retained and may not allow the site to meet the volume retention requirement.

If infiltration of stormwater runoff is desired, no underdrain pipe should be included in the planter in order to allow the WQV to infiltrate into the underlying soil profile. The underlying soils must be rapidly permeable with a permeability greater than the sand/peat layer (typically Type A or B soil). Typical stormwater planter configurations are presented in Figure 8-9 and Figure 8-10.
Figure 8-9. Infiltration Stormwater Planter Schematic

Figure 8-10. Flow-through Stormwater Planter Schematic
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 area available for stormwater treatment.
- Reduces peak flows during small storm events.
- Enhances site aesthetics.
- Easy maintenance.

Disadvantages

- Irrigation typically required to maintain vegetation. May conflict with water conservation ordinances or landscape requirements.
- May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination. An impermeable liner may be used, but the benefit of volume retention will be eliminated.
- Not suitable for areas with steep slopes.
- Potential increased cost associated with waterproofing exterior building walls, if needed.

Planning and Site Considerations

- Select location where site topography is relatively flat and allows stormwater runoff drainage to the stormwater planter.
- Integrate stormwater planters into other landscaping areas when possible.
- Stormwater planters may have non-rectangular footprint to fit the site landscape design.
- Irrigation is typically required to maintain viability of stormwater planter vegetation. Coordinate design of general landscape irrigation system with that of a stormwater planter, as applicable.
- In expansive soils, locate stormwater planters far enough from structure foundations so as to avoid damage to structures (as determined by a structural or geotechnical engineer).

Design Criteria

Principal design criteria for stormwater planters are listed in Table 8-22.
Table 8-22. Stormwater Planter Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage area</td>
<td>≤ 1 acre</td>
<td>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.</td>
</tr>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2</td>
</tr>
<tr>
<td>Design drawdown time</td>
<td>12 hr</td>
<td>Period of time over which WQV drains from stormwater planter</td>
</tr>
<tr>
<td>Design average surcharge</td>
<td>6-12 in</td>
<td></td>
</tr>
<tr>
<td>depth (dₚ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth to groundwater</td>
<td>&gt; 10 ft</td>
<td>From planter soil surface (without underdrain)</td>
</tr>
<tr>
<td>Topsoil layer</td>
<td>6 in (minimum)</td>
<td>Sandy loam topsoil. Deeper layer recommended for better vegetation establishment. Note: planting media specified for Bioretention without an Underdrain (R-4) may be used as an alternate topsoil and sand and peat layers.</td>
</tr>
<tr>
<td>Sand-peat layer</td>
<td>18 in (minimum)</td>
<td>75% ASTM C-33 Sand + 25% peat</td>
</tr>
<tr>
<td>Gravel layer</td>
<td>9 in</td>
<td>Class 2 Aggregate per Caltrans Spec 68-1.025</td>
</tr>
</tbody>
</table>

Design Procedure

**Step 1 – Calculate WQV**

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

**Step 2 – Design Average Ponding Zone Depth (Dₚz)**

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

**Step 3 – Calculate Stormwater Planter Surface Area (Aₛ)**

The design surface area for the stormwater planter is determined from the design WQV and Dₚz as follows:

\[
A_s = \frac{WQV}{D_{pz}}
\]

Where:

\[
WQV = \text{water quality volume (ft}^3\text{)}; \text{ and}
\]

Dₚz = average ponding depth (ft).
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 Figure 8-9 and Figure 8-10. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants. (Note: The planting media mix specified in Fact Sheet R-4 may be used as an alternate to the top soil and sand/peat mix.)

Gravel envelope (for subsurface drain pipe) – Place drain pipe on a 3-foot wide, 3-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover top and sides of pipe with gravel to a minimum depth of six (6) inches. Place a strip of non-woven filter fabric on top of gravel layer that extends 18 inches on either side of the drain pipe. Do not wrap drain pipe 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 8-10).

Step 6 – Design Subsurface Drain Pipe (if required)

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

Step 7 – Select Vegetation

Select vegetation that:

- 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 Integrated Pest Management practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

Examples of appropriate vegetation for the Modesto area are presented in Appendix G.
Step 8 – Design Irrigation System

Provide irrigation system to maintain viability of vegetation, if applicable. The irrigation system must include a City-approved automatic timer.

Step 9 – Design Overflow Device

Provide an overflow device with an inlet to the storm drain system. Set the overflow inlet elevation above the WQV surcharge water level. A drop inlet or an overflow standpipe with an inverted or grated opening are appropriate overflow devices (see Figure 8-9 and Figure 8-10). See Appendix I for more information on overflow device design.

Volume Retention Calculation

Stormwater planters may be used to achieve the volume retention requirement in addition to treatment control requirements. The volume retention for a stormwater planter is less if a subsurface drain pipe is provided because less infiltration will occur. The calculation procedure for volume retention for stormwater planters is presented in Table 8-23.

Construction Considerations

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the stormwater planter to prevent high sediment loads from entering the stormwater planter during ongoing construction activities.
- Avoid compaction of native soils below planting media layer or gravel zone for infiltration stormwater planter.
- Repair, seed, or re-plant damaged areas immediately.
- For stormwater planters next to buildings, provide water-proofing of exterior building walls as directed by an architect or structural engineer.
Table 8-23. Stormwater Planter Volume Retention Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stormwater Planter without Subsurface Drain Pipe</td>
<td></td>
<td>Recommended for Type A or B soil</td>
</tr>
<tr>
<td>1. Ponding zone</td>
<td></td>
<td>Infiltration allowance for water in ponding zone water = 1.0</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pz} = \quad ) ft</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pz} = \quad ) ft²</td>
<td></td>
</tr>
<tr>
<td>2. Planting media layer</td>
<td></td>
<td>Available water holding capacity of planting media layer = 0.1 x volume</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pm} = \quad ) ft</td>
<td>18 in (minimum)</td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pm} = \quad ) ft²</td>
<td></td>
</tr>
<tr>
<td>3. Volume retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume retention for stormwater planter</td>
<td>( V_{ret} = \quad ) ft³</td>
<td>( (D_{pz} \times A_{pz}) + (D_{pm} \times A_{pm} \times 0.10) )</td>
</tr>
<tr>
<td>Stormwater Planter with Subsurface Drain Pipe</td>
<td></td>
<td>Required for Type C or D soil and impermeable liners</td>
</tr>
<tr>
<td>1. Ponding zone</td>
<td></td>
<td>Infiltration allowance for water in ponding zone water = 0.25</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pz} = \quad ) ft</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pz} = \quad ) ft²</td>
<td></td>
</tr>
<tr>
<td>2. Planting media layer</td>
<td></td>
<td>Available water holding capacity of planting media layer = 0.1 x volume</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pm} = \quad ) ft</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pm} = \quad ) ft²</td>
<td></td>
</tr>
<tr>
<td>3. Gravel zone</td>
<td></td>
<td>Porosity of gravel zone = 0.30</td>
</tr>
<tr>
<td>Depth below pipe</td>
<td>( D_{gz} = \quad ) ft</td>
<td>Depth below pipe = 6 in (minimum)</td>
</tr>
<tr>
<td>Area below pipe</td>
<td>( A_{gz} = \quad ) ft²</td>
<td>Width of gravel = 3 ft (minimum)</td>
</tr>
<tr>
<td>4. Volume retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume retention for stormwater planter</td>
<td>( V_{ret} = \quad ) ft³</td>
<td>( (D_{pz} \times A_{pz} \times 0.25) + (D_{pm} \times A_{pm} \times 0.10) + (D_{gz} \times A_{gz} \times 0.30) )</td>
</tr>
<tr>
<td>without impermeable liner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume retention for stormwater planter</td>
<td>( V_{ret} = \quad ) ft³</td>
<td>Volume retention credit is only given for retention in the planting media layer:</td>
</tr>
<tr>
<td>with impermeable liner</td>
<td></td>
<td>( D_{pm} \times A_{pm} \times 0.1 )</td>
</tr>
</tbody>
</table>
Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as stormwater planters. Such agreements typically include requirements such as those outlined in Table 8-24. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-24. Inspection and Maintenance Requirements for Stormwater Planters

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from landscape area.</td>
<td>As required</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect stormwater planter to determine if stormwater runoff is infiltrating properly.</td>
<td>At least twice per year during storm events. Additional inspections after periods of heavy stormwater runoff are desirable</td>
</tr>
<tr>
<td>If infiltration is significantly reduced, remove and replace topsoil and sand/peat layer.</td>
<td>May be required every five (5) to ten (10) years or more frequently depending on sediment loads</td>
</tr>
</tbody>
</table>
R-11: Tree-Well Filter

Description

A tree-well filter is similar to bioretention and stormwater planters 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 a street tree might normally be planted, and is designed to receive, retain, and infiltrate stormwater runoff from adjoining paved areas. During storm events, stormwater 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.

Stormwater runoff treatment occurs through a variety of natural mechanisms as the stormwater runoff filters through the root zone of the vegetation and during detention of the stormwater runoff in the pore space of the engineered soil matrix. A portion of stormwater runoff held in the root zone of the soil media is returned to the atmosphere through transpiration by the vegetation.

Source: Low Impact Development Center (top) and University of New Hampshire Stormwater Center (bottom)
A tree-well filter may be installed in open or closed bottom chambers. If underlying soils have a permeability greater than the engineered soil layers (typically Type A or B soil), the tree-well filter can be constructed with an open bottom with an underdrain pipe. If less permeable underlying soils (Type C or D soil) are present, an underdrain pipe is required. If infiltration must be avoided due to site constraints, an impermeable liner or concrete bottom may be included 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.
- May be used in variety of site conditions.
- Reduces stormwater runoff volume and pollutant discharge.

Disadvantages

- May require individual owners/tenants to perform maintenance.
- Irrigation typically required to maintain vegetation. May conflict with water conservation ordinances for landscape requirements.
- May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination. An impermeable liner may be used, but the benefit of volume retention will be eliminated.

Planning and Site Considerations

- Select location where site topography is relatively flat and allows stormwater runoff drainage to the tree-well filter.
- Integrate tree-well filter into other landscape areas when possible.
- Tree-well filters may have a non-rectangular footprint to fit site landscape design.
- Irrigation is typically required to maintain viability of tree-well filters. Coordinate design of general landscape irrigation system with that of tree well-filters, as applicable.
- If necessary, connect underdrain into storm drain system.

Design Criteria

Principal design criteria for tree-well filters are listed in Table 8-25. A design data summary sheet is provided at the end of this fact sheet.
Table 8-25. Tree-well Filter Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage area</td>
<td>≤ 1 acre</td>
<td>Ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features</td>
</tr>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2</td>
</tr>
<tr>
<td>Design drawdown time</td>
<td>12 hr</td>
<td>Period of time over which WQV drains from tree-well filter</td>
</tr>
<tr>
<td>Design average ponding depth</td>
<td>6-12 in</td>
<td></td>
</tr>
<tr>
<td>(d_s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth to groundwater</td>
<td>&gt; 10 ft</td>
<td>From tree-well filter soil surface (without underdrain)</td>
</tr>
<tr>
<td>Topsoil layer</td>
<td>6 in (minimum)</td>
<td>Sandy loam topsoil. Deeper layer recommended for better vegetation establishment</td>
</tr>
<tr>
<td>Sand-peat layer</td>
<td>18 in (minimum)</td>
<td>75% ASTM C-33 Sand + 25% peat (Note: planting media specified for Bioretention without an Underdrain (R-4) may be used as an alternate for topsoil and sand and peat layers</td>
</tr>
<tr>
<td>Gravel layer</td>
<td>9 in</td>
<td>Class 2 Aggregate per Caltrans Spec 68-1.025</td>
</tr>
</tbody>
</table>

Design Procedure

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

Step 2 – Design Average Ponding Depth (d_s)

Select average WQV depth between six (6) and twelve (12) inches. Average depth is defined as water volume divided by the water surface area of the tree-well filter.

Step 3 – Calculate Tree-Well Filter Surface Area (A_s)

The design surface area of the tree-well filter is determined from the design WQV and d_s as follows:

\[ A_s = \frac{WQV}{d_s} \]

Where:

WQV = water quality volume (ft³); and
d_s = average ponding depth (ft).
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 Figure 8-11. Thoroughly mix 75% sand (ASTM C-33) with 25% peat for filtration and adsorption of contaminants. (Note: The planting media mix specified in Fact Sheet R-4 may be used as an alternate to the top soil and sand/peat mix.)

Gravel envelope (for subsurface drain pipe) – Place drain pipe on a 3-foot wide, 3-inch deep bed of gravel (Class 2 Permeable Material per Caltrans Spec 68-1.025). Cover top and sides of pipe with gravel to a minimum depth of six (6) inches. Place a strip of non-woven filter fabric on top of gravel layer that extends 18 inches on either side of the drain pipe. Do not wrap drain pipe 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 tree-well filter with an impermeable liner.

Step 6 – Design Subsurface Drain Pipe (if required)

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

Step 7 – Select Tree

Select tree that:

- 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 Integrated Pest Management practices;
- Will withstand being inundated for periods of time; and
- Is consistent with local water conservation ordinance requirements.

A list of recommended trees is presented in Appendix H.
Step 8 – Design Irrigation System

Provide irrigation system to maintain viability of vegetation, if applicable. The irrigation system must include a City-approved automatic timer.

Step 9 – Design Overflow Device

Provide an overflow device with an inlet to the storm drain system. Set the overflow inlet elevation above the WQV ponding water level. A drop inlet or an overflow standpipe with an inverted or grated opening are appropriate overflow devices (Figure 8-11). See Appendix I for more information on overflow device design.

Figure 8-11. Tree-well Filter Schematic
Volume Retention Calculation

Tree-well filters may be used to achieve the volume retention requirements in addition to treatment control measure requirements. The volume retention for a tree-well filter is less if an impermeable bottom is used because less infiltration will occur. The calculation procedure for volume retention for tree-well filters is presented in Table 8-26.

Construction Considerations

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the tree-well filter to prevent high sediment loads from entering the planter during ongoing construction activities.
- Avoid compaction of native soils below planting media layer or gravel zone.
- Repair, seed, and re-plant damaged areas immediately.
Table 8-26. Tree-well Filter Volume Retention Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree-well Filter without Subsurface Drain Pipe</td>
<td>Recommended for Type A or B soil</td>
<td>Infiltration allowance for water in ponding zone water = 1.0</td>
</tr>
<tr>
<td>1. Ponding zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pz} = )</td>
<td>( ft )</td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pz} = )</td>
<td>( ft^2 )</td>
</tr>
<tr>
<td>2. Planting media layer</td>
<td></td>
<td>Available water holding capacity of planting media layer = 0.1 x volume</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pm} = )</td>
<td>( ft ) 18 in (minimum)</td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pm} = )</td>
<td>( ft^2 )</td>
</tr>
<tr>
<td>3. Volume retention</td>
<td></td>
<td>( V_{ret} = ) ( ft^3 ) (( D_{pz} \times A_{pz} ) + (( D_{pm} \times A_{pm} \times 0.10) ))</td>
</tr>
<tr>
<td>Tree-well Filter with Subsurface Drain Pipe</td>
<td>Required for Type C or D soil and impermeable liners</td>
<td>Infiltration allowance for water in ponding zone water = 0.25</td>
</tr>
<tr>
<td>1. Ponding zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pz} = )</td>
<td>( ft )</td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pz} = )</td>
<td>( ft^2 )</td>
</tr>
<tr>
<td>2. Planting media layer</td>
<td></td>
<td>Available water holding capacity of planting media layer = 0.1 x volume</td>
</tr>
<tr>
<td>Depth</td>
<td>( D_{pm} = )</td>
<td>( ft )</td>
</tr>
<tr>
<td>Area</td>
<td>( A_{pm} = )</td>
<td>( ft^2 )</td>
</tr>
<tr>
<td>3. Gravel zone</td>
<td></td>
<td>Porosity of gravel zone = 0.30</td>
</tr>
<tr>
<td>Depth below pipe</td>
<td>( D_{gz} = )</td>
<td>( ft ) Depth below pipe = 6 in (minimum)</td>
</tr>
<tr>
<td>Area below pipe</td>
<td>( A_{gz} = )</td>
<td>( ft^2 ) Width of gravel = 3 ft (minimum)</td>
</tr>
<tr>
<td>4. Volume retention</td>
<td></td>
<td>( V_{ret} = ) ( ft^3 ) (( D_{pz} \times A_{pz} \times 0.25 ) + (( D_{pm} \times A_{pm} \times 0.10 )) + (( D_{gz} \times A_{gz} \times 0.30 )) )</td>
</tr>
<tr>
<td>Volume retention for tree-well filter without</td>
<td></td>
<td>Volume retention credit is only given for retention in the planting media layer:</td>
</tr>
<tr>
<td>impermeable liner</td>
<td>( V_{ret} = )</td>
<td>( ft^3 ) ( D_{pm} \times A_{pm} \times 0.1 )</td>
</tr>
<tr>
<td>Volume retention for tree-well filter with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>impermeable liner</td>
<td>( V_{ret} = )</td>
<td></td>
</tr>
</tbody>
</table>
Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as tree-well filters. Such agreements typically include requirements such as those outlined in Table 8-27. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-27. Inspection and Maintenance Requirements for Tree-well Filters

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from landscape area.</td>
<td>As required</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect tree-well filter to determine if stormwater runoff is infiltrating properly.</td>
<td>At least twice per year during storm events. Additional inspections after periods of heavy stormwater runoff are desirable</td>
</tr>
<tr>
<td>If infiltration is significantly reduced, remove and replace topsoil and sand/peat layer.</td>
<td>May be required every five (5) to ten (10) years or more frequently depending on sediment loads</td>
</tr>
</tbody>
</table>
R-12: Vegetated Swales

Description

Vegetated swales are long, narrow, landscaped depressions used to collect and convey stormwater runoff. Pollutants are removed via settling and filtration as water flows over the swale surface or infiltrates into the ground. Check dams are provided every 12-20 feet to slow flow and pool water to enhance treatment and infiltration. Vegetated swales reduce stormwater runoff volume by infiltration. 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 Figure 8-12 and Figure 8-13 for typical vegetated swale configurations.

Advantages

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

Limitations

- Irrigation typically required to maintain vegetation. May conflict with water conservation ordinances for landscape requirements.
- May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
- Not suitable for areas with steep slopes.
Figure 8-12. Vegetated Swale without an Underdrain Schematic

Source: Adapted from City of Portland
Planning and Site Considerations

- Can receive stormwater runoff from parking lots, rooftops, and streets.
- Integrate vegetated swales into overall site design.
- Connection to the storm drain system or another treatment control measure must be provided at the end of the vegetated swale, and possibly at points along the swale to allow discharge of high flows and stormwater runoff that do not infiltrate.
- Slopes and depths should be kept as mild as possible to avoid safety risks, and prevent erosion within the vegetated swale.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the vegetated swale, and cars are allowed to overhang the vegetated swale.
- Irrigation is typically required to maintain viability of the vegetated swale vegetation. Coordinate design of general landscape irrigation system with that of vegetated swale, as applicable.
- When vegetated street swales are used, all applicable requirements for other street elements (e.g., curbs, sidewalks, trees) must be met.
### Design Criteria

Principal design criteria for vegetated swales are listed in Table 8-28.

#### Table 8-28. Vegetated Swale and Vegetated Street Swale Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>12 hr (maximum)</td>
<td></td>
</tr>
<tr>
<td>Side slopes (H:V)</td>
<td>3:1 (maximum)</td>
<td></td>
</tr>
<tr>
<td>Flat bottom width</td>
<td>2 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 ft (minimum)</td>
<td>Street swale</td>
</tr>
<tr>
<td>Top width</td>
<td>5 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 ft (minimum)</td>
<td>Street swale</td>
</tr>
<tr>
<td>Longitudinal slope</td>
<td>6% (minimum)</td>
<td></td>
</tr>
<tr>
<td>Setbacks</td>
<td>5 ft</td>
<td>From centerline of swale to property lines</td>
</tr>
<tr>
<td></td>
<td>10 ft</td>
<td>From building foundations (unless lined with impermeable fabric or approved by City)</td>
</tr>
<tr>
<td>Check dams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Length</td>
<td>12 in</td>
<td></td>
</tr>
<tr>
<td>- Width</td>
<td>Width of swale</td>
<td></td>
</tr>
<tr>
<td>- Height</td>
<td>3-6 in</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12 ft</td>
<td>Street swale</td>
</tr>
<tr>
<td>- Spacing interval</td>
<td>12-20 ft</td>
<td></td>
</tr>
<tr>
<td>Water storage depth above bottom</td>
<td>6-12 in</td>
<td></td>
</tr>
<tr>
<td>Distance from tire stops or curb cut</td>
<td>6 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Curb cut clean flow area</td>
<td>12 in x 12 in</td>
<td></td>
</tr>
<tr>
<td>Topsoil layer</td>
<td>12 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Permeable filter fabric</td>
<td>--</td>
<td>Optional for vegetated swale below topsoil layer. Required for street swale below topsoil and gravel layer.</td>
</tr>
<tr>
<td>Overflow device</td>
<td>--</td>
<td>Required</td>
</tr>
<tr>
<td>Underdrain layer</td>
<td></td>
<td>Required for Type C and D soils and street swales</td>
</tr>
<tr>
<td>- Bottom slope (H:V)</td>
<td>10:1 (minimum)</td>
<td>Slope to drain away from street</td>
</tr>
<tr>
<td>- Gravel layer depth</td>
<td>12 in</td>
<td>Use 3/4-in diameter drain rock</td>
</tr>
<tr>
<td>Design Parameter</td>
<td>Design Criteria</td>
<td>Notes</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-----------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>- Permeable filter fabric</td>
<td>--</td>
<td>Use under gravel layer</td>
</tr>
<tr>
<td>- Impermeable fabric</td>
<td>--</td>
<td>Use along street edge side of swale</td>
</tr>
<tr>
<td>- Perforated PVC pipe diameter</td>
<td>6 in</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>No./100 ft²</td>
<td>Trees, shrubs, grasses, and groundcover. Quantity based on surface area of swale facility. See Design Procedure for minimum quantities.</td>
</tr>
</tbody>
</table>

**Design Procedure**

**Step 1 – Calculate WQV**

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

**Step 2 – Determine Swale Geometry**

Based on the design criteria in Table 8-28 and site conditions, determine appropriate values for the following vegetated swale geometry design elements:

- Bottom width;
- Side slope;
- Ponding zone storage depth ($D_{pz}$);
- Top width; and
- Longitudinal slope.

**Step 3 – Determine Cross-Sectional Area of Swale Storage ($A_{storage}$)**

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

Where:

- $D_{pz}$ = ponding zone storage depth (ft);
- $W_{bottom}$ = bottom width of vegetated swale (ft); and
- $W_{top}$ = top width of vegetated swale (ft).

**Step 4 – Determine Swale Length ($L_{swale}$)**

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

Where:

- $WQV$ = water quality volume (ft³); and
- $A_{storage}$ = cross-sectional area of vegetated swale storage.
Step 5 – Design Inlet Controls

For flow introduced along the length of the vegetated swale through curb cuts, provide minimum curb cut widths of twelve (12) inches. For swales that receive concentrated stormwater 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 vegetated swale. See Figure 8-15 for schematic of a pea gravel flow spreader.

Step 6 – Select Vegetation

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:

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Number</th>
<th>Containers</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large shrubs or small trees</td>
<td>4</td>
<td>3-gallon containers</td>
<td>Or equivalent</td>
</tr>
<tr>
<td>Shrubs or large grass-like plants</td>
<td>6</td>
<td>1-gallon containers</td>
<td>Or equivalent</td>
</tr>
<tr>
<td>Groundcover plants</td>
<td>1 per ft</td>
<td>4-in pot (minimum)</td>
<td>On center, triangular spacing, for the groundcover planting area only, unless seed or sod is specified</td>
</tr>
</tbody>
</table>

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 viability of vegetated swale landscaping. The irrigation system must include a City-approved automatic timer.

Volume Retention Calculation

The vegetated swale may be used to achieve the volume retention requirement in addition to treatment control requirements. The volume retention for a vegetated swale area is less if a subsurface drain pipe is provided because less infiltration will occur. The calculation procedure for volume retention for vegetated swales is presented in Table 8-29.
Table 8-29. Vegetated Swale Volume Retention Calculation

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetated Swale without Subsurface Drain Pipe</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Ponding zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>(D_{pz} = ) _______ ft</td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>(A_{pz} = ) _______ ft(^2)</td>
<td>Infiltration allowance for water in ponding zone water = 1.0</td>
</tr>
<tr>
<td>2. Planting media layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>(D_{pm} = ) _______ ft</td>
<td>Available water holding capacity of planting media layer = 0.1 x volume</td>
</tr>
<tr>
<td>Area</td>
<td>(A_{pm} = ) _______ ft(^2)</td>
<td>18 in (minimum)</td>
</tr>
<tr>
<td>3. Volume retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume retention for vegetated swale</td>
<td>(V_{ref} = ) _______ ft(^3)</td>
<td>((D_{pz} \times A_{pz}) + (D_{pm} \times A_{pm} \times 0.10))</td>
</tr>
<tr>
<td><strong>Vegetated Swale with Subsurface Drain Pipe</strong></td>
<td></td>
<td>Required for Type C or D soil and street swales</td>
</tr>
<tr>
<td>1. Ponding zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>(D_{pz} = ) _______ ft</td>
<td>Infiltration allowance for water in ponding zone water = 0.25</td>
</tr>
<tr>
<td>Area</td>
<td>(A_{pz} = ) _______ ft(^2)</td>
<td></td>
</tr>
<tr>
<td>2. Planting media layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>(D_{pm} = ) _______ ft</td>
<td>Available water holding capacity of planting media layer = 0.1 x volume</td>
</tr>
<tr>
<td>Area</td>
<td>(A_{pm} = ) _______ ft(^2)</td>
<td></td>
</tr>
<tr>
<td>3. Gravel zone</td>
<td></td>
<td>Porosity of gravel zone = 0.30</td>
</tr>
<tr>
<td>Depth below pipe</td>
<td>(D_{gz} = ) _______ ft</td>
<td>Depth below pipe = 6 in (minimum)</td>
</tr>
<tr>
<td>Area below pipe</td>
<td>(A_{gz} = ) _______ ft(^2)</td>
<td>Width of gravel = 3 ft (minimum)</td>
</tr>
<tr>
<td>4. Volume retention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume retention for vegetated swale</td>
<td>(V_{ref} = ) _______ ft(^3)</td>
<td>((D_{pz} \times A_{pz} \times 0.25) + (D_{pm} \times A_{pm} \times 0.10) + (D_{gz} \times A_{gz} \times 0.30))</td>
</tr>
</tbody>
</table>

**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 that specifically used to construct the vegetated swale, should be allowed within ten (10) feet of the swale areas.
• Divert stormwater runoff (other than necessary irrigation) during the period of vegetation establishment. Where stormwater runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials such as silt fences.
• Install sediment controls, such as silt fences, around the swale area to prevent high sediment loads from entering the swale area during ongoing construction activities.
• Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as vegetated swales. Such agreements typically include requirements such as those outlined in Table 8-30. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-30. Inspection and Maintenance for Vegetated Swales

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove litter and debris from landscape area.</td>
<td>As required</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect vegetated swales to determine if stormwater runoff is infiltrating properly.</td>
<td>At least twice per year during storm events. Additional inspections after periods of heavy stormwater runoff are desirable</td>
</tr>
<tr>
<td>If infiltration is significantly reduced, remove and replace topsoil.</td>
<td>May be required every five (5) to ten (10) years or more frequently depending on sediment loads</td>
</tr>
</tbody>
</table>
R-13: Grassy Swale

Description

A grassy swale is a shallow, open channel planted with dense, sod-forming vegetation and designed to accept stormwater runoff from adjacent surfaces. As stormwater runoff slows and travels through the vegetation and over the soil surface, pollutants are removed by a variety of physical, chemical, and biological 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 swale vegetation and to provide sufficient contact time to promote settling and filtration of stormwater runoff flowing through it. Greater surface area and contact time promote greater stormwater runoff treatment efficiencies. The stormwater runoff volume can also be reduced through infiltration into underlying soils. A typical grassy swale configuration, which is presented in Figure 8-15, may not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat of groundwater contamination. An impermeable liner may be used, but the benefit of volume retention will be eliminated.

Other names

Vegetated swale, bioswale

Advantages

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

Disadvantages

- May conflict with local water conservation ordinances for landscape irrigation requirements.
- May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination. An impermeable liner may be used, but the benefit of volume retention will be eliminated.

Figure 8-14. Grassy Swale Schematic
Planning and Site Considerations

- Select location where site topography allows for design of a grassy swale with sufficiently mild slopes (unless small drop structures are used) and enough surface area to maintain non-erosive velocities in the channel.
- Integrate swales into open space buffers and other landscape areas when possible.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the grassy swale, and cars are allowed to overhang the grassy swale.
- The required swale length to meet treatment control 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 stormwater runoff coefficient for the site.
- Impermeable liners may be required in areas where grassy swales may be impacted by hazardous materials or where spills may occur (e.g., retail gasoline outlets, automobile maintenance businesses, processing/manufacturing areas).
- Surface flow into the grassy swale is preferred over underground conveyance.
- Irrigation is typically required to maintain viability of the swale vegetation. Coordinate design of general landscape irrigation system with that of grassy swale, as applicable.
- The potential for mosquitoes due to standing water will be greatly reduced or eliminated if the grassy swale is properly designed, constructed, and operated.

Design Criteria

Principal design criteria for grassy swales are presented in Table 8-31.
Table 8-31. Grassy Swale Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary drainage area</td>
<td>≤ 10 acres</td>
<td>For larger areas, break up into drainage areas of ten (10) acres or less, with a grassy swale for each drainage area</td>
</tr>
<tr>
<td>Design flow</td>
<td>WQF</td>
<td>See Fact Sheet C-2</td>
</tr>
<tr>
<td>Roughness coefficient (n) for treatment</td>
<td>0.2</td>
<td>Reflects roughness associated with shallow flow through dense vegetation</td>
</tr>
<tr>
<td>Roughness coefficient (n) for conveyance</td>
<td>0.1</td>
<td>Reflects roughness of swale when flow depth is above the height of the grass. Used to determine capacity of swale to convey peak hydraulic flows</td>
</tr>
<tr>
<td>Contact time for WQF treatment</td>
<td>7 min (minimum)</td>
<td>Provide sufficient length to yield minimum contact time for WQV</td>
</tr>
<tr>
<td>Bottom width</td>
<td>0.5-10 ft</td>
<td>Grassy swales wider than ten (10) feet can be divided by internal berms to conform to maximum width criteria</td>
</tr>
<tr>
<td>Side slopes</td>
<td>3:1 (maximum)</td>
<td>Side slopes allow for ease of mowing. Steeper slopes may be allowed with adequate slope stabilization</td>
</tr>
<tr>
<td>Longitudinal slope</td>
<td>1-4%</td>
<td>For longitudinal slope &gt; 4% and as a means of promoting more infiltration. Space dams as required to maintain maximum longitudinal bottom slope ≤ 4%</td>
</tr>
<tr>
<td>Check dams</td>
<td>As required</td>
<td>For longitudinal slope &lt; 1%</td>
</tr>
<tr>
<td>Underdrains</td>
<td>As required</td>
<td>For longitudinal slope &lt; 1%</td>
</tr>
<tr>
<td>Depth of flow at WQF</td>
<td>3-5 in (maximum)</td>
<td>1 inch below top of vegetation</td>
</tr>
<tr>
<td>Flow velocity (treatment)</td>
<td>1 ft/s (maximum)</td>
<td>Based on Manning’s n = 0.20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Concentrated inlet flow must be spread</td>
</tr>
<tr>
<td>Inlet design</td>
<td>≥ 12 in wide</td>
<td>To prevent clogging and promote flow spreading. Pavement should be slightly higher than swale. Include energy dissipaters.</td>
</tr>
</tbody>
</table>

**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 water quality flow (WQF) and as a conveyance system to pass the peak hydraulic design flows, if the swale is located “on-line”.

**Step 2 – Calculate WQF**

Use Fact Sheet C-2 to calculate the effective tributary drainage area and WQF.
**Step 3 – Provide for Peak Hydraulic Design Flow**

Calculate flows greater than the WQF to be diverted around or flow through the grassy swale. Design the diversion structure, if necessary.

**Step 4 – Design the Grassy Swale Using Manning’s Equation**

Grassy swales can be trapezoidal (as illustrated in Figure 8-14) or parabolic in shape. While trapezoidal channels are the most efficient channel design for conveying flows, parabolic configurations provide good water quality treatment and may be easier to mow since they do not have sharp breaks in slope.

Use a roughness coefficient (n) of 0.20 with Manning’s Equation to design the treatment area of the grassy swale to account for 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.

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

Where:

- WQF = water quality flow;
- \(A\) = cross-sectional area of flow;
- \(P\) = wetted perimeter of flow;
- \(s\) = bottom slope in flow direction; and
- \(n\) = 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 three (3) to five (5) inches at the design WQF and the swale geometry (i.e., side slope and \(s\) value) for the site under design. The minimum design bottom width is six (6) inches.

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

$$L = t_c \times \text{Flow velocity} \times 60$$

Where:

- \(L\) = swale length (feet); and
- \(t_c\) = contact time (minutes, 7 min minimum).

**Step 5 – Design Inlet Controls**

For swales that receive direct concentrated stormwater 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 8-15 for schematic of a 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 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.

**Step 7 – Design Irrigation System**

Provide an irrigation system to maintain viability of grassy swale vegetation. The irrigation system must include a City-approved automatic timer.

**Volume Retention Calculation**

A grassy swale may be used to achieve the volume retention requirements in addition to treatment control requirements. The calculation procedure for volume retention for grassy swales is presented in Table 8-32.

**Table 8-32. Grassy Swale Volume Retention Calculation**

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. WQV for contributing area</td>
<td>WQV</td>
<td>ft³</td>
</tr>
<tr>
<td>2. Volume retention factor</td>
<td>V_{rf}</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Volume retention for grassy swale</td>
<td>V_{ret}</td>
<td>ft³</td>
</tr>
</tbody>
</table>

**Construction Considerations**

- Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
- Install sediment controls, such as silt fences, around the grassy swale to prevent high sediment loads from entering the swale during ongoing upstream construction activities.
- Repair, seed, and re-plant damaged areas immediately.
- Apply erosion control measures as needed to stabilize side slopes and inlet areas.

**Long-Term Maintenance**

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as grassy swales. Such agreements typically include requirements such as those outlined in Table 8-33. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

**Table 8-33. Inspection and Maintenance Requirements for Grassy Swales**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mow grass to maintain height of 4-6 inches or above flow depth at WQF.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove grass clippings.</td>
<td>As required</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove trash and debris from grassy swale.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect grassy swale for signs of erosion, vegetation damage/coverage,</td>
<td>At least twice annually. Schedule one inspection at the end of wet season so that summer maintenance can be scheduled to prepare grassy swale for wet season. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>channelization problems, debris build-up, and excess sedimentation in</td>
<td></td>
</tr>
<tr>
<td>bottom of channel. Correct problems or remove debris and sediment as</td>
<td></td>
</tr>
<tr>
<td>as soon as possible.</td>
<td></td>
</tr>
<tr>
<td>Remove sediment in inlet areas, the channel, culverts, and outlets</td>
<td>As required</td>
</tr>
<tr>
<td>whenever flow into the grassy swale is retarded or blocked.</td>
<td></td>
</tr>
<tr>
<td>Repair ruts or holes in the channel by removing vegetation, adding and</td>
<td>As required</td>
</tr>
<tr>
<td>tamping suitable soil, and reseeding. Replace damaged vegetation.</td>
<td></td>
</tr>
<tr>
<td>Inspect grassy swale for obstructions (e.g., debris accumulation,</td>
<td>At least twice during wet season after significant storm events. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>invasive vegetation) and pools of standing water that can provide</td>
<td></td>
</tr>
<tr>
<td>mosquito-breeding habitat. Correct observed problems as soon as possible.</td>
<td></td>
</tr>
</tbody>
</table>
Description
A vegetated filter strip is a gently sloped soil surface planted with dense, sod-forming vegetation and designed to receive and treat sheet flow from adjacent surfaces. As the stormwater 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 stormwater runoff treatment effectiveness. Stormwater runoff volume can be retained in the underlying soils. A typical vegetated filter strip configuration is presented in Figure 8-15.

Other names
Biofilter

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

Disadvantages
- Possible conflicts with local water conservation irrigation ordinances for landscape irrigation requirements.
- May not be appropriate for industrial sites or locations with contaminated soils or where spills may occur because of the potential threat to groundwater contamination.
Figure 8-15. Vegetated Filter Strip Schematic

**SHEET FLOW CONTROL**

NOT TO SCALE

**CONCENTRATED FLOW CONTROL**

NOT TO SCALE

---

Planning and Site Considerations

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

Design Criteria

Principal design criteria for vegetated filter strips are presented in Table 8-34.

Table 8-34. Vegetated Filter Strip Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary drainage area</td>
<td>≤ 5 acres</td>
<td>For larger areas, break up into sub-watersheds of five (5) acres or less, with a vegetated filter strip for each sub-watershed</td>
</tr>
<tr>
<td>Design flow</td>
<td>WQF</td>
<td>See Fact Sheet C-2.</td>
</tr>
<tr>
<td>Linear application rate (qa)</td>
<td>0.005 ft³/s/ft width (maximum)</td>
<td>Rate at which stormwater runoff is applied across the top width of vegetated filter strip. This rate, combined with the WQF, will define the design width of the vegetated filter strip.</td>
</tr>
<tr>
<td>Slope in flow direction</td>
<td>1-4%</td>
<td>Gentler slopes are prone to ponding of water on surface, while steeper slopes are prone to channeling. Terracing may be used for slopes greater than 4%.</td>
</tr>
<tr>
<td>Length in flow direction</td>
<td>20 ft (minimum)</td>
<td>Most treatment occurs in the first 20 feet of flow. Longer lengths will typically provide somewhat higher levels of treatment.</td>
</tr>
<tr>
<td>Typical vegetation height</td>
<td>2-4 in</td>
<td>Vegetation should be maintained at a height greater than the flow depth at WQF but sufficiently low to prevent lodging or shading of vegetation.</td>
</tr>
</tbody>
</table>
Design Procedure

Step 1 – Calculate WQF

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQF.

Step 2 – Calculate Minimum Width of Vegetated Filter Strip (W_{GFS})

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

\[ W_{GFS} = \frac{WQF}{q_a} \]

\[ W_{GFS} = \frac{WQF}{0.005 \, cf/s/ft} \text{ (minimum)} \]

Where:

- WQF = water quality flow (ft^3/s); and
- q_a = linear application rate (ft^3/s/ft).

Step 3 – Determine Minimum Length of Vegetated Filter Strip in Flow Direction

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

Step 4 – Determine Design Slope

The vegetated filter strip slope 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 vegetated filter strip to evenly distribute flow along the top width. Concentrated flow delivered to the vegetated filter strip must be distributed evenly by means of a pea gravel flow spreader as shown in Figure 8-15.

Step 6 – Select Vegetation

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

Select vegetation that:
• 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.

See Appendix G for recommended vegetation for vegetated 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 viability of the vegetated filter strip. The irrigation system must include a City-approved automatic timer.

**Volume Retention Calculation**

Vegetated filter strips may be used to achieve the volume retention requirement in addition to the treatment control requirement. The calculation procedure for volume retention for vegetated filter strips is presented in Table 8-35.

<table>
<thead>
<tr>
<th>Table 8-35. Vegetated Filter Strip Volume Retention Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design Parameter</strong></td>
</tr>
<tr>
<td>1. WQV for contributing area</td>
</tr>
<tr>
<td>2. Volume retention factor for vegetated filter strip</td>
</tr>
<tr>
<td>3. Volume retention for vegetated filter strip</td>
</tr>
</tbody>
</table>

**Construction Considerations**

• Divert stormwater runoff during period of vegetation establishment. Where stormwater runoff diversion is not feasible, cover graded and seeded areas with suitable temporary erosion control materials, such as silt fences.
• Install sediment control, such as silt fences, around the vegetated filter strip to prevent high sediment loads from entering the vegetated filter strip during ongoing upstream construction activities.
• Repair, seed, and re-plant damaged areas immediately.
Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as vegetated filter strips. Such agreements typically include requirements such as those outlined in Table 8-36. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-36. Inspection and Maintenance Requirements for Vegetated Filter Strips

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mow grass to maintain height of 2-4 inches (typical).</td>
<td>As required</td>
</tr>
<tr>
<td>Remove grass clippings.</td>
<td>As required</td>
</tr>
<tr>
<td>Use Integrated Pest Management practices.</td>
<td>As required</td>
</tr>
<tr>
<td>Remove trash and debris from vegetated filter strip.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect vegetated filter strip for signs of erosion, vegetation damage/coverage, channelization problems, debris build-up, and excess sedimentation on surface of vegetated filter strip. Correct problems or remove debris and sediment as soon as possible.</td>
<td>At least twice annually. Schedule one inspection at the end of wet season so that summer maintenance can be scheduled to prepare vegetated filter strip for wet season. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the vegetated filter strip is retarded or blocked.</td>
<td>As required</td>
</tr>
<tr>
<td>Repair ruts or holes in the vegetated filter strip by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect vegetated 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.</td>
<td>At least twice during wet season after significant storm events. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
</tbody>
</table>
C-1: Media Filter

Description

A media filter is a two-stage constructed treatment system including a pretreatment settling basin and a filter bed containing sand or other absorptive filtering media. The filter bed is supported by a gravel base course with an underdrain system. As stormwater runoff flows into the system, large particles settle out in the first basin and finer particles and other pollutants are removed in the filtration bed. Three variations of public domain media filters are presented in this fact sheet – the above-ground Austin Sand Filter, the DC Underground Sand Filter, and the linear or perimeter (Delaware) Sand Filter.

A typical configuration for an Austin sand filter is presented in Figure 8-16. Principal components of the unit include a sedimentation basin and a filter bed. The sedimentation basin is designed to hold the entire WQV and to release that volume to the filter bed over the design drawdown time of 48 hours. Large sediment is removed through settling in the sedimentation basin. Fine particles and other pollutants are removed in the filtration basin as stormwater runoff passes through the filter media. Stormwater runoff volumes in excess of the WQV are bypassed around the unit.

A typical District of Columbia (DC) Underground Sand Filter, which was developed by the DC Environmental Regulation Administration, is presented in Figure 8-17. The DC Underground Sand Filter contains in a structural shell with three chambers. The shell may consist of precast or cast-in-place concrete. The plunge pool in the first chamber and the throat of the chamber, which are hydraulically connected by an underwater rectangular opening, absorbs energy and provides pretreatment, trapping grit and floating organic material such as oil, grease, and tree leaves. The second chamber contains a typical sand filter with a subsurface drainage system consisting of a perforated PVC pipe in a stone bed. The third chamber, or clearwell, collects the flow from the underdrain pipes, and overflow pipes when installed, and directs treated stormwater runoff to the storm drain system.

A typical Delaware sand filter is presented in Figure 8-18. The system consists of two parallel concrete trenches, sedimentation and filter, divided by a close-spaced wall. Stormwater runoff enters the sedimentation trench and causes the sedimentation pool to rise and overflow into the filter trench through weir notches at the top of the dividing wall. The weirs allow stormwater runoff to enter the filter bed as sheet flow to prevent scouring the sand. The permanent pool in the sedimentation trench is dead storage, which inhibits resuspension of particles deposited from earlier storm events and
prevents heavier sediment from being washed into the filtration trench. Floatable materials can reach the filter media through the surface overflow. Stormwater runoff entering the filtration trench is treated with media filtration and removed from the filtration unit through an underdrain pipe where it can be discharged to the storm drain system. Stormwater runoff volumes larger in excess of the WQV are bypassed around the filtration unit.

**Figure 8-16. Austin Sand Filter Schematic**

![Sand Filter Schematic](image)

Source: Austin, Texas
Figure 8-17. DC Underground Sand Filter Schematic

Figure 8-18. Delaware Sand Filter Schematic
**Advantages**

- Provides effective treatment 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 site conditions. The presence of permeable soils is not a requirement.
- Reduces peak stormwater runoff flows during small storm events.

**Disadvantages**

- Potential for clogging of media. Pretreatment or upstream treatment control measures to remove large sediment may be required to minimize or prevent media clogging.
- Significant head loss through treatment units may limit use on flat surfaces.
- May be more expensive to construct than many other types of treatment control measures.

**Planning and Site Considerations**

- Media sand filters are generally suited for sites where there is no base flow, and the sediment load is relatively low.
- Media sand filters are well suited for drier areas and/or urban areas because they do not require vegetation and require less surface space than many other treatment control measures.
- Selection of a media sand filter type depends on the size of the drainage area and the facility location. For large watersheds (i.e., up to 50 acres), an Austin Sand Filter is recommended. For small catchments requiring underground facilities (i.e., up to 1.5 acres), a DC Underground Sand Filter is recommended. Delaware Sand Filters are especially suitable for paved sites and industrial sites (up to 5 acres) because they can be situated to accept sheet flow from adjacent pavement.
- Because the filter media is imported sand or engineered adsorptive material, media filters are suited for most soil conditions, and the presence of permeable soils is not a requirement.
- Approximately four (4) feet of hydraulic head is required to achieve design flow through the Austin and DC Underground Sand Filters. Delaware Sand Filters can operate with as little as two (2) feet of hydraulic head.
- For underground media filters, the load-carrying capacity of the filter structure must be considered if it is located under parking lots, driveways, roadways, and certain sidewalks.
- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the media filter is properly designed, constructed, and operated to maintain its infiltration capacity.

**Design Criteria**

Principal design criteria for Austin Sand Filters are presented in Table 8-37.

**Table 8-37. Austin Sand Filter Design Criteria**

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sedimentation Basin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tributary drainage area</td>
<td>≤ 50 acres</td>
<td></td>
</tr>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2.</td>
</tr>
<tr>
<td>Sedimentation basin drawdown time</td>
<td>40 hr (maximum)</td>
<td>Based on WQV</td>
</tr>
<tr>
<td>Basin water depth</td>
<td>3-10 ft</td>
<td></td>
</tr>
<tr>
<td>Length to width ratio</td>
<td>2:1 (minimum)</td>
<td></td>
</tr>
<tr>
<td>Freeboard</td>
<td>1 ft</td>
<td>Above maximum water surface elevation</td>
</tr>
<tr>
<td>Inlet velocity</td>
<td>3 ft/sec (maximum)</td>
<td>Provide inlet energy dissipater as required to limit inlet velocity.</td>
</tr>
<tr>
<td><strong>Filtration Basin</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage volume above filter bed</td>
<td>20% (minimum)</td>
<td>Based on WQV</td>
</tr>
<tr>
<td>Storage depth above filter bed</td>
<td>3 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>Gravel depth over sand filter</td>
<td>2 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Sand depth in filter bed</td>
<td>18 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Permeability coefficient for sand filter</td>
<td>3.5 ft/day</td>
<td></td>
</tr>
<tr>
<td>Sand filter surface slope</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Grave cover over underdrain</td>
<td>2 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Sand size (diameter)</td>
<td>0.02-0.04 in</td>
<td></td>
</tr>
<tr>
<td>Underdrain gravel size (diameter)</td>
<td>0.5-2 in</td>
<td></td>
</tr>
<tr>
<td>Inside diameter of underdrain</td>
<td>6 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Underdrain pipe type</td>
<td>PVC</td>
<td>Schedule 40 or heavier</td>
</tr>
<tr>
<td>Underdrain slope</td>
<td>1% (minimum)</td>
<td></td>
</tr>
<tr>
<td>Underdrain perforation diameter</td>
<td>3/8 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Perforations per row</td>
<td>6 (minimum)</td>
<td></td>
</tr>
<tr>
<td>Space between perforation rows</td>
<td>6 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Gravel bed depth</td>
<td>16 in (minimum)</td>
<td></td>
</tr>
</tbody>
</table>
Principal design criteria for DC Underground Sand Filters are presented in Table 8-38.

Table 8-38. DC Underground Sand Filter Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary drainage area</td>
<td>≤ 1.5 acres</td>
<td></td>
</tr>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2.</td>
</tr>
<tr>
<td>Drawdown time</td>
<td>48 hr (maximum)</td>
<td>Based on WQV</td>
</tr>
<tr>
<td>Gravel depth over filter media</td>
<td>2 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Sand filter depth</td>
<td>18 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Depth of cover gravel over underdrain pipe</td>
<td>2 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Filter coefficient</td>
<td>2 ft/day</td>
<td></td>
</tr>
<tr>
<td>Volume of WQV in sediment chamber</td>
<td>20% (minimum)</td>
<td></td>
</tr>
<tr>
<td>Underdrain slope</td>
<td>1% (minimum)</td>
<td></td>
</tr>
<tr>
<td>Diameter of upper level gravel cover</td>
<td>1 in (maximum)</td>
<td></td>
</tr>
<tr>
<td>Clearwell length</td>
<td>3 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>Filter sand sizing</td>
<td>–</td>
<td>ASTM C 33 concrete sand</td>
</tr>
<tr>
<td>Gravel diameter size in underdrain</td>
<td>0.5-2 in</td>
<td></td>
</tr>
<tr>
<td>Underdrain pipe size</td>
<td>6 in (minimum)</td>
<td>Schedule 40 reinforced PVC pipe</td>
</tr>
<tr>
<td>Perforation diameter in drainage pipe</td>
<td>3/8 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Perforations per underdrain pipe</td>
<td>6 (minimum)</td>
<td></td>
</tr>
<tr>
<td>Spacing between perforations</td>
<td>6 in (maximum)</td>
<td></td>
</tr>
<tr>
<td>Spacing between underdrain pipes</td>
<td>27 in (maximum)</td>
<td>Center to center</td>
</tr>
</tbody>
</table>

Principal design criteria for Delaware Sand Filters are presented in Table 8-39.
Table 8-39. Delaware Sand Filter Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tributary drainage area</td>
<td>≤ 5 acres</td>
<td></td>
</tr>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2.</td>
</tr>
<tr>
<td>Drawdown time</td>
<td>48 hr</td>
<td>Based on WQV</td>
</tr>
<tr>
<td>Weir height between sedimentation chamber and sand filter</td>
<td>2 in</td>
<td></td>
</tr>
<tr>
<td>Gravel depth over sand</td>
<td>2 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Sand depth</td>
<td>18 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Gravel underdrain depth</td>
<td>16 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Filter coefficient</td>
<td>2 ft/day</td>
<td></td>
</tr>
<tr>
<td>Top layer/underdrain gravel size, diameter</td>
<td>0.5-2 in</td>
<td></td>
</tr>
<tr>
<td>Sand size</td>
<td>–</td>
<td>ASTM C33 concrete sand</td>
</tr>
<tr>
<td>Top layer slope</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Underdrain or bottom of filter slope</td>
<td>0.5% (minimum)</td>
<td></td>
</tr>
<tr>
<td>Underdrain pipe size, diameter</td>
<td>6 in (minimum)</td>
<td>PVC Schedule 40</td>
</tr>
<tr>
<td>Perforation size, diameter</td>
<td>3/8 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Number of holes per row</td>
<td>6 (minimum)</td>
<td></td>
</tr>
<tr>
<td>Spacing between rows</td>
<td>6 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Weephole diameter</td>
<td>3 in (minimum)</td>
<td></td>
</tr>
<tr>
<td>Spacing between weepholes</td>
<td>9 in (minimum)</td>
<td>Center to center</td>
</tr>
<tr>
<td>Sedimentation chamber and sand filter width</td>
<td>18-30 in</td>
<td></td>
</tr>
</tbody>
</table>

Design Procedures

The design procedures for an Austin sand filter system are listed below:

Step 1 – Calculate WQV

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV.

Step 2 – Determine Sedimentation Basin Volume ($V_{sb}$)

The sedimentation basin volume must be greater than or equal to the WQV.

$$V_{sb} \geq WQV$$

Where:

$WQV =$ water quality volume ($\text{ft}^3$).
Step 3 – Determine Sedimentation Basin Depth \( (d_{sb}) \)

The allowable depth of water in the sedimentation basin \( (d_{sb}) \) is limited by the available hydraulic head at the project site, which is based on the difference in elevation between the sedimentation basin inlet and filter bed outlet. The design sedimentation basin depth should be between three (3) and ten (10) feet. Select a design depth in the allowable range that yields the required \( V_{sb} \) given any footprint area constraints for the project site.

Step 4 – Determine Sedimentation Basin Area \( (A_{sb}) \)

\[
A_{sb} = \frac{V_{sb}}{d_{sb}}
\]

Where:

\( V_{sb} = \) sedimentation basin volume \( (\text{ft}^3) \); and
\( d_{sb} = \) sedimentation basin depth \( (\text{ft}) \).

Step 5 – Determine Sedimentation Basin Shape

Determine overall length \( (L_{sb}) \) and width \( (W_{sb}) \) dimensions to yield the \( A_{sb} \) for any given footprint constraints for the project site.

\[
A_{sb} = L_{sb} \times W_{sb}
\]

Where:

\( L_{sb} = \) sedimentation basin length \( (\text{ft}) \); and
\( W_{sb} = \) sedimentation basin width \( (\text{ft}) \).

The length-to-width ratio should be a minimum of 2:1. Internal baffling may be necessary to achieve this ratio and to mitigate short-circuiting and/or dead storage problems.

If the sedimentation basin is not rectangular, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. The sedimentation basin design should maximize the distance from where the heavier sediment is deposited near the inlet to where the outlet structure is located. This configuration will improve basin performance and reduce maintenance requirements.

Step 6 – Determine Sedimentation Basin Inlet/Outlet Design

The sedimentation basin inlet and outlet points should be provided with energy dissipation structures and/or erosion protection. Energy dissipation devices may be necessary to reduce inlet velocities that exceed three (3) feet per second.
An outlet works must be provided that is designed to release the WQV to the filtration basin over a 40-hour period. See Fact Sheet C-3 Extended Detention Basin for outlet works design procedures.

**Step 7 – Determine Sedimentation Basin Outlet Trash Rack Design**

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 purpose of inspection and cleaning. Trash racks shall be sized to prevent clogging of the primary water quality outlet without restricting the hydraulic capacity of the outlet control orifices.

**Step 8 – Determine Sediment Trap Design (Optional)**

A sediment trap is a storage area that captures and removes sediment from the basin flow regime. In doing so, the sediment trap inhibits resuspension of solids during subsequent stormwater runoff events and improves long-term removal efficiency. The trap also maintains adequate volume to hold the WQV that would otherwise be partially lost due to sediment storage. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to ten (10) percent of the sedimentation basin volume. All water collected in the sediment trap shall drain within 40 hours. The drain pipe invert should be above the filtration basin sand bed surface. The minimum piping grading to the filtration basin should be 1/4 inch per foot, or two (2) percent slope. Access for cleaning the sediment trap drain system is necessary.

**Step 9 – Determine Sedimentation Basin Liner Design**

If the sedimentation basin is an earthen structure, and an impermeable liner is required to protect groundwater quality, the impermeable liner shall provide a maximum permeability of 1 x 10^{-6} \text{ cm/sec} (ASTM Method D-2434). If an impermeable liner is not required, then a geosynthetic fabric liner, which meets the specifications listed in Table 8-40, shall be installed unless the sedimentation basin is excavated to bedrock.

**Step 10 – Determine Minimum Filtration Basin Storage Volume (V_{fbs})**

The filtration basin storage capacity above the filter media surface should be greater than or equal to 20 percent of the WQV. This capacity is necessary to account for backwater effects resulting from partially clogged filter media.

\[ V_{fbs} \geq 0.2 \times WQV \]

Where:

WQV = water quality volume (ft³).
Step 11 – Determine Filter Bed Surface Area (A_{fbs})

Surface area is the primary design parameter for the filter bed and is a function of sand permeability, filter bed depth, hydraulic head, and filtration rate. The filter bed area should be the larger of the minimum area required for storage (A_{fbs}) and the minimum area required for flow (A_{ff}).

Determine minimum filter surface area required for storage (A_{fbs})

\[ A_{fbs} = \frac{V_{fbs}}{d_{fbs}} \]

Where:

- \( V_{fbs} \) = Storage volume above filter bed (ft\(^3\)); and
- \( d_{fbs} \) = Depth of storage above filter bed (ft), 3 ft minimum.

Determine minimum filter surface area required for flow (A_{ff})

\[ A_{ff} = \frac{WQV \times d_f}{k \times (d_{fbs} + d_f) \times t_f} \]

Where:

- \( WQV \) = water quality volume (ft\(^3\));
- \( d_f \) = filter bed depth (ft);
- \( k \) = sand filter permeability coefficient (ft/hr) = 0.146 ft/hr;
- \( d_{fbs} \) = depth of storage above filter bed (ft); and
- \( t_f \) = drawdown time for filter (hr) = 40 hr.

Use the larger of \( A_{fbs} \) or \( A_{ff} \) as the design value for filter bed area.

Step 12 – Design Filtration Basin Inlet Structure

The inlet structure should spread flow uniformly across the filter media surface. Flow spreaders, weirs, or multiple orifice openings are recommended.

Step 13 – Design Filter Bed

The filter (sand) bed may be either of the two configurations described below. Note that sand bed depths are final, consolidated depths. Consolidation effects must be taken into account.

Configuration A – Sand Bed with Underdrain (see Figure 8-19)

The sand layer shall be a minimum depth of 18 inches and shall consist of 0.02-0.04 inch diameter sand. Below the sand is a layer of 0.5-2 inch diameter gravel that provides a minimum of two (2) inches of cover over the top of lateral underdrain pipes.
No gravel is required under the lateral pipes. A layer of geotextile fabric meeting the specifications in Table 8-40 must separate the sand and gravel, and must be wrapped around the lateral pipes.

Drainage matting meeting the specifications in Table 8-40 should be placed under the lateral pipes to provide for adequate vertical and horizontal hydraulic conductivity to the later pipes.

In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L), the two- (2-) inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in Table 8-40.

Configuration B –Sand Bed with Trench Underdrain (see Figure 8-20)

The top layer shall be 12-18 inches of 0.02-0.04 inch diameter sand. Lateral pipes shall be placed in trenches with a covering of 0.5-2 inch diameter gravel and geotextile fabric (see Table 8-40). The lateral pipes shall be underlain by a layer of drainage matting (see Table 8-40).

In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L), the two- (2-) inch layer of stone on top of the sand filter should be underlain with Enkadrain 9120 filter fabric or equivalent meeting the specifications in Table 8-40.

**Figure 8-19. Austin Sand Filter Bed with Underdrain**
Step 14 – Design Filtration Basin Underdrain Piping

Underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes, and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be Schedule 40 PVC or greater strength. The minimum grade of piping shall be 1/8 inch per foot, or one (1) percent slope (slopes down to one-half [0.5] percent are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

Note: No drawdown time is associated with the sand filter, only the sedimentation basin. Thus, it is not necessary to have a specifically-design orifice for the filter bed outlet structure.

Step 15 – Design Filtration Basin Liner

If the filtration basin is an earthen structure and an impermeable liner is required to protect groundwater quality, the liner shall provide a maximum permeability of $1 \times 10^{-6}$ cm/sec (ASTM Method D-2434). If an impermeable liner is not required, then a geotextile fabric liner shall be installed that meets the specifications listed in Table 8-40 unless the basin has been excavated to bedrock.
Table 8-40. Geotextile Fabric Specifications for Media Filters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Method</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geotextile Fabric</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Nonwoven geotextile fabric</td>
<td></td>
</tr>
<tr>
<td>Unit weight</td>
<td>8 oz/yd² (minimum)</td>
<td></td>
</tr>
<tr>
<td>Filtration rate</td>
<td>0.08 in/sec (minimum)</td>
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</tr>
<tr>
<td>Puncture strength</td>
<td>ASTM D-751 (Modified)</td>
<td>125 lbs (minimum)</td>
</tr>
<tr>
<td>Mullen burst strength</td>
<td>ASTM D-751</td>
<td>400 lb/in² (minimum)</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>AST D-1682</td>
<td>300 lbs (minimum)</td>
</tr>
<tr>
<td>Equiv. opening size</td>
<td>US Standard Sieve</td>
<td>No. 80 (minimum)</td>
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<td><strong>Drainage Matting</strong></td>
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<tr>
<td>Material</td>
<td>Non-woven geotextile fabric</td>
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<tr>
<td>Unit weight</td>
<td>20 oz/yd² (minimum)</td>
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</tr>
<tr>
<td>Flow rate (fabric)</td>
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<tr>
<td>Permeability</td>
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<td>12.4 x 10⁻² cm/sec</td>
</tr>
<tr>
<td>Grab strength</td>
<td>ASTM D-1682</td>
<td>Dry: Lg 90/Wd 70</td>
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<tr>
<td></td>
<td></td>
<td>Wet: Lg 95/Wd 70</td>
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<tr>
<td>Puncture strength</td>
<td>COE CW-02215</td>
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<tr>
<td>Mullen burst strength</td>
<td>ASTM D-1117</td>
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<tr>
<td>Equiv. opening size</td>
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<tr>
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<td>Drexel University</td>
<td>14 gpm/ft width</td>
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<tr>
<td><strong>Filter Fabric</strong></td>
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</tr>
<tr>
<td>Material</td>
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<td>Unit weight</td>
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<tr>
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<td>Puncture strength</td>
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</tr>
<tr>
<td>Thickness</td>
<td>0.8 in (minimum)</td>
<td></td>
</tr>
</tbody>
</table>

The design procedures for a DC Underground Sand Filter system are listed below:

**Step 1 – Determine Maximum Water Depth**

Determine maximum allowable depth of water (2h) in the filtration basin considering elevation differences between inlet and outlet invert elevations. This height will establish weir height or elevation of inlet invert for bypass and orifices.
**Step 2 – Determine Sand Filter Area (Af,m)**

Determine the minimum area of the DC Underground Sand Filter using the Austin Filter formula for partial sedimentation treatment.

\[
A_{f,m} = \frac{WQV \times d_f}{k \times (h + d_f) \times t_f}
\]

Where:
- \(WQV\) = water quality volume (ft\(^3\));
- \(d_f\) = filter sand bed depth (ft);
- \(k\) = sand filter permeability coefficient (ft/hr) = 0.0833 ft/hr;
- \(h\) = one-half the maximum allowable water depth (2h) (ft); and
- \(t_f\) = drawdown time for filter (hr) = 40 hr.

**Step 3 – Determine Filter Width (Wf)/Length (Lf)**

Considering site constraints, select a filter width (Wf). Calculate the filter length (Lf) using the minimum area required (Af,m).

\[
L_f = \frac{A_{f,m}}{W_f}
\]

Where:
- \(A_{f,m}\) = filter surface area based on flow (ft\(^2\)); and
- \(W_f\) = filter bed width (ft).

Round the length and determine the adjusted area (Af).

\[
A_f = W_f \times L_f
\]

Where:
- \(W_f\) = filter bed width (ft); and
- \(L_f\) = filter bed length (ft).

Note: From this point forward, formulae assume a rectangular cross-section of the filter shell.

**Step 4 – Determine Storage Volume**

Above filter voids (Vf):

\[
V_{tf} = A_f \times 2h
\]

Where:
- \(A_f\) = adjusted filter surface area (ft\(^2\)); and
- \(h\) = one-half the maximum allowable water depth (2h) (ft).
In filter voids \((V_v)\), assuming 40% voids:

\[
V_v = 0.4 \times A_f \times (d_f + d_g)
\]

Where:
- \(A_f\) = adjusted filter surface area (ft\(^2\));
- \(d_f\) = filter sand bed depth (ft); and
- \(d_g\) = filter gravel bed depth (ft).

**Step 5 – Determine Flow-through Filter Volume during Filling \((V_Q)\)**

\[
V_Q = \frac{k \times A_f \times (d_f + d_g) \times t_f}{d_f}
\]

Where:
- \(k = 2 \text{ ft/day} = 0.0833 \text{ ft/hr}\);
- \(A_f\) = adjusted filter surface area (ft\(^2\));
- \(d_f\) = filter sand bed depth (ft);
- \(d_g\) = filter gravel bed depth (ft); and
- \(t_f = 1 \text{ hr (to fill voids).}\)

**Step 6 – Determine Net Volume to be Stored in Sediment Chamber awaiting Filtration \((V_{st})\)**

\[
V_{st} = WQV - V_{tf} - V_v - V_Q
\]

Where:
- \(WQV\) = water quality volume (ft\(^3\));
- \(V_{tf}\) = storage volume above filter voids (ft\(^3\));
- \(V_v\) = storage volume in filter voids (ft\(^3\)); and
- \(V_Q\) = flow-through filter volume during filling (ft\(^3\)).

**Step 7 – Determine Minimum Permanent Pool Length \((L_{pm})\)**

\[
L_{pm} = \frac{V_{st}}{2h \times W_f}
\]

Where:
- \(V_{st}\) = net volume stored in sediment chamber (ft\(^3\));
- \(h = \text{one-half the maximum allowable water depth (2h) (ft)}\); and
- \(W_f\) = filter bed width (ft).
See Figure 8-21 for dimensional relationships.

**Step 8 – Determine Minimum Sediment Chamber Length (Ls)**

If $V_{st} > 0.2 \times WQV$:

$$L_s = \frac{V_{st}}{2h \times W_f}$$

If $V_{st} < 0.2 \times WQV$:

$$L_s = \frac{0.2 \times WQV}{2h \times W_f}$$

Where:
- $V_{st}$ = net volume stored in sediment chamber $(ft^3)$;
- $h$ = one-half the maximum allowable water depth $(2h)$ (ft);
- $W_f$ = filter bed width (ft); and
- $WQV$ = water quality volume $(ft^3)$.

Note: It may be economical to adjust final dimensions to correspond with standard precast structures or to round off results to simplify measurements during construction.
Step 9 – Determine Final Permanent Pool Length \( (L_p) \)

If \( L_{pm} < (L_s + 2) \):

\[
L_p = L_{pm}
\]

If \( L_{pm} > (L_s + 2) \):

Where:
- \( A_p \) = Area of sediment chamber
- \( A_f \) = Area of sand filter
- \( A_{cw} \) = Area of clearwell
- \( W_f \) = Width of filter
- \( L_s \) = Minimum length of sediment chamber
- \( L_p \) = Final length of permanent pool
- \( L_f \) = Filter length
- \( L_{cw} \) = Length of clearwell
- \( L_t \) = Total length, sum of \( L + L_p + L_f \)
- \( 2h \) = Maximum achievable ponding depth over filter
- \( d_f \) = Sand bed depth
- \( d_g \) = Gravel depth

60" Minimum Headspace for maintenance

Under drain @ minimum 0.5% slope
\[ L_p = L_s + 2 \]

Where:
\[ L_{pm} = \text{minimum permanent pool length (ft)}; \text{ and} \]
\[ L_s = \text{minimum sediment chamber length (ft)}. \]

**Step 10 – Determine Clearwell Length \( (L_{cw}) \)**

Set the clearwell length \( (L_{cw}) \) for adequate maintenance and/or access for monitoring flow rate and effluent water chemistry (minimum 3 feet).

**Step 11 – Design Filter Bed**

**Top Gravel Layer**

The washed gravel at the top of the filter should be two (2) inches thick, and composed of 0.5-2-inch diameter stone. In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L), the 2-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 8-40.

**Sand Layer**

The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 8-40 must separate the sand and gravel layer below.

**Gravel Layer**

The gravel layer surrounding the underdrain pipes should be at least 16 inches thick, and composed of 0.5-2-inch diameter stone that provides at least a two (2) inch cover over the tops of the underdrain pipes.

**Step 12 – Design Underdrain Piping**

Underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand overburden weight. Internal diameters of lateral branch pipes should be six (6) inches or greater with perforations of 3/8 inch. Each row of perforations should contain at least six (6) holes, and the maximum spacing between rows of perforation should not exceed six (6) inches. All piping must be Schedule 40 PVC or greater strength. The minimum grade of piping shall be 1/8 inch per foot, or one (1) percent slope (slopes down to one-half [0.5] percent are acceptable with prior approval). Access for cleaning all underdrain pipes is needed.
Step 13 – Design Weepholes

In addition to an underdrain system, weepholes should be installed between the filter chamber and the clearwell to provide relief in case of pipe clogging. The weepholes should be three (3) inches in diameter with a minimum spacing of nine (9) inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12-inch high plastic hardware cloth of ¼-inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, No. 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of six (6) inches back under the bottom stone.

Step 14 – Design Dewatering Drain

A six (6) inch diameter DIP or PVC dewatering drain with a gate valve must be installed at the top of the stone/sand filter bed through the partition separating the filtration chamber from the clearwell chamber.

Step 15 – Design Bypass Pipe

Where a bypass pipe is needed, it shall be DIP or PVC with supports at a minimum of every 18 inches. See Appendix I for more information on bypass pipe design.

The design procedures for a Delaware sand filter system are listed below:

Step 1 – Determine Maximum Water Depth

Based on site constraints, determine the maximum ponding depth over the filter (2h). If an overflow device is built into the filter shell, size the overflow weir using the procedures outlined in Appendix I.

Step 2 – Determine Sand Filter/Sediment Chamber Surface Area (A_{sm})

The filter shell must have the capacity to accept and store the WQV. The dimensions are sized to provide a filter area, which process the WQV in the desired drawdown time (48 hours). The areas of the sedimentation chamber and filter bed are typically set equal. The required areas are calculated as follows depending on the maximum depth of water above the filter bed:

If \(2h < 2.67 \text{ ft}\):

\[ A_{sm} = A_{fm} = \frac{WQV}{4.1h + 0.9} \]

If \(2h > 2.67 \text{ ft}\):

\[ A_{sm} = A_{fm} = \frac{WQV \times d_f}{k \times (h + d_f) \times t_f} \]
Where:
\[ A_{im} = \text{filter surface area based on flow (ft}^2) ; \]
\[ WQV = \text{water quality volume (ft}^3) ; \]
\[ h = \text{one-half the maximum allowable water depth (2h) (ft)} ; \]
\[ d_f = \text{filter bed depth (ft)} ; \]
\[ k = \text{sand filter permeability coefficient (ft/hr) = 0.0833 ft/hr} ; \]
\[ t_i = \text{drawdown time for filter (hr) = 48 hr} . \]

**Step 3 – Determine Sediment Chamber and Filter Width**

Site considerations usually dictate final dimensions of the facility. Sediment chambers and filter chambers are normally 18 to 30 inches wide. Use of standard grates requires a width of 26 inches.

**Step 4 – Determine Sediment Chamber and Filter Length and Adjusted Area**

\[ L_s = L_f = \frac{A_{fm}}{W_f} \]

Where:
\[ L_f = \text{filter length (ft)} ; \]
\[ A_{im} = \text{filter surface area based on flow (ft}^2) ; \]
\[ W_f = \text{filter width (ft)} . \]

Round the length upward as appropriate, and calculate the adjusted area.

\[ A_s = A_f = W_f \times L_f \]

Where:
\[ A_f = \text{adjusted filter surface area (ft}^2) ; \]
\[ L_f = \text{filter length (ft)} ; \]
\[ W_f = \text{filter width (ft)} . \]

**Step 5 – Determine Storage Volume in Filter Voids (V_v)**

Assuming 40% voids:

\[ V_v = 0.4 \times A_f \times (d_f + d_g) \]

Where:
\[ A_f = \text{adjusted filter surface area (ft}^2) ; \]
\[ d_f = \text{filter sand bed depth (ft)} ; \]
\[ d_g = \text{filter gravel bed depth (ft)} . \]
Step 6 – Determine Flow-through Filter during Filling ($V_Q$)

\[
V_Q = \frac{k \times A_f \times (d_f + d_g) \times t_f}{d_f}
\]

Where:
- $k = 2$ ft/day = 0.0833 ft/hr;
- $A_f$ = adjusted filter surface area (ft$^2$);
- $d_f$ = filter sand bed depth (ft);
- $d_g$ = filter gravel bed depth (ft); and
- $t_f$ = 1 hr (to fill voids).

Step 7 – Determine Net Volume to be Stored in Chambers awaiting Filtration ($V_{sd}$)

\[
V_{sd} = WQV - V_v - V_Q
\]

Where:
- $WQV$ = water quality volume (ft$^3$);
- $V_v$ = storage volume in filter voids (ft$^3$); and
- $V_Q$ = flow-through filter volume during filling (ft$^3$).

Step 8 – Determine Available Storage in Chambers ($V_{sf}$)

\[
V_{sf} = 2h \times (A_f + A_s)
\]

Where:
- $h$ = one-half the maximum allowable water depth (2h) (ft);
- $A_f$ = adjusted filter surface area (ft$^2$); and
- $A_s$ = adjusted sediment chamber area (ft$^2$).

If $V_{sf} \geq V_{sd}$, proceed with design.

If $V_{sf} < V_{sd}$, adjust width and/or length, and repeat Steps 3-8.

Step 9 – Design Filter bed

Top Gravel Layer

The washed gravel at the top of the filter should be two (2) inches thick, and composed of 0.5-2-inch diameter stone. In areas with high sediment load (total suspended solids concentrations greater than or equal to 200 mg/L), the 2-inch layer of stone on top of the sand filter should be underlain with filter fabric meeting the specifications in Table 8-40.
Sand Layer

The sand layer should be a minimum depth of 18 inches consisting of ASTM C33 concrete sand. A layer of geotextile fabric meeting the specifications in Table 8-40 must separate the sand and gravel layer below.

Gravel Layer

The gravel layer surrounding the underdrain pipes should be at least 16 inches thick, and composed of 0.5-2-inch diameter stone that provides at least a two (2) inch cover over the tops of the underdrain pipes.

Step 10 – Design Underdrain Piping

Underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes. The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six (6) inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six (6) holes, and the maximum spacing between rows of perforations should not exceed six (6) inches. All piping is to be Schedule 40 PVC or greater strength. The minimum grade of piping shall be 1/8 inch per foot, or one (1) percent slope (slopes down to one-half [0.5] percent are acceptable with prior approval). Access for cleaning all underdrain piping is needed.

Note: No drawdown time is associated with the sand filter, only the sedimentation basin. Thus, it is not necessary to have a specifically-design orifice for the filter bed outlet structure.

Shallow rectangular drain tiles may be fabricated from such materials as fiberglass structural channels, saving several inches of filter depth. Drain tiles should be in two (2) foot lengths and spaced to provide gaps 1/8-inch less than the smallest gravel size on all four sides. Sections of tile may be cast in the dividing wall between the filter and the sedimentation chamber to provide shallow outfall orifices.

Step 12 – Design Weepholes

In addition to an underdrain system, weepholes should be installed between the filter chamber and the sedimentation chamber to provide relief in case of pipe clogging. The weepholes should be three (3) inches in diameter with a minimum spacing of nine (9) inches center to center. The openings on the filter side of the dividing wall should be covered to the width of the trench with 12-inch high plastic hardware cloth of ¼-inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, No. 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of six (6) inches back under the bottom stone.
Step 12 – Design Grates and Covers

Grates and cast steel covers are designed to take the same wheel loads as adjacent pavement. Where possible, use standard size grates to reduce costs. Grates and covers should be supported by a galvanized steel perimeter frame.

Step 13 – Design Hood/Traps

In applications where trapping of hydrocarbons or other floating pollutants is required, large-storm overflow weirs should be equipped with a 10-gauge aluminum hood or commercially available catch basin trap. The hood or trap should extend a minimum of one (1) foot into the sedimentation chamber.

Step 14 – Design Dewatering Drain

A six (6) inch diameter dewatering drain with gate valve is to be installed at the top of the stone/sand filter bed through the partition separating the filter chamber from the sedimentation chamber.

Volume Retention Calculation

No volume retention credit is available for media filters because they do not fully retain the WQV. However, media filters may be used to meet treatment control requirements.

Construction Considerations

- Erosion and sediment control measures must be configured to prevent any inflow of stormwater runoff into the media filter during its construction.
- The media filter must be adequately protected once constructed and not placed in service until all soil surfaces in the drainage watershed have been stabilized with vegetated cover. If stormwater runoff from the project site enter the media filter system prior to site revegetation, all contaminated materials must be removed and replaced with new, clean materials.
- The top of the media filter must be completely level. No grade is allowed.
- The inverts of the notches, multiple orifices, or weirs dividing the sedimentation chamber from the filter chamber must be completely level. Otherwise, water will not arrive at the filter as sheet flow, and only the downgradient end of the filter will function.
- Inflow grates or slotted curbs may conform to the grade of the completed pavement as long as the filters, notches, multiple orifices, and weirs connecting the sedimentation and filter chambers are completely level.
- If precast concrete lids are used, lifting rings or threaded sockets must be provided to allow easy removal with lifting equipment. Lifting equipment must be readily available to the facility operators.
• Where underdrains are used, the minimum slope of the pipe shall be one-half (0.5) percent. Where only gravel-filtered water conveyance is provided, the filter floor must be sloped towards weepholes at a minimum slope of one-half (0.5) percent.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as media filters. Such agreements typically include requirements such as those outlined in Table 8-41. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

<table>
<thead>
<tr>
<th>Table 8-41. Inspection and Maintenance Requirements for Media Filters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity</strong></td>
</tr>
<tr>
<td>Remove cover grates or precast lids on the chambers and inspect to determine if the system is functioning properly.</td>
</tr>
<tr>
<td>Inspect for standing water, sediment, trash, and debris. Identify and correct observed problems.</td>
</tr>
<tr>
<td>Inspect facility after a large storm even to determine if the facility is draining completely within its design drawdown period.</td>
</tr>
<tr>
<td>Prevent grass and vegetative waste from washing into the filter.</td>
</tr>
<tr>
<td>Remove trash and debris collected on the inlet grates to maintain the inflow capacity of the filter.</td>
</tr>
<tr>
<td>Remove top two (2) inches of sand and dispose of sediment if the facility drain time exceeds its design drawdown period. Restore media depth to 18 inches when overall media depth drops to 12 inches.</td>
</tr>
<tr>
<td>Remove accumulated sediment in the sedimentation basin.</td>
</tr>
<tr>
<td>Dispose of sand, gravel, or filter cloth contaminated with petroleum hydrocarbons in accordance with applicable laws.</td>
</tr>
</tbody>
</table>
C-2: Constructed Wetland

Description

A constructed wetland is a single-stage treatment system consisting of a forebay and permanent pool with aquatic plants. Constructed wetlands function similarly to wet ponds in that influent stormwater runoff mixes with and displaces a permanent pool as it enters the system. The surcharge volume above the permanent pool is slowly released over a specified period (24 hours for WQV). 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 compared to wet ponds. A base flow is required to maintain the permanent water pool. Constructed wetlands also differ from wet ponds because 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 illustrated in Figure 8-22.

constructed wetlands differ from natural wetlands in that they are man-made and designed to enhance stormwater runoff quality. Stormwater runoff diversion directly to natural wetlands is not recommended because natural wetlands need to be protected from the adverse effects of development. This is especially important because natural wetlands provide stormwater runoff and flood control on a regional scale. Natural wetlands can be incorporated into the constructed wetlands system, but such action requires approval of federal and state regulating authorities. Constructed wetlands generally are 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 a permanent wet pool, constructed wetlands can provide significant water quality improvement for many pollutants including dissolved nutrients.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by stormwater runoff flow changes.
Disadvantages

- Constructed 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 public safety concerns where there may be public access to the constructed wetlands.
- Mosquito and midge breeding is likely to occur in constructed wetlands.
- Constructed wetlands cannot be placed on steep, unstable slopes.
- Constructed wetlands require a relatively large footprint.
Planning and Site Considerations

- Appropriate land uses include large residential developments and commercial, institutional, and industrial areas where incorporation of a green space and a constructed wetland into the landscape is desirable and feasible.
- Can be used effectively in combination with upstream treatment control measures, such as vegetated filter strips and vegetated swales.
- Required relatively large areas (typically four to six percent of the tributary area) and are usually larger than wet ponds because the average depth is smaller.
- Most appropriate for sites with low-permeability soils (Type C or D soil) 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 the presence of a shallow groundwater table.
- Wetland bottom channels require a near-zero slope.
- A base flow of water is required to maintain aquatic conditions.

Design Criteria

Principal design criteria for constructed wetlands are listed in Table 8-42.
Table 8-42. Constructed Wetland Basin Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>See Fact Sheet C-2.</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>24 hr (maximum)</td>
<td>Based on WQV</td>
</tr>
<tr>
<td>Permanent pool volume</td>
<td>75% (minimum)</td>
<td>Percentage of WQV</td>
</tr>
<tr>
<td>Inlet/outlet erosion control</td>
<td>–</td>
<td>Provide energy dissipaters to reduce volume</td>
</tr>
<tr>
<td>Forebay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Volume</td>
<td>5-10%</td>
<td>Percentage of WQV</td>
</tr>
<tr>
<td>- Area</td>
<td>5-10%</td>
<td>Percentage of permanent pool surface area</td>
</tr>
<tr>
<td>- Depth</td>
<td>2-4 ft</td>
<td></td>
</tr>
<tr>
<td>Open-water zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Area</td>
<td>10-40%</td>
<td>Percentage of permanent pool surface area</td>
</tr>
<tr>
<td>- Depth</td>
<td>2-4 ft</td>
<td></td>
</tr>
<tr>
<td>Wetland zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Area</td>
<td>50-70%</td>
<td>Percentage of permanent pool surface area</td>
</tr>
<tr>
<td>- Depth</td>
<td>0.5-1 ft</td>
<td>30-50% should be 0.5 ft deep</td>
</tr>
<tr>
<td>Outlet zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Area</td>
<td>5-10%</td>
<td>Percentage of permanent pool surface area</td>
</tr>
<tr>
<td>- Depth</td>
<td>3 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>Surcharge depth above permanent pool</td>
<td>2 ft (maximum)</td>
<td></td>
</tr>
<tr>
<td>Basin length to width ratio</td>
<td>2:1 (minimum)</td>
<td>Larger is preferred</td>
</tr>
<tr>
<td>Basin freeboard</td>
<td>1 ft (minimum)</td>
<td>Wetland</td>
</tr>
<tr>
<td>zone bottom slope</td>
<td>10% (maximum)</td>
<td></td>
</tr>
<tr>
<td>Embankment side slope (H:V)</td>
<td>≥ 4:1</td>
<td>Inside</td>
</tr>
<tr>
<td></td>
<td>≥ 3:1</td>
<td>Outside (without retaining wall)</td>
</tr>
<tr>
<td>Maintenance access ramp slope (H:V)</td>
<td>10:1 or flatter</td>
<td></td>
</tr>
<tr>
<td>Maintenance access ramp width</td>
<td>10 ft (minimum)</td>
<td>Paved with concrete or permeable pavement</td>
</tr>
</tbody>
</table>

**Design Procedure**

**Step 1 – Calculate WQV**

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 24-hour drawdown period.
Step 2 – Determine Basin Minimum Volume for Permanent Pool (V_{pp})

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

\[ V_{pp} \geq 0.75 \times WQV \]

Where:
\[ WQV = \text{water quality volume (ft}^3) \].

Step 3 – Determine Basin Depths and Surface Areas

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent of Permanent Pool Surface Area</th>
<th>Design Water Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forebay</td>
<td>5-10%</td>
<td>2-4 ft</td>
</tr>
<tr>
<td>Open-water zone</td>
<td>10-40%</td>
<td>2-4 ft</td>
</tr>
<tr>
<td>Wetland zone with emergent vegetation</td>
<td>50-70%</td>
<td>6-12 in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(30-50% of this area should be 6 inches deep with a bottom slope ≤ 10%)</td>
</tr>
<tr>
<td>Outlet zone</td>
<td>5-10%</td>
<td>3 ft (minimum)</td>
</tr>
</tbody>
</table>

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

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

\[ A_{pp} = \frac{V_{pp}}{D_{avg}} \]

Where:
\[ V_{pp} = \text{volume of permanent pool (ft}^3) \]; and
\[ D_{avg} = \text{average depth of permanent pool (ft)} \].

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

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

The WQV surcharge depth above the permanent pool’s water surface (D_{WQV}) should be less than or equal to two (2) feet.
Estimate WQV surcharge depth \(D_{WQV}\) based on \(A_{pp}\)

\[
D_{WQV} = \frac{WQV}{A_{pp}}
\]

Where:
- \(WQV\) = water quality volume (ft\(^3\)); and
- \(A_{pp}\) = surface area of permanent pool (ft\(^2\)).

If \(D_{WQV}\) is greater than two (2) feet, adjust value of \(V_{pp}\) and/or \(D_{avg}\) to increase \(A_{pp}\) to yield a \(D_{WQV}\) less than or equal to two (2) feet.

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

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

Recalculate final \(D_{WQV}\) based on \(A_{WQV}\) and \(A_{pp}\). Note: \(V_{pp}\) and/or \(D_{avg}\) can be adjusted to yield a final \(D_{WQV}\) that is less than or equal to two (2) feet.

\[
Final\ D_{WQV} = \frac{WQV}{0.5 \times (A_{WQV} + A_{pp})}
\]

Where:
- \(WQV\) = water quality volume (ft\(^3\));
- \(A_{WQV}\) = maximum water surface area (ft\(^2\)); and
- \(A_{pp}\) = surface area of permanent pool (ft\(^2\)).

Calculate maximum water surface elevation in basin with WQV \((WS\ Elev_{WQV})\).

\[
WS\ Elev_{WQV} = WS\ Elev_{pp} + Final\ D_{WQV}
\]

Where:
- \(WS\ Elev_{pp}\) = water surface elevation of permanent pool (ft); and
- \(Final\ D_{WQV}\) = final surcharge depth of WQV (ft).

**Step 5 – Determine Inflow Requirement \((Q_{in})\)**

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.

\[
Q_{in} = Q_{R-p} + Q_s + Q_{ET}
\]
Where:
\[ Q_{E,P} = \text{Loss due to evaporation minus the gain due to precipitation (acre-ft/month)}; \]
\[ Q_s = \text{Loss or gain due to seepage to groundwater (acre-ft/month); and} \]
\[ Q_{ET} = \text{Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface) (acre-ft/month)}. \]

**Step 6 – Design Forebay**

The forebay provides a location for sedimentation of larger particles, and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay is part of the permanent pool, and has a water surface area comprising five (5) to ten (10) percent of the permanent pool water surface area and a volume comprising of five (5) to ten (10) percent of the WQV. The permanent pool depth in the forebay should be two (2) to four (4) feet. Provide forebay inlet with an energy dissipation structure and/or erosion protection. Trash screens at the inlet are recommended to reduce 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 ElevWQV. The outlet works are to be designed to release the WQV 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 WQV depth. A single orifice outlet control is depicted in Figure 8-25.

For single orifice outlet control or single row of orifices at the permanent pool elevation (WS Elevpp) (see Figure 8-22), use the Orifice Equation based on the WQV (ft³) and depth of water above orifice centerline D (ft) to determine orifice area (in²):

\[ Q = C \times A \times \sqrt{2gD} \]

Where:
\[ C = \text{orifice coefficient (use 0.61)}; \]
\[ A = \text{area of orifice (in²)}; \]
\[ g = \text{acceleration due to gravity (32.2 ft/sec²); and} \]
\[ D = \text{depth of water above orifice centerline (D_{WQV}, ft)}. \]

The equation can be solved for A based on the WQV and design drawdown time (t) using the following conversion of the Orifice Equation:

\[ A = \frac{WQV}{61.19 \times D^{0.5} \times t} \]

Where:
\[ WQV = \text{water quality volume (ft³)}; \]
\[ D = \text{depth of water above orifice centerline (D_{WQV}); and} \]
\[ t = \text{drawdown period (hr)} = 24 \text{ hours} \]
For perforated pipe outlets or vertical plates with multiple orifices (see Figure 8-24), use the following equation to determine required area per row of perforations, based on the WQV (acre-ft) and depth of water above centerline of the bottom perforation, D (ft).

\[ A_r = \frac{WQV}{K_{24}} \]

Where:

- \( WQV \) = water quality volume (acre-ft);
- \( K_{24} = 0.012 \times D^2 + 0.14 \times D - 0.06 \) (from Denver UDFCD, 1999); and
- \( D \) = depth of water above orifice centerline (\( D_{WQV} \)).

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

\[ n_r = 1 + (D \times 3) \]

Where:

- \( D \) = depth of water above orifice center line.

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

\[ Total \, Orifice \, Area = A_r \times n_r \]

Where:

- \( A_r \) = required area per row of perforations; and
- \( n_r \) = number of rows.

**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 erosion and to 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 Area

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

Step 11 – Design Security Fencing

Provide aesthetic security fencing around the constructed wetland to protect habitat except when specifically waived by the City. Fencing design shall adhere to the City of Modesto Standard Specifications, and be approved by the City.

Step 12 – Select Vegetation

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

Volume Retention Calculation

No volume retention credit is provided for a constructed wetland system because it does not fully retain the WQV. However, a constructed wetland may be used to meet treatment control requirements.

Construction Considerations

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

Maintenance Requirements

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as constructed wetlands. Such agreements typically include
requirements such as those outlined in Table 8-43. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.

Table 8-43. Inspection and Maintenance Requirements for Constructed Wetland

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove litter and debris from constructed wetland area.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect basin to identify potential problems such as trash and debris accumulation, damage from burrowing animals, and sediment accumulation.</td>
<td>At beginning and end of wet season. Additional inspections after periods of heavy stormwater runoff are desirable.</td>
</tr>
<tr>
<td>If permitted by the California Department of Fish and Game or other regulatory agency, stock basin with mosquito fish to enhance natural mosquito and midge control.</td>
<td>As required</td>
</tr>
<tr>
<td>Harvest vegetation for vector control and to maintain open water surface area.</td>
<td>Annually or more frequently if required</td>
</tr>
<tr>
<td>Remove sediment when accumulation reaches ten (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.)</td>
<td>Clean in early spring so vegetation damaged during cleaning has time to reestablish.</td>
</tr>
<tr>
<td>Clean forebay to minimize frequency of main basin cleaning.</td>
<td>As required</td>
</tr>
</tbody>
</table>
C-3: Extended Detention Basin

Description

Extended detention basins are permanent basins formed by excavation and/or construction of embankments to temporarily detain stormwater runoff to allow for sedimentation of particulates to occur before the stormwater runoff is discharged. An extended detention basin reduces peak stormwater flow rates and provides stormwater runoff treatment. Extended detention basins are typically dry between storm events, although a shallow pool, one (1) to three (3) 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 stormwater runoff over a specified period of time. Extended detention basins can also be used to provide flood control by including additional storage capacity. The basic elements of an extended detention basin are presented in Figure 8-23. This configuration is most appropriate for large sites.

Advantages

- May be designed to provide other benefits such as recreation (i.e., 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 low hydraulic head requirements allow basins to be sited within the constraints of the existing storm drain system. Can be designed into flood control basins or sometimes retrofitted into existing flood control basins.

Disadvantages

- 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 property value of nearby property due to the adverse aesthetics of dry, bare areas, and exposure of inlet and outlet structures. Appropriate vegetation selection and maintenance can help mitigate these adverse effects.
Planning and Site Considerations

- If constructed early in the land development cycle, extended detention basins can serve as sediment traps during construction within the tributary area.
- Surface basins are typical, but underground vaults may be appropriate in a small commercial development.
- Small- to medium-sized tributary areas with available open space and drainage areas greater than five (5) acres are typical drainage area sizes.
- Approximately 0.5 to 2 percent of the tributary development area is the required area needed for an extended detention basin.
- Extended detention basins 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.
**Design Criteria**

Design criteria for extended detention basins are listed in Table 8-44. Extended detention basins may also serve as a flood control detention basin under the City’s Storm Drainage System Engineer Design Standards. Such dual-purpose basins must also conform to design criteria for detention basins set forth in Chapter 4 of the City’s Standard Specifications.

**Table 8-44. Extended Detention Basin Design Criteria**

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>80% annual capture. Use Figure 6-1.</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>48 hr (minimum)</td>
<td>Outlet controls or pumping stations must be designed to withdraw WQV over a minimum period of 48 hours</td>
</tr>
<tr>
<td>Drawdown time for 50% WQV</td>
<td>12 hr (minimum)</td>
<td>Time before release of 50% WQV</td>
</tr>
<tr>
<td>Basin design volume</td>
<td>120%</td>
<td>Percentage of WQV. Provide 20% for sediment storage volume</td>
</tr>
<tr>
<td>Inlet/outlet erosion control</td>
<td>–</td>
<td>Provide energy dissipaters to reduce velocity</td>
</tr>
<tr>
<td>Forebay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Volume</td>
<td>5-10%</td>
<td>Percentage of WQV</td>
</tr>
<tr>
<td>- Drain time</td>
<td>&lt; 45 min</td>
<td></td>
</tr>
<tr>
<td>Low-flow channel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Depth</td>
<td>9 in</td>
<td></td>
</tr>
<tr>
<td>- Flow capacity</td>
<td>200%</td>
<td>Percentage of forebay outlet release capacity</td>
</tr>
<tr>
<td>Upper stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Bottom slope</td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>- Depth</td>
<td>2 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>- Width</td>
<td>30 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>Length to width ratio</td>
<td>2:1 (minimum)</td>
<td>Larger preferred</td>
</tr>
<tr>
<td>Bottom stage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Volume</td>
<td>5-20%</td>
<td>Percentage of WQV</td>
</tr>
<tr>
<td>- Depth</td>
<td>1.5-3 ft</td>
<td>Deeper than upper stage</td>
</tr>
<tr>
<td>Freeboard</td>
<td>1 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>Embankment side slope (H:V)</td>
<td>≥ 4:1</td>
<td>Inside</td>
</tr>
<tr>
<td></td>
<td>≥ 3:1</td>
<td>Outside (without retaining wall)</td>
</tr>
<tr>
<td>Maintenance access ramp slope (H:V)</td>
<td>10:1 or flatter</td>
<td></td>
</tr>
<tr>
<td>Maintenance access ramp width</td>
<td>16 ft (minimum)</td>
<td>Approach paved with asphalt concrete</td>
</tr>
</tbody>
</table>
Design Procedure

*Step 1 – Calculate WQV*

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 48-hour drawdown period.

*Step 2 – Determine Minimum Basin Storage Design Volume \( (V_{bs}) \)*

The volume of the basin \( (V_{bs}) \) shall not be less than 120% of the WQV. The additional 20% provides allowance for sediment accumulation.

\[
V_{bs} \geq 1.2 \times WQV
\]

Where:

\( WQV = \) water quality volume \( (ft^3) \).

*Step 3 – Design Outlet Works*

The outlet works, including pump stations, are to be designed to release the WQV over a minimum 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 WQV depth. See Figure 8-24 and Figure 8-25 for schematics pertaining to structure geometry, grates, trash racks, and screens for perforated riser pipe and orifice plate outlets.

For single orifice outlet control or single row of orifices at the basin bottom surface elevation (see Figure 8-23), use the Orifice Equation based on the WQV \( (ft^3) \) and depth of water above orifice centerline \( D \) \( (ft) \) to determine orifice area \( (in^2) \):

\[
Q = C \times A \times \sqrt{2gD}
\]

Where:

\( C = \) orifice coefficient \( (use 0.61) \);
\( A = \) area of orifice \( (in^2) \);
\( g = \) acceleration due to gravity \( (32.2 \text{ ft/sec}^2) \); and
\( D = \) depth of water above orifice centerline \( (D_{WQV}, \text{ ft}) \).
The equation can be solved for A based on the WQV and design drawdown time (t) using the following conversion of the Orifice Equation:

\[ A = \frac{WQV}{61.19 \times D^{0.5} \times t} \]

Where:
- \( WQV \) = water quality volume (ft\(^3\));
- \( D \) = depth of water above orifice centerline (\( D_{WQV} \), ft); and
- \( t \) = drawdown period (hr) = 48 hours.

For perforated pipe outlets or vertical plates with multiple orifices (see Figure 8-24), use the following equation to determine required area per row of perforations \( A_r \), based on the WQV (acre-ft) and depth of water above centerline of the bottom perforation, \( D \) (ft).

\[ A_r = \frac{WQV}{K_{48}} \]

Where:
- \( WQV \) = water quality volume (acre-ft); and
- \( K_{48} = 0.013 \times D^2 + 0.22 \times D - 0.10 \).

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

\[ n_r = 1 + (D \times 3) \]

Where:
- \( D \) = depth of water above orifice center line (ft).

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

\[ Total \, Orifice \, Area = A_r \times n_r \]

Where:
- \( A_r \) = required area per row of perforations; and
- \( n_r \) = number of rows.

**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. Trash racks 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 form 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 fills often with frequently occurring stormwater runoff, minimizes standing water and sediment deposition in the remainder of the basin.

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

Bottom stage: The active storage basin of the bottom stage should be 1.5 to 3 feet deeper than the upper stage and store 5-20% of the WQV. 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 Forebay**

The forebay provides a location for sedimentation of larger particles, and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay has a volume comprising of five (5) to ten (10) percent of the WQV. 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. Lining the low-flow channel with concrete is recommended. The channel depth should be at least nine (9) inches. The channel flow capacity should be twice the release capacity of the forebay outlet.

**Step 9 – Select Vegetation**

Bottom vegetation provides erosion protection and sediment entrapment. Basin bottoms, berms, and side slopes may be planted with native grasses or irrigated turf. Examples of types of vegetation that may be planted on the basin bottom are provided in Appendix G.
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 the 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 all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be ten (10) percent and minimum width should be sixteen (16) feet. Ramps should be paved with concrete.

Step 13 – Design Diversion Structure

Provide stormwater runoff bypass or overflow for volumes in excess of the WQV. Spillway and overflow structures should be designed in accordance with the applicable City of Modesto Standard Specifications. See Appendix I for more information on diversion structure design.

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 8-45.

Table 8-45. Non-woven Geotextile Fabric Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Method</th>
<th>Specifications (^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grab strength</td>
<td>ASTM D4632</td>
<td>90 lb</td>
</tr>
<tr>
<td>Elongation at peak load</td>
<td>ASTM D4632</td>
<td>50%</td>
</tr>
<tr>
<td>Puncture strength</td>
<td>ASTM D3787</td>
<td>45 lb</td>
</tr>
<tr>
<td>Permittivity</td>
<td>ASTM D4491</td>
<td>0.7 sec(^{-1})</td>
</tr>
<tr>
<td>Burst strength</td>
<td>ASTM D3786</td>
<td>180 psi</td>
</tr>
<tr>
<td>Toughness</td>
<td>ASTM D4595</td>
<td>5,500 lb</td>
</tr>
<tr>
<td>Ultraviolet resistance (percent strength retained at 500 Weatherometer hours)</td>
<td>ASTM D4355</td>
<td>70%</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Adapted from SSPWC, 1997.
Step 15 – Design Security Fencing

Provide aesthetic security fencing around the extended detention basin to protect habitat except when specifically waived by the City. Fencing design shall adhere to the City of Modesto Standard Specifications, and be approved by the City.

Volume Retention Calculation

No volume retention credit is provided for an extended detention basin because it does not fully retain the WQV. However, an extended detention basin may be used to meet treatment control requirements.

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.

Long-Term Maintenance

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as extended detention basins. Such agreements typically include requirements such as those outlined in Table 8-46. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.
Table 8-46. Inspection and Maintenance Requirements for an Extended Detention Basin

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove litter and debris from banks and basin bottom.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect extended detention basin for the following items:</td>
<td></td>
</tr>
<tr>
<td>clogging of outlet; differential settlement; cracking; erosion;</td>
<td></td>
</tr>
<tr>
<td>leakage; tree growth on the embankment; the condition of riprap</td>
<td></td>
</tr>
<tr>
<td>in the inlet, outlet, and pilot channels; sediment accumulation in</td>
<td></td>
</tr>
<tr>
<td>the basin; trash and debris accumulation; damage from</td>
<td></td>
</tr>
<tr>
<td>burrowing animals; and the health and density of grass turf on the</td>
<td></td>
</tr>
<tr>
<td>basin side slopes and floor. Correct observed problems.</td>
<td></td>
</tr>
<tr>
<td>If permitted by the California Department of Fish and Game or</td>
<td>As required</td>
</tr>
<tr>
<td>other regulatory agency, stock basin with mosquito fish to</td>
<td></td>
</tr>
<tr>
<td>enhance natural mosquito and midge control.</td>
<td></td>
</tr>
<tr>
<td>Remove sediment when accumulation reaches 25 percent of</td>
<td>Clean in early spring so vegetation</td>
</tr>
<tr>
<td>original design depth or if resuspension is observed. (Note:</td>
<td>damaged during cleaning has time to reestablish.</td>
</tr>
<tr>
<td>Sediment removal may not be required in the main basin for as</td>
<td></td>
</tr>
<tr>
<td>long as 20 years.)</td>
<td></td>
</tr>
<tr>
<td>Clean forebay to minimize frequency of main basin cleaning.</td>
<td>As required</td>
</tr>
<tr>
<td>Trim vegetation and inspect monthly to prevent establishment of</td>
<td>At beginning and end of wet season</td>
</tr>
<tr>
<td>woody vegetation and for aesthetic and vector purposes.</td>
<td></td>
</tr>
<tr>
<td>Control mosquitoes.</td>
<td>As necessary</td>
</tr>
</tbody>
</table>
Figure 8-24. Perforated Pipe Outlet Structure

OUTLET WORKS
NOT TO SCALE

Notes:
1. The outlet pipe shall be sized to control overflow into the concrete riser.
2. Alternate designs include a Hydrobrake outlet (or orifice designs) as long as the hydraulic performance matches this configuration.

Notes:
1. Minimum number of holes = 8
2. Minimum hole diameter = 1/4" 
3. Maximum hole diameter = 3/4"

Maximum Number of Perforated Columns

<table>
<thead>
<tr>
<th>Riser Diameter (in.)</th>
<th>1/4&quot;</th>
<th>1/2&quot;</th>
<th>3/4&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>8</td>
<td>16</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>24</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hole Diameter (in.)</th>
<th>Area of Hole (in²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>0.0083</td>
</tr>
<tr>
<td>3/16</td>
<td>0.0492</td>
</tr>
<tr>
<td>5/32</td>
<td>0.0810</td>
</tr>
<tr>
<td>3/16</td>
<td>0.1037</td>
</tr>
<tr>
<td>7/32</td>
<td>0.1442</td>
</tr>
<tr>
<td>1/2</td>
<td>0.283</td>
</tr>
</tbody>
</table>

ADAPTED FROM UDFCD, 1999

PERFORATED VERTICAL RISER PIPE
NOT TO SCALE

OUTLET CONFIGURATIONS USING MULTIPLE ORIFICE FLOW CONTROL
Figure 8-25. Orifice Plate Outlet Configuration

PERFORATED RISER PIPE WITH VERTICAL FLOW CONTROL ORIFICE
NOT TO SCALE

CONTROL MANHOLE WITH SUBMERGED HORIZONTAL ORIFICE PLATE
NOT TO SCALE
C-4: Wet Pond

Description

Wet ponds are open earthen basins that feature a permanent pool of water that is displaced by stormwater runoff, in part or in total, during storm events. Like extended detention basins, wet ponds are designed to temporarily retain stormwater runoff and slowly release this volume over a design drawdown period. Wet ponds differ from extended detention basins in that influent stormwater runoff mixes with and displaces the permanent pool as it enters the basin. The design drawdown time for wet ponds (12 hours) is shorter than that for extended detention basins (48 hours), because enhanced treatment is provided in the permanent pool. Wet ponds differ from constructed wetlands because wet ponds have a greater average depth. A dry weather base flow is required to maintain a permanent pool in the wet pond. The primary treatment mechanism is sedimentation as stormwater runoff resides in this pool, but pollutant removal, particularly nutrients, also occurs through biological activity in the pond. The basic elements of a wet pond are illustrated in Figure 8-26.

Advantages

- Wet ponds can be designed to provide other benefits such as recreation, wildlife habitat, and open space.
- Wet 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 pollutants including dissolved nutrients.
- Wet ponds can serve essentially any size tributary area.

Disadvantages

- Public safety must be considered with respect to access and use.
- Potential for mosquito and midge breeding exists due to permanent pool.
- Discharge from wet ponds may pose a risk to cold-water receiving waters because stormwater runoff 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 wet ponds may be allowed to dry out during the dry season if non-stormwater runoff is negligible.
- Algae growth may be a potential issue if a permanent water pool is maintained during the summer dry season.
- Wet ponds require a relatively large footprint.
- Depending on volume and depth, wet pond design may require approval from the California Division of Safety of Dams.

Figure 8-26. Wet Pond Conceptual Layout

Planning and Site Considerations

- Wet ponds are appropriate for use in the following settings:
  - Where there is a need to achieve a reasonably high level of dissolved pollutant 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.

- Wet ponds are 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 ten (10) acres with available open space.
- Land area requirements are approximately two (2) to three (3) percent of the tributary development area.
- Most appropriate for sites with low-permeability soil (Type C or D soil).

**Design Criteria**

Principal design criteria for wet ponds are listed in Table 8-47.
Table 8-47. Wet Pond Design Criteria

<table>
<thead>
<tr>
<th>Design Parameter</th>
<th>Design Criteria</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design volume</td>
<td>WQV</td>
<td>80% annual capture. Use Figure 6-1.</td>
</tr>
<tr>
<td>Drawdown time for WQV</td>
<td>12 hr (maximum)</td>
<td>Based on WQV</td>
</tr>
<tr>
<td>Permanent pool volume</td>
<td>100-150% WQV (minimum)</td>
<td>Percentage of WQV</td>
</tr>
<tr>
<td>Inlet/outlet erosion control</td>
<td>-</td>
<td>Provide energy dissipaters to reduce velocity</td>
</tr>
<tr>
<td>Forebay</td>
<td>- Volume 5-10%</td>
<td>Percentage of WQV</td>
</tr>
<tr>
<td></td>
<td>- Drain time &lt; 45 min</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Depth 2-4 ft</td>
<td></td>
</tr>
<tr>
<td>Littoral zone</td>
<td>- Area 25-40%</td>
<td>Percentage of permanent pool surface area</td>
</tr>
<tr>
<td></td>
<td>- Depth 6-18 in</td>
<td></td>
</tr>
<tr>
<td>Deeper zone</td>
<td>- Area (including forebay) 55-65%</td>
<td>Percentage of permanent pool surface area</td>
</tr>
<tr>
<td></td>
<td>- Depth 4-8 ft (average) 12 ft (maximum)</td>
<td></td>
</tr>
<tr>
<td>Pond length to width ratio</td>
<td>2:1 (minimum)</td>
<td>Larger preferred</td>
</tr>
<tr>
<td>Bottom width</td>
<td>30 ft (minimum) Pond</td>
<td></td>
</tr>
<tr>
<td>freeboard</td>
<td>1 ft (minimum)</td>
<td></td>
</tr>
<tr>
<td>Embankment side slope (H:V)</td>
<td>≥ 4:1</td>
<td>Inside</td>
</tr>
<tr>
<td></td>
<td>≥ 3:1</td>
<td>Outside (without retaining walls)</td>
</tr>
<tr>
<td>Maintenance access ramp slope</td>
<td>10:1 or flatter</td>
<td></td>
</tr>
<tr>
<td>Maintenance access ramp width</td>
<td>16 ft (minimum)</td>
<td>Approach paved with asphalt concrete</td>
</tr>
</tbody>
</table>

**Design Procedure**

**Step 1 – Calculate WQV**

Using Fact Sheet C-2, calculate the effective tributary drainage area and WQV based on a 12-hour drawdown period.

**Step 2 – Determine Minimum Volume for Permanent Pool (Vpp)**

The volume of the permanent pool (Vpp) shall not be less than 100% and up to 150% of the WQV.

\[ V_{pp} = 1.0 \text{ to } 1.5 \times WQV \]
Where:
\[ WQV = \text{water quality volume (ft}^3\text{).} \]

**Step 3 – Determine Depth Zones**

Distribution of the permanent pool area is needed to achieve desired biodiversity. In addition to the forebay, two depth zones are required (see Figure 8-27). The littoral zone provides for aquatic plant growth along the perimeter of the pool. The deeper zone covers the remaining wet pond area and promotes sedimentation and nutrient uptake by phytoplankton.

**Figure 8-27. Wet Pond Depth Zones**

![Diagram of wet pond depth zones with labels: 10 ft (min.) for 10:1 or flatter, 6" for littoral zone, 18" (max.) for average depth, 4-8 ft (12 ft max.) for deeper zone.]

Distribute component areas as follows:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percent of Permanent Pool Surface Area</th>
<th>Design Water Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forebay</td>
<td>5-10%</td>
<td>2-4 ft</td>
</tr>
<tr>
<td>Littoral zone</td>
<td>25-40%</td>
<td>6-18 in</td>
</tr>
<tr>
<td>Deeper zone</td>
<td>55-65%</td>
<td>4-8 ft (average)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 ft (maximum)</td>
</tr>
</tbody>
</table>

Estimate average depth of permanent pool \((D_{avg})\) including all zones.
Estimate water surface area of the permanent pool \((A_{pp})\) based on actual \(V_{pp}\).

\[
A_{pp} = \frac{V_{pp}}{D_{avg}}
\]

Where:
\[ V_{pp} = \text{minimum volume of permanent pool (ft}^3\text{); and} \]
\[ D_{avg} = \text{average depth of permanent pool (ft).} \]

Estimate water surface elevation of the permanent pool \((WS \text{ Elev}_{pp})\) based on site elevations.
Step 4 – Determine Inflow Requirement \((Q_{in})\)

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.

\[
Q_{in} = Q_{E-P} + Q_s + Q_{ET}
\]

Where:
- \(Q_{E-P}\) = Loss due to evaporation minus the gain due to precipitation (acre-ft/mo);
- \(Q_s\) = Loss or gain due to seepage to groundwater (acre-ft/mo); and
- \(Q_{ET}\) = 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 sedimentation of larger particles and has a solid bottom surface to facilitate mechanical removal of accumulated sediment. The forebay is part of a permanent pool, and has a volume comprising of five (5) to ten (10) percent of the WQV. The depth of the permanent pool in the forebay should be two (2) to four (4) feet. Provide 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 eight (8) feet and side slopes no steeper than 4:1. Trash screens at the inlet are recommended to reduce dispersion of large trash articles throughout the basin.

Step 6 – Design Outlet Works

The outlet works are designed to release the WQV 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 WQV depth. An outlet works for a wet pond is depicted in Figure 8-28.
For single orifice outlet control or single row of orifices at the permanent pool elevation (WS Elevₚₚ) (see Figure 8-25), use the Orifice Equation based on the WQV (ft³) and depth of water above orifice centerline D (ft) to determine orifice area (in²):

\[ Q = C \times A \times \sqrt{2gD} \]

Where:

- \( C \) = orifice coefficient (use 0.61);
- \( A \) = area of orifice (in²);
- \( g \) = acceleration due to gravity (32.2 ft/sec²); and
- \( D \) = depth of water above orifice centerline (Dₓₚₚ, ft).

The equation can be solved for \( A \) based on the WQV and design drawdown time (t) using the following conversion of the Orifice Equation:
\[ A = \frac{WQV}{61.19 \times D^{0.5} \times t} \]

Where:

\( WQV \) = water quality volume (ft\(^3\));
\( D \) = depth of water above orifice centerline (\( D_{WQV} \), ft); and
\( t \) = drawdown period (hr) = 12 hours.

For perforated pipe outlets or vertical plates with multiple orifices (see Figure 8-24), use the following equation to determine required area per row of perforations (\( A_r \)), based on the WQV (acre-ft) and depth of water above centerline of the bottom perforation, D (ft).

\[ A_r = \frac{WQV}{K_{12}} \]

Where:

\( WQV \) = water quality volume (acre-ft); and
\( K_{12} = 0.008 \times D^2 + 0.056 \times D - 0.012 \).

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

\[ n_r = 1 + (D \times 3) \]

Where:

\( D \) = depth of water above orifice center line (ft).

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

\[ \text{Total Orifice Area} = A_r \times n_r \]

Where:

\( A_r \) = required area per row of perforations; and
\( n_r \) = number of rows.

**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 six (6) inches near the shore and extending to no more than twelve (12) inches at the furthest point from the short.

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 ten (10) percent and minimum width should be 16 feet. Ramps should be paved with concrete.

Step 11 – Design Diversion Structure

Provide for stormwater runoff bypass or overflow for volumes in excess of the WQV. Spillway and overflow structures should be designed in accordance with applicable City of Modesto Standard Specifications. See Appendix I for more information on diversion structure design.

Step 12 – Provide Underdrain Trenches

Provide underdrain trenches near the edge of the wet pond. The trenches should be no less than twelve (12) inches wide filled with ASTM C-33 sand to within two (2) feet of the wet pond’s permanent pool water surface, and with an underdrain pipe connected through a valve to the outlet. These underdrain trenches will permit the drying out of the pond when it has sediment must be removed to restore the pond’s volume.

Step 13 – Select Vegetation

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 four (4) to six (6) inch thick organic topsoil layer, and be vegetated with aquatic species.
**Step 14 – Design Security Fencing**

Provide aesthetic security fencing around the wet pond to protect habitat except when specifically waived by the City. Fencing design shall adhere to the City of Modesto Standard Specifications, and be approved by the City.

**Volume Retention Calculation**

No volume retention credit is provided for a wet pond because it does not fully retain the WQV. However, wet ponds may be used to meet treatment control requirements.

**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.

**Long-Term Maintenance**

The City requires execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, which includes treatment control measures such as wet ponds. Such agreements typically include requirements such as those outlined in Table 8-48. The property owner or property owner’s designee is responsible for compliance with the agreement. The maintenance agreement must provide the City with complete access to the treatment control measure and its immediate vicinity at any time. Treatment control measure maintenance is the responsibility of the property owner. A sample maintenance agreement is presented in Appendix D.
Table 8-48. Inspection and Maintenance Requirements for Wet Ponds

<table>
<thead>
<tr>
<th>Activity</th>
<th>Schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remove litter and debris from banks and pond bottom.</td>
<td>As required</td>
</tr>
<tr>
<td>Inspect wet pond for the following items: clogging of outlet;</td>
<td></td>
</tr>
<tr>
<td>differential settlement; cracking; erosion; leakage; tree growth on the</td>
<td></td>
</tr>
<tr>
<td>embankment; the condition of riprap in the inlet, outlet, and pilot</td>
<td></td>
</tr>
<tr>
<td>channels; sediment accumulation in the pond; trash and debris</td>
<td></td>
</tr>
<tr>
<td>accumulation; damage from burrowing animals; and the health and density</td>
<td></td>
</tr>
<tr>
<td>of grass turf on the side slopes and floor. Correct observed problems</td>
<td></td>
</tr>
<tr>
<td>as necessary.</td>
<td></td>
</tr>
<tr>
<td>If permitted by the California Department of Fish and Game or other</td>
<td>As required</td>
</tr>
<tr>
<td>regulatory agency, stock pond with mosquito fish to enhance natural</td>
<td></td>
</tr>
<tr>
<td>mosquito and midge control.</td>
<td></td>
</tr>
<tr>
<td>Harvest vegetation for vector control and to maintain effective</td>
<td>Annually or more frequently if required</td>
</tr>
<tr>
<td>permanent pool volume</td>
<td></td>
</tr>
<tr>
<td>Remove sediment when accumulation reaches 25 percent of original design</td>
<td>Clean in early spring so vegetation damaged during cleaning has time</td>
</tr>
<tr>
<td>depth or if resuspension is observed. (Note: Sediment removal may not</td>
<td>to reestablish.</td>
</tr>
<tr>
<td>be required in the main basin for as long as 20 years.)</td>
<td></td>
</tr>
<tr>
<td>Clean forebay to minimize frequency of main pond cleaning.</td>
<td>As required</td>
</tr>
</tbody>
</table>
P-1: Proprietary Treatment Control Measures

The 2001 Guidance Manual provided information for selecting and designing the more common on-site stormwater treatment control measures for development projects. The standard treatment control measures included in this section (R-1 to R-14 and C-1 to C-4) are non-proprietary (public domain) designs that have been reviewed and evaluated by the City and determined generally acceptable. Because the performance of these control measures has already been demonstrated and reviewed by the City, the plan check review and approval process will be routine for development projects that have selected one or more of these control measures.

However, the City recognizes that these non-proprietary treatment control measures may not be appropriate for all projects due to physical site constraints. Thus, if the volume retention requirement has been met through the use of LID control measures, the City will allow the use of proprietary control measures that have been approved for general use by the City in those projects where the use of non-proprietary treatment controls have been demonstrated by the applicant to the satisfaction of the City to be impractical. Proprietary devices that are approved by the City for general use are listed in Appendix J 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.

In general, any proprietary device must be designed to treat the WQF or WQV. Procedures to calculate the WQF and WQV are provided in Fact Sheet C-2. Stormwater runoff in excess of the WQF or WQV may be diverted around or through a treatment device. However, use of alternative sizing criteria is allowed for certain devices as indicated in Appendix J. Any proposed device must include all maintenance, operation, and construction requirements, as indicated in Appendix D and as recommended by the manufacturer.
SECTION 9. CONTROL MEASURE MAINTENANCE

Continued effectiveness of control measures specified in the 2011 Revised Guidance Manual depends on inspection and maintenance. To ensure that such maintenance is provided, the City requires the submittal of a Maintenance Plan and execution of a Maintenance Agreement with the owner/operator of stormwater control measures prior to issuance of the Building Permit for a private development project, which may include one or more of the control measures detailed in Sections 7 and 8. The property owner or his/her designee is responsible for complying with the Maintenance Agreement. Requirements for the Maintenance Plan and Maintenance Agreement are presented and discussed in this section. Sample Maintenance Agreements are provided in Appendix D.

9.1. Maintenance Plan

A post-construction Maintenance Plan shall be prepared and submitted to the City as part of the Project Stormwater Quality Control Measures Plan submittal. The Maintenance Plan should address items such as:

- Operation plan and schedule, including a site map;
- Maintenance and cleaning activities and schedule;
- Equipment and resource requirements necessary to operate and maintain facility; and
- Responsible party for operation and maintenance.

This section identifies basic information that shall be included in a Maintenance Plan. Refer to Fact Sheets for individual control measures regarding device-specific maintenance requirements.

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 a legend, identify 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.
• With a 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.

**Baseline Descriptions**

• List property owners and persons responsible for operation and maintenance of the stormwater control measures on-site. Include phone numbers and addresses.

• Identify intended method of funding (i.e., homeowners association fees) for operation, inspection, routine maintenance, and upkeep of stormwater control measures.

• List all permanent stormwater control measures. Provide a brief description of stormwater control measure selected and, if appropriate, fact sheets or additional information.

• As appropriate for each stormwater control measure, provide:
  
  o 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 to perform and document the maintenance.

  o A description of site inspection procedures and documentation system, including recordkeeping and retention requirements.

  o 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.

  o Identification of equipment and materials required to perform maintenance.

• As appropriate, list all housekeeping procedures for prohibiting illicit discharges or potential illicit discharges to the storm drain system. Identify housekeeping BMPs that reduce maintenance of treatment control measures.
Spill Plan

- Provide emergency notification procedures (phone and agency/persons to contact).
- As appropriate for site, provide emergency containment and cleaning procedures.
- Note downstream receiving waters, wetlands, or ESAs that may be affected by spills or chronic untreated discharges.
- As appropriate, create an emergency sampling procedure for spills. Emergency sampling can protect the property owner from erroneous liability for downstream receiving area cleanups.

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.

Training

- Identify appropriate persons to be properly trained and assure documentation of training.
- Training should include:
  - Good housekeeping procedures defined in the Maintenance Plan;
  - Proper maintenance of all pollution mitigation devices;
  - Identification and cleanup procedures for spills and overflows;
  - Large-scale spill or hazardous material response; and
  - Safety concerns when maintaining devices and cleaning spills.

Basic Inspection and Maintenance Activities

- Create and maintain on-site, a log for inspector names, dates, and stormwater control measure devices to be inspected and maintained. Provide a checklist for each inspection and maintenance category.
- Perform and document 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 bypass stormwater control measures.
• Perform an annual assessment of each pollution-generating operation and its associated stormwater control measures to determine if any part of the pollution reduction train can be improved. Annual assessment reports must be submitted to the City.

Revisions to Pollution Mitigation Measures

• If future correction or modification of past stormwater control measures or procedures is required, the owner shall obtain approval from the City prior to commencing any work. Corrective measures or modifications shall not cause discharges to bypass or otherwise impede existing stormwater control measures.

9.2. Maintenance Agreement

Verification of maintenance provisions is required for all stormwater control measures specified in the 2011 Revised Guidance Manual, whether Site Design Control Measures (Section 4), Source Control Measures (Section 5), LID Control Measures (Section 7), or Treatment Control Measures (Section 8). Verification, at a minimum, shall include:

• The owner/developer’s signed statement accepting responsibility for inspection and maintenance until the responsibility is legally transferred. A sample Owners Certification statement is provided in Appendix D; and either
• A signed statement from the public entity assuming responsibility for stormwater control measure inspection and maintenance and certifying that it meets all City design standards; or
• 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; or
• Written text in project conditions, covenants, and restrictions for residential properties that assign maintenance responsibilities to the Home Owners Association for inspection and maintenance of stormwater control measures; or

A legally enforceable maintenance agreement that assigns responsibility for inspection and maintenance of post-construction control measures to the owner/operator. A Maintenance Agreement with the City must be executed by the owner/operator before occupancy of the project is approved. Example Maintenance Agreement forms are provided in Appendix D.
APPENDIX A

Glossary of 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.

Berm: An earthen, asphalt, or concrete mound used to direct the flow of stormwater runoff around or through a structure.

Best Management Practices (BMPs): Methods, measures, or practices designed and selected to reduce or eliminate pollutant discharge to surface waters from point and nonpoint source discharges including stormwater. BMPs include structural and non-structural control measures 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 stormwater 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, commercial retail nurseries, car wash facilities, mini-malls, business complexes, shopping malls, hotels, office buildings, public warehouses, and light industrial facilities.

Conduit: Any channel or pipe for directing the flow of water.

Construction Activity: Includes clearing, grubbing, grading, excavation, demolition, and contractor activities that result in soil disturbance.

Construction General Permit: An NPDES permit issued by the SWRCB for the discharge of stormwater associated with construction and land disturbance activities equal to or greater than one (1) acre. (Construction General Permit No. CAS000002).

Conventional Treatment Control Measures: A subset of treatment control measures that can be designed to treat the WQV/WQF. These control measures typically do not reduce stormwater runoff volumes, and cannot be used to help meet the Volume Retention Requirement. For the purpose of this Guidance Manual, these are treatment control measures identified as C-XX.
Appendix A – Glossary of Terms and List of Acronyms

Conveyance System: Any channel or pipe for collecting and directing stormwater runoff.

Culvert: A covered channel or a large diameter pipe that crosses under a road, sidewalk, etc.

Denuded: Land stripped of vegetation or land that has had its vegetation worn down due to the impacts from the elements or humans.

Detention: The temporary storage of stormwater runoff to allow treatment by sedimentation and metered discharge of stormwater 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 land disturbing activities; structural development including construction or installation of a building or structure, creation of impervious surfaces; and land subdivisions.

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 via a man-made structure;
- Discharges through pipes, sewers, or other conveyance 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, grubbing, grading, demolition, and/or excavation.

Effluent Limitations: Limits on amounts of pollutants that may be contained in a discharge. Can be expressed in a number of ways including as a concentration over a time period (e.g., 30-day average must be less than 20 mg/L), as a total mass per time unit, or as a narrative limit.
Appendix A – Glossary of Terms and List of Acronyms

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, commercial, or industrial development, road building, or timber cutting.

Excavation: The process of removing earth, stone, or other materials, usually by digging.

Geotextile Fabric: Filter fabric of relatively small mesh or pore size that is used to allow water to pass through while keeping sediment out.

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 USEPA 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 USEPA or state lists. Regulated under the federal Resource Conservation and Recovery Act (RCRA) and the California Health and Safety Code.

Hydromodification: Change in 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. 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.

Illegal Discharge: Any discharge to the storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term “illegal discharge” includes all non-stormwater discharges except discharges pursuant to an NPDES permit and discharges authorized by the Central Valley Regional Water Quality Control Board.

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.
Appendix A – Glossary of Terms and List of Acronyms

Impermeable Liner: Filter fabric of relatively small mesh or pore size that is used to prevent both water and sediment from passing through.

Impervious Surface/Cover: A hard surface area that impedes the natural infiltration of stormwater and causes water to run off 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: An NPDES permit (No. CAS000001) issued by the State Water Resources Control Board (SWRCB) for the discharge of stormwater associated with industrial activity. Board Order 97-03-DWQ or subsequent reissuance of this Order.

Infiltration: The downward entry of water into the soil surface.

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 vegetation 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 Control Measure: A BMP that is used to reduce stormwater runoff volumes. The stormwater runoff reduction achieved by these BMPs can be used to help meet the Volume Retention Requirement.

Material Storage Areas: On-site locations where raw materials, products, final products, by-products, or waste materials are stored.

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 stormwater runoff, 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, reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under CWA §307, 402, 318, and 405.
Appendix A – Glossary of Terms and List of Acronyms

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 the storm drain system that is not composed entirely of stormwater runoff. 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 the State Water Resource Control Board (SWRCB) submitted by the owner/developer of an industrial facility or construction site that said owner seeks coverage under a General Permit for discharges associated with industrial or 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 Industrial General Permit or Construction General Permit.

Notice of Termination (NOT): Formal notice to the State Water Resources Control Board (SWRCB) submitted by owner/developer that a construction project is complete.

Outfall: The point where stormwater runoff 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: (for the purposes of this Guidance Manual only) 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 25 or more parking spaces.

Permeability: A soil property that enables water or air to move through it. Usually expressed in inches/hour or inches/day.

Permit Registration Documents (PRDs): A formal notice to the 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 construction or industrial activities. The PRDs provide information on the owner, location, type of project, and certifies that the owner will comply with the conditions of the Construction General Permit or Industrial General Permit.

Point Source: Any discernible, confined, and discrete conveyance from which pollutants and/or water flow 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 land use condition prior to the proposed development activity.

Receiving Stream: (for purposes of this Guidance Manual only) any natural or man-made surface water body that receives and conveys stormwater runoff.

Redevelopment: (for the purposes of this Guidance Manual only) Land-disturbing activity that results in the creation, addition, or replacement of 5,000 square feet or more of impervious surface area on an already developed site. Redevelopment includes, but is not limited to, expansion of a building footprint, 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 to structural or impervious surfaces. 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. (Examples: Routine repaving or resurfacing a parking lot is not considered redevelopment. Removing a parking area to construct or expand a structure is considered redevelopment. Re-roofing a building is not considered redevelopment. Removing a building and constructing a new structure is considered redevelopment.)

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: 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 runoff to prevent it from leaving the development site.

Runoff: Water originating from precipitation 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.
Appendix A – Glossary of Terms and List of Acronyms

Run-on: Water flow which enters property or area other than that where it originated. Off-site water 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 precipitation, 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 storm events.

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 the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); any chemical the facility is required to report pursuant of Section 313 of Title III of Superfund Amendments and Reauthorization Act (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, concentration, 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 schedule 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.

Storm Drains: Above- and below-ground structures for transporting stormwater runoff 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.
Appendix A – Glossary of Terms and List of Acronyms

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 as defined in the City’s Stormwater Permit.

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 plan 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.

Treatment Control Measure: An 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: 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.

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 Retention Requirement: New development and significant redevelopment priority projects must reduce post-project runoff volume to pre-project runoff volumes for the 0.50-inch rainfall event (85th percentile, 24-hour storm depth) using a combination of LID and Treatment Control Measures.

Volume Retention Treatment Control Measures: A subset of treatment control measures that can be designed to retain some or all of the WQV/WQF. For the purpose of this Guidance Manual, these are treatment control measures identified as R-XX.
**LIST OF ACRONYMS**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAT</td>
<td>Best available technology (economically achievable)</td>
</tr>
<tr>
<td>BCT</td>
<td>Best conventional technology (pollution control)</td>
</tr>
<tr>
<td>BMP</td>
<td>Best Management Practice</td>
</tr>
<tr>
<td>CASQA</td>
<td>California Stormwater Quality Association</td>
</tr>
<tr>
<td>CCR</td>
<td>California Code of Regulations</td>
</tr>
<tr>
<td>CERCLA</td>
<td>Comprehensive Environmental Response, Compensation, and Liability Act</td>
</tr>
<tr>
<td>CFR</td>
<td>Code of Federal Regulations</td>
</tr>
<tr>
<td>cfs</td>
<td>Cubic feet per second</td>
</tr>
<tr>
<td>CVRWQCB</td>
<td>Central Valley Regional Water Quality Control Board</td>
</tr>
<tr>
<td>CWA</td>
<td>Clean Water Act (1972)</td>
</tr>
<tr>
<td>EIR</td>
<td>Environmental Impact Report</td>
</tr>
<tr>
<td>ESA</td>
<td>Environmentally-sensitive area</td>
</tr>
<tr>
<td>FAR</td>
<td>Floor to area ratio</td>
</tr>
<tr>
<td>IPM</td>
<td>Integrated Pest Management</td>
</tr>
<tr>
<td>LID</td>
<td>Low Impact Development</td>
</tr>
<tr>
<td>MDL</td>
<td>Method detection limit</td>
</tr>
<tr>
<td>MEP</td>
<td>Maximum extent practicable</td>
</tr>
<tr>
<td>MGD</td>
<td>Million gallons per day</td>
</tr>
<tr>
<td>MS4</td>
<td>Municipal separate storm sewer system</td>
</tr>
<tr>
<td>MSDS</td>
<td>Material Safety Data Sheet</td>
</tr>
<tr>
<td>NOI</td>
<td>Notice of Intent</td>
</tr>
<tr>
<td>NOT</td>
<td>Notice of Termination</td>
</tr>
<tr>
<td>NPDES</td>
<td>National Pollutant Discharge Elimination System</td>
</tr>
</tbody>
</table>
### Appendix A – Glossary of Terms and List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRCS</td>
<td>National Resources Conservation Service</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations and maintenance</td>
</tr>
<tr>
<td>POC</td>
<td>Pollutant of concern</td>
</tr>
<tr>
<td>POTW</td>
<td>Publicly-owned treatment works</td>
</tr>
<tr>
<td>RCRA</td>
<td>Resource Conservation and Recovery Act</td>
</tr>
<tr>
<td>RGO</td>
<td>Retail gasoline outlet</td>
</tr>
<tr>
<td>SARA</td>
<td>Superfund Amendments Reauthorization Act</td>
</tr>
<tr>
<td>SIC</td>
<td>Standard Industrial Classification</td>
</tr>
<tr>
<td>SWPPP</td>
<td>Stormwater Pollution Prevention Plan</td>
</tr>
<tr>
<td>SWRCB</td>
<td>State Water Resources Control Board</td>
</tr>
<tr>
<td>TMDL</td>
<td>Total Maximum Daily Load</td>
</tr>
<tr>
<td>TSS</td>
<td>Total suspended solids</td>
</tr>
<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
</tr>
<tr>
<td>USEPA</td>
<td>United States Environmental Protection Agency</td>
</tr>
<tr>
<td>WQCF</td>
<td>City of Modesto Water Quality Control Facility</td>
</tr>
<tr>
<td>WQF</td>
<td>Water quality flow</td>
</tr>
<tr>
<td>WQV</td>
<td>Water quality volume</td>
</tr>
</tbody>
</table>
Volume Retention Requirement Summary Worksheet

| Project: | ______________________________________________________________________ |
| Detail: | ______________________________________________________________________ |
| Design by: | ______________________________________________________________________ |
| Date: | ______________________________________________________________________ |

1. **Project Drainage Area Characteristics: Pre-Project**
   - Weighted stormwater runoff coefficient: \( C_{r,\text{pre}} = \) ____________
   - See Section 6 of Guidance Manual
   - Total drainage area: \( A_{\text{pre}} = \) ____________ ft\(^2\)
   - Pre-project stormwater runoff volume: \( V_{\text{pre}} = \) ____________ ft\(^3\)
   - \( V_{\text{pre}} = (0.50/12) \times A_{\text{pre}} \times C_{r,\text{pre}} \)

2. **Project Drainage Area Characteristics: Post-Project**
   - Weighted stormwater runoff coefficient: \( C_{r,\text{post}} = \) ____________
   - See Section 6 of Guidance Manual
   - Total drainage area: \( A_{\text{post}} = \) ____________ ft\(^2\)
   - Post-project stormwater runoff volume: \( V_{\text{post}} = \) ____________ ft\(^3\)
   - \( V_{\text{post}} = (0.50/12) \times A_{\text{pre}} \times C_{r,\text{pre}} \)
   - Volume retention requirement: \( V_{\text{ret,req}} = \) ____________ ft\(^3\)
   - \( V_{\text{ret}} = V_{\text{post}} - V_{\text{pre}} \)

3. **Low Impact Development (LID) Control Measures**
   - Total number of LID control measures in project: \( n_{\text{LID}} = \) ____________
   - Total volume retention credits from LID control measures: \( V_{\text{ret,LID}} = \) ____________ ft\(^3\)
   - \( \Sigma V_{\text{ret,LID}} \)
   - Total tributary impervious area credits for application to effective area calculation: \( A_{\text{credit}} = \) ____________ ft\(^2\)
   - \( \Sigma A_{\text{credit}} \)
   - Remaining volume retention requirement after LID control measures: \( V_{\text{ret,rem}} = \) ____________ ft\(^3\)
   - \( V_{\text{ret,rem}} = V_{\text{ret,req}} - \Sigma V_{\text{ret,LID}} \)

4. **Volume Retention Control Measures**
   - Total volume retention credit from volume retention control measures: \( V_{\text{ret,vr}} = \) ____________ ft\(^3\)
   - \( V_{\text{ret,vr}} = \Sigma V_{\text{ret,vr}} \)
   - Total volume retention provided for project: \( V_{\text{ret,proj}} = \) ____________ ft\(^3\)
   - \( V_{\text{ret,proj}} = \Sigma V_{\text{ret,LID}} + \Sigma V_{\text{ret,vr}} \)
   - Volume retention remaining: \( V_{\text{ret,rem,f}} = \) ____________ ft\(^3\)
   - \( V_{\text{ret,rem,f}} = V_{\text{ret,req}} - V_{\text{ret,proj}} \)

Note: If \( V_{\text{ret,rem}} > 0 \), the volume retention requirement is not fully met. Meeting the volume retention requirement may be an iterative process for most sites. Designers should return to prior steps to explore alternative combinations of LID and volume retention control measures. If the meeting of the full volume retention requirement is infeasible, a Volume Retention Requirement Waiver Application must be submitted (see Section 8 and Appendix C).

* Apply reductions to volume retention requirement as appropriate for significant redevelopment.
### Project Drainage Area Characteristics: Pre-Project

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted stormwater runoff coefficient ( C_{r,pre} )</td>
<td>0.03</td>
<td>( C_{r,pre} = \frac{V_{pre}}{A_{pre}} )</td>
</tr>
<tr>
<td>Total drainage area ( A_{pre} )</td>
<td>84,000 ft(^2)</td>
<td></td>
</tr>
<tr>
<td>Pre-project stormwater runoff volume ( V_{pre} )</td>
<td>105 ft(^3)</td>
<td>( V_{pre} = \left( \frac{0.50}{12} \right) \times A_{pre} \times C_{r,pre} )</td>
</tr>
</tbody>
</table>

### Project Drainage Area Characteristics: Post-Project

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted stormwater runoff coefficient ( C_{r,post} )</td>
<td>0.74</td>
<td>( C_{r,post} = \frac{V_{post}}{A_{post}} )</td>
</tr>
<tr>
<td>Total drainage area ( A_{post} )</td>
<td>84,000 ft(^2)</td>
<td></td>
</tr>
<tr>
<td>Post-project stormwater runoff volume ( V_{post} )</td>
<td>2,590 ft(^3)</td>
<td>( V_{post} = \left( \frac{0.50}{12} \right) \times A_{post} \times C_{r,post} )</td>
</tr>
<tr>
<td>Volume retention requirement ( V_{ret,req} )</td>
<td>2,485 ft(^3)</td>
<td>( V_{ret} = V_{post} - V_{pre} )</td>
</tr>
</tbody>
</table>

### Low Impact Development (LID) Control Measures

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of LID control measures in project ( n_{LID} )</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Total volume retention credits from LID control measures ( V_{ret,LID} )</td>
<td>180 ft(^3)</td>
<td>( \sum V_{ret,LID} )</td>
</tr>
<tr>
<td>Total tributary impervious area credits for application to effective area calculation ( A_{credit} )</td>
<td>126 ft(^2)/tree</td>
<td>( \sum A_{credit} )</td>
</tr>
<tr>
<td>Remaining volume retention requirement after LID control measures ( V_{ret,rem} )</td>
<td>2,305 ft(^3)</td>
<td>( V_{ret,rem} = V_{ret,req} - \sum V_{ret,LID} )</td>
</tr>
</tbody>
</table>

### Volume Retention Control Measures

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total volume retention credit from volume retention control measures ( V_{ret, vr} )</td>
<td>650 ft(^3)</td>
<td>( V_{ret, vr} = \sum V_{ret, vr} )</td>
</tr>
<tr>
<td>Total volume retention provided for project ( V_{ret, proj} )</td>
<td>830 ft(^3)</td>
<td>( V_{ret, proj} = \sum V_{ret,LID} + \sum V_{ret, vr} )</td>
</tr>
<tr>
<td>Volume retention remaining ( V_{ret, rem, l} )</td>
<td>1,655 ft(^3)</td>
<td>( V_{ret, rem, l} = V_{ret, req} - V_{ret, proj} )</td>
</tr>
</tbody>
</table>

Note: If \( V_{ret, rem} > 0 \), the volume retention requirement is not fully met. Meeting the volume retention requirement may be an iterative process for most sites. Designers should return to prior steps to explore alternative combinations of LID and volume retention control measures. If the meeting of the full volume retention requirement is infeasible, a Volume Retention Requirement Waiver Application must be submitted (see Section 8 and Appendix C).

* Apply reductions to volume retention requirement as appropriate for significant redevelopment.
Volume Retention Requirement Waiver Application
Appendix C – Volume Retention Requirement Waiver Application

For Priority Redevelopment Projects, a waiver may be granted if the volume retention requirement cannot be met due to site constraints, such as a high groundwater table. All Priority New Development Projects are required to meet the volume retention requirement.

Even if the project cannot meet the full volume retention requirement, the project must still retain volume to the maximum extent practicable and treat the full water quality volume (WQV)/water quality flow (WQF). Meeting the volume retention requirement is an iterative process. Designers should return to prior steps to explore alternative combinations of low impact development (LID) and treatment control measures. The burden of proof is on the project applicant to justify why the full volume retention requirement cannot be met. Economic hardship is not an acceptable reason for noncompliance. In general, the City of Modesto (City) does not expect to grant waivers for the volume retention requirement.

The final determination will be made by City of Modesto Community and Economic Development Department. The City has the authority to reject a Volume Retention Requirement Waiver request if LID or treatment control measures are considered feasible at the project site.

Consideration of a waiver request requires applicants to:

• Retain volume to the maximum extent practicable, even if the full volume retention requirement cannot be met;
• Treat the full WQV/WQF;
• Consider all LID and treatment control measures. Applicants must show why certain LID and/or treatment control measures are not feasible at the development site.
• Submit this application with or prior to preliminary site plan submission.
• Obtain the signature and stamp of the project engineer, who must be registered in California.
• Submit the volume retention design summary worksheet (Appendix B) along with this application.
City of Modesto
Community and Economic Development Department
Volume Retention Requirement Waiver Application

1. Project Name

2. Project Category
(See Section 2 for categories)

3. Property Description
(include location, size, land uses, etc.)

4. Owner/Developer's Name
   Address
   Phone

5. Plan Preparer's Name
   Address
   Phone

6. Volume Retention
   Volume Retention Requirement
   (Volume Retention Requirement Summary
    Worksheet, $V_{ret,req}$)
   Volume Retention Provided
   (Volume Retention Requirement Summary
    Worksheet, $V_{ret,prov}$)
   Volume Retention Remaining
   (Volume Retention Requirement Summary
    Worksheet, $V_{ret,rem}$)

Type and Number of LID Control Measures Proposed:
   ____ Rain Garden (L-1)
   ____ Rain Barrel/Cistern (L-2)
   ____ Vegetated Roof (L-3)
   ____ Interception Tree (L-4)
   ____ Grassy Channel (L-5)
   ____ Vegetated Buffer Strip (L-6)
Type and Number of Treatment
Control Measures Proposed:

___ Infiltration Well (R-1)
___ Water Quality Infiltration Basin (R-2)
___ Water Quality Infiltration Trench (R-3)
___ Bioretention without an Underdrain (R-4)
___ Dry Well (R-5)
___ French Drain (R-6)
___ Permeable Pavement without an Underdrain (R-7)
___ Bioretention with an Underdrain (R-8)
___ Permeable Pavement an Underdrain (R-9)
___ Stormwater Planter (R-10)
___ Tree-Well Filter (R-11)
___ Vegetated Swale (R-12)
___ Grassy Swale (R-13)
___ Vegetated Filter Strip (R-14)
___ Media Filter (C-1)
___ Constructed Wetland (C-2)
___ Extended Detention Basin (C-3)
___ Wet Pond (C-4)

7. **Describe Why a Volume Reduction Requirement Waiver is Needed**
   (please include specifics regarding site constraints – e.g., results of any soil testing that may have been done)
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 D1

Stormwater Treatment Device Access and Maintenance Agreement
STORMWATER TREATMENT DEVICE
ACCESS AND MAINTENANCE AGREEMENT

OWNER: ________________________________

PROPERTY ADDRESS: ________________________________

APN: ________________________________

THIS AGREEMENT is made and entered into in Modesto, California, this _____ day of _____, ____, by and between ________________________________, hereinafter referred to as “Owner” and the CITY OF MODESTO, a municipal corporation, located in the County of Stanislaus, State of California hereinafter referred to as “CITY”;

WHEREAS, the Owner owns real property (“Property”) in the City of Modesto, County of Stanislaus, State of California, more specifically described in Exhibit “A” and depicted in Exhibit “B“, each of which exhibits is 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 of Modesto City Council Resolution No. ________________________________ or Planning Commission Resolution No. ________________________________ or Planning Department Certificate of Approval No. ________________________________ 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 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 maintenance or 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, filter material replacement and 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. The recitals set forth above, the exhibits set forth in the recitals, the introductory paragraph preceding the recitals, and all defined terms set forth in both, are hereby incorporated into this Agreement as set forth herein in full.

2. 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 Utilities Director 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. City shall make every effort at all times to minimize or avoid interference with Owner’s use of the Property.

3. Owner shall use its best efforts diligently to 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. As may be 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.

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 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, 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.

5. 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 state 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 respect to the property on which a Device has been installed until such time as Owner repays to City it’s reasonable cost incurred in accordance with paragraph 3 above.

6. This agreement shall be recorded in the Office of the Recorder of Stanislaus 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.

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 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.
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 City 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 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 the address set forth below. 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.

IF TO CITY:
City of Modesto
Utilities Department
P.O. Box 642
Modesto, CA 95353

IF TO OWNER:


IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

CITY OF MODESTO, a Municipal Corporation

By: __________________________
    JAMES HOLGERSSON, City Manager

ATTEST:

By: __________________________
    STEPHANIE LOPEZ, City Clerk

(SEAL)

OWNER:

By: __________________________
    (Signature)

        (Print Name & Title)

By: __________________________
    (Signature)

        (Print Name & Title)

Approved as to form:
ADAM U. LINDGREN, City Attorney

By: __________________________
    ROLAND R. STEVENS,
    Special Counsel

Approved as to sufficiency:

By: __________________________
    GAYLE ZIEGLER,
    Environmental Compliance Inspector II
Exhibit A
Legal Description of Property
Exhibit B
Property Map
APPENDIX D2

Stormwater Low Impact Development Structure
Access and Maintenance Agreement
STORMWATER LOW IMPACT DEVELOPMENT STRUCTURE ACCESS AND MAINTENANCE AGREEMENT

OWNER: ________________________________________________________________
PROPERTY ADDRESS: ___________________________________________________
APN: ________________________________________________________________

THIS AGREEMENT is made and entered into in Modesto, California, this______ day of____________, by and between ____________________________________________________________________________________________, hereinafter referred to as “Owner” and the CITY OF MODESTO, a municipal corporation, located in the County of Stanislaus, State of California hereinafter referred to as “CITY”;

WHEREAS, the Owner owns real property (“Property”) in the City of Modesto, County of Stanislaus, State of California, more specifically described in Exhibit “A” and depicted in Exhibit “B”, each of which exhibits is 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 of Modesto City Council Resolution No. _________________________________________________ or Planning Commission Resolution No. ________________________________ or Planning Department Certificate of Approval No. ________________________________ required the project to employ low impact development measures to minimize urban runoff;

WHEREAS, the Owner has chosen to install a ____________________________________________, herinafter referred to as “Structure”, as the on-site measure to minimize urban runoff;

WHEREAS, said Structure has been installed in accordance with plans and specifications accepted by the City;

WHEREAS, said Structure, with installation on private property and draining only private property, is a private facility with all maintenance or 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, filter material replacement and sediment removal, is required to assure peak performance of Structure 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. The recitals set forth above, the exhibits set forth in the recitals, the introductory paragraph preceding the recitals, and all defined terms set forth in both, are hereby incorporated into this Agreement as set forth herein in full.

2. Owner hereby provides the City or City’s designee complete access, of any duration, to the Structure and its immediate vicinity at any time, upon reasonable notice, or in the event of emergency, as determined by City’s Utilities Director no advance notice, for the purpose of inspection, sampling, testing of the Structure, and in case of emergency, to undertake all necessary repairs or other preventative measures at owner’s expense as provided in paragraph 3 below. City shall make every effort at all times to minimize or avoid interference with Owner’s use of the property.

3. Owner shall use its best efforts diligently to maintain the Structure 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 Structure and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be 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.

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 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, 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.

5. 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 state 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 with draw any previous stormwater related approval with respect to the property on which a Structure has been installed until such time as Owner repays to City its reasonable cost incurred in accordance with paragraph 3 above.

6. This Agreement shall be recorded in the Office of the Recorder of Stanislaus 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, as 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.

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 City in enforcing the terms of this Agreement, including reasonable attorney’s fees and costs, and that the same shall become 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 City 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 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 the address set forth below. 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.

IF TO CITY:
City of Modesto
Utilities Department
P.O. Box 642
Modesto, CA 95353

IF TO OWNER:
IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

CITY OF MODESTO, a Municipal Corporation

By: ____________________________
    JAMES HOLGERSSON, City Manager

OWNER:

By: ____________________________
    (Signature)

ATTEST:

By: ____________________________
    STEPHANIE LOPEZ, City Clerk
    (SEAL)

By: ____________________________
    (Signature)
    (Print Name & Title)

Approved as to form:
ADAM U. LINDGREN, City Attorney

By: ____________________________
    ROLAND R. STEVENS, Special Counsel

Approved as to sufficiency:

By: ____________________________
    GAYLE ZIEGLER,
    Environmental Compliance Inspector II
Exhibit B
Property Map
APPENDIX D3

Stormwater Treatment Device and Low Impact Development Structure Access and Maintenance Agreement
STORMWATER TREATMENT DEVICE AND LOW IMPACT DEVELOPMENT STRUCTURE ACCESS AND MAINTENANCE AGREEMENT

OWNER: ____________________________________________
PROPERTY ADDRESS: ____________________________________________
APN: ____________________________________________

THIS AGREEMENT is made and entered into in Modesto, California, this____ day of ________, ______, by and between __________________________, hereinafter referred to as "Owner" and the CITY OF MODESTO, a municipal corporation, located in the County of Stanislaus, State of California hereinafter referred to as “CITY”;

WHEREAS, the Owner owns real property ("Property") in the City of Modesto, County of Stanislaus, State of California, more specifically described in Exhibit “A” and depicted in Exhibit “B”, each of which exhibits is 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 of Modesto City Council Resolution No. __________________________ or Planning Commission Resolution No. __________________________ or Planning Department Certificate of Approval No. __________________________ required the project to employ on-site control measures to minimize pollutants in urban runoff and Low Impact Development (LID) devices, structures, and or areas to reduce or contain all storm water runoff on site.;

TREATMENT CONTROL DEVICE – STRUCTURE – AREA

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 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 maintenance or 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, filter material replacement and 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:

12. The recitals set forth above, the exhibits set forth in the recitals, the introductory paragraph preceding the recitals, and all defined terms set forth in both, are hereby incorporated into this Agreement as set forth herein in full.

13. 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 Utilities Director 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. City shall make every effort at all times to minimize or avoid interference with Owner’s use of the property.

14. Owner shall use its best efforts diligently to 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. As may be 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.

15. 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, 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.

16. 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 state 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 respect to the property on which a Device has been installed until such time as Owner repays to City its reasonable cost incurred in accordance with paragraph 3 above.

17. This Agreement shall be recorded in the Office of the Recorder of Stanislaus 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, as also a lien in such amount as will fully reimburse the City, including interest as herein above set forth, subject to foreclosure in even of default in payment.
18. 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 part of the lien against said Property.

19. 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.

20. 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.

21. Time is of the essence in the performance of this Agreement.

22. Any notice 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 the address set forth below. 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.

IF TO CITY:  IF TO OWNER:
City of Modesto
Utilities Department
P.O. Box 642
Modesto, CA  95353

City of Modesto
Revised February 2015
Stormwater Management Plan
IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

CITY OF MODESTO, a Municipal Corporation

By: JAMES HOLGERSSON, City Manager

(Owner:

By: ____________________________
(Signature)

ATTEST:

By: STEPHANIE LOPEZ, City Clerk

(SEAL)

By: ____________________________
(Signature)

(Print Name & Title)

Approved as to form:
ADAM U. LINDGREN, City Attorney

By: ROLAND R. STEVENS, Special Counsel

Approved as to sufficiency:

By: ____________________________
GAYLE ZIEGLER,
Environmental Compliance Inspector II
Exhibit A
Legal Description of Property
OWNER’s CERTIFICATION

STORMWATER QUALITY CONTROL MEASURES PLAN

For

___________ (PROJECT NAME) ________

This Project Stormwater Quality Control Measures 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 Modesto Stormwater Quality Control Measures Plan (SWQCMP) for new development and redevelopment projects.

The undersigned understands that stormwater pollution control measures are enforceable requirements under the SWQCMP. 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 SWQCMP.

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: ________________________________
This appendix identifies the basic information and format that shall be included in the Project Stormwater Quality Control Measures Plan. The Project Stormwater Quality Control Measures Plan must be submitted to and approved by the City of Modesto (City) stormwater staff prior to issuance of building or use permits for the project.

Cover Page

The cover page must include the following information:

- Project name;
- Owner/developer’s name and contact information;
- Plan preparer’s name and contact information;
- Date submitted (first submittal); and
- Date revised (subsequent submittals, if required).

Owner’s Certification Statement

The owner’s certification statement requires the owner to legally accept responsibility for inspection and maintenance of stormwater control measures. A sample owner’s certification statement is available in Appendix D.

Project Description

The project description provides general information about the project type, description of the project, and site information. The following information must be included in the Project Stormwater Quality Control Measures Plan:

- Project type (See Section 2);
- Narrative description of project – size, location, pollutants of concern, land uses, etc.; and
- Site maps
  - Provide a vicinity map showing the location of the project relative to principal landmarks.
  - 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.
  - Identify locations of existing and proposed storm drain facilities, private sanitary sewer systems, and grade-breaks for purposes of pollution prevention.
  - With a 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 a legend, indicate types and locations of stormwater control measures that will be built to permanently control stormwater pollution.

Stormwater Pollution Control Measures

The Project Stormwater Quality Control Measures Plan must identify the types of control measures provided for the project site. The following information must be submitted to the City stormwater staff for review and approval:

• List each type of stormwater control measure provided;
• Site design control measures
  • Describe the site design controls (Section 4, G-1 to G-4). Indicate how site design will conform to the design criteria listed in the 2010 Guidance Manual.
  • If a site design control measure is not applicable to the project, provide a statement of justification describing why the site design control measure is not applicable to the project.
  • If implementation of a site design control measure is not feasible due to project site conditions, provide a statement of justification describing why implementation is not feasible.
• Source control measures
  • Describe the source control measures to be provided (Section 5, S-1 to S-8). Note that S-1: Storm Drain Message and Signage is required for all projects. Indicate how design of source control measures will conform to design criteria listed in the 2010 Guidance Manual.
• Low impact development (LID) control measures
  • Describe the LID control measures to be provided (Section 7, L-1 to L-6).
  • Use the Volume Retention Requirement Worksheet (Appendix B).
• Treatment control measures
  • Describe the treatment control measures to be provided (Section 8, R-1 to R-14, C-1 to C-4, P-1). Treatment control measures designated as R-1 to R-14 may provide volume retention benefits towards the volume retention requirement in addition to treatment benefits. Treatment control measures designated as C-1 to C-4 and P-1 do not provide volume retention benefits, but do provide treatment benefits.
  • If the volume retention requirement is not fully met through use of LID and/or treatment control measures, other alternative combinations of LID and/or treatment control measures must be evaluated. If the volume retention requirement is still not met following an alternatives evaluation, use the
Volume Retention Requirement Waiver Application (Appendix C) to provide justification as to why the volume retention requirement cannot be met. The City may approve or reject the volume retention requirement waiver.

- Summarize design data for treatment control measures. Provide detailed supporting calculations for design data values in a clear and organized manner.

**Maintenance Plan and Responsibility**

The Project Stormwater Quality Control Measures Plan must include information on the responsible party(ies) that will operate, inspect, and maintain stormwater control measures. The owner/developer must sign a certified, legally-binding maintenance agreement.

- Provide a summary of stormwater control measures to be provided and parties responsible for maintenance of each control measure. Indicate any anticipated transfer of responsibility due to future transfer of ownership or annexation.
- Provide complete contact information for each listed responsible party.
- Provide a statement that a detailed Maintenance Plan will be prepared in accordance with 2011 Guidance Manual requirements (see Section 9).
This appendix includes information on the hydrologic soil groups in the City of Modesto to use in designing various stormwater control measures.

Relevance of Hydrologic Soil Type Information

The hydrologic soil type of a development area are pertinent to design of control measures that involve infiltration and for identifying sites appropriate for detention basins. The predominant soil type 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 Soil Infiltration Rates

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Infiltration Rate (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.00 – 8.30</td>
</tr>
<tr>
<td>B</td>
<td>0.50 – 1.00</td>
</tr>
<tr>
<td>C</td>
<td>0.17 – 0.27</td>
</tr>
<tr>
<td>D</td>
<td>0.02 – 0.10</td>
</tr>
</tbody>
</table>

Infiltration rates shown represent the range covered by multiple sources (e.g., ASCE, BASMAA, etc.)

Hydrologic Soil Group

The soil types are classified by the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), formerly the Soil Conservation Service. There are four soil types: A, B, C and D. Soils may be classified by two groups. Type A and B soils have the highest infiltration rates, unless they have been compacted during construction. Sites with Type A and B soils are typically the best candidate soils for construction of infiltration facilities while sites with Type C or D soils are usually more appropriate for detention basins because of their lower infiltration rates.

Type A soils, such as sands and gravels, have a low runoff potential and high infiltration rate. Type B soils, such as sandy loam with moderately fine to moderately coarse texture, have moderate infiltration rates when completely wetted. Type C soils, which are typically silty-loam soils with an impeding layer or soils with moderately fine to fine texture, have slow infiltration rates when thoroughly wetted. Type D soils, which include clay soils with high swelling potential, soils in a permanent high water table, and shallow soils over nearly impervious material, have a high runoff potential and very slow infiltration rate when thoroughly wetted.

The hydrologic soil information presented here should be used as a general overview. For more specific information, consult the City of Modesto or contact the NRCS at (530) 662-3986.
Plants Suitable for Vegetative Control Measures
The primary purpose of vegetation is 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, but 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 of Modesto (City) stormwater staff regarding selection of appropriate vegetation.

A sample list of appropriate vegetative covers is presented in Table G-1. Additional suggested vegetative species are listed in Table G-2. 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

<table>
<thead>
<tr>
<th>Common Plant Name (Latin)</th>
<th>Appropriate Species</th>
<th>Maintenance and Usage Notes (1)</th>
</tr>
</thead>
</table>
| Bermuda Grass (Cynodon)   | Santa Ana hybrid Common | • Moderate maintenance.  
                          |                           | • Heat tolerant.  
                          |                           | • Dormant (brown) in winter.  
                          |                           | • Used for erosion control, swales. |
| Fescue (Festuca)          | Red fescue (F. rubra) | • Low to moderate maintenance.  
                          |                           | • Tolerates some shade and poor soil.  
                          |                           | • Used for lawns, swales, erosion control. |
| "Kentucky 31" Tall Fescue (F. elatior) |   | • Low maintenance.  
                          |                           | • Tolerate shade and compacted soils.  
                          |                           | • Rapid germination.  
                          |                           | • Useful as overseed for Bermuda grass during dormant (winter) season.  
                          |                           | • Used for lawns, swales, erosion controls. |
| Ryegrass (Lolium)         | Perennial (L. perenne) | • Moderate maintenance.  
                          |                           | • Heat intolerant.  
                          |                           | • Fast sprouting.  
                          |                           | • Useful as overseed for Bermuda grass during dormant (winter season).  
                          |                           | • Used for 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.  
                          |                           | • Used for swales. |

(1) Generally, these species will require supplemental irrigation. Sources: ASCE, MWCG, Sunset.
## Appendix G – Plants Suitable for Vegetative Control Measures

### Table G-2. Additional Suggested Vegetative Covers

<table>
<thead>
<tr>
<th>Common Plant Name (Latin)</th>
<th>Appropriate Species</th>
<th>Maintenance and Usage Notes (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kentucky Bluegrass</td>
<td>(Poa pratensis)</td>
<td>Irrigated sites</td>
</tr>
<tr>
<td>Orchard grass (Dactylis)</td>
<td>“Akaroa” or “Berber” (D. glomerata)</td>
<td>Irrigated and non-irrigated sites</td>
</tr>
<tr>
<td>Wheatgrass (Agropyron)</td>
<td>“Luna” or “Topar” pubescent (A. intermedium trichophorum)</td>
<td>Irrigated and non-irrigated sites</td>
</tr>
<tr>
<td>Zorro Fescue (Vulpia)</td>
<td>(V. myuros)</td>
<td>Irrigated and non-irrigated sites</td>
</tr>
<tr>
<td>Creeping Wild Rye (Leymus)</td>
<td>(L. triticoides)</td>
<td>Non-irrigated sites</td>
</tr>
<tr>
<td>Brome (Bromus)</td>
<td>Blando (B. mollis)</td>
<td>Non-irrigated sites</td>
</tr>
<tr>
<td></td>
<td>California or “Cucamonga” (B. carinatus)</td>
<td>Non-irrigated sites</td>
</tr>
</tbody>
</table>

APPENDIX H

Suitable Trees for Stormwater Runoff Interception
The trees presented in Table H-1 are suitable for stormwater runoff interception. The volume retention credit is based on the canopy size.

Table H-1. Suitable Trees for Stormwater Runoff Interception

<table>
<thead>
<tr>
<th>Common Name/Botanical Name</th>
<th>Tree Type (1)</th>
<th>Mature Tree</th>
<th>Canopy (diameter in feet)</th>
<th>Height (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Chestnut/ Castanea dentata</td>
<td>Oval to rounded or wide spreading</td>
<td>40-60</td>
<td>80-120</td>
<td></td>
</tr>
<tr>
<td>American Hornbeam/ Carpinus caroliniana</td>
<td>Vase-shaped</td>
<td>20-30</td>
<td>25-30</td>
<td></td>
</tr>
<tr>
<td>American Linden/ Tilia americana</td>
<td>Oval and informal</td>
<td>30-60</td>
<td>60-80</td>
<td></td>
</tr>
<tr>
<td>American Sweetgum/ Liquidambar styraciflua</td>
<td>Conical</td>
<td>20-40</td>
<td>45-65</td>
<td></td>
</tr>
<tr>
<td>Amur Maackia Maackia amurensis</td>
<td>Vase-shaped</td>
<td>15-20</td>
<td>20-30</td>
<td></td>
</tr>
<tr>
<td>Amur Maple/ Acer tataricum ginnala</td>
<td>Rounded</td>
<td>15-20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Arizona Cypress/ Cupressus arizonica</td>
<td>E Conical to vase</td>
<td>25-30</td>
<td>40-50</td>
<td></td>
</tr>
<tr>
<td>Atlas (Blue) Cedar/ Cedrus atlantica</td>
<td>E Flat-topped, loose, open and spreading</td>
<td>30-40</td>
<td>40-60</td>
<td></td>
</tr>
<tr>
<td>Autumn Blaze Maple/ Acer fremanii ‘Autumn Blaze’</td>
<td>Oval</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Bald Cypress/ Taxodium distichum</td>
<td>Oval at maturity, uniform</td>
<td>20-30</td>
<td>50-70</td>
<td></td>
</tr>
<tr>
<td>Bechtel Crabapple/ Malus ioensis ‘Plena’</td>
<td>Broad-rounded</td>
<td>20</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Bigleaf Maple/ Acer macrophyllum</td>
<td>Broad-rounded</td>
<td>30-75</td>
<td>45-75</td>
<td></td>
</tr>
<tr>
<td>Blue Oak/ Quercus douglasii</td>
<td>Rounded umbrella</td>
<td>50-80</td>
<td>50-60</td>
<td></td>
</tr>
<tr>
<td>Burr Oak/ Quercus macrocarpa</td>
<td>Broad-rounded</td>
<td>75-85</td>
<td>70-80</td>
<td></td>
</tr>
<tr>
<td>California Bay/ Umbellularia californica</td>
<td>Round</td>
<td>30</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Callery Pear/ Pyrus calleryana</td>
<td>Oval</td>
<td>25</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Canary Island Date Palm/ Phoenix canariensis</td>
<td>Round head</td>
<td>25-30</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Common Name/Botanical Name</td>
<td>Tree Type&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>Mature Tree</td>
<td>Canopy (diameter in feet)</td>
<td>Height (feet)</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>--------------------------</td>
<td>---------------------------------</td>
<td>---------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Canary Island Pine/ &lt;em&gt;Pinus canariensis&lt;/em&gt;</td>
<td>E</td>
<td>Pyramidal</td>
<td>25-35</td>
<td>60-80</td>
</tr>
<tr>
<td>Canyon Live Oak/ &lt;em&gt;Quercus chrysolepis&lt;/em&gt;</td>
<td>E, N</td>
<td>Broad-rounded</td>
<td>50-70</td>
<td>50-75</td>
</tr>
<tr>
<td>Carob/ &lt;em&gt;Ceratonia siliqua&lt;/em&gt;</td>
<td>E</td>
<td>Broad to wide-rounded</td>
<td>30-45</td>
<td>30-40</td>
</tr>
<tr>
<td>Carolina Laurel Cherry/ &lt;em&gt;Prunus caroliniana&lt;/em&gt;</td>
<td>E</td>
<td>Irregular rounded</td>
<td>15-25</td>
<td>20-30</td>
</tr>
<tr>
<td>Chaste Tree/ &lt;em&gt;Vitex agnus-castus&lt;/em&gt;</td>
<td></td>
<td>Rounded</td>
<td>15-20</td>
<td>20-25</td>
</tr>
<tr>
<td>Chestnut-Leafed Oak/ &lt;em&gt;Quercus castaneaefolia&lt;/em&gt;</td>
<td></td>
<td>Broad and rounded</td>
<td>50-60</td>
<td>70-90</td>
</tr>
<tr>
<td>Chinese Evergreen Elm/ &lt;em&gt;Ulmus parvifolia&lt;/em&gt;</td>
<td></td>
<td>Rounded</td>
<td>40-50</td>
<td>40-50</td>
</tr>
<tr>
<td>Chinese Hackberry/ &lt;em&gt;Celtis sinensis&lt;/em&gt;</td>
<td></td>
<td>Rounded</td>
<td>50-60</td>
<td>40-80</td>
</tr>
<tr>
<td>Chinese Pistache/ &lt;em&gt;Pistacia chinensis&lt;/em&gt;</td>
<td></td>
<td>Broad-rounded</td>
<td>25-35</td>
<td>30-35</td>
</tr>
<tr>
<td>Chinese Wingnut/ &lt;em&gt;Pterocarya stenoptera&lt;/em&gt;</td>
<td></td>
<td>Broad-rounded</td>
<td>30-40</td>
<td>40-90</td>
</tr>
<tr>
<td>Coast Live Oak/ &lt;em&gt;Quercus agrifolia&lt;/em&gt;</td>
<td>E, N</td>
<td>Rounded</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Coast Redwood/ &lt;em&gt;Sequoia sempervirens&lt;/em&gt;</td>
<td>E</td>
<td>Narrow pyramidal to wide conical</td>
<td>50-60</td>
<td>350</td>
</tr>
<tr>
<td>Colorado Spruce/ &lt;em&gt;Picea pungens&lt;/em&gt;</td>
<td>E</td>
<td>Narrow pyramidal to broad conical</td>
<td>10-20</td>
<td>30-60</td>
</tr>
<tr>
<td>Common Horsechestnut/ &lt;em&gt;Aesculus hippocastanum&lt;/em&gt;</td>
<td></td>
<td>Pyramidal to oval</td>
<td>40-70</td>
<td>50-75</td>
</tr>
<tr>
<td>Collibah/ &lt;em&gt;Eucalyptus microtheca&lt;/em&gt;</td>
<td></td>
<td>Round head</td>
<td>30</td>
<td>25-50</td>
</tr>
<tr>
<td>Cork Oak/ &lt;em&gt;Quercus suber&lt;/em&gt;</td>
<td>E</td>
<td>Rounded</td>
<td>35-45</td>
<td>70-100</td>
</tr>
<tr>
<td>Crape Myrtle (Tree)/ &lt;em&gt;Lagerstroemia hybrids&lt;/em&gt;</td>
<td></td>
<td>Broad-rounded</td>
<td>15-20</td>
<td>6-30</td>
</tr>
<tr>
<td>Crimson Sentry Maple/ &lt;em&gt;Acer platanoides&lt;/em&gt;</td>
<td></td>
<td>Oval</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>
### Appendix H – Suitable Trees for Stormwater Runoff Interception

<table>
<thead>
<tr>
<th>Common Name/Botanical Name</th>
<th>Tree Type</th>
<th>Mature Tree</th>
<th>Canopy (diameter in feet)</th>
<th>Height (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>dawn redwood/metasequoia glyptostroboides</td>
<td>Conical to narrow pyramidal and formal</td>
<td>25-35</td>
<td>80-90</td>
<td></td>
</tr>
<tr>
<td>Deodar Cedar/cedrus deodara</td>
<td>Wide and slightly flat-topped</td>
<td>30-60</td>
<td>40-70</td>
<td></td>
</tr>
<tr>
<td>Douglas Fir/pseudotsuga menziesii</td>
<td>Broadly cylindrical</td>
<td>30-40</td>
<td>40-80</td>
<td></td>
</tr>
<tr>
<td>Eastern Dogwood/cornus florida</td>
<td>Broad-rounded</td>
<td>15-20</td>
<td>20-25</td>
<td></td>
</tr>
<tr>
<td>Eastern Redbud/cercis canadensis</td>
<td>Rounded</td>
<td>25-35</td>
<td>20-30</td>
<td></td>
</tr>
<tr>
<td>English Hawthorn ‘Paul’s Scarlet’/crataegus laevigata</td>
<td>Vase-shaped</td>
<td>20-25</td>
<td>18-25</td>
<td></td>
</tr>
<tr>
<td>English Oak/quercus robur</td>
<td></td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>European Beech/fagus sylvatica</td>
<td>Oval to rounded</td>
<td>35-45</td>
<td>50-60</td>
<td></td>
</tr>
<tr>
<td>European Hackberry/celtis australis</td>
<td>Rounded</td>
<td>50-60</td>
<td>40-80</td>
<td></td>
</tr>
<tr>
<td>European Hornbeam/carpinus betulus ‘Fastigiata’</td>
<td>Broad oval-vase shaped</td>
<td>20-30</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Evergreen Ash/fraxinus uhdei</td>
<td>Round head</td>
<td>70</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Flannel Brush/fremontodendron californicum</td>
<td>Flat-topped vase</td>
<td>20-25</td>
<td>20-25</td>
<td></td>
</tr>
<tr>
<td>Forest Green Oak/quercus frainetto</td>
<td>Rounded</td>
<td>30</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Formosan Flame/koelreuteria elegans</td>
<td>Broad rounded</td>
<td>35</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Fragrant Snowbell/styrax obassia</td>
<td>Rounded</td>
<td>15-20</td>
<td>20-30</td>
<td></td>
</tr>
<tr>
<td>Frontier Elm/ulmus ‘Frontier’</td>
<td></td>
<td>30</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Ginkgo Biloba (Male)/ginkgo biloba</td>
<td>Wide rounded-pyramidal</td>
<td>30-40</td>
<td>35-80</td>
<td></td>
</tr>
<tr>
<td>Golden Flame Tree/koelreuteria bipinnata</td>
<td>Rounded</td>
<td>15-25</td>
<td>20-40</td>
<td></td>
</tr>
<tr>
<td>Goldenchain Tree/laburnum anagyroides</td>
<td>Oval to round-headed</td>
<td>15-20</td>
<td>20-30</td>
<td></td>
</tr>
</tbody>
</table>
# Appendix H – Suitable Trees for Stormwater Runoff Interception

<table>
<thead>
<tr>
<th>Common Name/Botanical Name</th>
<th>Tree Type</th>
<th>Mature Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Shape</td>
</tr>
<tr>
<td>Goldenrain Tree/ Koelreuteria paniculata</td>
<td></td>
<td>Rounded</td>
</tr>
<tr>
<td>Grecian Laurel/ Laurus nobilis</td>
<td>E</td>
<td>Irregular rounded</td>
</tr>
<tr>
<td>Green Ash/ Fraxinus pennsylvanica</td>
<td></td>
<td>Oval, irregular</td>
</tr>
<tr>
<td>Hedge Maple/ Acer campestre</td>
<td></td>
<td>Rounded</td>
</tr>
<tr>
<td>Holly Oak/ Quercus ilex</td>
<td>E</td>
<td>Rounded</td>
</tr>
<tr>
<td>Honey Locust (thornless)/ Gleditsia triacanthos</td>
<td></td>
<td>Rounded to wide-rounded</td>
</tr>
<tr>
<td>Intense Cedar/ Calocedrus decurrens</td>
<td>E, N</td>
<td>Conical</td>
</tr>
<tr>
<td>Interior Live Oak/ Quercus wislizenii</td>
<td>E, N, P</td>
<td>Irregular</td>
</tr>
<tr>
<td>Italian Stone Pine/ Pinus pinea</td>
<td></td>
<td>Broad, flat-topped</td>
</tr>
<tr>
<td>Japanese Maple/ Acer palmatum</td>
<td></td>
<td>Broad-rounded</td>
</tr>
<tr>
<td>Japanese Pagoda Tree/ Sophora japonica</td>
<td></td>
<td>Rounded to broad-spreading</td>
</tr>
<tr>
<td>Japanese Red Pine/ Pinus densiflora</td>
<td>E</td>
<td>Broad-pyramidal and irregular</td>
</tr>
<tr>
<td>Japanese Snowdrop/ Styx japonicas</td>
<td></td>
<td>Rounded</td>
</tr>
<tr>
<td>Japanese White Birch/ Betula platyphylla japonica</td>
<td></td>
<td>Oval</td>
</tr>
<tr>
<td>Jelecote Pine/ Pinu patula</td>
<td>E</td>
<td>25</td>
</tr>
<tr>
<td>Kentucky Coffee Tree/ Gymnocladus dioica</td>
<td></td>
<td>Oval with coarse branching</td>
</tr>
<tr>
<td>Kobus Magnolia/ Magnolia kobus</td>
<td></td>
<td>Rounded</td>
</tr>
<tr>
<td>Little-Leaf Linden/ Tilia cordata</td>
<td></td>
<td>Rounded pyramidal</td>
</tr>
<tr>
<td>Mexican Fan Palm/ Washingtonia robusta</td>
<td>E</td>
<td>Round head</td>
</tr>
</tbody>
</table>
## Appendix H – Suitable Trees for Stormwater Runoff Interception

<table>
<thead>
<tr>
<th>Common Name/Botanical Name</th>
<th>Tree Type (1)</th>
<th>Mature Tree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Shape</td>
</tr>
<tr>
<td>Norwegian Sunset Maple/ <em>Acer truncatum</em></td>
<td></td>
<td>Uniformly pyramidal with a straight central ladder</td>
</tr>
<tr>
<td>Pin Oak/ <em>Quercus palustris</em></td>
<td>E, N</td>
<td>Conical</td>
</tr>
<tr>
<td>Ponderosa Pine/ <em>Pinus ponderosa</em></td>
<td></td>
<td>Broad-rounded</td>
</tr>
<tr>
<td>Prospector Elm/ <em>Ulmus ‘Prospector’</em></td>
<td></td>
<td>Oval to rounded</td>
</tr>
<tr>
<td>Purple Leaf Plum/ <em>Prunus cerasifera ‘Krauter Vesuvius’</em></td>
<td></td>
<td>Oval to rounded with an open habit</td>
</tr>
<tr>
<td>Red Maple/ <em>Acer rubrum</em></td>
<td></td>
<td>Oval/vase</td>
</tr>
<tr>
<td>Red Oak/ <em>Quercus rubra</em></td>
<td>E</td>
<td>Oval/vase</td>
</tr>
<tr>
<td>Saucer Magnolia/ <em>Magnolia x soulangiana</em></td>
<td></td>
<td>Oval</td>
</tr>
<tr>
<td>Scarlet Oak/ <em>Quercus coccinea</em></td>
<td>E</td>
<td>Rounded</td>
</tr>
<tr>
<td>“Seville” Sour Orange/ <em>Citrus ‘Seville’</em></td>
<td></td>
<td>Broad rounded, irregular</td>
</tr>
<tr>
<td>Southern Live Oak/ <em>Quercus virginiana</em></td>
<td>E</td>
<td>Broad pyramidal, rounded pyramidal, and rounded</td>
</tr>
<tr>
<td>Southern Magnolia/ <em>Magnolia grandiflora</em></td>
<td></td>
<td>Rounded</td>
</tr>
<tr>
<td>Southern Magnolia ‘St. Mary’/ <em>Magnolia grandiflora ‘St. Mary’</em></td>
<td></td>
<td>Oval to rounded</td>
</tr>
<tr>
<td>Strawberry Tree/ <em>Arbutus unedo</em></td>
<td>E</td>
<td>Oval to rounded</td>
</tr>
<tr>
<td>Sugar Maple/ <em>Acer saccharum</em></td>
<td></td>
<td>Oval/vase</td>
</tr>
</tbody>
</table>

(1) E = evergreen, N = deciduous
### Appendix H – Suitable Trees for Stormwater Runoff Interception

<table>
<thead>
<tr>
<th>Common Name/Botanical Name</th>
<th>Tree Type(1)</th>
<th>Mature Tree</th>
<th>Canopy (diameter in feet)</th>
<th>Height (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sycamore/Platanus species</td>
<td>S</td>
<td>Oval to round</td>
<td>30-50</td>
<td>40-100</td>
</tr>
<tr>
<td>Texas Red Oak/Quercus buckleyi</td>
<td></td>
<td>25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Trident Maple/Acer buergerianum</td>
<td></td>
<td>Oval</td>
<td>20-25</td>
<td>20-25</td>
</tr>
<tr>
<td>Tulip Tree/Liriodendron tulipifera</td>
<td></td>
<td>Oval-rounded with a strong central ladder</td>
<td>35-50</td>
<td>70-90</td>
</tr>
<tr>
<td>Tupelo/Sour Gum/Nyssa sylvatica</td>
<td></td>
<td>Rounded pyramidal</td>
<td>20-30</td>
<td>30-50</td>
</tr>
<tr>
<td>Valley Oak/Quercus lobata</td>
<td>N, P</td>
<td>Broad-rounded</td>
<td>50-80</td>
<td>70</td>
</tr>
<tr>
<td>Vine Maple/Acer circinatum</td>
<td>N</td>
<td>Rounded</td>
<td>25-35</td>
<td>5-35</td>
</tr>
<tr>
<td>Washington Hawthorn/Crataegus phaenopyrum</td>
<td></td>
<td>Rounded, vase-shaped</td>
<td>15-20</td>
<td>25</td>
</tr>
<tr>
<td>Western Red Cedar/Thuya plicata</td>
<td>E</td>
<td>Conical to wide conical</td>
<td>50-80</td>
<td>50-70</td>
</tr>
<tr>
<td>Western Redbud/Cercis occidentalis</td>
<td></td>
<td>Rounded</td>
<td>10-18</td>
<td>10-18</td>
</tr>
<tr>
<td>White Adler/Alnus rhombifolia</td>
<td>N</td>
<td>Pyramidal to rounded</td>
<td>15-25</td>
<td>30-45</td>
</tr>
<tr>
<td>White Ash/Fraxinus americana ‘Autumn Purple’, ‘Chicago Regal’</td>
<td></td>
<td>Oval</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>Willow Oak/Quercus phellos</td>
<td></td>
<td>Rounded</td>
<td>30-40</td>
<td>40-60</td>
</tr>
<tr>
<td>Zelkova/Zelkova serrata</td>
<td></td>
<td>Vase-shaped and rounded</td>
<td>30-60</td>
<td>50-80</td>
</tr>
</tbody>
</table>

(1) E = evergreen; N = native; P = protected species; S = some can be native

APPENDIX I

Standard Calculations for Diversion Structure Design
Appendix I – Standard Calculations for Diversion Structure Design

Introduction

Stormwater runoff in excess of the water quality volume (WQV) or water quality flow (WQF) is to be diverted around or through a treatment control measure. This appendix provides the equations and design criteria necessary to design diversion structures to divert stormwater runoff in excess of the WQV or WQF around or through treatment control measures.

Diversion Structure Design

Capturing or isolating the WQV is typically achieved by employing one of the following techniques:

- Divert the WQV 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.
- Bypass flows in excess of the WQV within the treatment control measure using weirs and pipes for channel or pipe storm drain systems or routing excessive flows through a swale (grassy or vegetated).

By employing diversion techniques, the WQV or WQF is treated and retained and stormwater runoff that exceeds the WQV or WQF is diverted or bypassed, untreated, directly to the downstream storm drain system or rockwells.

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 WQV or WQF. The drainage design storm is used to design the conveyance system (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 Measure

Diverting flow at the inlet to the treatment control measure is the most common approach to divert excess stormwater runoff. The most commonly used diversion structures are illustrated in Figure I-1. The height of the weir to divert the flow is determined as follows:

Treatment Control Measures (WQV-based)

1. Determine the WDV (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
Appendix I – Standard Calculations for Diversion Structure Design

measure when the entire WQV is being stored.

3. Set the height of the diversion weir to the maximum height of the water level.

4. Determine weir dimensions needed to divert peak stormwater runoff flows of the drainage design storm. The peak stormwater runoff flow rate for the drainage design storm \( Q_d \) is determined using the following equation for a rectangular sharp-crested weir:

\[
Q_d = C \times L \times h^{1.5}
\]

Where:

\[
Q_d = \text{peak flow rate for drainage design storm (ft}^3/\text{s);}
L = \text{effective length of weir (ft);}
C = \text{weir discharge coefficient; and}
\]

\[
h = \text{depth of flow above the crest of the weir (ft).}
\]

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. Approximations of C for rectangular sharp-crested weirs without end contractions are presented in Table I-1.

5. Provide sufficient head room in the treatment control measure to accommodate depth of flow over the weir.

### Table I-1. Weir Discharge Coefficient (C) for Rectangular Sharp-Crested Weirs Without End Contractions

<table>
<thead>
<tr>
<th>H/h</th>
<th>Head (h) Over Weir (ft)</th>
<th>0.2</th>
<th>0.4</th>
<th>0.6</th>
<th>0.8</th>
<th>1.0</th>
<th>2.0</th>
<th>5.0</th>
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<tr>
<td>0.5</td>
<td></td>
<td>4.18</td>
<td>4.13</td>
<td>4.12</td>
<td>4.11</td>
<td>4.11</td>
<td>4.10</td>
<td>4.10</td>
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<tr>
<td>1.0</td>
<td></td>
<td>3.75</td>
<td>3.71</td>
<td>3.69</td>
<td>3.68</td>
<td>3.68</td>
<td>3.67</td>
<td>3.67</td>
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<tr>
<td>2.0</td>
<td></td>
<td>3.53</td>
<td>3.49</td>
<td>3.48</td>
<td>3.47</td>
<td>3.46</td>
<td>3.46</td>
<td>3.45</td>
</tr>
<tr>
<td>10.0</td>
<td></td>
<td>3.36</td>
<td>3.32</td>
<td>3.30</td>
<td>3.30</td>
<td>3.29</td>
<td>3.29</td>
<td>3.28</td>
</tr>
<tr>
<td>∞</td>
<td></td>
<td>3.32</td>
<td>3.28</td>
<td>3.26</td>
<td>3.26</td>
<td>3.25</td>
<td>3.25</td>
<td>3.24</td>
</tr>
</tbody>
</table>

Source: Lindsay and Franzini, 1979.

### Treatment Control Measures (WQF-based)

1. Establish the size of the on-site drainage system (pipe diameter or dimensions) based on the drainage design storm.

2. Determine the WQF (see Section 6).

3. Determine the depth of flow in the on-site drainage system when carrying the
Appendix I – Standard Calculations for Diversion Structure Design

WQF using Manning’s equation.

\[
WQF = \frac{1.49}{n} \times A \times R^{2/3} \times s^{1/2}
\]

Where:
- \(WQF\) = water quality flow (ft\(^3\)/s);
- \(A\) = cross-sectional area of flow (ft\(^2\));
- \(R\) = hydraulic radius (ft);
- \(s\) = bottom slope of pipe or channel in flow direction (ft/ft); and
- \(n\) = roughness coefficient.

4. Using nomographs or computer programs, determine the depth of flow at WQF. Set the weir height at this depth.

5. Use the equation for \(Q_d\) above to 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 stormwater runoff in excess of the WQV must be achieved in the treatment control measure. When this occurs, the treatment control measure must be designed to ensure the bypass system can be accommodated in the unit (sufficient depth, width and length to accommodate pipes, length of weirs, etc.). The following sections discuss 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 excess of the WQV and WQF. Design of these bypass structures is similar to the approach described for 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 stormwater runoff. Determining the height of the weir is based on the maximum water elevation in a treatment control device when holding the entire WQV. To design the weir, use the procedures established under Diversion Structures for Treatment Control Measures (WQV-based).

Orifrices

Orifrices can be considered in place of weirs or pipes to bypass excess stormwater runoff. To avoid drawing floatables into the bypass, a hooded orifice may be used (see Figure I-2). Hoods should extend into one-third of the
permanent pool depth or one-foot whichever is greater. Commercial catch basin traps may be used in lieu of a hood. A hooded orifice is designed using the following equation:

\[ Q_d = C \times A \times (2 \times g \times h)^{1/2} \]

Where:
- \( Q_d \) = peak flow rate for drainage design storm (ft\(^3\)/s);
- \( C \) = orifice discharge coefficient = 0.60;
- \( A \) = cross-sectional area of orifice (ft\(^2\));
- \( h \) = depth of water above midpoint of orifice (ft); and
- \( g = 32.2 \text{ ft/s}^2 \).

The elevation of the orifice is based on determining the maximum water elevation in a treatment control measure when it is holding the entire WQV. Use the procedures established under Diversion Structures for Treatment Control Measures (WQV-based) to establish the elevation of the mid-point of the orifice opening.

Ensure sufficient head room in the treatment control measure to accommodate flows through the orifice.

**Pipes**

Pipes can also be employed to bypass excess stormwater runoff. The invert elevation of the bypass inlet is based on determining the maximum water elevation in a treatment control measure when it is holding the entire WQV. Use the procedures established under Diversion Structures for Treatment Control Measures (WQV-based) to design a diversion pipe.

For filtration treatment control measures (Fact Sheet C-1), 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 I-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 treatment measures (Fact Sheets R-1 to R-14), bypass pipes are perforated and wrapped with geotextile 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 and sized to divert the peak flow of the drainage design storm, and assume the bypass pipes are flowing full. With these assumptions, the Manning’s equation, reduces to:

\[ D = \left( \frac{2.159 \times Q_d \times n}{s^{1/2}} \right)^{3/8} \]
Appendix I – Standard Calculations for Diversion Structure Design

Where:

\[ D = \text{pipe diameter (ft)}; \]
\[ Q_d = \text{peak flow rate for drainage design storm (ft}^3/\text{s)}; \]
\[ n = \text{Manning's coefficient for pipe material}; \text{ and} \]
\[ s = \text{slope of pipe (ft/ft)} \text{ (A minimum 0.5\% is required.)} \]

Ensure sufficient head room in the treatment control measure to accommodate flows through the orifice.

Routing Excess Stormwater Runoff through a Swale

The depth of flow in a swale (vegetated or grassy) at WQF is determined using a roughness coefficient of 0.20. If additional flow beyond the WQF are directed to the swale, the roughness coefficient for the flow will be lower (approximately 0.03) because flow exceeding the WQF 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. For most on-site swale designs, there will be two different “n” values. An equivalent roughness coefficient \( (n_e) \) value can be determined using the following equation:

\[
N_e^{3/2} = \frac{\sum_{i=1}^{2} P_i \times n_i^{3/2}}{P}
\]

Where:

\( n_e = \text{equivalent roughness coefficient}; \)
\( P_i = \text{wetted perimeter of each area (ft)} \text{ (i = 1, 2)}; \)
\( n_i = \text{roughness coefficient of each area (i = 1, 2)}; \text{ and} \)
\( P = \text{total wetted perimeter (ft)} \)

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 to the equation presented in the Diversion Structures for Treatment Control Measures (WQV-based) section by substituting the \( Q_d \) for the WQF.
3. Use the calculated depth to determine the wetted perimeter for the drainage system.
4. Use the wetted perimeter associated for each “\( n \)” for the drainage system.
   Calculate the equivalent roughness coefficient (calculated “\( n_e \)”), and compare to the estimated “\( n_e \)”.
5. Continue the iterative process until the calculated “\( n_e \)” is equal to the estimated
“n_e”. This value is the equivalent roughness coefficient, and will be used to design the Vegetated Swale (Fact Sheet R-12) and Grassy Swale (Fact Sheet R-14).

Note that this approach results in conservative roughness coefficient values. High flows in the swale may cause some vegetation to bend resulting in a lower n_1 and lower equivalent roughness coefficient, n_e.

Figure I-1. Common Diversion Structures at Inlets

PIPE INTERCEPTOR ISOLATION/DIVERSION STRUCTURE

SURFACE CHANNEL DIVERSION STRUCTURE
Figure I-2. Pipe Bypass in a Filtration Treatment Control Measure

ELEVATION OF INLET INVERT FOR BYPASS PIPE EQUAL TO MAXIMUM SURFACE ELEVATION WHEN SQDV RETAINED IN UNIT

HOODED INLET

BYPASS PIPE

MIN. 0.5% SLOPE

TO STORM DRAINAGE SYSTEM

D.C. FILTER IN-LINE BY-PASS

EXAMPLE OF HOODED ORIFICE IN LIEU OF WEIR TO DRAW WQV INTO FILTER

Figure I-3. Pipe Bypass in an Infiltration Trench

HEIGHT OF INLET INVERT TO PERFORATED PIPE EQUAL TO MAXIMUM SURFACE ELEVATION WHEN SQDV BEING RETAINED IN UNIT

PERFORATED PIPE MINIMUM SLOPE 0.5% WRAPPED IN FABRIC FILTER (TABLE 5-16)
APPENDIX J

Approved Proprietary Control Measures
Appendix J – Approved Proprietary Control Measures

This appendix provides a list of proprietary stormwater treatment devices that have been approved for general use in new development and significant redevelopment projects. In order to use proprietary control measures, projects must first show that the volume retention requirement is met through the use of LID and/or appropriate treatment control measures.

To provide a rational basis for approval of proprietary devices, the City has elected to recognize 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. The City recognizes the lists of proprietary devices approved for general, conditional, and pilot use from the following stormwater programs:

- Sacramento Stormwater Quality Partnership (website: http://www.sacstormwater.org)

The City may recognize lists from other programs in the future, and will update this appendix accordingly.

General Use Designation

The proprietary devices currently approved for general use by the City are listed in Table J-1 along with contact information, sizing criteria and basis of approval. This list will be updated periodically when additional proprietary devices are added to the approved list.

Any device listed in Table J-1 proposed for use in the City must be designed, installed, and maintained in accordance with conditions stipulated by the approving program and must include all maintenance, operation, and construction requirements indicated in Appendix D and as recommended by the manufacturer. Conditional use designations are subject to expiration.

Any device proposed for use must have a currently valid use designation by the approving program at the time of approval by the City.
### Appendix J – Approved Proprietary Control Measures

Table J-1. Proprietary Stormwater Treatment Devices Approved for General Use for Basic Treatment by the City of Modesto

<table>
<thead>
<tr>
<th>Proprietary Device</th>
<th>Manufacturer</th>
<th>Approval Basis</th>
<th>Sizing Criteria (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filterra System and Filterra Boxless</td>
<td>CONTECH Engineered Solutions (2)</td>
<td>Washington DOE(^{(8)}) General Use Designation for basic treatment</td>
<td>Water Quality Flow @ 100 in/hr infiltration</td>
</tr>
<tr>
<td>Kristar FloGard Perk Filter</td>
<td>Kristar/Oldcastle Precast, Inc. (3)</td>
<td>Washington DOE General Use Designation for basic treatment</td>
<td>Water Quality Flow @ 1.5 gpm/ft(^{2}) of media surface area with ZPC media</td>
</tr>
<tr>
<td>Media Filtration System (MFS)</td>
<td>CONTECH Engineered Solutions (2)</td>
<td>Washington DOE General Use Designation for basic treatment</td>
<td>Water Quality Flow @ 1.0 gpm/ft(^{2}) with Perlite media</td>
</tr>
<tr>
<td>StormFilter</td>
<td>CONTECH Engineered Solutions (2)</td>
<td>Sacramento Stormwater Quality Partnership General Use Designation</td>
<td>Water Quality Flow @ 2 gpm/ ft(^{2}) with ZPG media</td>
</tr>
<tr>
<td>StormVault</td>
<td>Jensen Precast (4)</td>
<td>Sacramento Stormwater Quality Partnership General Use Designation</td>
<td>Water Quality Capture Volume at 6-hour drain time (ASCE Manual and Report on Engineering Practice No. 87)</td>
</tr>
<tr>
<td>BayFilter</td>
<td>BaySaver Technologies, LLC. (5)</td>
<td>Washington DOE General Use Designation for basic treatment</td>
<td>Water Quality Flow @ 0.7 gpm/ft(^{2}) for BFC cartridge with Silica Sand/Perlite/Activated Alumina media and @ 0.5 gpm/ft(^{2}) for EMC cartridge with Zeolite/Perlite/Activated Alumina media</td>
</tr>
<tr>
<td>MWS-Linear Modular Wetland (Treatment Train)</td>
<td>BioClean Environmental Services, Inc. (6)</td>
<td>Washington DOE General Use Designation for Basic treatment</td>
<td>Water Quality Flow @ 1.0 gpm/ft(^{2}) of wetland cell surface area with prefilters at 2.1 gpm/ft(^{2}) of cartridge surface area for commercial and industrial basins and 3.0 gpm/ft(^{2}) of cartridge surface area for low to medium density residential basins.</td>
</tr>
<tr>
<td>ecoStorm/ecoStorm Plus (Treatment Train)</td>
<td>Royal Environmental Systems, Inc. (7)</td>
<td>Washington DOE General Use Designation for Basic treatment</td>
<td>Water Quality Flow @ 30 gpm/ ft(^{2}) for the ecoStorm and 9.2 gpm/ ft(^{2}) per filter for the ecoStorm Plus. (Continual pH monitoring required for each system)</td>
</tr>
</tbody>
</table>

(1) Water quality flow (WOF) sizing criteria are presented in Section 6 of the 2011 Guidance Manual.
(2) CONTECH Engineered Solutions website: [www.contechs.com](http://www.contechs.com)
Appendix J – Approved Proprietary Control Measures

(3) Kristar/Oldcastle Precast, Inc. website: www.kristar.com
(4) Jensen Precast website: www.jensenprecast.com
(5) BaySaver Technologies, LLC. Website: www.BaySaver.com
(6) Bio Clean Environmental Services, Inc. website: www.biocleanenvironmental.net
(7) Royal Environmental Systems, Inc. website: www.royalenterprises.net
(8) Washington State Department of Transportation website: www.wsdot.wa.gov/Environment/waterquality

Pilot Use Designation

The proprietary devices currently approved for pilot use by the City are listed in Table J-2 along with contact information, sizing criteria, and basis of approval.

Any device listed in Table J-2 proposed for use in the City must be designed, installed, and maintained in accordance with conditions stipulated by the approving program and must include all maintenance, operation, and construction requirements as indicated in Appendix D and as recommended by the manufacturer. In addition, if the device is the first of its kind to be installed in the City, the performance of the unit must be monitored in accordance with the performance monitoring protocols stipulated by the approving program.

Pilot use designations are subject to expiration. Any device proposed for pilot use must have a currently valid use designation by the approving program at the time of approval by the City.

Table J-2. Proprietary Stormwater Treatment Devices Approved for Pilot Use for Basic Treatment by the City of Modesto

<table>
<thead>
<tr>
<th>Proprietary Device</th>
<th>Manufacturer</th>
<th>Approval Basis</th>
<th>Sizing Criteria (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxwell Plus Drainage System</td>
<td>Torrent Resources, Inc. (2)</td>
<td>Washington DOE pilot use designation for basic treatment</td>
<td>Water Quality Flow @ 0.25 cfs/system</td>
</tr>
</tbody>
</table>

(1) Water quality flow (WQF) sizing criteria are presented in Section 6 of the 2011 Guidance Manual.
(2) Torrent Resources website: www.torrentresources.com

Special Cases

The City recognizes that in special cases, typically small in-fill projects, the use of City-approved basic treatment control measures, either proprietary or non-proprietary, may not be feasible. In these special cases, the City will consider the use of substitute proprietary pretreatment devices in lieu of approved basic treatment control measures where it can be demonstrated to the satisfaction of the City, by means of a thorough engineering analysis, that use of approved general use treatment control measures are not feasible.

Proprietary devices are listed in Table J-3 proposed for use in the City must be designed, installed, and maintained in accordance with conditions stipulated by the approving program and must include all maintenance, operation, and construction requirements as indicated in Appendix D, and as recommended by the manufacturer.
## Table J-3. Proprietary Stormwater Treatment Devices Approved for General Use for Pretreatment Devices by the City of Modesto

<table>
<thead>
<tr>
<th>Proprietary Device</th>
<th>Manufacturer</th>
<th>Approval Basis</th>
<th>Sizing Criteria (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AquaSwirl System</td>
<td>AquaShield, Inc. (2)</td>
<td>Washington DOE General Use Level Designation for pretreatment</td>
<td>50% removal of 50 micron-mean size and 80% removal of 125 micron-mean size Total Suspended Solids for Influent concentrations between 100-200 mg/L</td>
</tr>
<tr>
<td>CDS</td>
<td>CONTECH Engineered Solutions (3)</td>
<td>Washington DOE General Use Level Designation for pretreatment</td>
<td>50% removal of 50 micron-mean size and 80% removal of 125 micron-mean size Total Suspended Solids for Influent concentrations between 100-200 mg/L</td>
</tr>
<tr>
<td>Downstream Defender</td>
<td>Hydro-International (4)</td>
<td>Washington DOE General Use Level Designation for pretreatment</td>
<td>50% removal of 50 micron-mean size and 80% removal of 125 micron-mean size Total Suspended Solids for Influent concentrations between 100-200 mg/L</td>
</tr>
<tr>
<td>Stormceptor System</td>
<td>Imbrium Systems Corporation (5)</td>
<td>Washington DOE General Use Level Designation for pretreatment</td>
<td>50% removal of 50 micron-mean size and 80% removal of 125 micron-mean size Total Suspended Solids for Influent concentrations between 100-200 mg/L</td>
</tr>
<tr>
<td>Vortechs</td>
<td>CONTECH Engineered Solutions (2)</td>
<td>Washington DOE General Use Level Designation for pretreatment</td>
<td>50% removal of 50 micron-mean size and 80% removal of 125 micron-mean size Total Suspended Solids for Influent concentrations between 100-200 mg/L</td>
</tr>
</tbody>
</table>

(1) Water quality flow (WQF) sizing criteria are presented in Section 6 of the 2011 Guidance Manual.
(2) AquaShield, Inc. website: [http://www.aquashieldinc.com](http://www.aquashieldinc.com)
(3) CONTECH Engineered Solutions website: [www.conteches.com](http://www.conteches.com)
(4) Hydro-International website: [http://www.hydro-international.biz](http://www.hydro-international.biz)
(5) Imbrium Systems Corporation website: [www.imbriumsystems.com](http://www.imbriumsystems.com)
Order 2008-0092 Planning and Land Development
This appendix provides the Planning and Development Program requirements of Order R-5-2008-0092. The text in this appendix is excerpted from pages 40-48 of the Order.

PLANNING AND LAND DEVELOPMENT PROGRAM

13. The objectives of the Planning and Land Development Program are as follows:

   a. Incorporate water quality and watershed protection principles into the Discharger’s policies and planning procedures;

   b. Ensure that selected post-construction storm water controls will remain effective upon project completion by requiring a maintenance agreement and transfer or establishing a maintenance district zone for all priority development projects;

   c. Provide a comprehensive review of development plans to ensure that storm water quality controls are properly selected to minimize storm water quality impacts;

   d. Provide regular internal training on applicable components of the SWMP; and

   e. As a part of the annual reporting process, conduct an assessment (at least annually) to determine the effectiveness of the Program Element and identify any necessary modifications.

14. The Discharger shall update and continue to implement the Planning and Land Development Component of its SWMP to minimize the short and long-term impacts on receiving water quality from new development and redevelopment. At a minimum the Planning and Land Development Program shall address the objectives listed above and include the following control measures:

   a. Incorporation of Water Quality Protection Principles into City Procedures and Policies

   b. New/Revised Development Standards

   c. Plan Review Sign-Off

   d. Maintenance Agreement and Transfer

   e. Training

   f. Effectiveness Assessment

   g. New Development Standards for Capital Improvement Projects

15. Water Quality Planning and Design Principles - In order to reduce pollutants and runoff flows from new development and redevelopment the Discharger shall address the following concepts:
a. The Discharger shall incorporate water quality and watershed protection principles into planning procedures and policies such as the Development Standards and requirements to direct land-use decisions and require implementation of consistent water quality protection measures for all development projects. These principles and policies shall be designed to protect natural water bodies, reduce impervious land coverage (such as through low impact development design), slow runoff to prevent hydromodification of waterways, and where feasible, maximize opportunities for infiltration of rainwater into soil. Such water quality and watershed protection principles and policies shall consider, at a minimum, the following:

i Minimize the amount of impervious surfaces and directly connected impervious surfaces in areas of new development and redevelopment and where feasible to maximize on-site infiltration of runoff (low impact development concepts).

ii Implement pollution prevention methods supplemented by pollutant source and treatment controls. Where practical, use strategies that control the sources of pollutants or constituents (i.e., the point where water initially meets the ground) to minimize the transport of urban runoff and pollutants offsite and into MS4s.

iii Preserve, and where possible, create or restore areas that provide important water quality benefits, such as riparian corridors, wetlands, and buffer zones.

iv Limit disturbances of natural water bodies and natural drainage systems caused by development including roads, highways, and bridges.

v Use methods available to estimate increases in pollutant loads in runoff flows resulting from projected future development. Require incorporation of structural and non-structural BMPs to mitigate the projected increases in pollutant loads.

vi Identify and avoid development in areas that are particularly susceptible to erosion and sediment loss; or establish development guidance that protects areas from erosion and sediment loss.

vii Coordinate with local traffic management programs to reduce pollutants associated with vehicles and increased traffic resulting from development.

viii Implement source and structural controls as necessary and appropriate to protect downstream receiving water quality from increased pollutant loads and flows (hydromodification concepts) from new development and significant redevelopment.

ix Control the post-development peak storm water runoff discharge rates and velocities to maintain or reduce pre-development downstream erosion, and to protect stream habitat.

b. Low Impact Development - New development and redevelopment projects shall integrate Low Impact Development (LID) principles into project design. LID is a storm water 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 predevelopment hydrologic functions. When developing the LID program, the City shall consider and incorporate all appropriate and applicable LID components and measures that have been successfully and effectively implemented in other municipal areas. Other programs include, but are not limited to, USEPA’s “Managing Wet Weather with Green Infrastructure, Action Strategy, 2008” and LID program elements specified in the permits or Storm Water Management Plans of other MS4s throughout the state.

c. The Discharger shall revise applicable ordinances/standards/specifications no later than one year after the adoption of the SWMP/Development Standards by the Regional Water Board.

16. The Discharger has adopted development standards in the City of Modesto Guidance Manual for New Development Stormwater Quality Control Measures, January 2001 and their Standard Specifications. The Development Standards shall be amended/revised in accordance with this Provision and Provision 23 to ensure that the storm water quality and watershed principles, as listed above in 16.a. and b., are integrated.

a. Post Development Standards: The Discharger shall ensure that all new development and significant redevelopment projects falling under the priority project categories listed below meet Development Standards. When the Development Standards are revised, the revised Development Standards shall apply to all priority projects or phases of priority projects at the date of adoption of the Development Standards which do not have one of the following: approval of a tentative map within two years prior to approval of the revised Development Standards, approval of improvement plans by the City engineers, or a permit for development or construction.

Any extensions of a tentative map after adoption of revised Development Standards shall ensure compliance with the revised Development Standards. In addition, those infill projects that require only a Use Permit from the City that apply to the Priority Development Project Categories are subject to the requirements under the Development Standards.

b. Priority Development Project Categories – Development Standards requirements shall apply to all new development and significant redevelopment projects falling under the priority project categories or locations as: (1) significant redevelopment; (2) home subdivision of 10 housing units or more; (3) commercial developments greater than 10,000 square feet of impervious surface area; (4) automotive repair shops; (5) restaurants; (6) parking lots 5,000 square feet or more or with 25 or more parking spaces and potentially exposed to urban runoff; (7) street and roads; and (8) retail gasoline outlets (RGO).

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. Where significant redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to the Development Standards, the numeric sizing criteria discussed below applies only to the addition, and not the entire development.

c. **BMP Requirements** – The Development Standards shall include a list of recommended pollution prevention, source control, and/or structural treatment control BMPs. The Development Standards shall require all new development and significant redevelopment projects falling under the above priority project categories or locations to implement a combination of BMPs selected from the recommended BMP list, including at a minimum: (1) source control BMPs and (2) structural treatment control BMPs.

d. **Numeric Sizing Criteria** – The Development Standards shall require structural treatment BMPs to be implemented for all priority development projects. In addition to meeting the BMP requirements listed above, all structural treatment BMPs for a single priority development project shall be sized collectively to comply with either the volume-based or flow-based numeric sizing criteria:

i. **Volume-based BMPs** shall be designed to mitigate (infiltrate or treat) either:

a) The volume of runoff produced from a 24-hour 85th percentile storm event, as determined from the local historical rainfall record; or

b) The volume of runoff produced by the 85th percentile 24-hour rainfall event, determined as the maximized capture storm water volume for the area, from the formula recommended in *Urban Runoff Quality Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87*, (1998); or

c) The volume of annual runoff based on unit basin storage volume, to achieve 80% or more volume treatment by the method recommended in *California Storm Water Best Management Practices Handbook – Industrial/Commercial*, (1993); or

d) A Discharger justified design storm volume that is determined as part of the Development Standard development and approved by the Executive Officer. The treatment of this volume shall achieve approximately the same reduction in pollutant loads achieved by treatment of the 85th percentile 24-hour runoff event.

ii. **Flow-based BMPs** shall be designed to mitigate (infiltrate or treat) either:
a) 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; or

b) The maximum flow rate of runoff, as determined from local historical rainfall records, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

e. **Equivalent Numeric Sizing Criteria** – The Discharger may develop an equivalent numeric sizing criteria or performance-based standard for post-construction structural treatment BMPs as part of the Development Standards. Such equivalent sizing criteria may be authorized for use in place of the above criteria. In the absence of development and subsequent authorization of such equivalent numeric sizing criteria, the above numeric sizing criteria requirement shall be implemented.

f. **Pollutants and Activities of Concern** – As part of the Development Standards, the Discharger shall identify pollutants and/or activities of concern for each new development or significant redevelopment project. The Discharger shall identify the pollutants of concern by considering the following (1) receiving water quality, including pollutants for which receiving waters are listed as impaired under CWA Section 303(d); (2) land use type of the development project and pollutants associated with that land use type; (3) pollutants expected to be present on site at concentrations that pose potential water quality concerns; (4) activities expected to be on the site; and (5) changes in flow rates and volumes resulting from the development project and sensitivity of receiving waters to changes in flow rates and volumes.

g. **Restaurants Less than 5,000 Square Feet** - New development and significant redevelopment restaurant projects where the land area development is less than 5,000 square feet of impervious surface area shall meet all Development Standards except for structural treatment BMP and numeric sizing criteria requirement above.

h. **Infiltration and Groundwater Protection** – To protect groundwater quality, the Discharger shall consider the type of development and resulting storm water discharge and, if appropriate, apply restrictions to the use of structural BMPs, which are designed to primarily function as infiltration devices (such as infiltration trenches and infiltration basins and rock wells).

i. **Regional Storm Water Mitigation** – The Discharger may apply to the Regional Water Board for approval of a regional or sub-regional storm water mitigation program to substitute in part or wholly Development Standard requirements. The Regional Water board may consider for approval such a program if its implementation will:

   a) Result in equivalent or improved storm water quality;
b) Protect stream habitat;

c) Promote cooperative problem solving by diverse interests;

d) Be fiscally sustainable and has secure funding; and

e) Be completed in five years including the construction and start-up of treatment facilities.

17. **Maintenance Agreement and Transfer**

The Discharger shall require that all developments subject to Development Standards and site specific plan requirements provide verification of maintenance provisions for Structural Treatment Control BMPs, including but not limited to legal agreements, covenants, California Environmental Quality Act (CEQA) mitigation requirements, and or conditional use permits. Verification at a minimum shall include:

   a. The developer’s signed statement accepting responsibility for maintenance until the responsibility is legally transferred; and either

   b. A signed statement from the public entity assuming responsibility for Structural Treatment Control BMP maintenance and that it meets all local agency design standards; or

   c. Written conditions in the sales or lease agreement, which requires the recipient to assume responsibility for maintenance and conduct a maintenance inspection at least once a year; or

   d. Written text in project conditions, covenants and restrictions for residential properties assigning maintenance responsibilities to the Home Owners Association for maintenance of the Structural Treatment Control BMPs; or

   e. Any other legally enforceable agreement that assigns responsibility for the maintenance of post-construction Structural Treatment Control BMPs.

18. **California Environmental Quality Act (CEQA) Document Update**

The Discharger shall incorporate into its CEQA process, procedures for considering potential storm water quality impacts and providing for appropriate mitigation when preparing and reviewing CEQA documents. The procedures shall require consideration of the following:

   a. Potential impact of project construction on storm water runoff;

   b. Potential impact of project post-construction activity on storm water runoff;

   c. Potential for discharge of storm water from material storage areas, vehicle or equipment fueling, vehicle or equipment maintenance (including washing), waste
handling, hazardous materials handling or storage, delivery areas or loading docks, or other outdoor work areas;

d. Potential for discharge of storm water to impair the beneficial uses of the receiving waters or areas that provide water quality benefit;

e. Potential for the discharge of storm water to cause significant harm to the biological integrity of the waterways and water bodies;

f. Potential for significant changes in the flow velocity or volume of storm water runoff that can cause environmental harm; and

g. Potential for significant increases in erosion of the project site or surrounding areas.

19. General Plan Update

a. The Discharger shall amend, revise, or update its General Plan to include watershed and storm water quality and quantity management considerations and policies when any of the following General Plan elements are updated or amended: (i) Land Use, (ii) Housing, (iii) Conservation, and (iv) Open Space.

b. The Discharger shall provide the Regional Water Board with the draft amendment or revision when a listed General Plan element or the General Plan is noticed for comment in accordance with California Government Code § 65350 et seq.

20. Planning Department Coordination, Enforcement and Tracking

a. The Discharger shall provide for the review of proposed project plan and require measures to ensure that all applicable development will be in compliance with their storm water ordinances, local permits, and all other applicable ordinances and requirements.

b. The Discharger shall develop a process by which Development Standards will be implemented. The process shall identify at what point in the planning process development projects will be required to meet Development Standards. The process shall also include identification of the roles and responsibilities of various municipal departments in implementing the Development Standards, as well as any other measures necessary for the implementation of Development Standards.

c. The Discharger shall develop and implement no later than (6 months from this Order's adoption) the following:

i. A GIS or other electronic system for tracking projects that have been conditioned for post-construction treatment control BMPs. The electronic system, at a minimum, should contain the following information:

   a) Municipal Project ID.
b) State General Construction Permit WDID No.

c) Project Acreage.

d) BMP Type and Description.

e) BMP Location (coordinates).

f) Date of Acceptance.

g) Date of Maintenance Agreement.

h) Inspection Date and Summary.

i) Corrective Action.

j) Date Certificate of Occupancy Issued.

21. **Targeted Employee Training**

The Discharger shall periodically train its employees in targeted positions (whose jobs or activities are engaged in development planning) to ensure they can adequately implement the Planning and Land Development Program requirements.

22. **Technical Guidance and Information for Developers**

By **12 June 2009** (or 1 year after the SWMP is adopted, whichever is later), the Discharger shall submit a revised/functionally updated Development Standards [e.g., *Guidance Manual for New Development Stormwater Quality Control Measures*] consistent with the requirements of this Order as a component of the SWMP. The Development Standards shall include guidelines and provide recommendations for low impact development/ hydromodification strategies for the development community in the Modesto Urbanized Area. The guidelines shall encourage the use of low impact development/ hydromodification strategies and be based on the existing site design control measures identified in the existing Development Standards. Prior to approval of the Development Standards, the early implementation of measures likely to be included in the Development Standards shall be encouraged by the Discharger.

*(Editor’s Note: Note SWMP was approved by the Central Valley Regional Water Quality Control Board on December 10, 2009)*
APPENDIX L

References
Appendix L – References


City of Alexandria Department of Transportation and Environmental Services, 1992. *Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filters BMPs.* Alexandria, VA.

City of Alexandria Department of Transportation and Environmental Services, February 1992. *Supplement to the Northern Virginia BMP Handbook.* Alexandria, VA.

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Appendix L – References


Appendix L – References

Woodward-Clyde Memorandum June 1995 to City of Fresno Metropolitan Flood Control District, *Vegetated Swale Guidelines*. 