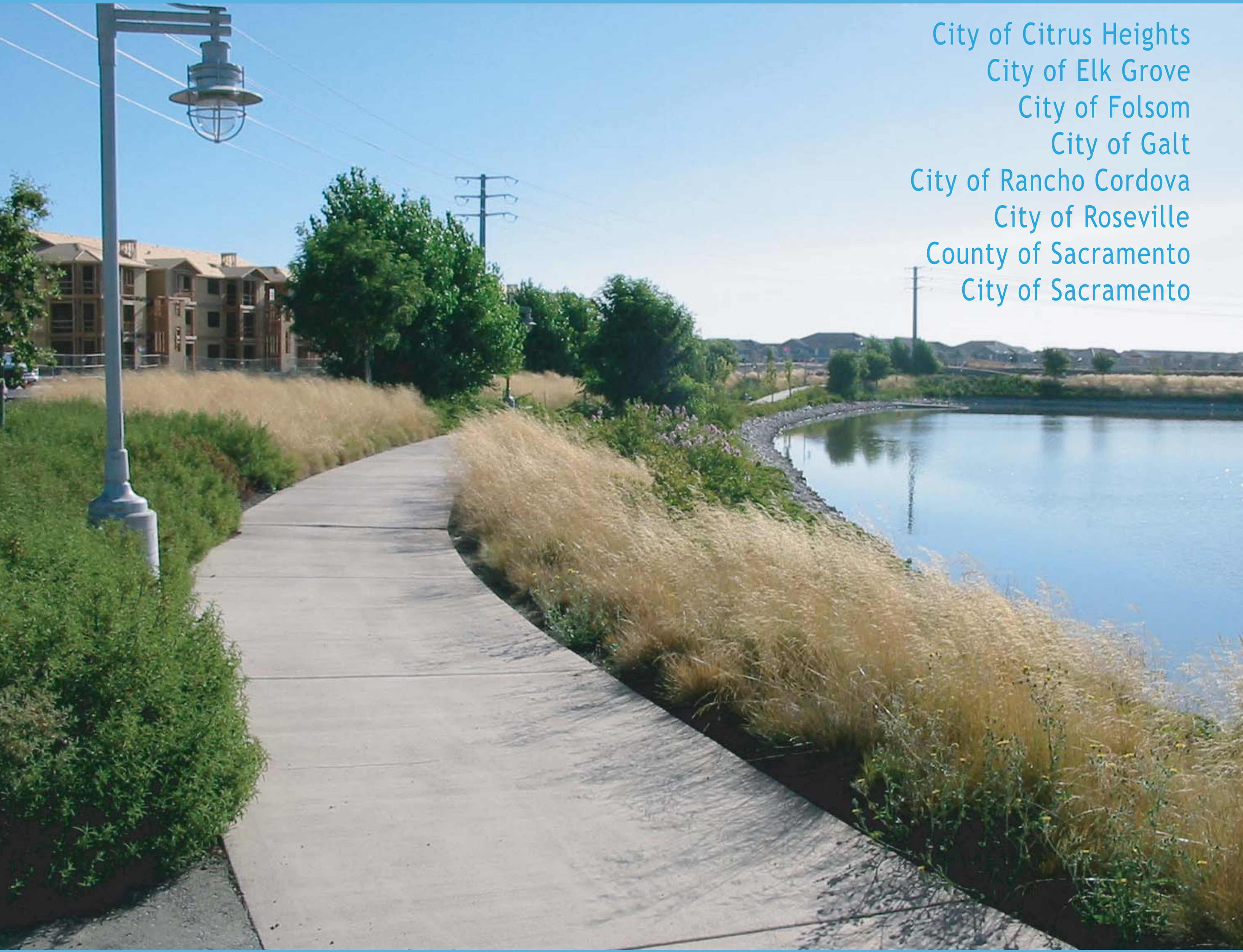
Stormwater Quality Design Manual
for the Sacramento and South Placer Regions



City of Citrus Heights
City of Elk Grove
City of Folsom
City of Galt
City of Rancho Cordova
City of Roseville
County of Sacramento
City of Sacramento

Integrated Design Solutions for Urban Development
Protecting Our Water Quality

May 2007

Stormwater Quality Design Manual

for the Sacramento and South Placer Regions

May 2007

Stormwater Quality Design Manual was created in partnership by:

May 2007

Table of Contents

First Edition — May 2007

List of Tables

List of Figures

Acknowledgements

This design manual was made possible by the combined efforts of many professionals:

Steering Committee

Sarah Amaya, City of Folsom
Dalia Fadl, Sacramento County
Bill Forrest, City of Galt
Summer Christensen, Sacramento County
Sherill Huun, City of Sacramento
Leslie Nguyen-Pickett, City of Elk Grove
Chris Kraft, City of Roseville
Kelye McKinney, City of Roseville
Kerry Schmitz, Sacramento County
Trung Trinh, City of Galt
Joan Weber, City of Roseville

Project Consultants

Carmel K. Brown, P.E. CKB Environmental Consulting, Inc. (Project Coordinator)
Shannon Brown, ECORP Consulting (runoff reduction credit system and fact sheets)
Robert Smith, P.E. and Mack Walker, P.E., Larry Walker Associates (selected treatment control fact sheets)
Mark Kubik, P.E., West-Yost Associates (Technical Reviewer, Water Quality Detention Basin Fact Sheet and Sizing)
Carlos Espana, P.E., G.E., Furgo West, Inc. (Geotechnical Engineering Review)
N. Alison Tucker (technical writing and editing)

Document Design and Production

Joan Kodani, Sacramento County
Darci Frank, City of Roseville (cover)

Building Industry Association Stormwater Committee

Tom Gamette, Elliott Homes
Mike Sweeney, P.G., CPESC, CPSWQ, and John Youngdahl, P.E., Youngdahl Consulting Group
Tim Crush, P.E. and Jennifer O'Neal, Wood Rodgers, Inc.
Ardie Zahedani, North State Building Industry Association

Other Development Community Reviewers and Contributors

Development Focus Group meetings were held in December 2006 and January 2007 and comments were solicited on the December draft manual. Attendance lists from these meetings are available upon request. The public draft was published in February 2007, followed by two public workshops in March 2007. A compilation of all written comments received, and corresponding Steering Committee responses, can be found at: *www.sacramentostormwater.org* (new development).

Agency Reviewers and Contributors

Staff from the various local and regional agencies reviewed and commented on the July 2006 Public Agency Review Draft Design Manual and various subsequent drafts. In particular, the Design Manual Steering Committee would like to acknowledge the contributions of these agencies and individuals:

Ken Menzer, Arborist, City of Folsom
Bob Rooker, Sacramento–Yolo Mosquito and Vector Control District
Jim Edwards and Melenia Davis, County Sanitation District–1 (CSD–1)

Disclaimer

The Sacramento/South Placer Counties Design Manual should be used as a general guidance document to aid with the selection, siting, design, operation and long-term maintenance of stormwater quality control measures. The control measures described herein are intended to serve as best management practices (BMPs) implemented to meet the standard of “reducing pollutants in urban runoff to the maximum extent practicable” set forth in the local agencies’ NPDES Municipal Stormwater Permits issued by the Central Valley Regional Water Quality Control Board.

The stormwater quality control measures should be designed using the criteria outlined in this manual and implemented at areas of new development and redevelopment in accordance with the policies and procedures of the local permitting agency. The control measures must be properly constructed and maintained to ensure long-term performance. Other measures not included in this manual may be allowed on a case-by-case basis, in consultation with the applicable permitting agency. In such cases, the applicant is encouraged to meet with permitting agency staff early in the planning process before proceeding with detailed design. Such projects may require additional time for agency review and approval.

The contributing agencies do not claim any responsibility for errors or omissions in this design manual, improper design, or ineffective maintenance practices that might contribute to non-performance of the stormwater quality control measures. The agencies will share the responsibility of verifying that publicly owned and maintained treatment controls are constructed properly; however, private controls are the owners’/applicants’ responsibility.

Most of the control measures described in this manual should be designed by, or under the supervision of, a California licensed professional engineer and/or other specialists as needed, depending on the type of control measure and site conditions. Check with the local permitting agency to verify the license requirement for the design project undertaken.

The science of stormwater quality management is evolving and new and innovative control measure technologies are constantly being introduced to design professionals. For this reason, this manual will need to be a dynamic document that will be reviewed and updated periodically. Manual users are responsible for ensuring that they are referencing the most current edition, by checking *www.sacramentostormwater.org* (new development) or contacting their local permitting agency.

1 Introduction

Purpose

This *Stormwater Quality Design Manual for the Sacramento and South Placer Regions* (manual) outlines planning tools and requirements to reduce urban runoff pollution to the maximum extent practicable (MEP) from new development and redevelopment projects.

This manual is a collaborative effort of the Sacramento Stormwater Quality Partnership[1] and the City of Roseville, and it is intended to satisfy the regulatory requirements of their respective municipal stormwater permits. (See the section *Background Information* later in this chapter for more about the Partnership and permit requirements.)

This Design Manual

This comprehensive manual outlines a consistent set of stormwater quality management design standards for many new and redevelopment projects in the urbanized parts of Sacramento County and the City of Roseville. It provides planning and design tools for use by planners, architects, landscape architects, engineers and environmental professionals.

Goals

The Sacramento and Roseville permitting agencies have the following goals for this manual:

- Protect the quality of our local creeks and rivers.
- Consolidate all stormwater quality design requirements into one document.
- Provide a consistent set of requirements for stormwater quality management that apply in the urbanized part of Sacramento County and the City of Roseville. That is intended to facilitate better areawide compliance with clean water laws.

The stormwater quality development standards are intended to protect our valuable creek and river resources for future generations.

[1] The Sacramento Stormwater Quality Partnership includes the County of Sacramento and the Cities of Citrus Heights, Elk Grove, Folsom, Galt, Rancho Cordova and Sacramento. For more information, see the Glossary.

- Promote the consideration of stormwater management early in the site planning and project design process; the optimal, most cost-effective approach often involves integrating stormwater controls into overall site design.
- Provide tools and criteria (including maintenance and construction considerations) for selecting and designing a range of stormwater quality control measures.
- Incorporate recommendations of the local vector control districts so that stormwater quality control facilities do not create mosquito breeding habitat.

Background Information

Under the federal Clean Water Act, stormwater discharges are regulated through National Pollutant Discharge Elimination System (NPDES) Municipal Stormwater Permits. In California, the State Water Board and its nine Regional Boards oversee implementation of the Clean Water Act, and the Central Valley Regional Water Quality Board (Regional Board) issues and enforces NPDES stormwater permits within the Central Valley. Phase I NPDES permits have been issued to municipalities with a population greater than 100,000 (and certain industries and construction projects) since 1990. The Regional Board began issuing Phase II NPDES general permits to smaller municipalities in 2003. Municipal stormwater permits require municipalities to regulate and manage the quality of urban runoff throughout their jurisdictions, including runoff from new development and significant redevelopment projects.

Sacramento Areawide Stormwater Permit Requirements

The Sacramento Areawide NPDES Municipal Stormwater Permit is a Phase I permit and applies to the County of Sacramento along with the Cities of Citrus Heights, Elk Grove, Folsom, Galt, Rancho Cordova and Sacramento. Originally issued in 1990, the Sacramento stormwater permit has been reissued several times. The current permit (NPDES Permit No. CAS082597) was adopted in December 2002 and is anticipated to be reissued in 2008. The permittees function independently on many tasks, including reviewing, processing and permitting plans for new development and redevelopment in their respective jurisdictions. However, they work together on other tasks and projects, such as the creation of this manual. This manual is an outgrowth of prior steps taken to comply with the municipal stormwater permit.

The permittees (collectively referred to as the Sacramento Stormwater Quality Partnership, or Partnership) began conditioning development projects in Sacramento County to include stormwater quality control measures in the mid 1990s. The City and County of Sacramento published the *Guidance Manual for On-Site Stormwater Quality Control Measures* in January 2000; that document was widely referenced by all the permittees and is now being replaced by this manual.

This manual replaces and is an expansion of, the *Guidance Manual for On-Site Stormwater Quality Control Measures* produced by the City and County of Sacramento in January 2000. It consolidates all stormwater quality design information previously published by the agencies in several different documents.

In July 2003, the permittees published their Stormwater Quality Improvement Plans, which describe their comprehensive program to comply with their municipal stormwater permit and reduce pollutants in urban runoff to the maximum extent practicable. The New Development program element of the plans called for an assessment of existing development standards and amendment/adoption of new standards as needed to better address the permit. (As used here, the term “development standards” collectively refers to the policies, ordinances, codes and design standards established and enforced by each of the permitting agencies.)

In December 2003, the Partnership submitted a Development Standards Plan (DSP) to the Regional Board; the DSP assessed the existing development standards (as of 2003) and proposed actions that would be taken to amend the standards within one year of approval of the DSP. The Regional Board officially approved the DSP on May 18, 2005, giving the Permittees until May 18, 2006 to complete the process of amending/adopting new standards. According to the municipal stormwater permit, the Permittees have until May 18, 2007 to publish technical design guidelines to help the development community understand and implement the new standards. This manual constitutes those required technical design guidelines, completing the work begun with the DSP.

The DSP affected the types of projects subject to this manual. The Sacramento municipal stormwater permit specifies eight categories of new development and redevelopment projects that are subject to development standards related to stormwater quality management. Some of the categories and corresponding thresholds specified in the stormwater permit were effectively modified when the Regional Board approved the DSP in May 2005. Those changes are reflected in this manual (Tables 1-2 and 3-2).

City of Roseville Phase II Stormwater Permit Requirements

The City of Roseville (located in South Placer County) obtained coverage under California’s Phase II NPDES Municipal General Stormwater Permit in July 2004. Prior to that time, Roseville did not require post-construction stormwater quality control measures for new development. Under the terms of their Phase II permit, Roseville’s program for controlling runoff pollution from development projects must comply with the requirements outlined in Attachment 4 of the permit or with a “functionally equivalent program” approved by the Regional Board.

The City of Roseville opted to work collaboratively with the Sacramento area permittees to create this manual as a functionally equivalent program. Since the Phase I Sacramento and Phase II Roseville municipal stormwater permits have slightly different requirements regarding development standards, staff conducted an analysis at the onset of the project to verify that this single design manual would satisfy both permits.

Agency Collaboration in Developing this Manual

This manual is the result of a collaborative planning effort by a steering committee comprised of managers and staff from the following agencies:

- County of Sacramento, Department of Water Resources (also representing the Cities of Citrus Heights and Rancho Cordova)
- City of Sacramento, Department of Utilities
- City of Elk Grove, Department of Development Services/Public Works
- City of Folsom, Department of Public Works
- City of Galt, Department of Public Works
- City of Roseville, Departments of Environmental Utilities and Public Works.

In addition, the local vector control districts were consulted, since several types of stormwater quality control measures could have the potential to support mosquito breeding habitat, if not properly designed, constructed and maintained. Other contributors included local sanitation districts, fire departments and districts and solid waste interests.

Using the Manual

Intended Audience

This manual is primarily intended for people involved in the design or review/approval of development projects. Table 1-1 lists the different professionals who typically should be involved at each phase of a project. It is important to involve many different design professionals early in the planning process when the initial site layout is determined. It is equally important that those involved in site planning and design work collaboratively throughout the site design process; that way, stormwater quality features can be optimally integrated into the site and project design. Benefits of the collaborative team approach and strategies for involving everyone throughout the process are discussed more in Chapter 2.

The manual also contains some information related to construction and maintenance of stormwater quality facilities; therefore it may be used by contractors, inspectors, property owners and others as shown in Table 1-1.

Finally, the manual may be used by developers, property owners, contractors, elected and appointed public agency officials, environmental regulatory agencies and interested citizens.

Projects Covered by the Manual

Table 1-2 lists the types of projects and land uses generally addressed by this manual. If a project falls into one of those categories, see Table 3-2 (in Chapter 3) to see if the project meets the size threshold that triggers the requirements and, if so, to see which specific requirements apply.

Development projects potentially subject to this manual include both new development as well as "significant redevelopment" projects. Significant redevelopment includes, but is not limited to: expansion of a building footprint; replacement of a structure; replacement of impervious surface that is not part of routine maintenance activity; and land-disturbing activities related to structural or impervious surfaces.

For redevelopment projects subject to this manual, the applicable design standards apply only to the redeveloped area, and not to the entire site, except in cases where untreated drainage from the existing developed portion is allowed to enter/flow through the redeveloped portion. In such cases, any new required treatment control measures must be designed for the entire contributing drainage area. Redevelopment and infill project applicants should check with the local permitting agency at the start of project design to verify whether or not the manual requirements apply.

Table 1-1. Applying the Design Manual to Every Phase of Development

Project Phase	Typical Decisions/Activities	Professionals Involved
Initial site layout and planning	Building and parking footprints; site access; preservation/integration of existing natural resource features (trees and other vegetation, creek buffers, wetlands, vernal pools, open space); use of topographic lows for siting certain stormwater quality features; identification of existing sewer and drainage facilities; preliminary on-site soils testing to determine which stormwater quality features will work on the site	Architects; planners; environmental consultants; geotechnical and drainage engineers; landscape architects; and permitting agency planning and engineering staff (initial consultations and pre-application meetings)
Site improvement design	Site contouring and grading; on-site drainage and connections to municipal system; other utilities (sanitary sewer, water, power); pavement selection for parking, roads and walkways	Civil and other engineers; landscape architects; permitting agency plan review staff (drainage engineers, traffic, fire, etc.)
Building design	Final building footprint; building access; roof type and materials; roof drainage/downspout system; location/type water features (e.g., ponds, waterfalls, fountains); location of landscaping around the building (and possibly selection of vegetation type/style to complement building design or provide consistency with existing vegetation to be preserved on site or in the surrounding area)	Architects; civil/structural, geotechnical and other engineers as appropriate
Landscape and irrigation design	Final selection of type of trees and other vegetation; final contouring of landscaped areas; installation of vegetation and bark/other ground cover materials; design and installation of irrigation system; construction of water features	Landscape architects, wetland specialists/ biologists if applicable
Construction	Installation of stormwater quality facilities; installation of erosion and sediment control measures to protect the facilities from receiving high sediment loads during construction process; final clean-out and preparation of stormwater facilities prior to permitting agency acceptance	Contractors; erosion control specialists; permitting agency inspectors
Maintenance	Building, grounds and landscape maintenance, including maintenance of vegetated stormwater quality facilities (mowing, watering schedule, application of fertilizers, herbicides and insecticides, replacing/ repairing damaged vegetation and eroded areas)	Property owners and managers; maintenance and landscape contractors; permitting agency maintenance staff

Table 1-2. Types of Projects Addressed By This Manual[1]

Project Category[2]	**Description**
Single Family Residential	In general, this category includes detached single-family homes and duplexes. Check with local permitting agency for verification.
Multi-Family Residential	In general, this category includes attached single-family homes (except duplexes), condominiums, townhomes, and apartments. Check with local permitting agency for verification.
Commercial and Light Industrial	Development on private land that is not for heavy industrial or residential uses. This category includes, but is not limited to hospitals, laboratories and other medical facilities, educational institutions, churches, recreational facilities, parks, commercial nurseries, car wash facilities, mini-malls and other business complexes, shopping malls, hotels, office buildings, public warehouses, and other light industrial facilities.
Automotive Repair Shops	A facility that is categorized by one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.
Retail Gasoline Outlets	Any facility engaged in selling gasoline
Restaurants	Any 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) and has 5,000 or more square feet of impervious area.
Hillside Developments	Any development that creates 5,000 square feet of impervious surface in an area with known erosive soil located in an area with natural slopes having a twenty-five percent or greater grade.
Parking Lots	All or portion of parking lots exposed to rainfall (uncovered impervious area) for the temporary parking or storage of motor vehicles used personally, for business, or for commerce.
Streets/Roads	Any paved surface used by automobiles, trucks, motorcycles, and other vehicles.
Heavy Industrial	Heavy industrial facilities (light industry covered under commercial category)

1 Thresholds for determining which types of stormwater quality measures apply to each project type can be found on Table 3-2 in Chapter 3.

2 Refer to applicable permitting agency's zoning definitions.

How the Manual is Organized

- Chapter 1 provides an introduction.
- Chapter 2 explains the benefits of integrating stormwater quality management into overall project design and describes strategies and principles for doing so.
- Chapter 3 outlines a step by step process for fulfilling the requirements of this manual and references the other chapters for more information.
- Chapters 4 through 6 provide specific siting and design criteria (as well as construction and maintenance considerations) for a range of stormwater quality control measures. Chapter 4 covers source controls, Chapter 5 covers runoff reduction measures, and Chapter 6 covers treatment controls.

- The Appendices provide additional detail on a number of topics. In addition:
- Appendix C lists permitting and contact information related to discharges to the sanitary sewer; that is included since some source control measures call for discharging potentially polluted site runoff to the sanitary sewer.
- Appendix H lists sources for stormwater management information not covered by this manual (as described in the next section).

Reference materials used to develop each chapter are listed at the end of that chapter, and references used to develop the various control measure fact sheets are presented at the end of each fact sheet in Chapters 4-6. The two main reference documents were the City and County of Sacramento's *Guidance Manual for On-Site Stormwater Quality Control Measures (January 2000)* and the California Stormwater Quality Association's statewide document, *California Storm Water Best Management Practice Handbook for Development* (May 2003).

CASQA's *California BMP Handbook for Development* was referenced in the creation of this Design Manual, with many adaptations made for the Sacramento Region. In the event of conflicts between this manual and the CASQA handbook, this manual will generally take precedence. Contact your local permitting agency for clarification.

Stormwater Management Information Not in the Manual

This manual does not include:

- drainage/flood control design standards
- temporary erosion and sediment controls and other pollution controls used during construction activities
- on-going operational practices to control pollution at industrial and commercial facilities once they are constructed (such as making sure employees don't dump hazardous or liquid wastes in the trash).

For information about those topics, see the references listed in Appendix H.

Obtaining the Manual and Updates

Go to *www.sacramentostormwater.org* to download this manual (PDF format) and obtain information for ordering a hard copy. Make sure that you are always using the most current edition.

The manual will be updated periodically to reflect new information. To determine if updated information or errata sheets are available, check *www.sacramentostormwater.org* regularly or contact one of the local permitting agencies listed in the front of this manual.

Questions and Comments

We welcome your questions and comments and will also consider this information in making future updates and improvements.

For information related to projects in Sacramento County, contact the appropriate permitting agency listed at *www.sacramentostormwater.org* (new development).

For projects in the City of Roseville, contact the Department of Public Works Engineering Division at (916) 774-5339 or e-mail the City at stormwater@roseville.ca.us.

Send questions and comments on the design manual to: *dwrw@saccounty.net* with "*stormwater design manual*" in the subject line.

Low-Impact Development Strategies and This Manual

The process and requirements included in this manual are intended to promote effective stormwater quality control measures that are optimally integrated into the site and project design. This approach will result in built projects with lowered impacts to the environment, and therefore reflects the "low impact development (LID)" philosophy.

For the purposes of this manual, LID is defined as follows: "Low impact development is a stormwater management strategy that emphasizes conservation and use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns in residential, commercial, and industrial settings." (*Puget Sound Action Team 2005).*

In this manual, Chapter 2 (and Step 3 in Chapter 3) promotes the conservation/use of natural site features, an important LID principle. Chapter 4 describes how site specific, lot-scale source control measures can keep pollutants from contacting runoff and leaving the site. Chapter 5 focuses on runoff reduction control measures integrated into site design; many of these techniques are intended to reduce site imperviousness, another important LID principle. And finally, Chapter 6 includes a variety of treatment control measures, some of which are intended to be applied at the lot level for pollution and runoff control.

2 An Integrated Approach to Effective Stormwater Management

Integrated Planning and Design Approach

In order for site designs to reflect the best stormwater management strategies, it is essential that stormwater be considered early in the site design process—before the site layout is established. Otherwise, the choice/location of stormwater controls will be constrained by prior site design decisions (e.g., predetermined grading contours), and may be limited to more expensive, higher-maintenance, and less aesthetically pleasing options.

When stormwater controls are considered early, they can be effectively integrated into site design and planning. There are often opportunities to use existing or proposed site features for stormwater controls and/or repeat small-scale stormwater controls over an entire site. Small-scale controls are typically low-cost and cumulatively very effective.

In some cases, site design necessitates trade-offs among competing goals; however, especially when considered early in the process, often stormwater goals can complement other goals and agency requirements, including those related to vegetation preservation, landscaping, aesthetics, open space, recreational areas, and/or habitat.

Benefits of the Integrated Approach

Benefits to the Property Owner/Developer

Stormwater quality features that are integrated into the fabric of a community and designed to be aesthetically pleasing and provide recreational opportunities and/or habitat may increase property values. Property values at a subdivision built in the 1970s in Davis, California (Village Homes) have been reported to be higher than those of comparable homes in nearby conventionally-designed subdivisions (*Start at the Source*). This community was designed with seasonal vegetated swales in place of storm drain pipes, community open space, a downstream constructed wetland (the West Davis Pond) and other environmental features.

Environmental benefits

There are various environmental benefits that can be achieved by protecting natural features, maintaining pre-developed drainage patterns, and/or integrating stormwater quality features into site design:

- Cleaner and cooler runoff delivered to local creeks and rivers
- Cleaner and cooler air due to protected and/or added trees and other vegetation and reduced impervious surfaces
- Protected, and/or added habitat for birds, fish and other wildlife

Community benefits

Well-designed stormwater quality facilities can add value to a community or business setting and improve the quality of life for residents and tenants. Whether or not these features are viewed as an asset depends in large part on how they are incorporated into the overall development project. When small-scale local stormwater controls are considered at the very beginning of the design process, there are more opportunities to integrate them into landscaping as attractive amenities rather than placing them underground. In the right setting, when stormwater quality facilities can be seen and appreciated and their function is explained to residents and tenants, they may foster a natural resource stewardship ethic. Also, landscape-based features, especially those designed using native and drought-tolerant plants, can have less intensive maintenance needs than underground devices.

Similarly, larger-scale regional facilities such as water quality detention basins can be designed to provide tremendous benefits when these are considered early in the process; they can be featured prominently as an attractive amenity and community resource with bonus recreational benefits. When such facilities are placed behind residents' backyards or in a forgotten fenced-off corner of the development, the community benefits are lost.

Strategies for Effectively Integrating Stormwater Quality Management into Project Design

Assemble a collaborative team early

In order for site designs to reflect the best stormwater management strategies, stormwater controls must be considered early in the site design process. To do that, involve the project engineer and other design professionals during the conceptual design stage, when the initial site layout is being determined. In the past, only planners and architects may have been involved at this stage of the design.

The collaborative design process may involve the following key players:

- Project Owner
- Permitting Agency Staff
- Planners
- Architects
- Engineers (Civil, Geotechnical)
- Landscape Architects
- Environmental Consultants

Table 1-1 in Chapter 1 indicated the various roles that each of these individuals can play in each phase of the planning and design work.

It is also helpful to arrange a meeting with the local permitting agency to get agency input at the conceptual design stage; in most jurisdictions, this is referred to as the pre-application meeting.

It is equally important that those involved in site planning and design work collaborate throughout the site design process; that way, stormwater quality features can be optimally integrated into the site and project design. This might be facilitated by periodic meetings of the project team and by routing various designs to the different disciplines for review and comment.

Consider the site and its surroundings

Gather information about the following site characteristics, which will greatly influence the type of stormwater quality controls used on your project:

- **Existing natural hydrologic features** and natural resources, including any contiguous natural areas, wetlands, watercourses, seeps, or springs.
- **Existing site topography**, including contours of any slopes of 4% or steeper, general direction of surface drainage, local high or low points or depressions, and any outcrops or other significant geologic features.
- **Zoning**, including requirements for setbacks and open space.
- **Soil types** (including hydrologic soil groups) and depth to groundwater, which may determine whether infiltration is a feasible option for managing site runoff. A preliminary determination of infiltration feasibility may be made using maps in hydrology and flood control design manuals published by the local permitting agency. Also, site-specific information (e.g. from boring logs or geotechnical studies) may be required by the permitting agency, depending on the site location and characteristics.
- **Existing site drainage.** For undeveloped sites, determine drainage patterns by inspecting the site and examining topographic maps and survey data. For previously developed sites, locate site drainage and connections to the municipal storm drain system from a site inspection, municipal storm drain maps, and/or the approved plans for the existing development (typically on file with the local municipality).
- **Existing vegetative cover** and impervious areas, if any.

Identify Opportunities and Constraints

Using the site features information gathered above, identify the principal opportunities and constraints for stormwater quality management on the site.

Opportunities might include existing natural areas, low (depressed) areas, oddly configured or otherwise un-developable parcels, easements, and open space (which potentially can double as locations for stormwater quality controls with the permitting agency's approval). Also look at elevation differences on the site which might provide hydraulic head for structural treatment control measures.

Constraints might include impermeable soils, high groundwater, contaminated soils or groundwater, steep slopes, geotechnical instability, high intensity land use, expected heavy pedestrian or vehicular traffic, safety concerns, or compatibility with surrounding land uses. Also there might be competing environmental concerns on the project site.

Preserve valuable site features

Consider these techniques to preserve natural and environmentally-sensitive features on your site:

- **Define development envelope** and protected areas, identifying areas that are most suitable for development and areas that should be left undisturbed.
- **Cluster the development** to conserve natural areas and provide open space for the new residents/tenants to enjoy.
- **Preserve natural vegetation.** Vegetation is an integral part of the natural hydrologic cycle. Vegetation intercepts rainfall, and plant roots take up water that soaks into the ground. Also, roots and decaying organic matter such as leaf litter protect the soil structure and soil permeability, and therefore help preserve the pollutant-removal processes that occur in soil. When designing a site, retain as much natural vegetation as possible.
- **Consider preserving significant trees**, even if the local jurisdiction would allow their removal, for all the reasons given above.
- **Set back the development** from creeks, wetlands, and riparian habitats. Check with the local agency regarding minimum setback requirements.
- **Designate and protect natural buffers** for waterways and natural areas. If disturbing buffer areas during construction is unavoidable, make plans to replant them with plants and trees adapted and suited to the site conditions, preferably low-water use plants. Such plants have a better chance of survival and adaptation to the site over time without an over reliance on water and fertilizers/pesticides.

Lay out the site with topography and soils in mind

To minimize stormwater-related impacts, consider applying the following design principles to the site layout:

- Choose a design that replicates the site's natural drainage patterns as much as possible.
- Where possible, conform the site layout to natural landforms.
- Identify topographic lows that might be suitable for locating stormwater quality treatment features.
- Concentrate development on portions of the site with less permeable soils, and preserve areas that will actively promote infiltration.
- When possible, avoid disturbing steep slopes and erodible soils.
- When possible, avoid excessive grading and disturbance of vegetation and soils.

Put landscaping to work

All permitting agencies require landscaping for most development projects, for both aesthetic and shading purposes, and sometimes for noise reduction. Stormwater quality features can often be integrated into landscape areas such as the site perimeter, parking medians, and roadside areas. For example, instead of mounding the landscaped areas in a business center parking lot, consider creating depressed areas (i.e., swales) to accept and filter the water before sending it off the site. Using landscape areas for stormwater quality features may require some changes in the conventional approach to landscape designs, and may result in larger/wider landscape areas. Check with your local permitting agency regarding specific landscaping and tree requirements and related requirements such as water conservation.

Stop pollution at its source

Rather than managing stormwater runoff only at the final point of discharge from a site, look for opportunities to manage pollution where it is first generated. Source control measures keep pollutants from entering stormwater to begin with, whereas treatment control measures remove pollutants from water. Chapter 4 presents a variety of source controls for new development and redevelopment, such as:

- Marking storm drain inlets with “No Dumping” messages to deter illegal dumping.
- Locating and designing outdoor trash enclosure areas so that polluted runoff from these areas does not enter the storm drain system.
- Designing vehicle wash areas so that soapy, polluted water is not delivered to the storm drain system.

Specific source controls are required for various types of development projects (see Table 4-1 in Chapter 4), but also look for additional ways to stop pollution at the source.

Reduce runoff close to its source

Another way to stop pollution at its source is to reduce runoff wherever possible. Reducing site runoff will also reduce the volume and duration of flows to local creeks, thus reducing the potential for downstream erosion and habitat impairment. Although runoff reduction measures may not be required by the permitting agency today, such controls may be required for certain areas in the future as the local municipal agencies’ stormwater permits are reissued. Runoff reduction measures can reduce project costs for projects that typically require runoff treatment because this can reduce the need for stormwater quality treatment.

The main ways to reduce runoff are to promote infiltration, minimize impervious surfaces, and disconnect impervious surfaces (disconnecting impervious surfaces means to intercept the runoff by draining the roof or pavement to a pervious area and not directly to the storm drain system).

Promote infiltration where feasible

On undeveloped, undisturbed land, rain slowly percolates into the soil and impurities are filtered out and transformed through natural biological processes. When designing a site, look for ways to promote infiltration and allow soil to filter and naturally transform impurities. For example, consider dispersing runoff over a landscaped area. Of course, infiltration is not appropriate where it would pose a threat to groundwater quality or cause other problems such as destabilizing a site.

Also consider infiltration stormwater quality treatment control measures for your site where feasible. Chapter 6 includes design information for two such devices: the infiltration basin and infiltration trench.

Minimize impervious surfaces

For all types of development, try to limit overall coverage of paving and roofs. This can be accomplished—where consistent with local zoning regulations and development standards—by designing compact, taller structures, narrower and shorter streets and sidewalks, smaller parking lots (fewer/smaller stalls where possible, and more efficient lanes), and indoor or underground parking. Examine site layout and circulation patterns and identify areas where landscaping or planter boxes can be substituted for pavement.

Where feasible, avoid draining impervious areas directly to a storm drain

When the built and landscaped areas are defined on your site drawings, look for opportunities to minimize impervious areas that are directly connected to the storm drain system. Chapter 5 presents information on several options that can be considered for this, including:

- **Direct runoff from impervious areas** to adjacent pervious areas or depressed landscaped areas.
- **Select porous pavements and surface treatments.** Inventory paved areas on the preliminary site plan and identify locations where permeable pavements, such as crushed aggregate, turf block, or unit pavers can be substituted for conventional concrete or asphalt paving. Typically, these materials work best in low-traffic parking areas, rather than high-traffic areas such as drive aisles.

Chapter 5 describes how to quantify the benefits achieved by your design decisions to reduce paved and roofed areas, to create landscaped areas and pervious pavements which retain water, and to direct runoff from impervious to pervious areas.

Treat runoff

Treating runoff is required for projects above certain size thresholds (which vary with respect to project category and in some cases with respect to the jurisdiction-- see Table 3-2). As previously noted, providing runoff reduction measures can reduce or possibly even eliminate the required treatment.

Treatment is accomplished by either detaining runoff long enough for pollutants to settle out or by filtering runoff through sand or soil. Typically, the limiting design factors will be available space, available hydraulic head (difference in water surface elevation between inflow and outflow), and soil permeability. In some cases, a small adjustment of elevations within the site plan can make a particular treatment option feasible and cost effective.

When developing a drainage and treatment strategy, also consider whether to route most or all drainage through a single detention and treatment control measure or to disperse smaller control measures throughout the site. Piping runoff to a single treatment area may be simpler and easier to design, but designs that integrate smaller techniques such as swales, small landscaped areas, and planter boxes throughout the site are typically more cost-effective, less maintenance intensive, and more attractive. Chapter 6 describes various treatment control measures that are acceptable for use in the Sacramento and South Placer regions, such as:

- Three types of water quality detention basins (dry, wet and combination)
- Infiltration basin and trench
- Sand filter
- Stormwater planter (a type of bioretention facility)
- Vegetated swale and filter strip

References

- *Start at the Source: Design Guidance Manual for Stormwater Quality Protection*, Bay Area Stormwater Management Agencies Association, 1999. *http://www.scvurppp-w2k.com/basmaa_satsm.htm*

- *Using Site Design Techniques to Meet Development Standards for Stormwater Quality: A Companion Document to Start at the Source*, Bay Area Stormwater Management Agencies Association, May 2003. *http://www.scvurppp-w2k.com/basmaa_satsm.htm*

- *Low Impact Development Design Strategies: An Integrated Design Approach*, Prince George's County, Dept. of Environmental Resources, Maryland, June 1999. *http://www.epa.gov/owow/nps/lidnatl.pdf*

- *California Storm Water Best Management Practice Handbook for Development*, California Stormwater Quality Association, May 2003.

Additional Resources

- *Stormwater Strategies: Community Responses to Runoff Pollution*, Chapter 12 – Low Impact Development, Natural Resources Defense Council, October 2001. *http://www.nrdc.org/water/pollution/storm/chap12.asp*

- *Site Planning for Urban Stream Protection*, Center for Watershed Protection (Tom Schueler), 1995.

- *Urban Small Sites Best Management Practice Manual*, Barr Engineering for Metropolitan Council of Governments (Minneapolis/St. Paul).

3 Steps to Managing Stormwater Quality

This chapter outlines steps to select and design stormwater quality features in order to effectively incorporate stormwater management into site design and satisfy the requirements of the permitting agencies in Sacramento and South Placer Counties. Figure 3-1 illustrates the process. As you proceed through the process, record project information and decisions and compile this information for submittal with the planning application and/or post-construction stormwater quality plan, described in Appendix A. Check with the local permitting agency before you begin, since they may require or recommend the use of special checklists, forms or formats for these submittals.

As explained in Chapter 2, developing optimal stormwater control strategies requires that stormwater be considered early in the site design process—before the site layout is established. Otherwise, the choice/location of stormwater controls will be constrained by prior site design decisions and it may not be possible to integrate stormwater controls throughout the project design. See Chapter 2 for more information about the integrated approach to effective stormwater management.

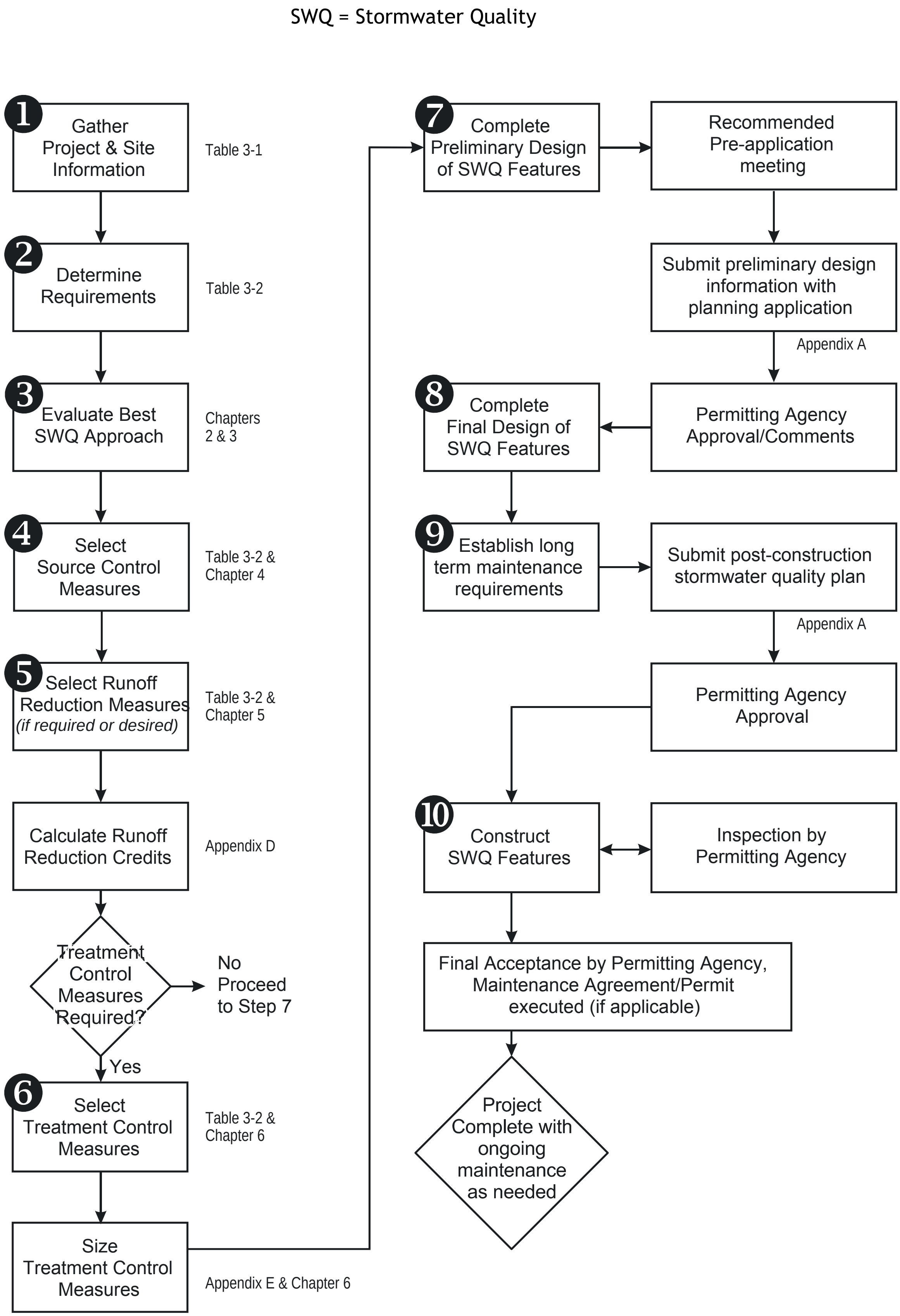
The steps outlined in this chapter are presented in sequence, but steps 3 through 6 are interrelated. Be sure to involve the engineers and other design professionals early during the conceptual design stage using the collaborative team approach discussed in Chapter 2.

Step 1: Gather Project and Site Information

Start by compiling information about the site and project. Some local development permitting agencies (e.g., Sacramento County) will require this information to be submitted with the initial planning application:

- Project gross area (acres)
- Proposed project net area (acres): this is the gross area minus protected open space and planned parks
- Proposed project density for residential projects (dwelling units per net area)
- Existing and proposed impervious area (acres)
- Name of watershed/receiving water and whether the project discharges directly to this receiving water or first to the municipal storm drain system
- Project category and associated potential pollutants, based on Table 3-1. Pollutant information will be used later to determine appropriate control measures for your project.

Figure 3-1. Process for Addressing Stormwater Quality Requirements



Gather other information about the site that is essential to choosing stormwater quality control measures, but does not necessarily need to be submitted to the local permitting agency during the initial planning phase:

- Topography
- Soil types
- Natural hydrologic features and existing site drainage
- Depth to groundwater
- Existing vegetation
- Receiving water quality conditions (e.g., State 303(d) List impaired water bodies)

See Chapter 2 for more information about evaluating site conditions to best integrate stormwater control measures into site design.

Table 3-1. Project Categories and Associated Potential Pollutants

Project Category	Potential Pollutant						
	Sediment	Nutrients	Trash	Metals [a]	Bacteria [a]	Oil and Grease	Organics/ Pesticides [a]
Residential	•	•	•	•	•	•	•
General Commercial	(b)	(b)	•	•	(b)	•	(b)
Auto Repair			•	•		•	
Retail Gas Outlet			•	•		•	
Restaurant			•		•	•	
Industrial	(b)	(b)	•	•		•	(b)
Hillside	•						
Parking Lot	•		•	•		•	
Road	•		•	•		•	

(a)Target Pollutants for Sacramento area: Metals (Copper, Lead, and Mercury), Coliform/Pathogens, and Organophosphate pesticides (Diazinon, Chlorpyrifos).

(b) This table provides a generalization of what pollutants to expect for different land uses, but actual pollutants will vary to some extent depending on the individual development. For example, sediment, nutrients and pesticides will be additional pollutants of concern for a commercial home improvement store with a garden center, and bacteria will be an additional pollutant of concern for a kennel operation.

Also see CASQA's New Development Handbook (May 2003; Table 1-1) for information about impacts of these various pollutants on water quality and beneficial uses.

Step 2: Determine Requirements

Use Table 3-2 (Selection Matrix) to determine stormwater quality requirements for your project. Requirements depend on the size and/or planned new impervious area of your project.

All projects require source control measures applicable to the planned site activities, as described in Chapter 4. Some of the local permitting agencies may require runoff reduction measures (Chapter 5). Many projects will also require treatment control measures (Chapter 6). For those requiring treatment control measures, applying runoff reduction first (even if not required) will result in a reduced volume or flow of runoff that needs to be treated.

Step 3: Evaluate Best Approach to Protect Stormwater Quality

Evaluate the best approach to protecting stormwater quality considering the site conditions, required controls, and the principles outlined in Chapter 2. As explained in Chapter 2:

- Identify opportunities and constraints given the site conditions
- Preserve valuable site features where possible (and where required) and work with the topography
- Seek to integrate stormwater controls throughout the site design, such as incorporating them into landscaping and reducing runoff close to its source
- Look for cost-effective, aesthetically-pleasing ways to treat runoff (if treatment is needed)

Step 4: Select Source Control Measures (Chapter 4)

Based on step 3, Chapter 4 and Table 4-1, select appropriate source control measures. Source controls are intended to keep pollutants from mixing with runoff and traveling off the site. All projects require permanent "no dumping-drains to creek/river" markings to be applied to storm drain inlets. In addition, source control measures are required for the following areas where there is the potential for pollutants to be exposed to stormwater runoff:

- Fueling areas
- Loading areas
- Outdoor storage areas
- Outdoor work areas (e.g., processing, manufacturing)
- Vehicle and equipment wash areas
- Waste management areas (garbage, recycling, restaurant food waste)

Source control measures keep pollutants from mixing with runoff and traveling off the site

Step 5: Select Runoff Reduction Measures (Chapter 5)

Include runoff reduction measures in your project design if any of the following apply:

- The project requires treatment controls (see Step 6) and you want to reduce the needed size (and associated cost) of required treatment.
- You conclude it is cost-effective to incorporate runoff reduction measures and you would like to provide the environmental benefit of doing so.
- They are required by the local permitting agency for the particular project.

Table 3-2. Stormwater Quality Control Measure Selection Matrix

✓ Required   * Optional   • Acceptable method   **NA** Not applicable or allowed

Control Measure / Project Category[(a)]	Residential			Commercial/Industrial							
	Single Family Residential ≥ 10 units (Roseville)	Single Family Residential ≥ 20 ac (Sacramento)	Multi-family Residential gross area ≥ 1 ac	Commercial [(b)] impervious area ≥ 1 ac	Auto Repair Shops impervious area ≥ 1 ac	Retail Gasoline Outlets impervious area ≥ 1 ac	Restaurants impervious area ≥ 1 ac	Industrial [(b)] impervious area ≥ 1 ac	Hillside Developments ≥ 25% slope	Parking lots [(c)] ≥ 5,000 sf or 25 spaces	Streets/Roads [(d)] (not Roseville) impervious area ≥ 5 ac
Source Control [(b) (e)]	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Storm Drain Markings and Signs	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Fueling Areas	NA		NA	✓	✓	✓	✓	✓	✓	NA	NA
Loading Areas	NA		NA	✓	✓	✓	✓	✓	✓	NA	NA
Outdoor Storage Areas	NA		NA	✓	✓	✓	✓	✓	✓	NA	NA
Outdoor Work Areas	NA		NA	✓	✓	✓	✓	✓	✓	NA	NA
Vehicle/Equipment Wash Areas	NA		✓	✓	✓	✓	✓	✓	✓	NA	NA
Waste Management Areas	NA		✓	✓	✓	✓	✓	✓	✓	✓	NA
Runoff Reduction [(f)]	*	*	*	*	*	*	*	*	*	*	*
Porous Pavement	(g)	(g)	•	•	NA	NA	•	•	•	•	(g)
Disconnected Pavement	•	•	•	•	•	•	•	•	•	•	•
Alternative Driveways	•	•	•	NA	NA	NA	NA	NA	•	NA	NA
Disconnected Roof Drains	•	•	•	•	•	•	•	•	•	NA	NA
Interceptor Trees	•	•	•	•	•	•	•	•	•	•	•
Green Roof	NA	NA	•	•	•	•	•	•	•	NA	NA
Treatment Control [(g) (h)]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Constructed Wetland Basin	•	•	•	•	NA	NA	•	•	NA	•	•
Detention Basin	•	•	•	•	•	•	•	•	•	•	•
Infiltration Basin	•	•	•	•	NA	NA	•	•	NA	•	•
Infiltration Trench	•	•	•	•	NA	NA	•	•	NA	•	•
Sand Filter (Austin Sand Filter)	•	•	•	•	•	•	•	•	•	•	•
Stormwater Planter (Flow-through)	•	•	•	•	•	•	•	•	•	•	•
Stormwater Planter (Infiltration)	•	•	•	•	NA	NA	•	•	•	•	•
Vegetated Swale	•	•	•	•	•	•	•	•	•	•	•
Vegetated Filter Strip	•	•	•	•	NA	NA	•	•	•	•	•
Proprietary Devices (i)	•	•	•	•	•	•	•	•	•	•	•

(a) Refer to Table 1-2 for more information on how each project category is generally defined and check with the local zoning code for the specific definition in a given jurisdiction.
(b) In Roseville, source control only required for commercial and industrial projects of 100,000 SF or greater.
(c) Only applies to stand-alone parking lots exposed to rainfall. Parking lots associated with buildings/facilities need to meet requirements of associated land use (commercial, industrial, etc.)
(d) Public road capital projects and expansions that are not a part of new residential, commercial and industrial developments.
(e) Storm drain markings required for all projects. Other source controls required for all projects with applicable site activities. Choice of source control for hillside development depends on type of land use (commercial, residential, etc.)
(f) Some agencies may require runoff reduction for the particular project; check with permitting agency.
(g) Consult local permitting agency to determine acceptability for use in public right-of-way.
(h) Alternative treatment controls may be proposed; subject to review and approval of local permitting agency. The need for treatment may be reduced through runoff reduction measures; see Appendix D. If the project drains to an adequately sized/designed regional treatment facility (e.g., detention basin), additional on-site treatment controls may not be needed.
(i) See discussion in Chapter 6 of this manual and *www.sacramentostormwater.org* for list of acceptable devices.

As the name implies (and as described in Chapter 2), runoff reduction measures are intended to reduce the amount of runoff traveling off the site. This is achieved by minimizing impervious surfaces, disconnecting impervious surfaces from the storm drain system, and promoting infiltration where possible. Even sites with clay soils can benefit from application of runoff reduction control measures. Several different types of runoff reduction measures are described in Chapter 5:

- Porous pavement
- Disconnected pavement
- Alternative driveways
- Disconnected roof drains
- Interceptor trees
- Green roof

Use of runoff reduction controls can decrease the size of required downstream water quality controls

Refer to Table 3-2 to identify which types of measures are acceptable for your project and then use the worksheets in Appendix D to calculate the runoff reduction credits you can achieve by incorporating one or more of these measures into your project. Then use the worksheets to calculate any remaining water quality volume or flow that needs to be treated and proceed to Step 6 to select the treatment control facilities. If the entire water quality volume (WQV) can be retained on-site using runoff reduction measures, treatment control measures will not be required and you can advance to Step 7.

Step 6: Select Treatment Control Measures

Treatment control measures are intended to filter and settle pollutants out of runoff before it travels off the site. If treatment controls are required per Table 3-2 (and still needed after the calculation of runoff reduction credits in Step 5), select the appropriate treatment control measures. To do so, use your analysis in step 3, the details in Table 3-2 regarding whether a given control measure is acceptable for the project category, and the information in Chapter 6. Chapter 6 includes fact sheets for a variety of treatment control measures:

- Constructed wetland basin
- Water quality detention basin (three types: wet, dry, combination)
- Infiltration basin
- Infiltration trench
- Sand filter
- Stormwater planter (two types: flow-through and infiltration)
- Vegetated filter strip
- Vegetated swale

Treatment control measures are intended to filter and settle pollutants out of runoff before it travels off the site

Proprietary devices, such as stormwater vaults, may also be allowed for the project. Selected devices must meet the local permitting agency's approval. For projects in Sacramento County, refer to *www.sacramentostormwater.org* for information about which devices are currently accepted, and for projects in Roseville, check with the City of Roseville Public Works Engineering Division. Additional information about the agencies' approval programs is provided in Chapter 6.

When you have made a preliminary selection of the treatment control measures for your site, refer to the fact sheets in Chapter 6 and the sizing methodology in Appendix E to ensure that there is adequate space on your site for the measure(s). This may require an iterative process working with various types of control measures until the right combination is identified for the project. Depending on your preliminary calculations, you may also want to reconsider runoff reduction control measures to reduce the needed size of treatment facilities (revisit Step 5).

Step 7: Design Facilities (Preliminary)

At this point in the process you have selected the suite of control measures for your project, calculated the runoff reduction credits (if desired) and determined preliminary sizing for the treatment facilities. Now it is time to compile and submit the information to the applicable permitting agency with the planning application. Check with the agency for their submittal requirements and be sure to consult with their stormwater quality staff before proceeding to Step 8. Consider scheduling a pre-application meeting just for this purpose, or include stormwater quality as an agenda item on a pre-scheduled pre-application meeting. The stormwater quality staff will review the proposal, check that the standards would be satisfied by the proposal, and provide suggestions, but final design and sizing of the facilities will not be checked by the permitting agency until later in the process.

Step 8: Design Facilities (Final)

Using feedback from permitting agency staff obtained in Step 7, complete the final design of the stormwater quality facilities for submittal with construction or improvement plans to the local permitting agency. Appendix A outlines the minimum submittal requirements for this post-construction stormwater quality plan submittal. The submittal must provide sufficient design details, calculations and other information to demonstrate the adequacy of the proposed stormwater quality design for the project. Record all this design information on the design data summary sheet found at the end of each fact sheet in Chapter 6.

Appendix A also presents an example of the post-construction plan submittal required by the County of Sacramento. Check the web site for additional agency examples as they become available: *www.sacramentostormwater.org*.

Some permitting agencies may require a certificate of control measure compliance or similar certification before the project is deemed complete. Since every agency does this somewhat differently, it is critical to check with the applicable agency.

Step 9: Establish Long Term Maintenance Requirements

Verification of long-term maintenance provisions is required for projects using stormwater quality treatment control measures such as vegetated swales and stormwater planters. See Appendix B for a complete list.

For projects using porous pavement or green roof (Chapter 5), or any of the treatment control measures (Chapter 6), verification of long-term maintenance provisions is required. This is mandated by the agencies' municipal stormwater permits. The local permitting agencies in the Sacramento and South Placer areas will ensure a maintenance plan is in place through the execution of a maintenance agreement, covenant or permit with the property owner.

Each fact sheet in Chapter 5 and 6 for a control measure that requires a maintenance plan includes a table listing inspection and maintenance recommendations. This table (as amended by the project designer/property owner, if applicable) is meant to be incorporated into the maintenance agreement for the project.

Typically maintenance agreements and covenants are recorded with the deed for the property and follow property ownership. The agreements generally include provisions for the permitting agency to recover costs for maintenance in the event that the property owner fails to fulfill their obligations. They also require reconstruction or replacement of the feature when it fails to function properly. For informational purposes, Appendix B presents projected lifespan information for the various control measures.

Check with the local permitting agency about the maintenance submittal requirements and timing for execution of the agreement. See Appendix B for additional information and sample maintenance agreements.

Step 10: Construct

During the construction phase, follow the construction guidelines for the stormwater quality control measures described in the fact sheets found later in this manual. It is particularly important to protect the facilities from receiving sediment loads during the construction process. To protect facilities from adjacent construction activities, educate the construction superintendent and use erosion and sediment control techniques, such as erosion control blankets and straw wattles/fiber rolls. For construction erosion and sedimentation control standards and details, reference the local permitting agency's standard specifications and/or guidance manuals (see Appendix H for contact information). Because the state of this practice is evolving rapidly, be sure to check with the permitting agency to verify that you have the most current edition.

Permitting agency inspection staff will check for proper siting and installation of stormwater quality facilities throughout the construction process. Projects will not be accepted until all stormwater quality measures are functioning properly.

4 Source Control Measures

Source Control Principles

Source control measures are designed to prevent pollutants from contacting site runoff, leaving the site and entering the municipal storm drain system or local waterways. Development and redevelopment projects are required to employ source control measures appropriate to the planned site operations/activities (see Table 3-2 in Chapter 3).

This design manual addresses source control measures that can be implemented as part of the project design process. As noted in Chapter 1, it does not include ongoing behavioral-based, operational source control measures such as good housekeeping practices, spill control procedures and employee training. For information about operational best management practices to reduce stormwater pollution, consult the local permitting agencies, visit *www.sacramentostormwater.org* (select "Industrial/Commercial Element"), and/or look for that information in the *California Stormwater Best Management Practice Handbook*.

Source control measures apply to both stormwater and prohibited non-stormwater discharges. Non-stormwater discharges include anything not composed entirely of stormwater (such as cooling water, process wastewater, etc). Stormwater that is mixed or commingled with other non-stormwater flows is considered non-stormwater. Local, state or federal permits may be required for discharges of stormwater and non-stormwater to the storm drain system or a water body. To verify this, check with your local permitting agency.

Selecting Source Control Measures for Your Project

Use Table 4-1 (next page) to determine which source control measures are required for your project.

Some of the source control measures described in this chapter suggest discharging potentially polluted site runoff to the sanitary sewer system. This requires prior approval of the local sanitation district and may require a permit. Discharges of certain types of flows to the sanitary sewer system may be cost prohibitive due to connection fees. Appendix C provides permitting and contact information for the various sanitation district agencies in this area.

Source Control Fact Sheets

This chapter includes fact sheets for the seven source control measures listed in Table 4-1. Each fact sheet describes the purpose of the control measure, applicability, design requirements, and any operation and maintenance issues that may affect its design.

Table 4-1. Source Control Measures Required By Project Category

This table is for general reference only. Refer to the fact sheets later in this chapter for details.

Source Control Measure	Project Category: SINGLE FAMILY RESIDENTIAL	MULTI-FAMILY RESIDENTIAL	COMMERCIAL/ LIGHT INDUSTRIAL	AUTO REPAIR SHOPS	RETAIL GASOLINE OUTLETS	RESTAURANT	HILLSIDE DEVELOPMENTS	PARKING LOTS	STREETS/ ROADS	HEAVY INDUSTRIAL
Storm Drain Markings and Signs	●	●	●	●	●	●	●	●	●	●
Fueling Areas			●	●	●	●	(a)			●
Loading Areas			●	●	●	●	(a)			●
Outdoor Storage Areas			●	●	●	●	(a)			●
Outdoor Work Areas			●	●	●	●	(a)			●
Vehicle/ Equipment Wash Areas		●	●	●	●	●	(a)			●
Waste Management Areas		●	●	●	●	●	(a)	●		●

(a) depends on planned site operations/activities

References

The following general references were used to develop this chapter and the fact sheets found at the end of this chapter.

- Sacramento Guidance Manual for On-Site Stormwater Quality Control Measures, January 2000
- California Stormwater Quality Association Handbook, January 2003
- Stormwater Management Manual for Western Washington, Volume 1, February 2005
- City of Portland Stormwater Management Manual, September 2004
- The City of Sunnyvale Interim Stormwater Quality BMP Guidance Manual—Stormwater Plan Preparation for New and Redevelopment Projects, October 2003
- Sacramento Stormwater Management Program. 2001. BMPs for Industrial Stormwater Pollution Control. Available from *http://www.emd.saccounty.net/Documents*.

Purpose

This fact sheet provides details about permanent "No dumping-drains to creek/river" messages at storm drain inlets and "No dumping" signs at public access points to channels and creeks on the development project site, where applicable. Storm drain markings are intended to help stop illegal dumping by alerting people that the drain leads directly to a water body and dumping is prohibited. Signs at access points to creeks and channels serve as reminders that dumping there is illegal.

Applicability

As indicated in Table 4-1, permanent storm drain inlet markings are required on all new drain inlets (also known as catch basins) installed in development/ redevelopment projects. Signs are also required at public access points to any creeks or drainage channels within or adjacent to the site.

Design Requirements

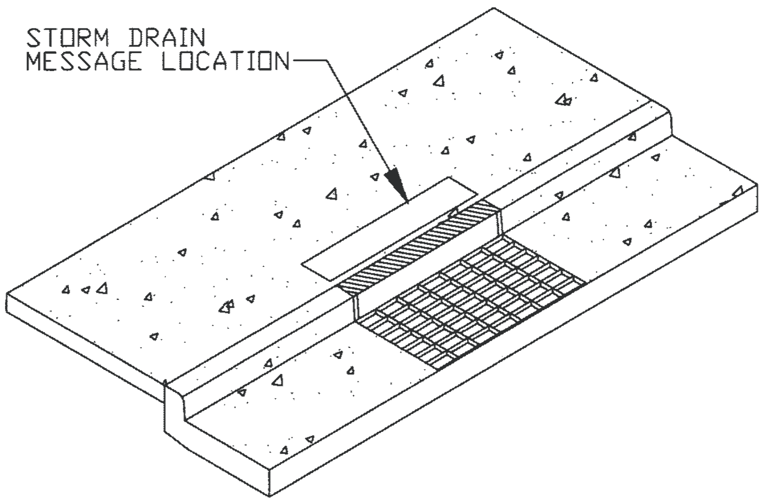
To protect water quality, follow the requirements shown in Table SD-1 to create consistent "no dumping" messages at storm drain inlets and public access points at creeks and channels.

Table SD-1. Design Requirements for Storm Drain Inlet Markings and Signage

Design Feature	Criteria
Location	Identify all storm drain inlets on the improvement plans and indicate they must be marked with appropriate storm drain messages. Locate the message on each inlet as described in the next section.
Message Layout and Content	Follow the message layout, content, and other specifications provided by the local permitting agency. Each agency may have its own design. See figure SD-1 for example detail. For signs posted at access points to waterways, consult the local permitting agency for their required/preferred message and style. Alternatively, obtain approval from the local jurisdiction for a different layout/message that clearly prohibits dumping using words or graphical icons. Consider the use of bilingual messages where appropriate based on local population.
Method of Application	Permanently apply the message at storm drain inlets by stamping it in concrete, affixing as a tile or cast-iron plate, or using an alternative approach approved by the local jurisdiction. For area drain markers, make sure any inset tiles or plates are flush with the surface of the inlet to avoid a tripping hazard. Consider permanently affix signs at access points to creeks and channels.

Operation and Maintenance

The legibility of storm drain inlet messages and signs must be maintained to ensure effective pollution prevention over time.



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.
3. FOR AREA DRAIN INLETS, STORM DRAIN MESSAGE SHALL BE PLACED ADJACENT AND PARALLEL TO THE LONG AXIS OF THE DRAIN.
4. LETTERS SHALL BE 1-1/2" IN HEIGHT. DIMENSIONS OF STORM DRAIN MESSAGE SHALL NOT EXCEED 12" X 33".
5. IF THE MESSAGE IS STAMPED IN CONCRETE, THE DEPTH SHOULD BE APPROXIMATELY 0.25".
6. IF AN ALTERNATIVE STORM DRAIN MESSAGE IS PROPOSED, IT SHALL BE APPROVED BY THE LOCAL AGENCY.

Figure SD-1. Storm Drain Inlet Message

Purpose

This fact sheet specifies how to locate and design vehicle and equipment fueling areas so that pollutants do not enter the storm drainage system and receiving waters. Leaked engine fluids and spilled fuel inevitably accumulate on the pavement around fueling areas, and they contain toxic materials and heavy metals that are not easily removed by stormwater treatment devices. The design requirements on this fact sheet are intended to prevent spilled fuel and other potential pollutants (such as oil and grease, solvents, car battery acid, and coolant) from contacting stormwater runoff or entering the storm drainage system.

Applicability

This fact sheet applies to design of fueling areas at new development or significant redevelopment of retail or commercial gasoline outlets, automobile maintenance/repair facilities, corporation yards, and any other facility incorporating a permanent fueling area. This fact sheet is intended for use during facility design and therefore does not address mobile fueling operations. It also does not include requirements for design of bulk fuel terminals (fuel farms). Contact the local permitting agency for requirements applicable to that type of industrial development.

Interceptor drains on the fueling pad perimeter at this retail gasoline outlet in Folsom catch spills and incidental contaminated wash water and direct it to an on-site 750-gal underground containment tank.

This retail gas outlet in Folsom has perimeter interceptor drains around both the concrete fueling pad and the concrete fuel transfer area. The drain carries spills and runoff to an on-site underground containment tank.

Design Requirements

To protect water quality, design vehicle or equipment fueling areas as explained in Table FA-1. Design requirements on this fact sheet are intended to supplement (not supercede) those in other codes (such as the Building, Fire, and Zoning Codes and the hazardous waste requirements in Title 22, California Code of Regulations, as applicable). Discuss any potential conflicts with the local permitting agency early in the planning process before proceeding with design.

Operation and Maintenance

The design features required by this fact sheet need to be maintained and properly operated and may be subject to inspections by local fire and/or sanitary sewer agencies, depending on the configuration.

Table FA-1. Design Requirements for Fueling Areas to Protect Water Quality[1]

Design Feature	Requirement
Paving	Use Portland cement concrete for the surface of the fuel dispensing area, which is defined as the entire area between adjacent fuel pumps and extending out at least 6.5 ft. beyond the outer edges of the perimeter pumps. Asphalt is not permitted. Use Portland cement concrete for the surface of the fuel transfer area. Asphalt is not permitted. Check with local permitting agency on dimensions of this pavement for your project site. Use asphalt sealant to protect any asphalt paved areas surrounding the concrete fueling and transfer areas.
Cover	Cover the fueling area with a roof structure or canopy unless the fueling area will be used routinely for oversized equipment or vehicles (such as cranes) that cannot be accommodated under cover. In such cases, special drainage requirements will apply; check with local permitting agency. Design the cover height per the building code (CBC 311.2.3.2 minimum cover height is currently 13'-6") Extend the cover at least 5 feet beyond the fuel dispensing area.
Grading/ Drainage	Design drainage system so that uncontaminated runoff from the roof/canopy terminates underground in a connection to the storm drain system. If possible, design the fuel dispensing and transfer area pads with no slope (flat) to keep minor spills on the pad and encourage proper cleanup. Check this with the local permitting agency. Do not place a storm drain inlet in or near the fuel dispensing area. Check with local permitting agency to determine if there are minimum spacing requirements between fueling area and nearest inlet. Hydraulically isolate the fuel dispensing and transfer areas from the rest of the site to contain spills and incidental wash water, prevent run-on, and prevent stormwater runoff from carrying pollutants away. Use one of the following methods:. ▪ **Berms**: Design the pad as a spill containment pad with a sill or berm raised at least 4 inches (raised sills are not required at open gate trenches that connect to an approved drainage-control system.) ▪ **Perimeter drains**: Locate drains around the perimeter of the pad. Drain accumulated water in one of two ways, depending on local permitting agency requirements: 1) to an on-site containment system (for eventual pump-out and off-site disposal), or 2) to the sanitary sewer, if equipped with automatic shutoff valve (see next section of table). Ensure that all grading, grade breaks and berms comply with applicable ADA requirements for disabled access.
On-site containment system	If the local permitting agency and fire district (in some cases two different agencies) allows the connection of inlets or interceptor drains in the fuel dispensing and/or transfer area(s) to an on-site containment tank, then size the tank according to applicable requirements.
Connections to sanitary system	If the sanitary sewer connection permitting agency allows inlets or interceptor drains that drain the fuel dispensing and/or transfer area(s) to connect to the sanitary sewer, equip such inlets and drains with a shutoff valve or spill control manhole (see below) to keep fuel out of the sanitary sewer in the event of a spill. See appendix "C" for contact information for the local sanitary sewer connection agencies. **Spill control manhole option**: Install manhole on the discharge line of the fueling pad (before the sanitary sewer line tie in); extend the tee section 18 inches below the outlet elevation and provide 60 cubic feet of dead storage volume (for oil, grease, and solids) below the outlet elevation.
Signage	If not otherwise required, post signs that state, "Do not top off gas tanks" to prevent spills. Post sign(s) explaining the operation of any shut-off valves for facility employees, if applicable.

[1] These requirements are intended to supplement, not supercede, those found in other codes (e.g, building, plumbing, fire). If conflicts are identified, consult with the local development permitting agency and other agencies as needed (e.g., fire, sanitation district) for resolution.

Purpose

This fact sheet specifies how to design loading/unloading areas to minimize the chance of spills and leaks and to keep any spilled/leaked materials out of the storm drain system and receiving waters. Potential pollutants addressed depend on the operations and materials being handled, but may include toxic compounds, oil and grease, nutrients, suspended solids, fluids leaked from delivery vehicles, and/or other contaminants. Leaked fluids from delivery vehicles can also accumulate in the loading area.

Applicability

Refer to Table 4-1 regarding the project land use types that need to comply with this fact sheet. The design requirements provided in this fact sheet are primarily intended for new development. If applied to significant redevelopment, the requirements would only apply in the case of complete redesign of the loading area.

Design Requirements

To protect water quality, design loading/unloading areas as explained in Table LA-1. These requirements are not intended to supercede other codes or other loading dock design or access requirements established by individual companies; discuss any potential conflicts with the local permitting agency early in the planning process before proceeding with design. It is recognized that some land uses (e.g., food-handling, chemical distribution, hazardous materials) have a greater potential to pollute stormwater if spills were to occur than other land uses and the level of control needed therefore varies. However, most times agency planners/reviewers will not know the use of the building at the time of plan approval. Further, warehouses and other buildings often have tenant turnover and use/materials handled will change over time. Therefore, a single set of design requirements is provided in order to address all anticipated land use types.

Operation and Maintenance

The design features required by this fact sheet need to be maintained and properly operated. This includes proper handling and disposal of any materials which may accumulate in the spill containment vault. In addition, features may be subject to inspections by local fire and/or sanitary sewer agencies, depending on the configuration.

Table LA-1. Design Requirements for Loading Areas to Protect Water Quality[1]

Design Feature	Requirements
Paving	Pave the loading area with an impervious paving material that is compatible with materials that will be loaded/unloaded. For example, use Portland Cement Concrete if gasoline or other materials that react with asphalt will be loaded/unloaded.
Cover	Several options are offered for covering the active loading area, to minimize the exposure of pollutants to rainfall and runoff; check with the local permitting agency on which of the options will be allowed for the project: **Option 1**. If feasible, design the facility so loading/unloading occurs inside an indoor loading bay. This is the best option from the perspective of protecting stormwater quality. If this is not feasible, consider the next option. **Option 2**. For buildings with less than 10 bays, provide a roof overhang that extends at least 10 feet beyond the loading dock (or the building face, if there isn't a loading dock). If the building includes 10 or more bays or a cover is deemed otherwise not feasible, consider the next option and proceed to "Grading/Drainage" element of this table. **Option 3**. Some local permitting agencies may allow use of a door skirt that fits snugly to both the trailer end and the building door during material transfers, on a case-by-case basis. Check with the permitting agency for verification.
Grading/Drainage	Direct runoff from roof downspouts away from the loading/unloading areas. Design outdoor loading areas so that the first 6 ft. of pavement, as measured from the dock face (or from the building if there is no elevated loading dock) is hydraulically isolated to prevent runon/runoff. This can be accomplished with berms, grading, or interceptor drains. See Figure LA-1 for suggested configuration using interceptor drains; check acceptability of this method with local permitting agency. Drain the hydraulically isolated area to a pretreatment device (e.g., oil/water separator) then to the sanitary sewer; equip the system with an emergency spill shut-off/diversion valve as described below. Verify that this is acceptable to the local permitting agency; the agency may require a cover on the entire area draining to the sanitary sewer.
Spill Control Diversion Valve and Containment Tank	Equip the drainage system with an emergency spill shut-off/diversion valve. The bypass on the shut-off valve should flow to an adequately-sized* spill containment vault located a safe distance away from structures due to potential for explosive/fire reaction (see Figure LA-1). This is subject to approval of local permitting agency and fire department/district (could be two different agencies). *The size of the spill containment vault should be equal to 125% of the volume of the largest container handled at the facility. If this is not known, assume that 250 gal is typically largest size handled at the loading areas. Containment vault would be 312 gal in this case.
Indoor Loading Areas — no obstruction zones	If loading is designed to occur indoors (beyond a bay door), provide a 10-ft. no obstruction zone within the building to allow the truck to extend inside and to provide a staging area. Clearly identify the no obstruction zone on the building plan. Clearly mark the no obstruction zone at an interior transfer area using bright or fluorescent floor paint.
Signage for Spill Control Features	Provide signage to identify the location and simple use instructions of any spill control/response design features (such as shutoff valves or spill response kits).

[1] These requirements are intended to supplement, not supercede, those found in other codes (e.g, building, plumbing, fire). If conflicts are identified, consult with the local development permitting agency and other agencies as needed (e.g., fire, sanitation district) for resolution.

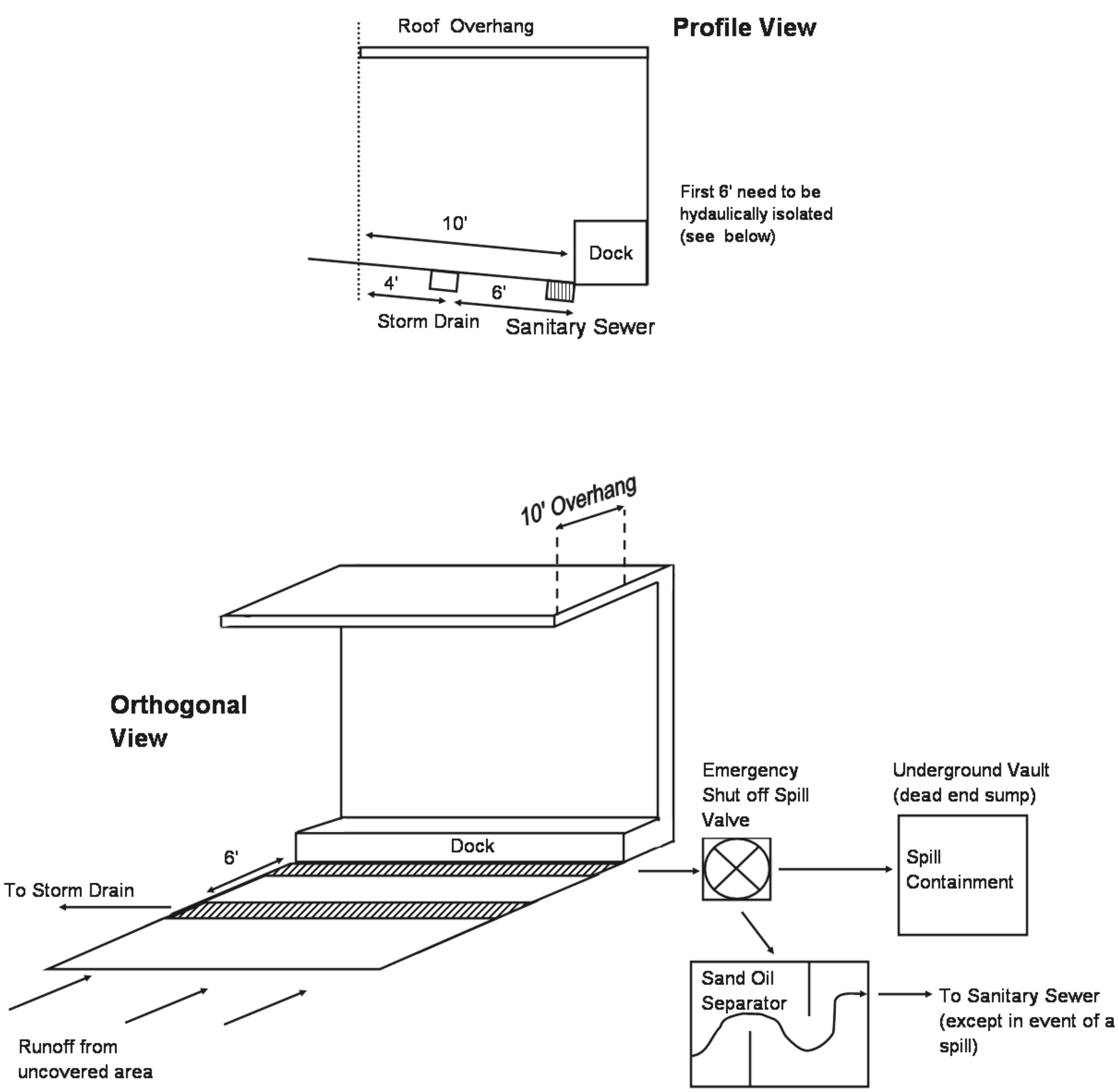


Figure LA-1. Recommended Loading Area Drainage Design

Photo: Sacramento County EMD, Water Protection Division

Purpose

This fact sheet specifies how to locate and design outdoor material storage areas so that materials do not get washed off-site with runoff and become sources of pollutants to the local municipal storm drain system, creeks and rivers. Such materials, including raw, by- and finished products, are not allowed in the storm drain system. Proper design of storage areas will also help ensure that stormwater and other site water does not come into contact with the stored materials and leach out pollutants. Potential pollutants addressed depend on the material stored, but may include toxic compounds, heavy metals, nutrients, suspended solids, and more.

Applicability

Refer to Table 4-1 regarding the project land use types that need to comply with this fact sheet. This fact sheet does not address storage of solid and recycling wastes; see the Waste Management Areas fact sheet elsewhere in this chapter.

Design Requirements

To protect water quality, design outdoor material storage areas as explained in Table OS-1. If possible, determine the types and quantities of materials likely to be stored prior to design.

Design requirements in this fact sheet are intended to supplement (not supercede) those in other codes (such as the Building, Fire, and Zoning Codes and the hazardous waste requirements in Title 22, California Code of Regulations, as applicable). Discuss any potential conflicts with the local permitting agency early in the planning process before proceeding with design. In addition, certain industries are subject to the State's Industrial Stormwater General Permit, which is also intended to protect stormwater quality: see *http://www.waterboards.ca.gov/stormwtr/industrial.html* regarding covered industries and applicable requirements.

Operation and Maintenance

The design features required by this fact sheet need to be maintained and properly operated. This includes proper handling and disposal of materials which accumulate in a secondary containment area, if applicable. In addition, features may be subject to inspections by local fire and/or sanitary sewer agencies, depending on the configuration.

Table OS-1.
Design Requirements for Outdoor Storage Areas to Protect Water Quality

Design Feature	Criteria
Size and Location	Size the storage area large enough for the expected materials and plan for segregation. Considering planned activities and traffic flow, locate the storage area where it will be convenient but not in the way of truck and vehicle traffic. Locate storage in a secure place to protect against vandalism and minimize accidents.
Paving	Construct the storage area base with a material impervious to leaks and spills. Contact your local permitting agency to determine if gravel surfaces are acceptable under certain conditions (e.g., storage of inert bulk materials).
Cover	Install a roof or other cover acceptable to the local permitting agency that extends beyond the storage area (enough to keep rain out), or use a storage shed or cabinet. If solid bulk materials (such as, wood chips and other landscaping materials, sand, lumber, scrap metal) will be stored and it isn't feasible to cover the storage area, then omit the cover and follow the drainage requirements for uncovered storage areas (see the next section.)
Grading/ Drainage	Direct runoff from downspouts/roofs away from storage areas. Hydraulically isolate the area using grades, berms or interceptor drains, to prevent run-on from surrounding areas or the runoff of spills. Refer to other fact sheets in this chapter for various options on how to accomplish this. Drainage Options for uncovered storage areas: (discharge to the storm drain system is not allowed) 1) If liquids (non-flammable, non-combustible) will be stored in the area, gently slope the storage area to drain to a dead-end sump. Accumulated water in the sump must be pumped to the sanitary sewer, an on-site stormwater quality treatment control measure, or land disposal, as appropriate based on the quality of the water and the sanitary sewer permit requirements. 2) If solid bulk materials will be stored in the area: Slope and arrange the storage area to minimize contact between stormwater and stored materials (such as wood chips, plant materials, and compost) that can leach potential pollutants.
Secondary containment for Bulk Liquids[1]	See notes above for liquids. As a general rule, size the secondary containment to accommodate at least 110% of the volume of the largest container or 10% of the volume of all the containers. If liquids will be stored in tanks, UL approved double-walled tanks can generally be used in lieu of other secondary containment. Verify this with the local permitting agency.

[1] Secondary containment is simply a structure/facility (such as a second container or bermed area) that would catch any spills or leaks from the primary storage container. Think of secondary containment as spill insurance.

Photo: CASQA, 2003

Purpose

This fact sheet pertains to work areas that are outdoors or that open to the outdoors. It specifies how to design such work areas to keep pollutants from contacting stormwater runoff and being carried into the storm drain system or receiving waters. Potential pollutants addressed depend on the work area but include any materials used on site or that could leak from vehicles or equipment. This includes: oil and grease, toxic substances, caustic or acidic substances, heavy metals, sediment, organic matter (depletes oxygen levels as it decays in water) and litter.

Applicability

Refer to Table 4-1 regarding the project land use types that need to comply with this fact sheet. This fact sheet addresses outdoor processing and manufacturing areas, as well as general "work" areas. Also, this fact sheet includes some requirements specific to vehicle repair areas, since auto repair shops are one of the priority project categories identified by the stormwater regulations (see Table 3-2 in Chapter 3). However, note that the most appropriate location for vehicle repair is indoors. All outdoor facilities will be subject to the approval of the local permitting agency.

Design Requirements

To protect water quality, use the requirements shown in Table OW-1 when designing work areas that are outdoors or open to the outdoors. The requirements are intended to keep such pollutants from soaking into the ground or reaching the storm drainage system and creeks and rivers. Alternative designs may be approved provided water quality is protected to an equal or greater extent. Check with the local permitting agency for verification.

Design requirements on this fact sheet are intended to supplement (not supercede) those in other codes (such as the Building, Fire, and Zoning Codes and the hazardous waste requirements in Title 22, California Code of Regulations, as applicable). Discuss any potential conflicts with the local permitting agency early in the planning process before proceeding with design. In addition, certain industries are subject to the State's Industrial Stormwater General Permit, which is also intended to protect stormwater quality: see *www.waterboards.ca.gov/stormwtr/industrial.html* regarding industries subject to the rules and applicable requirements.

Operation and Maintenance

The design features required by this fact sheet need to be maintained and properly operated. This includes proper handling and disposal of materials which may accumulate in containment devices/areas, ensuring that covers are not removed from outdoors work areas, and drains do not become disconnected. In addition, features may be subject to inspections by local fire and/or sanitary sewer agencies, depending on the configuration.

Table OW-1. Design Requirements for Outdoor Work Areas to Protect Water Quality

Design Feature	Requirement
Paving	Pave the work area with an impervious surface. Use Portland cement concrete (or equivalent smooth impervious surface) where vehicles or equipment will be repaired or hazardous materials could be used.
Cover	Conduct vehicle maintenance/repair indoors. Cover any other work areas that are not fully enclosed.
Grading/ Drainage	Locate the work area away from storm drain inlets. Hydraulically isolate the area using grades, berms or interceptor drains, to prevent run-on from surrounding areas or the runoff of spills. Refer to other fact sheets in this chapter for various options on how to accomplish this. Design a repair/maintenance bay drainage system to capture all wash water, leaks, and spills. Connect drains to a sump for collection and disposal. Direct connection to storm drain system or sanitary sewer is prohibited. Drain other work areas addressed by this fact sheet to a dead-end sump, containment area, sanitary sewer, or pretreatment facility (which in turn discharges to the sanitary sewer or storm drain as approved by the local permitting agency), as appropriate. The appropriate drainage destination will depend on potential pollutants and whether it is feasible to cover the work area. Discuss the project with the local permitting agency to determine the best solution, and whether a shut-off valve or other spill control device is warranted. If the site will include air compressors or other equipment that automatically produces small amounts of contaminated blowdown water, connect the blowdown to the sanitary sewer, subject to approval of the local permitting agency. Where processing operations are planned that will release wash water or process liquids, drain the area to the sanitary sewer (assuming approval is obtained).
Spill control	Some agencies may require an isolation valve, drain plug, or drain cover, to keep spills from entering the storm drainage system. Check with local permitting agency. Provide secondary containment structures (not double walled containers) where wet material processing occurs, to contain any spills or unplanned releases.
Signage	If the area drains to an inlet with a shut-off valve, post a sign locating the valve and explaining its operation.

Central Wash Area in Apartment Complex Parking Lot.
Source: City of Palo Alto, CA

Purpose

This fact sheet specifies how to locate and design permanent wash areas for vehicles and equipment (including restaurant mats) so that wash water does not enter the storm drain system and receiving waters. Wash water typically carries an array of pollutants harmful to the aquatic environment. Potential pollutants depend on what is being washed but typically include oil and grease, metals, suspended solids, soluble organics, food waste, fats/oils/greases from food, and/or detergents or other cleaning chemicals.

Applicability

Table 4-1 indicates the project land use types that need to comply with this fact sheet if a permanent wash area (including steam cleaning) is planned for the development project. In these cases, the wash area must be designed according to the design requirements specified in this fact sheet. Some permitting agencies may require the inclusion of a permanent designated wash area for some land uses. Check with the local permitting agency for verification. This fact sheet also pertains to the washing of equipment in outdoor areas, particularly, restaurant mats and similar equipment, which can send food waste and fats, oils and grease to the storm drain system.

Design Requirements

To protect water quality, design equipment and vehicle wash areas following the requirements in Table WA-1. Design requirements on this fact sheet are intended to supplement (not supercede) those in other codes. Discuss any potential conflicts with the local permitting agency early in the planning process before proceeding with design.

Table WA-1.
Design Requirements for Equipment and Vehicle Wash Areas to Protect Water Quality[1]

Design Feature	Requirement
Small Equipment Wash Areas — Applies to washing of restaurant mats and other kitchen supplies, as well as small equipment used at other commercial facilities.	
Size and Location-	Locate the designated wash area indoors. Provide a sink or contained wash area large enough to accommodate the largest item that will typically be washed.
Drainage and Pretreatment	Drain the sink/wash area to the sanitary sewer (or a zero-discharge water recycling system, subject to approval of permitting agency). For food-handling facilities: equip the wash area with a grease interceptor to meet the approval of the applicable permitting agency.

[1] These requirements are intended to supplement, not replace, those found in other codes (e.g, building, plumbing, fire). If conflicts are identified, consult with the local development permitting agency and other agencies as needed (e.g., fire, sanitation district) for resolution.

Design Feature	Requirement
Vehicle and Large Equipment Wash Areas	
Size and Location-	Locate the wash area such that access is from paved areas only (to prevent tracking of sediment). Size vehicle and equipment wash areas to extend at least 4 ft. in all directions around the largest piece of equipment/vehicle to be washed. For vehicle wash areas where vehicle size is unknown, size the wash area to be at least 25 ft. long and 15 ft. wide.
Paving	Pave the wash area with asphalt or concrete.
Cover	Cover the entire wash area with a roof or other type of approved permanent canopy. For covers 10 feet high or less, extend at least 3 feet beyond the perimeter of the hydraulically isolated wash area. For covers higher than 10 feet, extend at least 5 feet beyond the wash area. For new development in infill areas, or for redevelopment projects where there is no space to add a covered wash area, or for airport facilities, a diversion valve is required (see the Grading/Drainage section of this table). (Note: new facilities servicing oversize vehicles [bus, fire] can provide covered building or structure and redevelopment of such facilities should consider addition of diversion valve).
Grading/ Drainage – General	Hydraulically isolate the wash area to contain the wash water and prevent runoff from leaving the area and run-on from surrounding areas from entering the wash area. Use grade breaks, berms, or interceptor drains (around the perimeter or in the entrance and exit zones) to accomplish this.
Drainage – Covered areas	Connect the covered wash area to an appropriate pretreatment device (e.g., oil/water separator), then to the sanitary sewer. Alternatively, install a zero-discharge water recycling system. For any of these options, first obtain approval from the applicable permitting agency.
Drainage - Cover not feasible	When a cover is not feasible (see “cover” discussion earlier in this table), connect the hydraulically isolated area to the storm drain system and equip the drainage system with a diversion valve that can temporarily redirect polluted wash water to the sanitary sewer when washing activities are taking place. Various types of actuated valve configurations have been used in the Sacramento area for truck washing areas and children’s water parks. Diversion valves could be triggered when the water supply faucet is turned on or by a rain gage. Check with the local permitting agency early in the planning process before proceeding with design of this type of system.
Trash Receptacle	Locate a covered garbage receptacle within or immediately adjacent to a vehicle wash area to provide a convenient means for people to dispose of trash and keep the materials out of the storm drain system.
Signage	Post signs that clearly identify the facility’s intended use for employees and tenants. Post signs that prohibit: ▪ the use of cleaning products that contain hazardous substances (hydrofluoric acid, muriatic acid, sodium hydroxide, bleach, etc.) and can turn wastewater into hazardous waste. ▪ the use of specific cleaning products incompatible with any pre-treatment device (check with local permitting agency) ▪ dumping of vehicle fluids in wash areas ▪ engine/car repair in the wash area ▪ dumping in storm drains

Operation and Maintenance

The design features required by this fact sheet need to be maintained and properly operated. In addition, actuated valve installations may be subject to inspections by the local sanitary sewer agency.

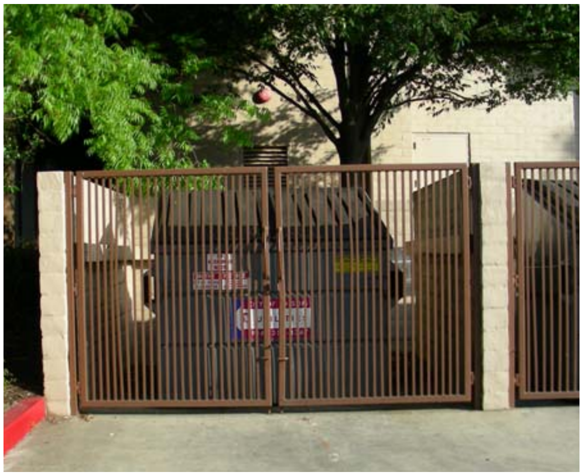


Photo: City of Folsom

Purpose

This fact sheet specifies how to design waste and recycling storage areas so that they aren't sources of pollutants to the storm drainage system and receiving waters. A properly designed waste/recycling storage area keeps rain, runoff, and other site water from leaching away pollutants; minimizes the chance of spills and leaks; and prevents any spilled or leaked wastes from entering the storm drainage system. Potential pollutants from waste include fats/oils/greases (from food), particulates, organic matter, toxic chemicals, and more.

Applicability

Refer to Table 4-1 regarding the project land use types that need to comply with this fact sheet. The design requirements provided in this fact sheet are primarily intended for new development. If applied to significant redevelopment, the requirements would only apply in the case of complete redesign of the portion of the facility involving the waste management/trash enclosure area(s).

Design Requirements

To protect water quality, design waste and recycling storage areas as explained in Table WM-1. Design requirements in this fact sheet are intended to supplement (not supercede) those in other codes (such as the Building, Fire, and Zoning Codes and the hazardous waste requirements in Title 22, California Code of Regulations, as applicable). Discuss any potential conflicts with the local permitting agency early in the planning process before proceeding with design. In addition, check with the appropriate waste hauler regarding design or access requirements.

Covered Storage for Waste and Recycling Bins and Compactor, Pleasanton, CA. Photo: CKB Environmental.

Operation and Maintenance

The design features required by this fact sheet need to be maintained and properly operated. This includes regular maintenance of the grease interceptor and handling and disposal of materials which accumulate in the interceptor, and maintenance of covers and sanitary sewer connections, if applicable.

Table WM-1.
Design Requirements for Waste Management Areas to Protect Water Quality[1]

Design Feature	Requirement
Location and Enclosure – General	Design an enclosed area for waste and recycling storage and collection on the site so that containers cannot be knocked over and where unauthorized use or vandalism is unlikely. This will help keep debris from being blown off site and pollutants from entering the storm drain system.
Location/Access – Enclosure Area	Provide adequate room for waste collection trucks to pick up and empty dumpsters to minimize chance of accidents and spillage. Check with the local solid waste agency for access standards. In the absence of local standards, design the enclosure to have direct access for collection trucks, meaning the truck can drive directly at the bin and insert the forks into the sides of the bin. A minimum straight approach of 50-65 feet is recommended to line up directly with the bin.
Paving	Pave the waste/recycling storage area with Portland Cement Concrete.
Space and Waste Segregation	Provide ample space inside the waste management area for bins to contain the maximum amount of expected waste and recycling matter to be generated at the facility, considering the typical waste collection schedule. Check with the local solid waste agency for detail drawings if available. For areas designated to contain tallow bin(s), provide a separate enclosed area for storage of the tallow bin, segregated from the area used to store solid and recycling wastes, and covered if acceptable to permitting agency (some agencies may not want solid waste enclosure covered [see discussion below], but will allow tallow bin enclosure to be covered due to different loading practices).
Cover	Provide a cover for the entire waste area if acceptable to permitting agency. Some local waste haulers may not allow a cover, due to vertical clearance/accessibility needs for front loading trucks. If a cover will be installed, check with local fire department about possible sprinkling requirements.
Grading/Drainage	Direct runoff from roof downspouts away from the waste/recycling storage area. Locate the waste management area at least 35 feet from the nearest storm drain inlet. The intention is to deter employees/tenants/contractors from directing wash water to the storm drain system with a hose or pressure washer. Hydraulically isolate the area; this can be achieved by reverse grading at the perimeter, perimeter curbing or berming, or the use of perimeter or area drains to collect and divert runoff.
Sanitary Sewer Connection	If acceptable to the permitting agency, connect the hydraulically isolated area to the sanitary sewer via a trench drain at the back of the enclosure or similar, to facilitate proper disposal of polluted wash water. Check with the local solid waste agency for detail drawings if available. Provide pretreatment with an approved grease interceptor prior to discharge to the sanitary sewer. Check with the local sanitary sewer permitting agency for specifics and approval. Note that the Plumbing Code limits the number of connections to a single grease interceptor at a facility. See Appendix C for sanitary sewer connection and contact information.
Signage	Post signs inside the enclosure and/or on the bins prohibiting the disposal of liquids and hazardous materials therein. Consider posting signs on the inside of the enclosure walls to educate employees and tenants about proper wash down procedures (procedures will vary depending on whether or not the area is connected to the sanitary sewer system).

[1] These requirements are intended to supplement, not supercede, those found in other codes (e.g, building, plumbing, fire, hazardous waste). If conflicts are identified, consult with the local permitting agency and other agencies as needed (e.g., fire, sanitation district) for resolution.

5 Runoff Reduction Control Measures

Runoff Reduction Principles

The goal of runoff reduction control measures is to mimic a site's predevelopment balance of runoff and infiltration by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Runoff reduction controls are integrated into site design and can be distributed throughout the site in a series of small-scale (or micro-scale) measures. As explained in chapter 1, this approach is one of the key elements in low impact development (LID) design.

The goal of runoff reduction control measures is to mimic a site's predevelopment balance of runoff and infiltration by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. This approach is one of the key elements of low impact development (LID) design.

Runoff reduction controls are typically integrated into site landscaping (including open space, yards, streetscapes, road medians, and parking lot and sidewalk planters) or into the design of paved and other impervious areas, such as the building roof. Small-scale runoff controls integrated into the project design and located close to the source of the water and pollutants can help reduce the need to convey water and treat it in large, often more costly end-of-pipe facilities located at the bottom of drainage sheds. By reducing the total runoff volume, these measures can also help alleviate potential downstream habitat degradation and erosion problems.

Although runoff reduction control measures can reduce the size/need for stormwater quality treatment, other drainage and flood control design requirements for the project still apply, as specified by the local permitting agency. References for drainage and flood control requirements are listed in Appendix H.

Use of runoff reduction controls can reduce the amount of water requiring treatment on a site

This chapter addresses the following three basic runoff reduction control strategies:

- Replace Conventional Impervious Surfaces with Pervious Surfaces
- Disconnect Impervious Surfaces
- Plant More Trees To Intercept Stormwater

Replace Conventional Impervious Surfaces with Pervious Surfaces

This manual describes several ways to reduce runoff by replacing conventional impervious surfaces with pervious ones; the covered approaches are:

- Porous Pavement
- Alternative Driveways
- Green Roof

Traditional asphalt and concrete pavement can be substituted with one of several different types of porous pavements, such as pervious concrete and pavers. The degree of permeability varies by type of material (for example, reinforced grass pavement is more pervious than cobblestone pavers), and the appropriate type to use depends on anticipated traffic loads and uses. There are various examples of pervious concrete, and many examples of pavers installed throughout the Sacramento area. Alternative driveways are one design application which involves replacing all or a portion of a standard impervious driveway with pervious materials such as grass or pavers. Check with the local permitting agency for any restrictions associated with the use of porous pavements or alternative driveway designs.

Instead of using conventional roofs, which generate a lot of runoff during a rain storm, consider installing an “green roof”, also known as an “ecoroof.” The roof functions like a sponge, using several inches of soil and a top layer of vegetation to capture and slow rainwater as it flows from the rooftop to the ground. The concept has been popular in Europe for centuries, has become more common in the Pacific Northwest and Midwest (e.g., Chicago), and is gaining popularity in California. Various green roof installations have been completed since the late 1990s in the San Francisco Bay Area and more recently in southern California. See the references at the end of this chapter for more information.

Disconnect Impervious Surfaces

In conventional designs, runoff and associated pollutants from impervious surfaces (such as parking lots and roof tops) flow directly to a storm drain system . In other words, the impervious areas are “directly connected” to the storm drains. Impervious areas can be “disconnected” when the runoff from the area is redirected to flow over landscaping, into stormwater planters, or through pervious pavement. In the Sacramento and Roseville areas, many projects are already constructed with disconnected roof drains, but there have been no design standards published to date about what to do with the runoff, short of routing it through a splash block or downspout extender to protect the building foundation. This chapter addresses that need.

This chapter introduces several measures that involve disconnecting impervious surfaces from the storm drain system:

- Disconnected Pavement
- Disconnected Roof Drains

Plant More Trees To Intercept Stormwater

Trees intercept stormwater and can retain a significant amount of the captured water on their leaves and branches, allowing for evaporation and dissipation of the energy of runoff. Their root structures absorb and uptake runoff and associated pollutants. The shade provided by trees keeps the ground under the trees cooler, thereby reducing the amount of heat gained in runoff as it flows over the surface and into the storm drain. In turn, this helps keep stream temperatures cool and healthy for fish and other aquatic life.

Developers and designers who use trees as part of an integrated stormwater quality plan can receive interceptor tree credits, as described in this chapter. In addition, shade trees may also be counted as interceptor trees if they are listed on the approved interceptor tree list in Appendix D.

Selecting Runoff Reduction Control Measures for Your Project

Refer to Table 3-2 to determine which runoff reduction control measures may be used in your project. Work with your civil/geotechnical engineer and planner to study the infiltration capacity of the soils and the future use of the site when making this determination. The local permitting agency may require permeability tests, depending on the type of control measure and site conditions. For pervious pavement, identify parking areas, walkways and patios that will not experience high traffic loadings. Involve your landscape architect in the initial site layout to locate and slope paved areas toward vegetated areas whenever possible. Once you've selected the measures most appropriate for the site, refer to the runoff reduction credit worksheets (Appendix D) to prepare the site design.

Runoff Reduction Fact Sheets

Fact sheets are included at the end of this chapter for the six runoff reduction control measures listed in Table 3-2 and introduced above. Each fact sheet describes the purpose of the control measure, applicability, design requirements, and any operation and maintenance issues that may affect design of the measure.

Runoff Reduction Credit Worksheets

Appendix D includes worksheets for calculating runoff reduction credits for residential and commercial developments and background information documenting the process used to derive the credits. Use the worksheets to determine to what extent you can reduce project runoff by incorporating one or more of the runoff reduction control measures described in this chapter. Use the worksheets to determine the required treatment water quality volume or flow adjusted for runoff reduction use, and then use Chapter 6 and Appendix E to guide you through the process of selecting and sizing your treatment measures.

References

The following general references were used to develop this chapter and Appendix D. Additional references and/or resource lists may be included at the end of each fact sheet in this chapter.

- Adams, M.C. 2003. Porous Asphalt pavement with recharge beds: 20 years & still working. Stormwater. May/June 2003.
- California Stormwater Best Management Handbook: New Development and Redevelopment. California Stormwater Quality Association, 2003.
- Cappiella, K. 2004. Urban Watershed Forestry Manual (draft). Prepared for USDA Northeastern Area State and Private Forestry. Center for Watershed Protection, Ellicott City, MD.
- City of Davis Community Forest Management Plan , September 11, 2002. *http://www.cityofdavis.org/pcs/trees/cfmp.cfm*
- City of Pasadena. California Code of Regulations. Hollywood Driveway. *http://www.ci.pasadena.ca.us/zoning/P-8.html* accessed March 6, 2006.
- City of Portland Stormwater Management Manual. Revision 3, September 1, 2004.
- High Point Community Site Drainage Technical Standards. Seattle, WA, June 2004.
- National Menu of Best Management Practices for Storm Water Phase II. United State Environmental Protection Agency. 2002. *http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm*
- New York State Stormwater Management Design Manual. Center for Watershed Protection, New York State Department of Environmental Conservation, Albany, NY, October 2001.
- Nonpoint Education for Municipal Officials. University of Connecticut. accessed May 26, 2006. *http://nemo.uconn.edu*
- Paris N. and M. Chusid. 2006. Coloring Pervious Pavement...because protecting the environment should be beautiful. *www.ConcreteDecor.net* Dec/Jan 2006.
- Post-Construction Urban Runoff Management. City Council Policy. City of San Jose, California. February 3, 1998.
- Shueler T., Swann C., Wright T, and S. Sprinkle. 2004. Urban Subwatershed Restoration Manual No 8: Pollution Source Control Practices. Version 1.0. Center for Watershed Protection. Ellicot City, MD. July 2004.
- SMRC, The Stormwater Manager's Resource Center. Fact Sheets. *http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm* accessed June 14, 2006.

- SMRC, The Stormwater Manager's Resource Center. Manual Builder. *http://www.stormwatercenter.net/Manual_Builder/Credits/SITE/reforestation.htm*
- SMRC, The Stormwater Manager's Resource Center. Manual Builder. *http://www.stormwatercenter.net/Manual_Builder/Credits/SITE/rooftop.htm*
- Start at the Source - Design Guidance Manual for Stormwater Quality Protection, Bay Area Stormwater Management Agencies Association, 1999.
- Stormwater C.3 Guiedbook: Stormwater Quality Requirements for Development Applications. Contra Costa Clean Water Program. Contra Costa, CA, March 2005.
- Sustainable Infrastructure Alternative Paving Materials Subcommittee Report. City of Portland. October 3, 2003.
- Truckee Meadows Regional Storm Water Quality Management Program: Draft Low Impact Development Handbook. August 2005.
- Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices. Urban Drainage and Flood Control District. Denver, CO. September, 1999 (Rev. June, 2002).
- Virginia Stormwater Management Program Handbook. Virginia Department of Conservation and Recreation. 1999.
- Xiao Q., and E.G. McPherson. 2003. Rainfall interception by Santa Monica's municipal urban forest. Urban Ecosystems
- Xiao, Q., E.G. McPherson, S.L. Ustin and M.E. Grismer. 2000. A new approach to modeling tree rainfall interception. Journal of Geophysical Research 105(D23) :29,173-29,188.
- Xiao, Q. 1998. Rainfall interception by urban forests. Davis, CA: University of California. Ph.D. Dissertation.
- Xiao, Q., E.G. McPherson, S.L. Ustin, M.E. Grismer, and J.R. Simpson. 2000. Winter rainfall interception by two mature open grown trees in Davis, CA. Hydrological Processes. 14(4) :763-784.

Description

Porous pavement allows stormwater runoff to infiltrate into the ground through voids in the pavement materials. There are many types of porous pavement, including pervious concrete and asphalt, modular block, reinforced grass, cobblestone block and gravel. When properly installed, and in the proper setting, porous pavement can be as functional and durable as traditional surfaces.

Siting Considerations

- Soil permeability: 0.6-2 in/hr (permeability test required to confirm).
- Depth to groundwater: minimum 10 feet below aggregate base.
- Grade: 10% maximum.
- Loading: pavement material and design must accommodate anticipated load.

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the porous pavement is properly designed, constructed, and operated to maintain its infiltration capacity.

Advantages

- Replaces regular pavement, so does not require additional land on the site.
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat.
- Allows for tree preservation in areas requiring pavement.
- Sometimes more attractive than traditional pavement.

Limitations

- Generally, not ideal for high usage parking lots and roadways with high traffic loadings.
- Do not use on sites with a likelihood of oil, grease or other hazardous spills.
- Certain types (e.g., modular block pavement) may not be acceptable to local fire authority.
- Porous asphalt will be considered on case by case basis.

Maintenance Recommendations (Low to Moderate[1])

- Block pavers with voids filled with sand or sandy loam may require occasional replacement of fill material if infiltration capacity is lost.
- All of the hard surfaces will benefit from occasional vacuuming.
- Grassed pavements require regular mowing.
- Pervious pavements may need to be replaced after several years, depending on the amount of fine material deposited on the surface.

[1] Compared to stormwater quality treatment control measures discussed in Chapter 6.

How does Porous Pavement work?

Porous pavements include a variety of stabilized surfaces with void spaces designed to infiltrate stormwater runoff into the ground or slowly release the water into a subsurface drainage system. Using porous pavement minimizes impervious areas, thereby reducing the amount of site runoff requiring treatment.

Planning and Siting Considerations

Development type/land use

In developments where it is difficult to provide stormwater treatment (such as small or redeveloping sites or high-density residential developments), porous pavement may provide the best or only opportunity to reduce site imperviousness.

All land uses contain potentially suitable locations for porous pavement. Consider porous pavement for:

- Residential driveways, patios, and walkways (also see Alternative Driveway Fact Sheet elsewhere in this chapter)
- Commercial plazas and courtyards, overflow parking areas, parking stalls, some types of storage areas, walkways, and entryway features
- Employee parking and entryway features at industrial sites
- Fire lanes, maintenance access roads and other roadways where infrequent or low traffic loads and volume are expected (check with fire department for minimum specifications)
- Within parks and open space for parking areas, sports courts, playgrounds, and pedestrian/bike trails.

Porous pavement is not suitable for commercial drive aisles, loading and waste management areas and other heavy traffic areas. It is also not appropriate where spills may occur, due to the potential for soil and groundwater contamination. Such areas include retail gas outlets, auto maintenance businesses, processing/manufacturing areas, food-handling businesses, and chemical handling/storage areas.

Other Siting Considerations

- Consult a geotechnical engineer to determine what types of porous pavement are suitable for the expected traffic load and volume.
- Consult a geotechnical engineer to determine set back from building foundation, or use 10 feet.
- Determine site soil type and permeability before selecting porous pavement as a runoff reduction strategy; a soil permeability of 0.6-2.0 in/hr is required. The local permitting agencies will require a permeability soils test to verify infiltration capacity of native soils. May be used over soils with lower permeability in selected situations if underdrain is provided (check with permitting agency to verify).
- Address seasonal shrink/swell in sites with expansive subgrade. Use the expansion index test (ASTM D4828) to provide insight as to degree of surface deformation in choosing paving sections.
- Consider opportunities for directing runoff from impervious surfaces across porous pavement to achieve runoff reduction credits. See the Disconnected Pavement Fact Sheet located elsewhere in this chapter.
- Select the porous pavement type based on the type of anticipated pedestrian traffic; most types of porous pavement can be designed to be Americans with Disabilities Act (ADA) compliant.
- A water barrier or interceptor drain will be required where porous material abuts regular asphalt/concrete pavement and there is concern about water infiltrating the regular pavement subbase. The water barrier should be 24 inch wide thick visqueen run down the 12 inch deep

excavation and 12 inch under the drain rock. Interceptor drains should tie into an open landscape area or treatment control measure to quickly relieve the water pressure in the pavement section and prolong the pavement life.

- For manufactured products, check the manufacturer's specifications for any additional siting considerations.

A water barrier or interceptor drain will be required between regular load-bearing pavement/streets and porous pavement materials. Photo: City of Portland

Porous Pavement Types

Six types of porous pavement material are presented in this fact sheet: 1) pervious concrete, 2) pervious asphalt (considered on case by case basis), 3) modular block, 4) reinforced grass, 5) cobblestone block and 6) gravel. Additional types may be allowed on a case-by-case basis; check with the local permitting agency for verification before proceeding with design.

Pervious Concrete and Asphalt

Pervious concrete and pervious asphalt have a higher load bearing capacity than the other porous pavement options discussed in this chapter. Table PP-1 (presented later in this chapter) lists and compares the design criteria for all featured porous pavement types.

Pervious concrete parking lot; Bannister Park, Fair Oaks, CA
Photo: CNCPC and Fair Oaks Recreation and Parks District

Pervious asphalt roadway. Photo: City of Portland

Pervious concrete is poured like traditional concrete pavement, but is made from a specially-formulated mixture of Portland Cement and no sand; the result is 15% to 21% void space. See Figure PP-1 for a typical installation detail. Colorants can be added for aesthetic reasons, and surfaces can be ground for smoothness. Owners, architects, and engineers are encouraged to visit local sites where pervious concrete has been installed before deciding to use the material (see list of selected local installations in Table PP-3 at the end of this fact sheet).

Pervious asphalt consists of an open-graded coarse aggregate, bound together by asphalt cement into a coherent mass, with sufficient interconnected voids to provide a high rate of permeability. As long as the appropriate asphalt mix and design specification is used, pervious asphalt may be as durable as regular asphalt (Adams 2003). Pervious asphalt is less expensive than pervious concrete, but both types cost more than regular asphalt or concrete.

Most available pervious asphalt design specifications include the use of a collection system and underlying recharge bed, which at this time are not being proposed. Pervious asphalt installations are currently being examined, and it is anticipated that applicable design standards will soon be available. Pervious asphalt may be accepted for installation as specifications are developed, and at the discretion of the permitting agency. Additional information will be included in future manual updates.

The key to success with both pervious concrete and asphalt is proper installation by certified or otherwise experience contractors, and protection during construction activities to prevent clogging by fine construction sediment.

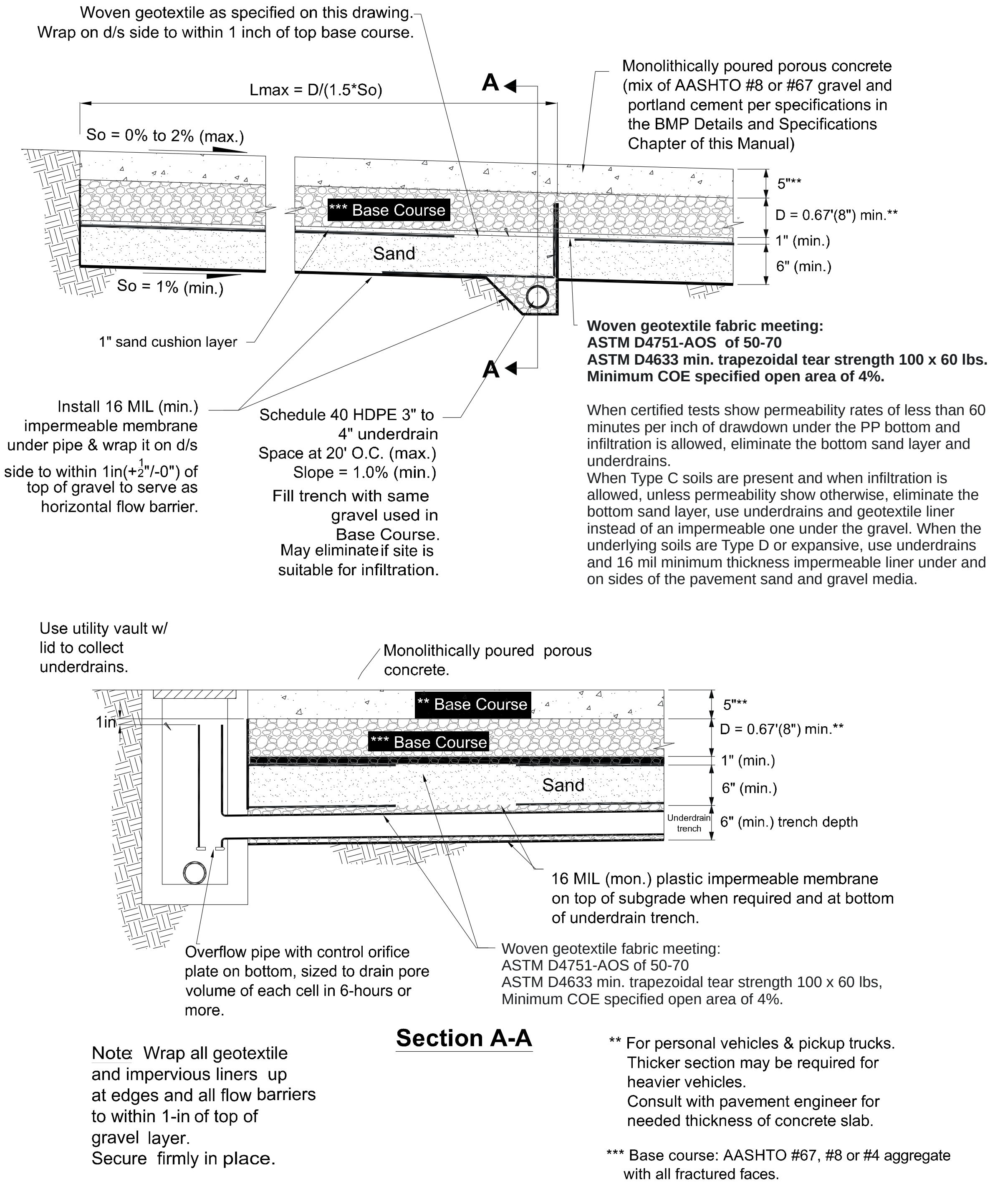


Figure PP-1. Typical Pervious Concrete Sections*

(Source: adapted from Denver) *Installation specifications may vary by site; check with local permitting agency

Modular Block Pavement

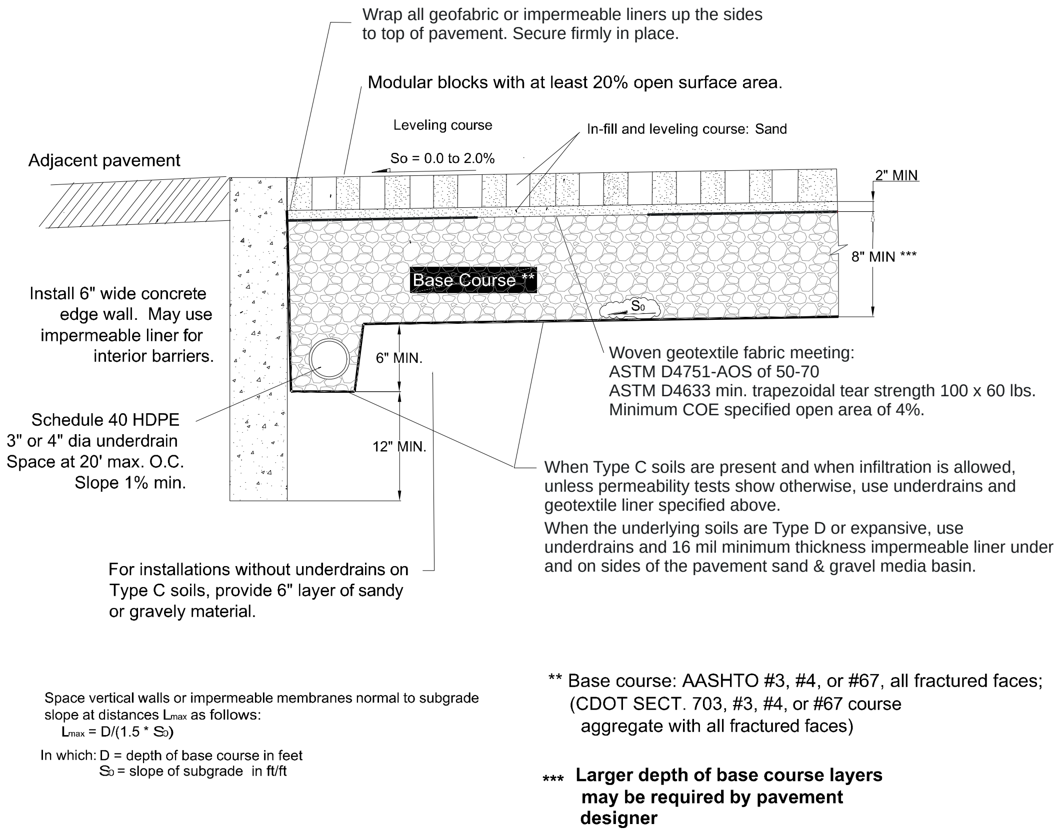
Porous modular block pavement (Figure PP-2) consists of concrete blocks with 20% or more open area, which is filled with sand or sandy loam turf. The units are installed over a gravel subgrade. This type of pavement is best suited for areas with low traffic loadings and seasonal/infrequent vehicle traffic, such as courtyards, driveways, overflow parking areas, and maintenance access roads. Check with the local fire authority about whether this option is acceptable for fire access lanes. One benefit is that it does not require utility cuts; instead the blocks can be taken out and replaced after utilities have been installed. Refer to Table PP-1 for design criteria for this type of porous pavement.

Other Names: Open-celled unit pavers, turf block, Grasscrete™

Photo: M&C Pavers, Florida

Figure PP-2. Modular Block Pavement, Typical Section*

(Source: adapted from Denver) *Installation specifications may vary by site; check with local permitting agency



Reinforced Grass Pavement

Reinforced grass pavement (Figure PP-3) consists of an irrigated surface, typically stabilized with a manufactured product over which soil and seed mix is spread. Of the various porous pavement options, this may provide the greatest stormwater quality benefit due to its high permeability and evapotranspiration and nutrient uptake by vegetation. This pavement type is well suited in low-traffic areas, such as overflow parking areas (stalls can be marked with athletic field paint) and maintenance roads. (Source: NEMO). However, it is not suitable for fire access lanes. Load bearing capacity varies by product, so select the reinforcement grid based on anticipated load. Because of the reinforcement, the area can be used even when the ground is saturated. Irrigation is required to maintain the vegetation. Refer to Table PP-1 for design criteria for this type of porous pavement.

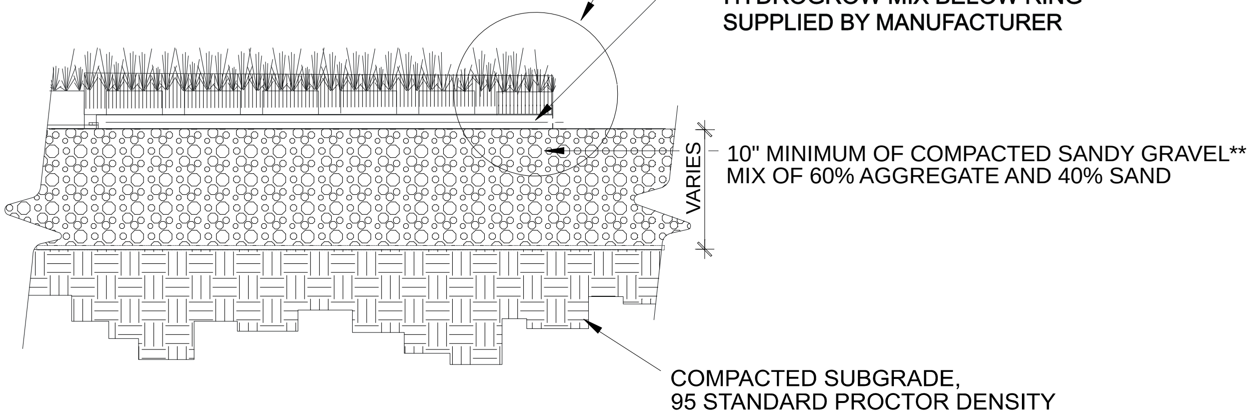
New installation of reinforced grass pavement. *Photo: Puget Sound Action Team, WA*

Other names: grid pavers, green parking, Grasspave™

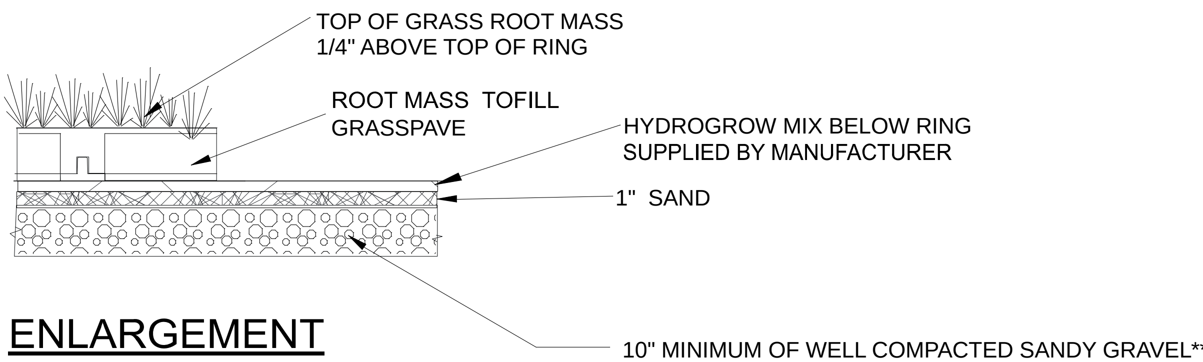
Figure PP-3. Reinforced Grass Pavement, Typical Sections*

(Source: adapted from Denver)
*Installation specifications may vary by site; check with local permitting agency

SPECIFICATIONS



SECTION



ENLARGEMENT

NOTES:

1. INSTALL GRASSTURF REINFORCING LAYER PER MANUFACTURER'S RECOMMENDATIONS INCLUDE MODIFICATIONS SHOWN ON THIS DRAWING.

2. DETAIL BASED ON INVISIBLE STRUCTURES, INC., ET AL DETAILS, BUT MODIFIED TO SUIT USDCM REQUIREMENTS.

****GREATER DEPTH OF PAVEMENT MAYBE REQUIRED BY PAVEMENT DESIGNER**

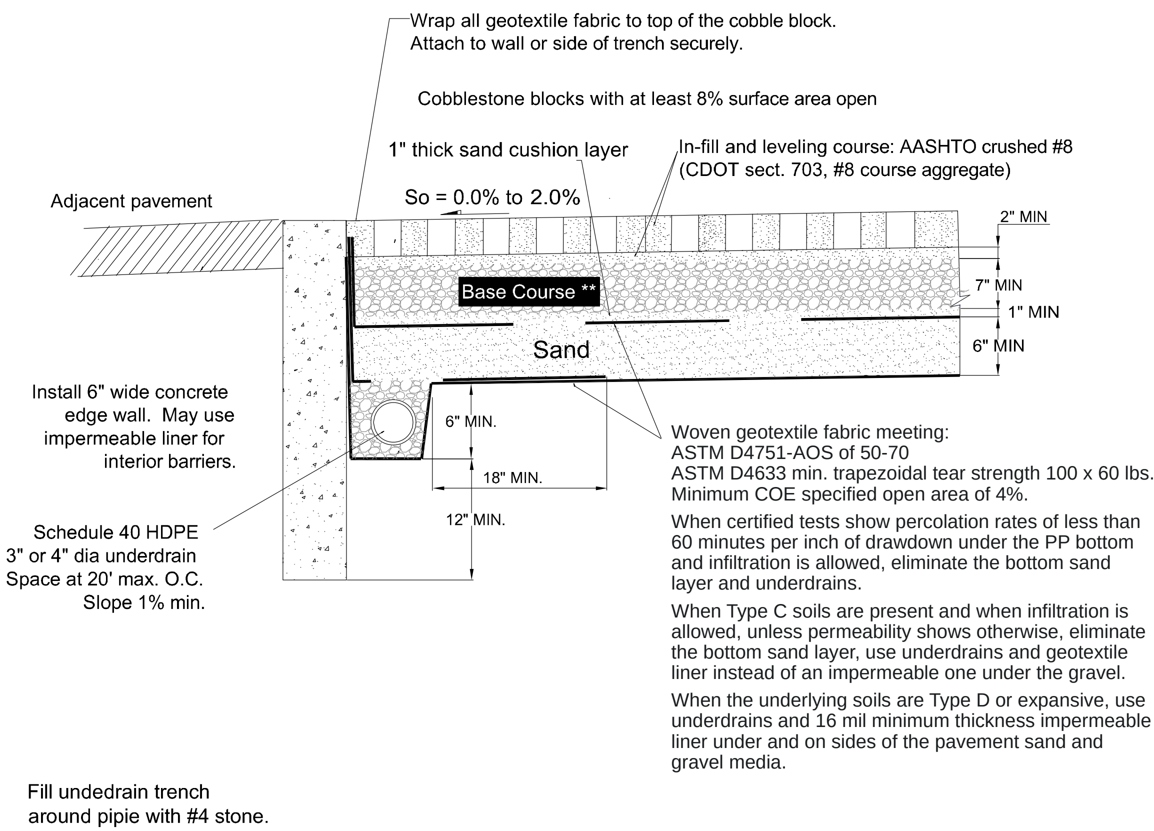
Cobblestone Block Pavement

Cobblestone block pavement (Figure PP-4) consists of concrete block units with at least 8% void space where the beveled corners meet. The units are installed on a gravel subgrade, and the void space is filled with sand. This is one of the most attractive porous pavement options and allows for the greatest flexibility in pattern and color. Cobblestone block pavement can be used wherever modular block pavement is appropriate, and similarly, does not require utility cuts; instead the blocks can be taken out and replaced after utility installation. Refer to Table PP-1 for design criteria for this type of porous pavement.

Photo: Puget Sound Action Team

Figure PP-4. Cobblestone Block Pavement, Typical Section*

(source: adapted from Denver)
*Installation specifications may vary by site; check with local permitting agency



Space vertical walls or impermeable membranes normal to subgrade slope at distances L_{max} as follows:

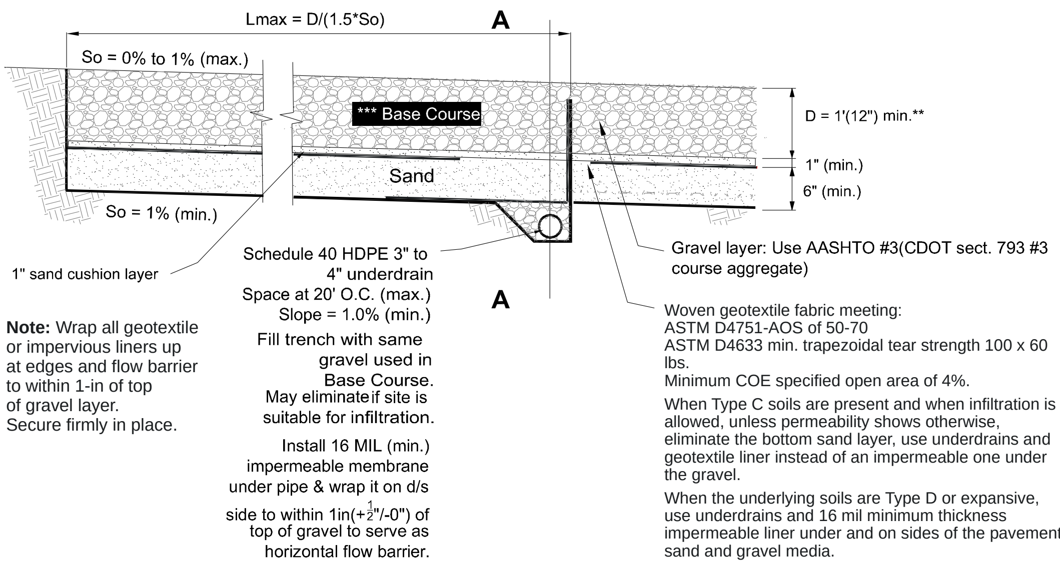
$L_{max} = D/(1.5 * S_0)$

In which: D = depth of base course in feet
S_0 = slope of subgrade in ft/ft

** Base course: AASHTO #67, #8 or #4 aggregate with all fractured faces.

Porous Gravel Pavement

Porous gravel pavement (Figure PP-5) consists of a loose gravel surface installed with or without additional stabilization depending on anticipated loads and traffic. This type of pavement must be placed over a sufficient aggregate base to allow for storage and infiltration. Where drainage is slow, an underdrain may be required. It is ideal for temporary use areas where permanent pavement would be too costly, as well as rural and park settings, overflow parking lots, maintenance roads, fire access lanes, and materials storage areas. However, check with the local permitting agency, since some agencies in the Sacramento area don't allow gravel except for certain types of storage yards. Refer to Table PP-1 for design criteria for this type of porous pavement.



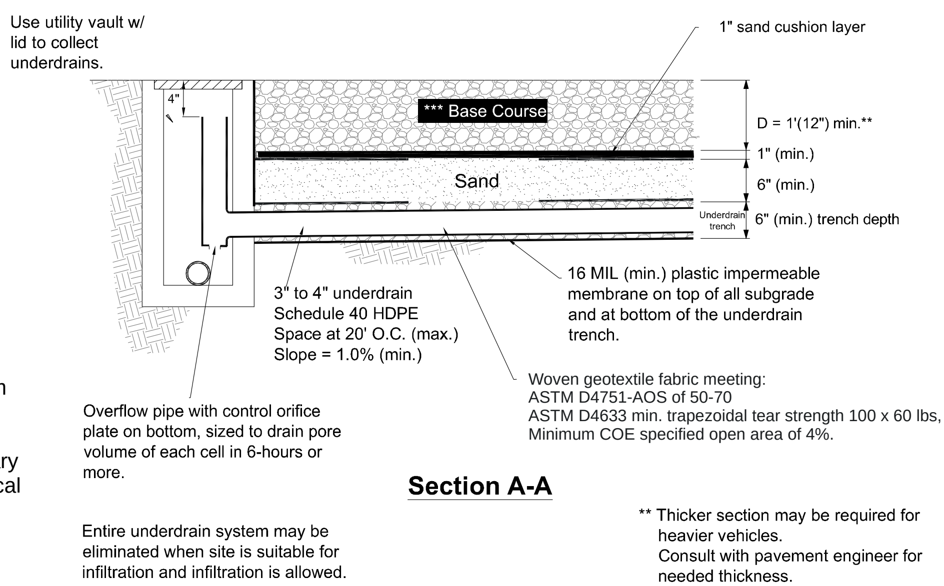


Figure PP-5. Porous Gravel Pavement, Typical Sections*

(source: adapted from Denver)
*Installation specifications may vary by site; check with local permitting agency

Design Criteria

Design criteria for porous pavement are listed in Table PP-1.

Table PP-1. Design Criteria for Porous Pavement*

Also see Appendix D for information on calculating runoff reduction credits.

Pavement Type/ Parameter	Criteria
Pervious Concrete (Figure PP-1)	
Void space	Minimum 15% throughout material
Base Course	With underdrain - 8” minimum of coarse aggregate over 7” minimum sand over 3” minimum coarse aggregate; without underdrain - 12” minimum coarse aggregate
Liner	Impermeable liner required when Type C or D soils are present; A or B soils types require geotextile filter cloth with 60 to 80 pores per inch.
Underdrain	Required when specified permeability range is not available in native soils. Use a gravel trench or perforated pipe embedded in a 6-12-inch layer of crushed rock. Connect to storm drain (not sanitary sewer).
Water Barrier	The water barrier should be 24 inch wide thick visqueen run down the 12 inch deep excavation and 12 inch under the drain rock, or use interceptor drain. Check with the geotechnical engineer.
Modular Block Pavement (Figure PP-2)	
Void space	Minimum 20% surface area as open annular spaces
Base Course	8” minimum of coarse aggregate
Liner	Same as pervious concrete.
Reinforced Grass Pavement (Figure PP-3)	
Base Course	10” minimum of compacted sandy gravel mix
Cobblestone Block Pavement (Figure PP-4)	
Void space	Minimum 8% surface area as open annular spaces
Base Course	7” minimum of coarse aggregate over 7” minimum of sand.
Liner	Same as pervious concrete.
Porous Gravel Pavement (Figure PP-5)	
General	With underdrain - 12” minimum of coarse aggregate over 7” minimum sand over 3” minimum coarse aggregate; without underdrain - 14” minimum coarse aggregate
Liner	Same as pervious concrete.

Source: Urban Drainage and Flood Control District. Denver, Colorado

*Design criteria may vary by permitting agency; check before proceeding with design. A permeability test will be required to verify suitability of this technique for the site. A qualified engineer must provide site-specific design specifications for pavement installation. In addition, the manufacturer’s specifications apply.

Construction Considerations

- Proper installation is important for all porous pavement types, but it is especially critical for pervious concrete and asphalt, which must be installed by certified or otherwise qualified contractors. Certification programs are now offered by various National and State associations (contact National Ready Mixed Concrete Association for more information).
- The designer should define compaction criteria to protect infiltration capacity of pervious materials and satisfy roadway loading requirements.
- Weather conditions can affect the final product. Avoid extremely high or low temperatures during installation. The bottom of the crushed rock reservoir below the pavement should be flat so that runoff will be able to infiltrate across the entire sub surface area (unless subsurface drain required).
- Additional information must be incorporated into construction specifications depending on the type of porous pavement proposed and addressing site-specific pavement design. Manufacturer's recommendations could be incorporated into the project specifications.
- After installation, and as construction continues elsewhere on the site, prevent fine sediment from clogging the material by covering the surface with plastic, using staked straw wattles around the perimeter, etc.
- As soon as possible, stabilize the entire tributary area to keep sediment-laden runoff from contacting the new pavement.

Long-term Maintenance Recommendations

Table PP-2 presents inspection and maintenance recommendations for porous pavement. The local permitting agencies will require that the property owner be responsible for maintaining the features to ensure continued, long-term performance. The pervious features should not be removed or replaced with impervious surfaces in the future, or all water quality benefits will be lost. Check with your local permitting agency to determine if and when a maintenance agreement will be required for your project.

Table PP-2. Inspection and Maintenance Recommendations for Porous Pavement

Surface Maintenance	▪ Keep the surface clean and free of leaves, debris, and sediment, and do not replace or cover it with an impermeable paving surface. ▪ Regularly sweep or vacuum pervious concrete and asphalt, modular block pavement or cobblestone Block Pavement (typically three to four times per year). ▪ Do not store loose material such as bark or sand on porous pavement.
Care of Vegetation	▪ Mow, irrigate, fertilize, and—when necessary—reseed grasses planted in pavement. Keep grasses healthy and dense enough to provide filtering while protecting underlying soils from erosion. ▪ Mow grass to less than four inches and remove grass clippings. ▪ Avoid planting trees and shrubs near non-flexible porous pavement types because roots may crack pavement and excessive leaves may clog the surface. Use of structural soil material may alleviate this concern.
Vector Control	▪ Eliminate any standing water, since that provides an environment for insect larvae. ▪ If sprays are considered, then use a licensed pest controller to apply an approved mosquito larvicide.
Maintenance of Reinforcement Products	▪ Where reinforcement products are used to stabilize grass or gravel, replace individual grid sections when they become damaged.
Manufacturer's Recommendations	▪ For manufactured products, follow manufacturer's maintenance recommendations.
Replacement	▪ Reconstruct or replace when it is no longer functioning properly (see projected lifespan in Appendix B for informational purposes).

Table PP-3. Selected Local Pervious Concrete Installations

Type	Location	Contact
Residential Driveway	4600 McDonald Drive, Sacramento, CA	Private residence (do not disturb residents)
Parking Lot	Bannister Park, Miller Park and Phoenix Community Park, Fair Oaks	Fair Oaks Recreation and Park District
	Mace Ranch Park, Davis	City of Davis Parks Department
Garden (Pathways, etc)	Fair Oaks Park Water Wise Garden, Fair Oaks	Fair Oaks Recreation and Park District
	UC Berkeley Botanical Gardens, Berkeley	UC Berkeley
School	Linden High School Pervious Parking Lot, 3247 Linden Street, Linden, CA	
Municipal Bus/ Corporation Yard	City of Elk Grove Corporation Yard, Elk Grove	City of Elk Grove Public Works Department

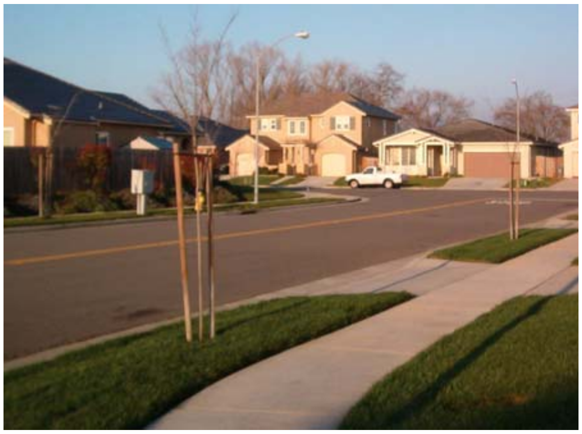
Resources for More Information

- California Nevada Cement Association, *www.cncement.org*
- Concrete Promotion Council of Northern California, *www.cpcnc.org*
- National Ready Mixed Concrete Association (NRMCA), *http://www.nrmca.org*
- Pacific Southwest Concrete Alliance, *http://www.concreteresources.net/*
- Northern California Asphalt Pavement Association, *www.apaca.org*
- National Precast Concrete Association, *www.precast.org*
- Portland Cement Association, *www.portcement.org*
- National Asphalt Pavement Association, *www.hotmix.org*
- Asphalt Emulsion Manufacturers Association, *www.aema.org*
- American Concrete Pavement Association - Southwest Chapter, *www.acpa-southwest.org*
- Association of Asphalt Paving Technologists, *www.asphalttechnology.org*
- American Concrete Paving Association, *www.pavement.com*

References Used to Develop This Fact Sheet

- Adams, M.C. 2003. Porous Asphalt pavement with recharge beds: 20 years & still working. Stormwater. May/June 2003.
- City of Portland Stormwater Management Manual. Revision 3, September 1, 2004.
- Start at the Source - Design Guidance Manual for Stormwater Quality Protection, Bay Area Stormwater Management Agencies Association, 1999.
- National Menu of Best Management Practices for Storm Water Phase II. United State Environmental Protection Agency. 2002. *http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm*
- Nonpoint Education for Municipal Officials. University of Connecticut. accessed May 26, 2006. *http://nemo.uconn.edu*
- Paris N. and M. Chusid. 2006. Coloring Pervious Pavement…because protecting the environment should be beautiful. *www.ConcreteDecor.net Dec/Jan 2006.*

- SMRC, The Stormwater Manager's Resource Center. Fact Sheets. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm accessed June 14, 2006.
- Sustainable Infrastructure Alternative Paving Materials Subcommittee Report. City of Portland. October 3, 2003.
- Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices. Urban Drainage and Flood Control District. Denver, CO. September, 1999 (Rev. June, 2002).
- Virginia Stormwater Management Program Handbook. Virginia Department of Conservation and Recreation. 1999.



Divided sidewalks in a new residential subdivision are one form of disconnected pavement. *Photo: ECORP Consulting*

Description

Disconnected pavement is any impervious pavement designed to sheet flow runoff over adjoining vegetated areas or porous pavement before it reaches the storm drain system. As the runoff slows and travels though vegetation or over a porous surface, water is infiltrated into the soil with some pollutant removal through filtration.

It is recommended that you read the Porous Pavement Fact Sheet before using this one. Also, Alternative Driveway Design, the next fact sheet in the series, is a technique which employs principles from this and the Porous Pavement fact sheet.

Siting Considerations

- Soils: Appropriate for all soil types but porous pavement requires an underdrain for soil types C and D.
- Grade: 10% maximum.
- Traffic loading: Select and design surface material with consideration of anticipated load.

Vector Considerations

- Potential for mosquitoes due to standing water in vegetated features will be greatly reduced or eliminated if the feature is properly designed, constructed, and maintained to ensure complete drainage.

Advantages

- Takes advantage of already-required landscape areas; no additional space required.
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat.
- Allows for tree preservation in areas requiring pavement.
- Vegetated areas provide green space. Combination of impervious and porous pavement can be more attractive than traditional installation.

Limitations

- Do not use on sites with a likelihood of oil, grease or other hazardous spills.
- Water barrier will be required where porous material abuts regular asphalt/concrete pavement and there is concern about water infiltrating the regular pavement subbase.

Maintenance Recommendations (Low to Moderate[1])

- See inspection and maintenance recommendations in the Porous Pavement fact sheet.

[1] As compared to treatment control measures, presented in Chapter 6.

How does Disconnected Pavement work?

Impervious surfaces, such as those paved with regular asphalt or concrete, that convey stormwater to a storm drain system without allowing the water to flow over any impervious surface are considered "directly connected". Compared to pervious areas, directly connected impervious surfaces contribute increased runoff and associated pollutants to the downstream storm drain system. "Disconnection" of impervious surfaces can be achieved by sloping surfaces toward relatively small or narrow vegetated or porous areas where the water is filtered before entering the storm drain system, and/or infiltrated into the underlying soils. Areas that can be disconnected include parking lots, driveways, sport courts, sidewalks, patios, courtyards, and roadways.

Other names: Not directly connected pavement, divided sidewalks, separated sidewalks, bifurcated walk.

Planning and Siting Considerations

- Maximize the use of landscaping and natural areas that are planned for the site already. Design landscaping to sit below adjacent impervious surfaces. The width of the vegetation needed is dependent on the area of contributing pavement; the ratio of impervious to pervious surface should be 2:1 or less.
- When draining pavement to open spaces, avoid environmentally-sensitive and protected wetlands areas. These applications will not qualify for the runoff reduction credits discussed in this fact sheet.
- Check with the local permitting agency to determine if credit will be given for paved surfaces draining to vegetated creek buffer areas.
- Locate porous features in well drained soils (Types A or B) whenever possible. If porous pavement is used in C or D soils, an underdrain will be required.
- Eliminate curbs and slope pavement to sheet flow into vegetation where possible. Where curbs are required for safety or other reasons, use curb cutouts to convey flow into the vegetation.
- Maximize the use of Porous Pavement (as an alternative to conventional pavement) where it can double as a disconnected conveyance zone. When draining an impervious area into porous pavement, refer to Porous Pavement Fact Sheet elsewhere in this chapter for planning and design requirements.

Suitable Land Use Types

Residential: Driveways, patios, and walkways can be disconnected. Also see Alternative Driveways Fact Sheet elsewhere in this chapter.

Commercial: Plazas and courtyards, parking lots/stalls, overflow parking areas, some types of storage areas, walkways, and as entryway features. <u>Not appropriate</u> for retail gas outlets, auto maintenance businesses or locations where spills may occur.

Industrial: Employee parking stalls, entryway, and pedestrian walk features. <u>Not appropriate</u> for processing/manufacturing areas involving extractive, chemical/petroleum, food, printing processes, and chemical storage areas.

Roadways: Slope roadways to drain across vegetation or other porous surfaces.

Parks and Open Space: Parking lots, park hardscape areas, pedestrian and bike trails, sports courts and playgrounds. See notes above about draining to natural open spaces, environmentally-sensitive areas and creek buffers.

Variations

Two variations of disconnected pavement that qualify for runoff reduction credits are discussed in this fact sheet: 1) Pavement draining to landscaping, and 2) pavement draining to porous pavement.

Pavement Draining to Landscaping

Curb cutouts deliver runoff from a parking lot to a vegetated swale. Vegetation must be lower than pavement to prevent clogging and sediment build-up at the curb. *Photo: City of Fremont*

Vegetated areas used to disconnect impervious surfaces can include either uniformly graded formal landscape features or densely vegetated open space/natural areas on the site. The impervious surface must sheet flow into and through the vegetated area to promote filtration and settling. These vegetated features differ from Vegetated Filter Strips (see fact sheet in Chapter 6) as they collect runoff from very small areas, more variability in dimension is allowed and they do not qualify as "treatment" techniques per Table 3-2 (Selection Matrix). Look for opportunities to use small pockets of landscaping and strips of turf grass for this application. The ratio of impervious to pervious surfaces must be 2:1 or less to qualify for the runoff reduction credits presented in this manual.

Use of reinforced grass pavement ("grasscrete") allows for pedestrian access without vegetation damage and reduces runoff through infiltration. Photo: Alameda Countywide Clean Water Program.

Examples:

Sidewalks – Establish a vegetated strip between sidewalks and the curb and gutter system in the street to allow for infiltration and filtration of sidewalk runoff.

Driveways – Slope residential driveways toward yard vegetation or divert flow from the driveway to the yard through a slotted trench or other approved means. See the Alternative Driveways Fact Sheet elsewhere in this chapter for more information.

Plazas, patios and walkways – Consider constructing these surfaces using porous pavement materials (see Porous Pavement fact sheet elsewhere in this chapter) to reduce imperviousness and reduce runoff. If that is not possible, slope the impervious areas to sheet flow into adjacent vegetated areas.

Commercial parking lots **–** Parking lot landscape areas between stalls or at the lot perimeter (typically already required by permitting agency codes) can be designed to double as stormwater quality control measures. As a first choice, design these areas to treat and filter parking lot runoff by integrating vegetated swales or stormwater planters (see fact sheets for these measures in Chapter 6). For smaller landscape pockets where it is infeasible to run the water through vegetated swales or stormwater planters, apply the disconnected pavement concept to reduce runoff. Grade the parking areas to drain to these features, with slotted curbs or curb cutouts to allow the runoff to flow into and through the vegetation (see photo). This may help reduce the size of needed downstream treatment measures for the site.

Pavement Draining to Porous Pavement

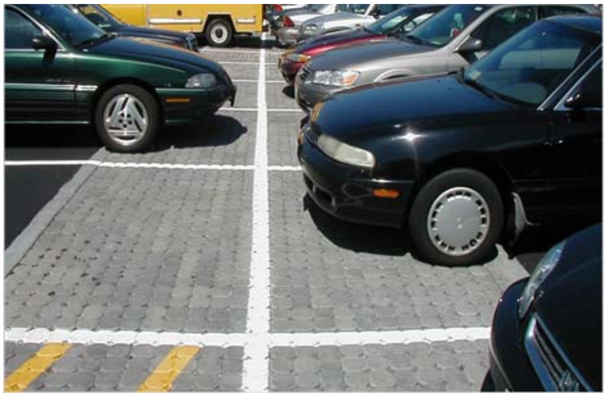
Consider replacing or combining conventional paved surfaces (concrete, asphalt) with porous paved surfaces to meet paving area requirements, in order to accept and infiltrate runoff from adjoining impervious surfaces. The porous pavement may be any of the variations described in the Porous Pavement fact sheet presented elsewhere in this chapter.

Examples:

Divided Sidewalks and parking lot medians – Consider the use of porous pavement in vegetated sidewalk strips and parking lot medians to provide paths for pedestrians to walk across the area without damaging vegetation. See photo.

Hybrid Parking Lot **-** Traffic loading requirements typically differ between parking lot drive aisles and stalls in parking lots. More durable conventional pavement surfaces will typically be required for the main drive aisles and areas used by garbage, delivery and fire trucks, while porous pavement may be appropriate for the stalls (or a portion of the stalls) used by cars. The permeable stalls may be used to carry flow from the main drive aisles to the storm drain system, allowing for infiltration and disconnecting the main aisle pavement from the system. A water barrier may be required between regular load-bearing pavement/streets and porous pavement materials to keep water from undermining the regular pavement subbase; verify this with the local permitting agency.

This hybrid parking lot concept has been applied successfully in many areas of the country, including the San Francisco Bay Area. Generally, pervious pavement or cobblestone block set in sand will be preferred by the permitting agency, however, depending on frequency and type of use, modular block pavement, reinforced grass, or gravel may be appropriate. For example, these techniques could work well in a seasonal overflow parking lot, a public park or a trailhead.



Pavers in parking lot. Photo: City of Emeryville..

In hybrid parking lots, stall markings can be indicated with one of several techniques, depending on the type of permeable surface: wood headers laid in a field of pervious pavement, a change in cobblestone block color, concrete bands, or rounded raised pavement markers similar to those used on highways (“Botts’ Dots”). *(Start at the Source, 1999)*

Bike and Pedestrian Trails – Consider the use of gravel or other porous material alongside bike and pedestrian trails to infiltrate and filter some of the runoff. For example, the City of Folsom requires a gravel shoulder for its Class I bike trails.

Design Criteria

Design criteria for disconnected pavement are listed in Table DP-1.

Construction Considerations

- Ensure that flow entering a porous area from an impervious surface is spread evenly and the area accepting the flow is lower than the impervious surface.
- If using porous pavement, follow the construction guidelines given in the Porous Pavement Fact Sheet located elsewhere in this chapter.
- Once construction is complete, stabilize the entire tributary area and the vegetation within the feature itself, before allowing runoff to enter the feature.

Long-term Maintenance Recommendations

Refer to the inspection and maintenance recommendations in the Porous Pavement fact sheet.

Table DP-1. Disconnected Pavement Design Criteria

Also see Appendix D for information on calculating runoff reduction credits.

Variation/ Design Parameter	Criteria
Pavement Draining to Landscaping	
Impervious Surface	Spread sheet flow into vegetated area (to maximize contact with vegetation) using curb cutouts or notches as acceptable to local permitting agency.
Impervious-Porous Ratio	2:1 maximum (see Appendix D)
Vegetation	Ensure that there are no channels, low conveyance areas or other features that would cause short-circuiting. Plant with dense vegetation appropriate for erosive flows.
Drainage	Place an area drain in vegetated feature, located to maximize travel distance of flow through landscaping, or allow for overflow water to sheet flow out of vegetated area to drainage system, as approved by local permitting agency.
Underdrain	Required in C and D soils. Use a gravel trench or perforated pipe embedded in a 8-12-inch layer of crushed rock. Connect to storm drain (not sanitary sewer).
Pavement Draining to Porous Pavement	
Impervious-Porous Ratio	2:1 maximum (see Appendix D)
Other	See design criteria for Porous Pavement Fact Sheet elsewhere in this chapter.

Sources: Ventura and Denver.

References

- Adams, M.C. 2003. Porous Asphalt pavement with recharge beds: 20 years & still working. Stormwater. May/June 2003.
- City of Portland Stormwater Management Manual. Revision 3, September 1, 2004.
- *National Menu of Best Management Practices for Storm Water Phase II*. United States Environmental Protection Agency. 2002. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm
- Nonpoint Education for Municipal Officials. University of Connecticut. accessed May 26, 2006. http://nemo.uconn.edu
- Paris N. and M. Chusid. 2006. *Coloring Pervious Pavement…because protecting the environment should be beautiful*. www.ConcreteDecor.net Dec/Jan 2006.
- SMRC, The Stormwater Manager's Resource Center. Fact Sheets. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm accessed June 14, 2006.
- Start at the Source - Design Guidance Manual for Stormwater Quality Protection, Bay Area Stormwater Management Agencies Association, 1999.
- Stormwater C.3 Guiedbook: Stormwater Quality Requirements for Development Applications. Contra Costa Clean Water Program. Contra Costa, CA, March 2005.
- Sustainable Infrastructure Alternative Paving Materials Subcommittee Report. City of Portland. October 3, 2003.
- Truckee Meadows Regional Storm Water Quality Management Program: Draft Low Impact Development Handbook. August 2005.
- *Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices*. Urban Drainage and Flood Control District. Denver, CO. September, 1999 (Rev. October, 2005).
- *Virginia Stormwater Management Program Handbook*. Virginia Department of Conservation and Recreation. 1999.

Description

Alternative driveways are designed to reduce the volume and rate of runoff and increase localized infiltration. These driveways exhibit one or more of these features: they have permeable surfaces, drain to landscaping, provide access to more than one house, and/or limit concrete use to narrow driving strips.

It is recommended that you read the Porous Pavement and Disconnected Pavement fact sheets before using this one, since this technique employs principles from those.

Siting Considerations

- Land use: Single-family residential development and redevelopment.
- Driveway slope: 10% maximum.
- Soils: Appropriate for all soil types but porous pavement requires an underdrain for soil types C and D.

Vector Considerations

- Potential for mosquitoes in vegetated features of alternative driveways due to standing water will be greatly reduced or eliminated if the driveway is properly designed, constructed, and operated to maintain its infiltration capacity.

Advantages

- Replaces regular pavement, so does not require additional land on the site.
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat.
- Sometimes more attractive than traditional pavement.

Limitations

- If driveway includes a public right-of-way or utility easement, contact local permitting agency to determine if alternative driveway design is acceptable and if so, any special requirements.
- See Siting Considerations.

Maintenance Recommendations (None to Low[1])

- Driveways with disconnected pavement require no additional maintenance over traditional driveways, but accumulations of sediment adjacent to driveway need to be removed periodically to keep surface water flowing evenly into the adjacent porous area.
- Refer to Porous Pavement fact sheet for maintenance requirements related to pavers, modular block and other porous materials.

[1] Compared to stormwater quality treatment control measures discussed in Chapter 6.

How do Alternative Driveways work?

Driveways can comprise a significant portion of the total transportation network in a conventional suburban residential development. Alternative driveways reduce a development's total directly connected impervious surface by using permeable materials, reducing the amount of pavement, paving area and/or by draining to landscaped areas. This, in turn, reduces the runoff and may provide incidental pollutant removal. Alternative driveway designs are easily adopted into most residential construction projects, can improve the aesthetics, and, if incorporated early in project design, may reduce the size and associated cost of treatment controls.

Planning and Siting Considerations

- Consult a geotechnical engineer as to the suitability of each type of Alternative Driveway for specific load requirements.
- For Alternative Driveways using porous pavement, see planning and siting considerations on the Porous Pavement Fact Sheet elsewhere in this chapter
- Specific design considerations apply to each type of Alternative Driveway (see variations discussed below).

Variations

Four types of Alternative Driveways are discussed in this fact sheet: 1) pervious driveway, 2) "Hollywood" driveway, 3) disconnected driveway, and 4) shared driveway. Alternative designs may be acceptable on a case-by-case basis; check with the local permitting agency for verification before proceeding with design.

Pervious Driveway. Photo: Carrera Construction

Pervious Driveway

Pervious driveways allows water to pass through the drive-way surface via void spaces in the material and/or between units. Various types of pavement may be used to make the driveway surface permeable: pervious concrete or asphalt, modular block, cobblestone block or porous gravel (see Porous Pavement Fact Sheet elsewhere in this chapter for details).

Design Criteria: See Table AD-1 for design criteria. Also, refer to the Porous Pavement fact Sheet.

"Hollywood" Driveway in Natomas area, Sacramento, CA. Photo: ECORP Consulting

"Hollywood" Driveway

A Hollywood Driveway, where only the wheel tracks are paved with concrete, is a viable, inexpensive design if the driveway is straight. The center strip can be left open to be planted with grass or groundcover, or filled with a permeable material such as gravel, modular block pavement, or pervious pavement if water conservation/ irrigation is a concern.

Design Criteria: See Table AD-1 for design criteria.

Other names: ribbon driveway, paving-under-wheels driveway

Disconnected Driveway

Conventional driveways are considered "directly connected" to the storm drain system because stormwater runoff from the driveway enters the storm drain system directly. Driveways disconnected from the storm drain system reduce runoff and provide incidental pollutant removal by passing runoff over an adjacent vegetated or otherwise porous surface that intercepts, infiltrates and filters the runoff. There are various design approaches: 1) slope the driveway to drain onto adjacent turf or groundcover, 2) install a slotted drain near the lower third of the driveway and discharge the drain to a landscaped area (if this is not considered a safety/tripping hazard), and 3) install grooves in the driveway pavement to help direct flow to the vegetated area. Some agencies may also allow an under sidewalk drain which connects the depressed landscape area adjacent to the driveway with the gutter/storm drain.

Design Criteria: See Table AD-1 for design criteria.

Shared Driveway

Driveways can be configured to provide access to two or more garages. Consult the local permitting agency to determine if this practice will be allowed for your project.

Table AD-1. Design Criteria for Alternative Driveways

Also see Appendix D for information on calculating runoff reduction credits.

Variation	Design Parameter	Requirement
Pervious Driveway	General	See Porous Pavement Fact Sheet for specifications. Surface sloped to provide positive drainage away from building foundations.
	Subgrade drain	Required in C and D soils. Use a gravel trench or perforated pipe embedded in a 8-12-inch layer of crushed rock. Connect to storm drain (not sanitary sewer).
Hollywood Driveway	General	Tracks 2.5 to 3.5 feet wide, separated by a porous center strip at least three feet wide. Slope driveway toward center strip to promote drainage or install grooves to help direct flow into porous strip. Porous center strip groundcover, grass or drain rock.
	Porous center strip	Groundcover, grass, drain rock or porous pavement.
	Irrigation	Consider irrigation for center strip vegetation.
Disconnected Driveway	General	Design the driveway cross slope greater than the longitudinal slope so that runoff is directed across landscape. Size the adjacent landscape area to accommodate flow from the driveway. Water from driveway surface should flow an average of 8 feet over landscaping prior to reaching the right of way. If a slotted drain is used, install it perpendicular to the flow path to direct flow into vegetation, and provide removable grates for cleaning. If runoff flows across sidewalk, it must sheet flow and spread at least two feet wide to avoid concentrated flows.
	Edge of driveway	Must be approximately 3 inches above the vegetated area.
Shared Driveway	General	Configurations vary, consult local permitting agency.

Construction Considerations

- *Disconnected driveway*: Properly slope the grade of the driveway and adjacent porous area to allow for even sheet flow over the porous material. Level of turf should be below top of pavement.
- *Porous Pavement*: See Porous Pavement Fact Sheet Construction Considerations, elsewhere in this chapter.

Long-term Maintenance Recommendations

Refer to the inspection and maintenance recommendations in the Porous Pavement fact sheet.

Resources for More Information

- California Nevada Cement Promotion Council (CNCPC), http://www.cnccp.org
- National Ready Mixed Concrete Association (NRMCA), http://www.nrmca.org
- Pacific Southwest Concrete Alliance, http://www.concreteresources.net/
- Asphalt Pavement Association, www.apaca.org
- National Precast Concrete Association, www.precast.org
- Portland Cement Association, www.portcement.org
- National Asphalt Pavement Association, www.hotmix.org
- Asphalt Emulsion Manufacturers Association, www.aema.org
- Western States Chapter of the American Concrete Pavement Association, http://www.wscacpa.com/
- Association of Asphalt Paving Technologists, www.asphalttechnology.org
- American Concrete Paving Association, www.pavement.com

References

- Adams, M.C. 2003. Porous Asphalt pavement with recharge beds: 20 years & still working. Stormwater. May/June 2003.
- California Stormwater Best Management Handbook: New Development and Redevelopment. California Stormwater Quality Association, 2003.
- City of Pasadena. California Code of Regulations. Hollywood Driveway. http://www.ci.pasadena.ca.us/zoning/P-8.html accessed March 6, 2006.
- City of Portland Stormwater Management Manual. Revision 3, September 1, 2004.
- National Menu of Best Management Practices for Storm Water Phase II. United States Environmental Protection Agency. 2002. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm
- Nonpoint Education for Municipal Officials. University of Connecticut. Accessed May 26, 2006. http://nemo.uconn.edu
- Paris N. and M. Chusid. 2006. Coloring Pervious Pavement…because protecting the environment should be beautiful. www.ConcreteDecor.net Dec/Jan 2006.
- Start at the Source - Design Guidance Manual for Stormwater Quality Protection, Bay Area Stormwater Management Agencies Association, 1999.
- SMRC, The Stormwater Manager's Resource Center. Fact Sheets. Accessed June 14, 2006. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm

- Sustainable Infrastructure Alternative Paving Materials Subcommittee Report. City of Portland. October 3, 2003.
- Truckee Meadows Regional Storm Water Quality Management Program: Draft Low Impact Development Handbook. August 2005.
- Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices. Urban Drainage and Flood Control District. Denver, CO. September, 1999 (Rev. June, 2002).
- Virginia Stormwater Management Program Handbook. Virginia Department of Conservation and Recreation. 1999.

Source: City of Portland

Description

Roof drains can be disconnected from the storm drain system by directing the roof runoff across vegetation or into subsurface infiltration devices where it is filtered or infiltrates into the ground. The water may be directed across lawns, through dense groundcover, into devices such as a dispersal trench or dry well, if acceptable to the permitting agency. Roof runoff can also be directed into vegetated swales and stormwater planters for stormwater quality treatment (see fact sheets for these measures in Chapter 6).

Consult a geotechnical engineer about site suitability and other design considerations.

Siting Considerations

- Soils: Infiltration structures are generally suitable for Type A and B soils.
- Depth to groundwater: For infiltration structures, minimum depth to groundwater table 10 feet below bottom of facility.
- Setback: infiltration structures must be min. 20 feet from buildings (Smaller setback maybe allowed with geotechnical engineer approval, verify with local permitting agency).
- Slope: up to 25%
- Vegetation: sufficient vegetated area must be available for overland conveyance.

Vector Considerations

- Potential for mosquitoes due to standing water in vegetated features will be greatly reduced or eliminated if the feature is properly designed, constructed, and maintained to ensure complete drainage.

Advantages

- Takes advantage of existing/planned landscape areas; no additional space required.
- Can reduce size of downstream stormwater quality treatment measures by reducing the volume required to treat.

Limitations

- Plant materials in landscaped areas receiving the runoff should be designed to withstand occasional inundation.
- Subsurface infiltration devices may eventually clog with sediment, requiring costly reconstruction.
- Soil permeability may limit applicability of subsurface infiltration structures.

Maintenance Recommendations (Low[1])

- Irrigate and maintain vegetated areas to maintain infiltration and filtering capacity.
- Periodically check for clogging of any subsurface pipes or infiltration systems (e.g., dry well) and repair as needed.

[1] Compared to stormwater quality treatment control measures discussed in Chapter 6.

How do Disconnected Roof Drains work?

Disconnected Roof Drains effectively disconnect the rooftop from the local storm system, which helps reduce runoff and provides incidental pollutant removal as the water travels over and through the vegetation and soil. In this approach, roof runoff is directed to spread over a vegetated area (the conveyance zone), or into underground infiltration devices, if approved by the local permitting agency. Greater surface area and contact time within the conveyance zone promote greater runoff treatment efficiencies.

Other Names: Disconnected downspouts, disconnected roof leaders

Planning and Siting Considerations

- Consult a geotechnical engineer about site suitability and other design considerations.
- Assess soil permeability to determine if infiltration option is viable for the type of system desired. Consult an engineer if needed, particular in areas adjacent to building foundations.
- Design buildings to take advantage of vegetated areas. Direct roof flow away from paved surfaces.
- Design site with a minimum of 2% positive slope away from building foundations.
- Maximize the length, and minimize the slope, of the conveyance zone. The land surrounding the downspout/emitter should be graded to spread and convey storm water (minimum 2 feet wide) and prevent concentration of flows.
- Integrate the disconnected roof drain system into the site landscaping plan.
- Consider using dry wells or dispersal trenches where the conveyance zone slope exceeds 25% and local permitting agency allows. Such devices must typically be located a minimum of 20 feet from any buildings, but verify with local permitting agency.
- Use of dispersal trenches and dry wells maybe restricted on commercial and industrial projects depending on pollutant potential; check with local permitting agency.

Variations

Four types of disconnected roof drain systems are discussed in this fact sheet: 1)splash block, 2) pop-up drainage emitter, 3) dispersal trench and 4) drywell. Check with the local permitting agency to determine if all types are allowed and if they have any local specifications or details to add to, or replace, those shown here.

Splash Block

Splash Blocks reduce the velocity and impact of water exiting the roof downspout and direct water to a pervious conveyance zone. Storm water traveling across the conveyance zone is filtered and infiltrated. Where the slope of the conveyance zone is greater than 8%, a gravel level spreader is required at the end of the splash block. A gravel spreader is a pocket of gravel that collects water and encourages sheet flow. The spreader may be covered with geotextile, soil and vegetation to fit with site landscaping.

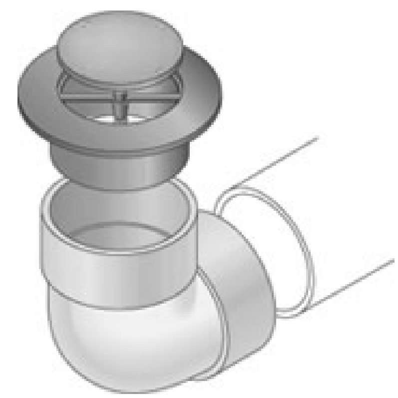
For single family residential sites, the stormwater must flow across appropriate vegetation throughout the entire conveyance zone (from the downspout to the sidewalk). For commercial and multi-family sites, minimum travel distances across vegetation are specified based on contributing roof area (see Table DRD-1).

Source: Alemeda Countywide Clean Water Program

Table DRD-1.
Conveyance Zone for Splash Blocks and Pop-up Drainage Emitters: Commercial and Multi-Family Residential Areas

Maximum Roof Size (sf)	Minimum Travel Distance Across Vegetation
3,500	21 feet
5,000	24 feet
7,500	28 feet
10,000	32 feet

Pop-up Drainage Emitter



(Check with local permitting agency for any local specifications before using this information).

Pop-up drainage emitters are appropriate when it is not possible to convey water directly from the downspout due to grading, paving or other site constraints. Pop-up Drainage Emitters are also useful in conveying storm water from backyard downspouts to front yard conveyance zones. Roof runoff is piped then released through a capped device that opens with water pressure. Yard drains may be used as component of the pop-up emitter system. For example, roof-top runoff directed to a back yard may be collected in a yard drain, then directed to a front yard pop-up emitter system.

For single-family residential development, pop-up emitters must daylight no closer than five feet from the building with positive drainage away from building foundations and slabs for another five feet, where possible. The five feet limit is to allow for maximum travel distance across the yard.

Dispersal Trench

(Check with local permitting agency for any local specifications before using this information).

A Dispersal Trench is appropriate for situations where the slope from the building does not meet the slope requirements or there is limited conveyance zone area available. The downspout may be piped directly to a Dispersal Trench through a perforated or slotted pipe that allows water to seep into the drain rock and surrounding soil. A maximum of 1750 square feet of roof area can be allowed to drain into one 8-foot long dispersal trench. These underground structures may be topped with geotextile fabric and 6 inches of soil for planting. See Figure DRD-1 for an example of the dispersal trench system design.

A debris collection point, or pretreatment sump, is required to prevent sedimentation and clogging of the dispersal trench. Once the pretreatment sump has filled with debris, it should cause a noticeable amount of overland flow bypassing the dispersal trench, which indicates that it is time to maintain the device.

The roof gutters should be fitted with mesh screens to prevent leaf litter and other debris from entering the system where there is tree cover. The expected growth of newly planted trees should be considered.

An overflow outlet should be provided on the downspout at the surface elevation to allow flow to bypass the system when either the infiltration trench or pretreatment sump are clogged or when hydrologic capacity is exceeded.

To reduce the potential for costly maintenance and/or system reconstruction, it is strongly recommended that dispersal trenches be located in lawn areas (or other vegetated areas) and as close to the surface as possible.

Other names: Perforated Pipe System, French drain

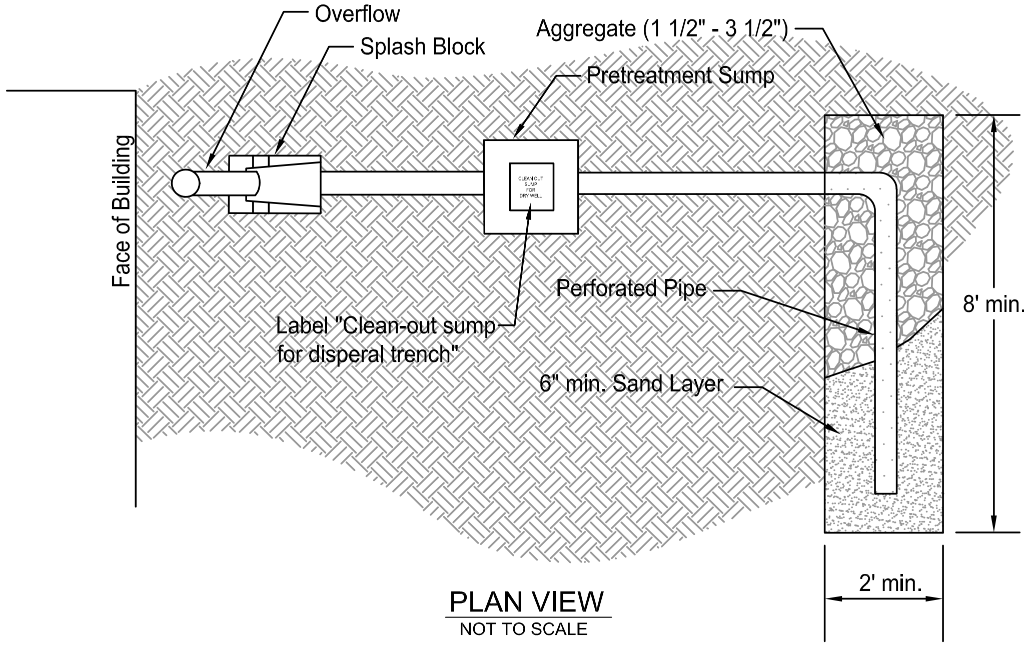
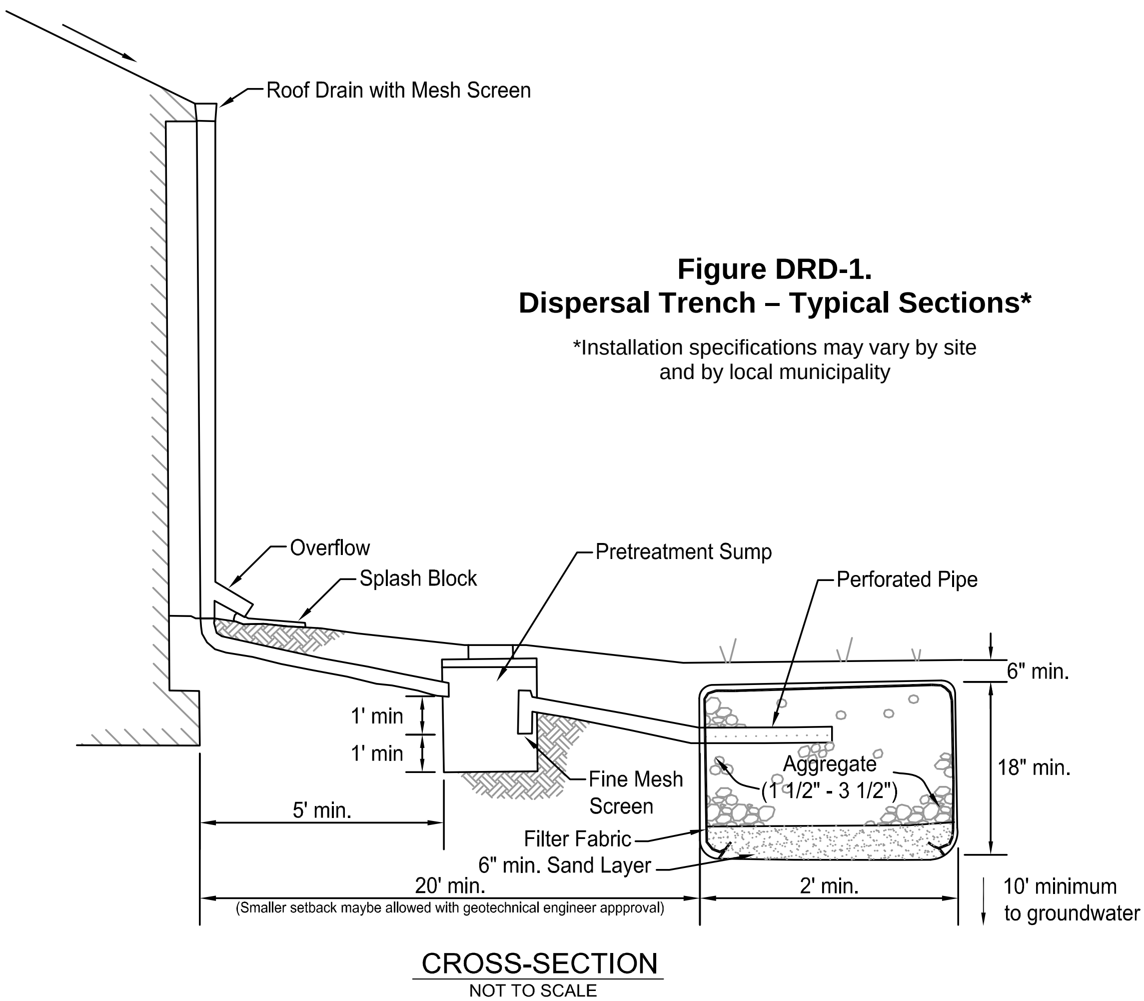


Figure DRD-1.
Dispersal Trench – Typical Sections*

*Installation specifications may vary by site and by local municipality



Dry Well

(Check with local permitting agency for any local specifications before using this information).

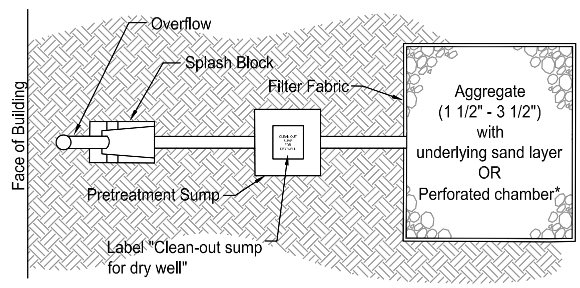
Dry Wells are similar to Dispersal Trenches except that the dimensions maybe different and the underground structure may consist of a prefabricated or manufactured vault or box that may or may not be filled with gravel. The dry well may be concrete or plastic (or other approved material), cylindrical or square, with perforations large enough to take full advantage of the infiltration capacity of the surrounding soil.

All design requirements related to pretreatment sumps, gutter protection, and overflows are the same as those for Dispersal Trenches. See Figure DRD-2 for an example of the dry well design.

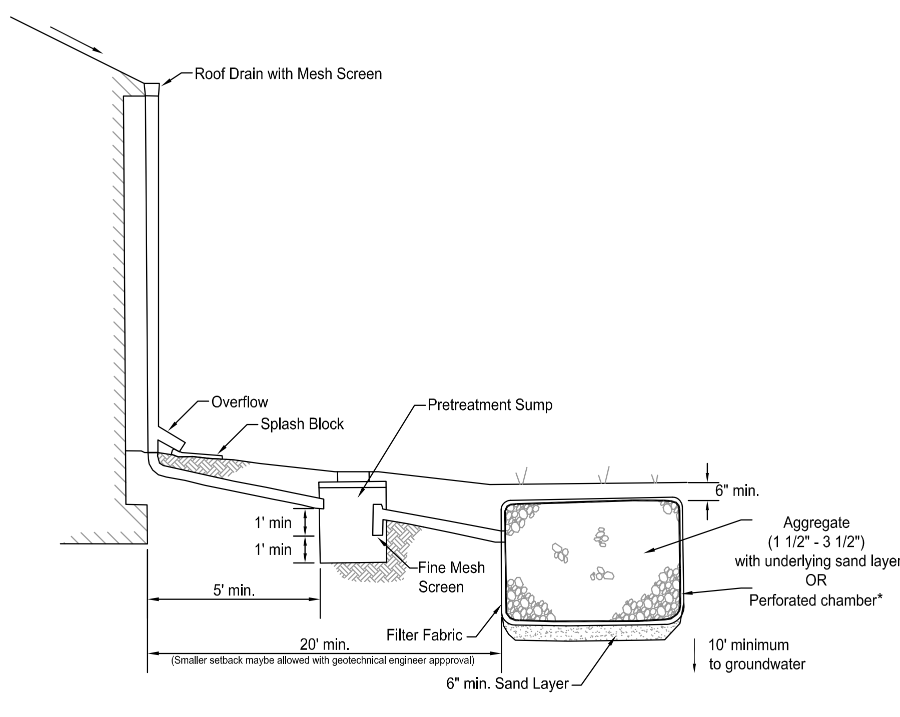
These underground structures may be topped with geotextile fabric and 6 inches (or more depending on approved specifications) of soil for planting.

Figure DRD-2.
Drywell – Typical Sections*

*Installation specifications may vary by site and by local municipality



PLAN VIEW
NOT TO SCALE



CROSS-SECTION
NOT TO SCALE

* Subject to approval of permitting agency. Manufacture's specifications and additional restrictions apply (consult permitting agency).

Design Criteria

Design criteria for disconnected roof drains and discharge variations are listed in Table DRD-2.

Construction Considerations

Splash Block and Pop-up Drainage Emitter

- Site must be graded to prevent ponding of water at base of building.
- Splash blocks must be secured in place over compacted soil.
- Roof drainage conveyance areas must be protected from erosion during vegetation establishment period. Temporary measures such as erosion control blanketing may be used, however it may be necessary to bypass the stormwater around the conveyance zone during the stabilization period.

Dispersal Trench and Dry Well

- Do not allow soil below trench area to be compacted during construction.
- The floor of the trench/well must be level to allow for spreading of flow across the trench.
- To prevent sedimentation of the structure, the inlet pipe must be plugged until soil on the site is stabilized. To protect the structure *during* construction, provisions for sediment control must be included in the design.

Long-term Maintenance Recommendations

Table DRD-3 presents inspection and maintenance recommendations for disconnected roof drains in general and two design variations related to disconnected roof drains (dispersal trench and dry well). The local permitting agencies require that the property owner be responsible for maintaining the features to ensure continued, long-term performance. The pervious features should not be removed or replaced or all water quality benefits will be lost. In general, a maintenance agreement will not be required for this type of installation. However, developers are responsible for educating new homeowners that such devices are installed on their property and should be maintained following the recommendations provided in Table DRD-3. Where possible, such recommendations should be included in Covenants, Codes and Restrictions for new residential subdivisions.

Table DRD-2. Design Criteria for Disconnected Roof Drains

Also see Appendix D for information on calculating runoff reduction credits.

Variation/Parameter	Criteria
Splash Block/Pop-up Drainage Emitter	
Surface	Minimum 2% positive slope away from building foundations for 4 feet minimum. Surface must be contoured to allow for sheet flow at least 5 feet wide. Must be planted with erosion resistant vegetation (turf or dense groundcover). Ground cover use limited to slopes less than 4**%.**
Splash Block	Must be at least 24 inches long, 2 inches deep and 10-12 inches wide where it meets the conveyance zone. Must weigh at least 10 pounds and be sloped away from building.
Spreader	Where slope more than 8%, spreader required at end of splash block; spreader must be drain rock, 24 inches long, 6 inches wide, and 8 inches deep, and level at surface. Gravel may be placed below surface and covered with geotextile fabric, 4 inches of soil and grass.
Emitter/pipe	Pipe must be at least 6 inches below the surface and a minimum of 4 inches in diameter (may not be suitable for large contributing roof areas). Emitter elevation must be lower than the finished grade of the base of the downspout and the yard drain (if used). Emitter must daylight no less than 5 feet from building (residential only).
Travel Distance	See Table DRD-1 and Appendix D.
Dispersal Trench and Dry Well	
Soils	Soil type extending 3 feet from bottom of facility must have infiltration rate between 0.52 inches per hour and 8.27 inches per hour. Soil may be amended to achieve infiltration rate.
Pretreatment Sump	Must be located a minimum of 5 feet from building. Must be labeled at surface “clean-out sump for dispersal trench or dry well”.
Overflow	Must be set on splash block.
Loading	Must demonstrate that the appropriate loading tolerance is achieved for proposed use of surface. Provide psi rating for structure/design.
Surface	Minimum 2% positive slope away from building foundations (4 feet minimum) (per Building Code).
Dispersal Trench only	
Setback	Must be located a minimum of 20 feet from building. A smaller setback maybe allowed with geotechnical engineer approval.
Configuration	Must be installed parallel to site contours; must be a minimum of 2 feet wide and 18 inches deep; must be a minimum of 8 feet long; must be lined with geotextile fabric (sides and top) and filled with drain rock.
Surface Label	Surface identification label may be required; check with the local permitting agency.
Perforated Pipe	Must be a minimum of 6 inches below grade.

Variation/Parameter	Criteria
Dry Well only	
Setback	Must be located a minimum of 20 feet from building. A smaller setback maybe allowed with geotechnical engineer approval.
Capacity	Must design a minimum 24 cubic feet of storage capacity for every 1750 square feet of contributing roof area.
Drain Rock	Must be filled with drain rock or use perforated chamber (with or without rock) upon approval of permitting agency.
Perforated Chamber (if allowed)	Perforated chambers must be designed and installed according to manufacturers specifications. Perforations in structure must allow for discharge of water at a rate higher than soil infiltration rate. Must be lined with geotextile fabric. Consult manufacturer's specifications for additional design requirements.
Surface Label	Surface identification label may be required; check with the local permitting agency.

Source: High Point Community Site Drainage Technical Standards. Seattle, WA

Table DRD-3.
Inspection and Maintenance Recommendations for Dispersal Trenches and Dry Wells

Disconnected Roof Drains - General	
Gutters	▪ When cleaning gutters, repair wire mesh as needed to keep leaves and debris out of drain pipes.
Overflow	▪ Periodically inspect and clear overflow pipe.
Dispersal Trench and Dry Well	
Surface and Vegetation Maintenance	▪ Keep the surface clean and free of leaves, weeds, debris, and sediment, and do not replace or cover it with an impermeable paving surface. ▪ Do not store loose material such as bark or sand over dry well or trench area; this can clog the infiltration facility. ▪ Do not plant trees or shrubs over infiltration structures. Grass and plants (especially drought-tolerant varieties) are best. ▪ Use integrated pesticide management techniques and minimize use of fertilizers, herbicides and insecticides in vegetated areas. ▪ Remove grass clippings in grass areas over infiltration structures. ▪ Reseed grasses when needed and keep healthy and dense enough to provide filtering while protecting underlying soils from erosion.
Pretreatment Sump	▪ Inspect sump monthly and after heavy rainfall and clean out accumulated sediment/debris as needed.
Ponding Water/Mosquito Control	▪ Check for and eliminate any ponding water that does not drain within 48 hours, since that provides an environment for insect larvae. ▪ Standing water is usually an indication that the facility is clogged (the overflow and/or the sump needs to be cleaned and/or the device needs to be reconstructed).
Manufacturer's Recommendations	▪ For manufactured products, follow manufacturer's maintenance recommendations. ▪ Make structural repairs when necessary to restore function.
Replacement	▪ Reconstruct or replace when it is no longer functioning properly. For planning purposes, estimated life expectancies are as follows: dispersal trench - 30 years, dry well – 30 years. *(Source: City of Portland, OR)*

References

- City of Portland Stormwater Management Manual. Revision 3, September 1, 2004.
- High Point Community Site Drainage Technical Standards. Seattle, WA, June 2004.
- National Menu of Best Management Practices for Storm Water Phase II. United State Environmental Protection Agency. 2002. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm
- New York State Stormwater Management Design Manual. Center for Watershed Protection, New York State Department of Environmental Conservation, Albany, NY, October 2001.
- Shueler T., Swann C., Wright T, and S. Sprinkle. 2004. Urban Subwatershed Restoration Manual No 8: Pollution Source Control Practices. Version 1.0. Center for Watershed Protection. Ellicot City, MD. July 2004.
- SMRC, The Stormwater Manager's Resource Center. Manual Builder. http://www.stormwatercenter.net/Manual_Builder/Credits/SITE/rooftop.htm
- Start at the Source - Design Guidance Manual for Stormwater Quality Protection, Bay Area Stormwater Management Agencies Association, 1999.
- Stormwater C.3 Guidebook: Stormwater Quality Requirements for Development Applications. Contra Costa Clean Water Program. Contra Costa, CA, March 2005.
- Truckee Meadows Regional Storm Water Quality Management Program: Draft Low Impact Development Handbook. August 2005.
- Virginia Stormwater Management Program Handbook. Virginia Department of Conservation and Recreation, 1999.

Description

Interceptor trees are those used in residential and commercial settings as part of the stormwater quality management plan to reduce runoff and pollution from the development project. Interceptor trees can be placed on residential lots, throughout landscape corridors, in commercial parking lots, and along street frontages. Trees installed in municipal right-of-ways may be protected through ordinances and can provide years of aesthetic benefit.

Siting Considerations

- Soils: Drainage and soil type must support selected tree species.
- Location: Locate within 25 feet of impervious surface.
- Other structures: Maintain appropriate distance from infrastructure and structures that could be damaged by roots and avoid overhead power lines, underground utilities, septic systems, sidewalks, curbs, patios, etc.

Vector Considerations

- Potential for mosquitoes due to standing water where excess irrigation is applied or planter box is not designed to properly drain.

Advantages

- Reduces the amount of pollutants entering the storm drain system.
- Can reduce size of downstream stormwater quality treatment measure(s) by reducing the volume required to treat.
- Enhances aesthetic values.
- Provides shade to cool pavement and reduces surface runoff temperatures.
- Aids in removal of air pollutants and noise reduction.
- Shade trees required by the permitting agency may be counted as interceptor trees.
- Extends life of asphalt paving.

Limitations

- Fire safety may be a consideration in areas with increased risk for fire hazard.

Maintenance Recommendations (Low[1])

- Pruning of trees may be required to maintain tree, ensure safety, and prevent damage to structures.
- Diseased/damaged tree, and those with poor structure should be removed and replaced as soon as possible.
- Irrigation system may be required in perpetuity.

[1] Compared to stormwater quality treatment control measures discussed in Chapter 6.

How do interceptor trees protect water quality?

Interceptor trees are ideal for all projects, including those where space is limited, in which trees can be placed along street frontages and in common space. Urban areas with higher numbers of trees exhibit hydrology more similar to natural conditions compared to urban areas without a tree canopy. Trees intercept storm water and retain a significant volume of the captured water on their leaves and branches allowing for evaporation and providing runoff reduction benefits. For example, a large oak tree can intercept and retain more than 500 to 1,000 gallons of rainfall in a given year (Cappiella, 2004). While the most effective Interceptor Trees are large canopied evergreen trees, deciduous trees can also provide a benefit. For example, a leafless Bradford pear will retain more than one half the amount of precipitation intercepted by an evergreen cork oak (Xiao et al., 2000).

The shade provided by trees keeps the ground under the trees cooler, thereby reducing the amount of heat gained in runoff that flows over the surface under the trees. This attenuation of heat in storm water helps control increases in stream temperatures. On slopes, tree roots hold soil in place and prevent erosion.

Planning and Siting Considerations

Check with the local permitting agency about requirements for trees located in public utility easements. A tree permit may be required to plant, prune or remove such trees. Also, consultation with an arborist is recommended for selecting and locating appropriate tree species for the unique site conditions.

New trees

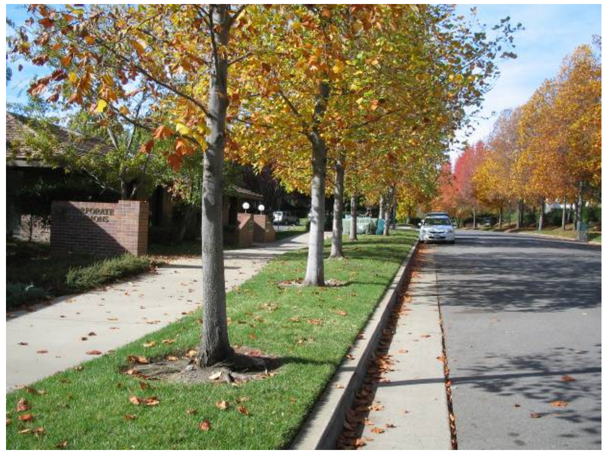
- Select trees from a list of approved species established by the permitting agency (see Table INT-1 for examples, but check with appropriate agency for verification). Native species and those with a larger canopy at maturity are generally preferred, depending on available space for root and canopy.
- Select tree species based on the soils found on the site, available water, and aesthetics. Soil in planter areas may be amended to satisfy species requirements. Consult a landscape architect or arborist to ensure suitability of species for site conditions and design intent.
- Do not plant monocultures of same family, genus and/or cultivar. Do not plant trees too close together.
- Interceptor trees should be incorporated into the site's general landscaping plan, but trees designated for storm water credits must be clearly labeled on plans submitted for local agency approval and other planning submittals.
- Do not place trees near structures that may be damaged by the growing root system. These include, but are not limited to, overhead utilities and lighting, underground utilities, signage, septic systems, curb/gutter and sidewalks, paved surfaces, building foundations and existing trees. Utilize approved root barriers (deflectors) when trees are planted close to infrastructure, per the local permitting agency standards.

Existing trees

- New landscaping under existing trees must be carefully planned to avoid any grade changes and any excess moisture in trunk area, depending on tree species. Existing plants which are compatible as to irrigation requirements and which compliment the trees as to color, texture and form are to be saved.
- Grade changes greater than six inches within the critical root zone should be avoided. Also, soil compaction and texture in the drip-line area greatly affect tree survival.

Examples of Suitable uses of Interceptor Trees

Residential: large and small subdivisions, small-scale developments, located in or out of municipal right-of-way. The tree pictured is an evergreen Camphor.



Commercial: plazas and courtyards, landscape areas in parking lots and road frontages.

Industrial: Employee parking lots, entryway features, and road frontages.

Parks and Open Space: parking lots, park hardscape areas.

Variations

Three types of interceptor trees are discussed in this fact sheet: 1) new evergreen trees, 2) new deciduous trees, and 3) existing trees.

New Evergreen Trees

Evergreen trees provide the greatest benefit to water quality. Generally, the larger the tree and the smaller the leaves, the more rain is intercepted. Further, evergreen trees retain their leaves throughout the rainy season.

New Deciduous Trees

Since the interceptor tree’s water quality benefit increases with increasing surface area of leaves and branches, deciduous trees, which lose their leaves early in the Central Valley’s rainy season, have less value than evergreen trees. However, even deciduous trees contribute to interception and shading, and credits are applied for inclusion of such trees in site plans.

Existing Trees

Conservation of existing trees provides aesthetic value to a site as well as a water quality benefit. Credits may be applied for protected trees located within 25 feet of an impervious surface, as long as the trees are not located in the designated "open space" for the project, for which credit has already been applied.

Design Criteria

Design criteria for interceptor trees are listed in Table INT-1.

Table INT-1. Design Criteria for Interceptor Trees

Also see Appendix D for information on calculating runoff reduction credits and a list of Trees Qualifying for Interceptor Tree Runoff Reduction Credits.

Variation	Parameter	Criteria
All Planted Trees	Size	15 gallon container (min.)
	Location	Must be planted within 25 feet of ground-level impervious surfaces. Must not be spaced such that the crowns overlap (at 15 years of growth).
	Installation and Irrigation	Trees must be installed and irrigated in accordance with local permitting agency Landscaping Standards.
New Evergreen and Deciduous Trees	See Appendix D for suggested tree species meeting size requirement.	
Existing Trees	Species	Any landscape appropriate tree species

Construction Considerations

New trees

- Do not allow soil in planter areas to be compacted during construction.
- Do not allow soil in planter areas to become contaminated with construction related materials such as lime or limestone gravel.
- Install irrigation system according to proper specifications.
- When installing lawn around trees, install the grass no closer than 24 inches from the trunk.
- Install protective fencing if construction is ongoing, to avoid damage to new trees.
- Mulch with hardwood chips (not redwood or cedar)

Existing trees

- Proposed development plans and specifications must clearly state protection procedures for trees that are to be preserved.
- Existing trees must be protected during construction through the use of high-visibility construction fencing set at the outer limit of the critical root zone. The fence must prevent equipment traffic and storage under the trees. Excavation within this zone should be accomplished by hand, and roots 1/2" and larger should be preserved. It is recommended that pruning of the branches or roots be completed by, or under the supervision of, an arborist. Soil compaction under trees should to be avoided.
- Ensure that trees that receive irrigation continue to be watered during and after construction.

Long-Term Maintenance

Maintenance recommendations for interceptor trees are provided in Table INT-2. The property owner is responsible for all costs associated with the maintenance.

Trees that are removed or die should be replaced with similar species, or all water quality benefits will be lost. Trees should be properly pruned for safety purposes, to protect structures, or for the improvement of the health and structure of the tree. The property owner is responsible for all costs associated with the replacement of interceptor trees.

Table INT-2. Inspection and Maintenance Recommendations for Interceptor Trees

Activity	Description
Removal of Leaves and Debris:	Fallen leaves and debris from tree foliage should be raked and removed regularly to prevent the material from being washed into the storm water. Nuisance vegetation around the tree should be removed when discovered. Dead vegetation should be pruned from the tree on a regular basis.
Pruning	It is recommended that a certified arborist or similarly qualified professional be retained to prune trees, or the property owner should learn proper pruning methods. A tree should never be topped. Topping is the practice of removing major portions of a large tree's crown by cutting branches to stubs or to the trunk. Tree topping shortens the life of the tree, creates weakly attached limbs prone to breakage, decay and disfigures the tree. It also eliminates the interception canopy.
Mulching	Add 4-6 inch deep hardwood mulch around newly planted trees and shrubs (avoid redwood and cedar, it is light and blows away and does not decompose fast enough to be beneficial to the soil health and tree's growth).
Irrigation	An irrigation system should be installed at the time of planting and maintained during the establishment period or, if necessary to maintain the tree, in perpetuity.
Pesticides and Fertilizers	Minimize the use of chemicals to only what is necessary to maintain the health of the tree. Consider using mulch around the base of the tree as a substitute to fertilizer. Do not place mulch within six inches of the trunk of the tree.
Lawn maintenance	Keep lawn at least 24 inches from trunk of tree.
	Competition from turfgrass stunts tree growth, and even additional fertilizer and water will not overcome this effect. A bare area around the trunk also helps prevent injury to the tree from a mower or string trimmer. Trunk wounds to a young tree can have a severe dwarfing effect.
Other Activities	Plant evergreen shrubs and ground covers around trees when possible. Care should be taken when digging near tree roots. Once tree has become established, planting of vegetation near base of tree and subsequent watering of such vegetation may result in over-saturation and damage to the tree.
Removal/ Replacement	See Long-term Maintenance

References

- Schueler T., Swann C., Wright T, and S. Sprinkle. 2004. *Urban Subwatershed Restoration Manual No 8: Pollution Source Control Practices*. Version 1.0. Center for Watershed Protection. Ellicot City, MD. July 2004.
- Cappiella, K. 2004. *Urban Watershed Forestry Manual* (draft). Prepared for USDA Northeastern Area State and Private Forestry. Center for Watershed Protection, Ellicott City, MD.
- *City of Davis Community Forest Management Plan* , September 11, 2002. http://www.cityofdavis.org/pcs/trees/cfmp.cfm
- *City of Portland Stormwater Management Manual*. Revision 3, September 1, 2004.
- *National Menu of Best Management Practices for Storm Water Phase II*. United State Environmental Protection Agency. 2002. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm
- *Post-Construction Urban Runoff Management.* City Council Policy. City of San Jose, California. February 3, 1998.
- *Start at the Source - Design Guidance Manual for Stormwater Quality Protection*, Bay Area Stormwater Managemnt Agencies Association, 1999.
- SMRC, The Stormwater Manager's Resource Center. Manual Builder. http://www.stormwatercenter.net/Manual_Builder/Credits/SITE/reforestation.htm
- Xiao Q., and E.G. McPherson. 2003. *Rainfall interception by Santa Monica's municipal urban forest.* Urban Ecosystems
- Xiao, Q., E.G. McPherson, S.L. Ustin and M.E. Grismer. 2000. *A new approach to modeling tree rainfall interception*. Journal of Geophysical Research 105(D23) :29,173-29,188.
- Xiao, Q. 1998. *Rainfall interception by urban forests.* Davis, CA: University of California. Ph.D. Dissertation.
- Xiao, Q., E.G. McPherson, S.L. Ustin, M.E. Grismer, and J.R. Simpson. 2000. *Winter rainfall interception by two mature open grown trees in Davis, CA.* Hydrological Processes. 14(4) :763-784.

Photo Credits

All photographs provided by Dena Parish and Shannon Brown, ECORP Consulting, Inc., Rocklin, CA

Premier Automotive North American Headquarters, Irvine, CA.
Photo: Roofscapes, Inc.

Description

A green roof is a multi-layered, vegetated rooftop system designed for filtering, absorbing, and retaining stormwater. Green roofs comprise lightweight 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 green roof captures stormwater within the pore space of the growth medium and then releases the water slowly via evaporation, transpiration and discharge to the roof drains. There are two types of green roofs—extensive (shallow growth media, simple vegetation) and intensive (deeper growth media, complex vegetation).

Siting Considerations

- Space requirements; No additional space needed.
- Land use: Most appropriate for commercial or multi-family land uses, particularly infill development and multi-story buildings in dense urban areas, parking garage and retail/warehouse roofs.

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the green roof is properly designed, constructed, and maintained.

Advantages

- Requires no additional land.
- Improves outdoor air quality; aids in smog reduction.
- Decreases roof and runoff temperature (heat island effect).
- Provides insulation and lowers building cooling costs.
- Protects underlying roof material from climatic extremes, ultraviolet light, and costly long-term damage.
- Can provide green space for building occupants to enjoy.
- Provides habitat for wildlife, particularly birds.

Limitations

- Special structural design requirements to support green roof, irrigation needs and leak protection elements (due to roof irrigation) are likely to increase building costs.
- Erosion controls such as jute or cellulose netting and/or soil stabilizers will be required; additional controls such as cross-battens or steps may be required on sloped roofs.
- General Maintenance Requirements (Moderate to High)
- Irrigate to establish vegetation (first two years) and thereafter as needed.
- Routinely inspect and maintain the roof membrane, drainage layer flow paths and irrigation system.
- Repair eroded areas and replace vegetation as needed to maintain required cover.

How does a Green Roof work?

Green roofs are a proven technology and have been used/tested in Europe for over 40 years. They are gaining recognition in the US for the environmental, economic, and social benefits they provide. There are now numerous applications in the San Francisco/San Jose Bay Area of California.

Green roofs reduce runoff volume and peak flow through several mechanisms. When it rains, the green roof's foliage, growth medium, and root uptake zone retain a substantial portion of the stormwater that would otherwise flow from the roof to the storm drain system. The retention volume depends on many factors, including rainfall amount, depth and composition of the growth medium, and the type, diversity, and maturity of the vegetation. Some of the retained stormwater is released to the atmosphere via evaporation and transpiration (after uptake by plants). The remainder slowly infiltrates through the growth medium to the roof underdrains and is discharged to the storm drain system with the volume and peak flow rate reduced.

Green roofs improve runoff water quality through a variety of biological, physical, and chemical processes within the plants and growth media. At the roof surface, airborne particulate matter (encompassing a range of organic and inorganic compounds) is intercepted and taken up by plant foliage. When it rains, stormwater (and associated air pollutants) is retained within and filtered through the growth media and root uptake zone. Contaminants sorb to clay and organic matter within the growth media. Further pollutant removal is achieved by bioremediation and phytoremediation, carried out by bacteria and fungi present within the root systems. Pollutant removal increases as the vegetation and root systems mature.

Other Names: Ecoroof, green rooftop, nature roofs, vegetated roof covers

Planning and Siting Considerations

- Involve the landscape architect, licensed structural engineer and mechanical engineer early in the design process with the project architect, since architectural roof style (pitch/slope, configuration), roof structural requirements, building heating/cooling needs, vegetation selection, and irrigation needs go hand in hand.
- Proper design and management of drainage is essential. Inadequate drainage may result in more load that the roof can sustain; plant mortality; and/or degeneration of the growth medium.
- Choose plants suitable for the local climate and considering desired future irrigation. Check with the local permitting agency for recommended plants and planting guides for green roofs.
- Consider designing the green roof to serve as a greenspace amenity accessible to building tenants and/or the general public. This is particularly important quality of life benefit in dense, downtown urban areas where space for parks and natural areas is at a premium.

Pedestrian Walkway on Stanford University Parking Garage Green roof, Palo Alto, CA. Design by Rana Creek Living Architecture.

Design Criteria

Table GR-1 provides design criteria for green roofs; many parameters vary depending on the type of green roof (intensive or extensive). A Design Data Summary Sheet for green roofs (Table GR-3) is provided at the end of this fact sheet. Presently, the only widely-accepted, established standards for green roof construction are the comprehensive FLL standards developed in Germany. An American Standard Testing Methods (ASTM) task group is developing new standards for green roof installation; this fact sheet will be updated after the new standards are approved and published.

Table GR-1. Green Roof Design Criteria

Design Criteria	Extensive Green Roof	Intensive Green Roof
Design Volume	WQV, see Appendix D in this Design Manual for design requirements for volume-based control measures	Same
Design Drawdown time	12 hours	12 hours
Growth Media[2]	Typical depth: <6 in.	Typical depth: 12+ in.
Vegetation	Low-growing, low water-use vegetation such as Sedum, herbs, grasses, and perennials	More complex gardens including the species listed for extensive green roofs, but also incorporating trees, shrubs
Load[2]	12-54 lbs/ft^2 Average weight of saturated extensive roofs is 17 lbs/ft^2 , comparable to gravel ballast in some conventional roofs	72+ lbs/ft^2
Roof slope	5:1 maximum	5:1 maximum
Access	Required for maintenance. Not generally designed for public access	Required for maintenance. Public access often accommodated and encouraged
Maintenance	Generally minimal once established	Significant maintenance required due to greater loading and complex plantings
Irrigation	Simple irrigation. If roof well-designed, needed only during plant establishment and droughts.	Complex irrigation
Drainage	Simple drainage system	Complex drainage system

Notes:
1. Adapted from USEPA website on Green Roofs: http://www.epa.gov/hiri/strategies/greenroofs.html
2. Range of values obtained from description of Roofmeadow® products: http://www.roofmeadow.com/assemblies.html

Design Procedure

Use the **Design Data Summary Sheet** (Table GR-3) to record design information for the permitting agency's review.

General Design

Green roofs vary from small-scale designs using a single plant species to complex gardens with many types of plants. A typical configuration for multi-layer green roof systems is provided in Figure GR-1 and the design steps are briefly discussed below.

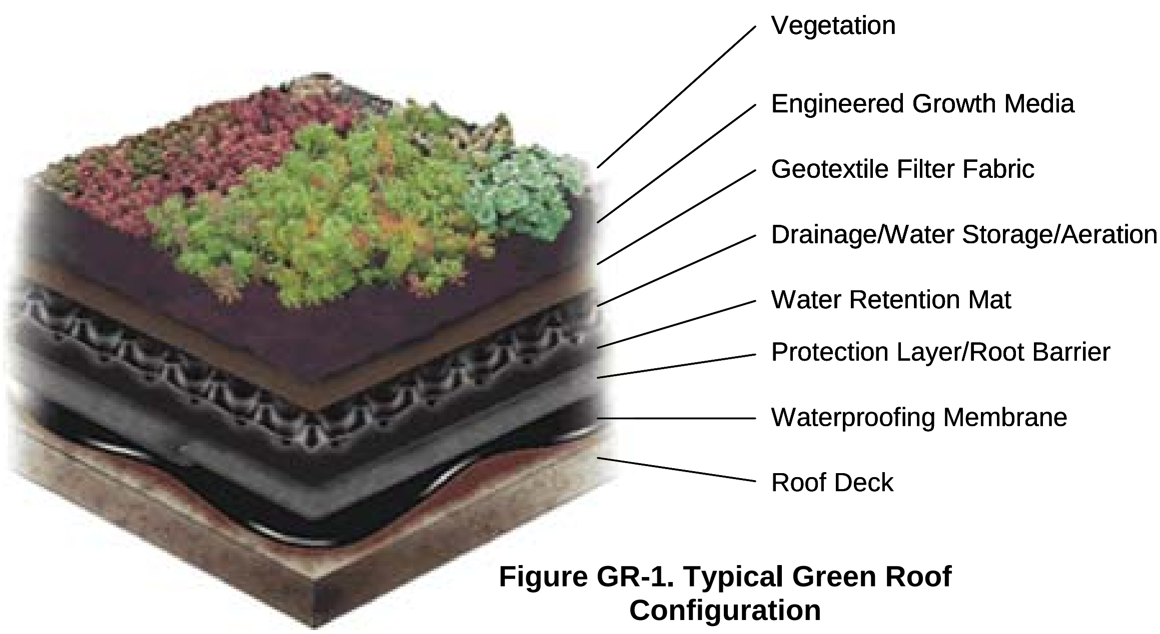


Figure GR-1. Typical Green Roof Configuration

Image source: American Hydrotech, Inc.®, http://www.hydrotechusa.com/. Text detail added.

Step 1 – Choose Vendor and Specialized Consultants

Green roofs are typically designed and installed by an established vendor. At a minimum, also consult:

- Structural engineer – to ensure the roof loading capacity is adequate
- Architect—to integrate green roof design with the building design, including planning for possible use by future building occupants
- Landscape architect – to design the planting areas, select vegetation and design the irrigation system
- Mechanical engineer – to calculate the heating and cooling implications of the green roof and to discuss how to integrate the green roof with rooftop mechanical equipment and drainage needs

Step 2 – Calculate Water Quality Volume (WQV)

The growth media volume is a key criterion governing the sizing of the green roof. Provide sufficient volume within the pore space of the growth medium to contain the water quality design volume (WQV), which is determined using Appendix E information, based on a 12-hour drawdown period. Take into account the presence of established vegetation when determining the needed pore space. To calculate the volume of growth medium required to contain the WQV in the available pore space, use the following equation:

Volume of growth medium = WQV/Porosity of growth media (with vegetation)

Step 3 – Select Green Roof Type

Decide whether to install an extensive or intensive green roof. Extensive green roofs, which have simple vegetation and shallow growth medium, are characterized by their low weight, low capital cost, and low maintenance, and can be retrofitted onto existing structures with little or no additional structural support. Intensive green roofs, which have complex vegetation and deeper growth medium, are characterized by their higher weight, capital cost, and higher maintenance requirements. They are more elaborate in design (sometimes even incorporating fountains and ponds), are typically intended for human use and interaction, and need to be engineered to conform to the load requirements. Characteristics of each green roof type are summarized in Table GR-1.

Make the decision whether or not to provide public access in this step, since this affects green roof type and load design (Step 4). If access will be provided then at a minimum foot traffic must be accommodated with walkways or turf grass. (Turf grass must be irrigated and requires the deeper growth media of an intensive green roof). Typically, green roofs with public access have a complex array of vegetation (i.e. are intensive green roofs) and may even have other garden features such as a fountain, ornamental pond, or patio/deck.

Step 4 – Determine Required Structural Support and Green Roof Design

Design the structure to support the green roof, considering the saturated weight of the mature green roof system and the expected live load from human activity on the roof (e.g., maintenance staff, tenants, visitors). If a green roof is planned for a new building, the architects and structural engineers need to factor the green roof into the architectural and building design process. To retrofit an existing building, confer with an architect, structural engineer, and/or green roof consultant to ensure the proposed green roof can be supported—either as is or with additional support such as additional decking, roof trusses, joists, columns, and/or foundations, as indicated in Table GR-1.

If the roof will be accessible to the public, design the traffic flow paths and integrate decks, patios, or pavers into the design. Turf grass will stand up to regular foot traffic but requires an intensive green roof system with deeper soil and mandatory irrigation. Alternatively, less intrusive, lightweight stepping stones or decomposed gravel walkways can be used to provide access and interpretation with extensive green roofs. Design roof entrance and exit routes to design standards to be safe and efficient for maintenance staff or the public.

Step 5 – Select Component Layers

Green roof systems typically contain the following specialized component layers (see Figure GR-1):

Waterproofing Membrane — Choose an adequate waterproof membrane that resists penetration by roots. The waterproofing component is essential to the long-term success of a green roof. Generally, a composite of several layers of protective materials is used . Materials used include modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC.

Protection Layer/Root Barrier — The need for a separate root barrier (dense materials that inhibit root penetration) depends on the selected waterproof membrane . Modified asphalts usually require a root barrier, while synthetic rubber (EPDM) and reinforced PVC generally do not. Check with the manufacturer to determine if a root barrier is required for a particular product.

Insulation/Air Barrier (optional) — If the thermal requirements of a building necessitate additional insulation, a layer of moisture-resistant insulation may be added.

Water Retention Mat — If additional water retention is necessary to sustain the selected vegetation, a moisture retention mat may be used.

Drainage/Water Storage/Aeration Layers — A green roof must safely drain runoff from the roof to an approved stormwater destination. Provide a drainage layer over the entire roof area to convey excess water to the building's drainage system. Drainage layers usually consist of molded drainage channels and retention cups.

Geotextile Filter Fabric — Include a geotextile filter fabric layer to keep the growth media out of the drainage layer.

Engineered Growth Media — Green roof growth media differ from soil in that they generally comprise lightweight mineral material containing a minimum of organic matter. Use a growth medium uthat meets established FLL or ASTM guidelines for both water retention and drainage.

Growth media need to remain viable for decades for both plant growth and water control. The growth medium used in green roofs should:

- Not degrade or compress over time;
- Be accompanied by third-party laboratory data confirming its essential properties; and
- Be covered under warranty if it is defective or degrades within a certain timeframe.

Gravel Ballast (if needed) — Gravel ballast is sometimes placed along the roof perimeter and at air vents or other vertical elements. The need for ballast depends on operational and structural design issues. Ballast is sometimes used to provide maintenance access, especially to vertical elements requiring periodic maintenance. In some situations a header or separation board may be placed between the gravel ballast and adjacent elements (e.g., growth media, drains). If a root barrier is used, it must extend under the gravel ballast and growth medium and up the side of the vertical elements.

Step 6 – Select Vegetation

Hire experienced horticulturists and/or landscape/green roof contractors who understand the local climate as well as the restrictions of a rooftop environment to select, install and maintain vegetation for the green roof.

Typical green roof vegetation ranges from low-growing succulent plants (e.g., sedums) or groundcovers (characteristic of extensive green roofs) to an assortment of native grasses, shrubs, and trees (more typical of intensive green roofs). Select plants that:

- are adapted to the local climate, considering seasonal temperature ranges and average rainfall, the harsh rooftop environment (exposure to direct sun, frost, wind) and desired irrigation
- will tolerate short periods of inundation from storm events during the wet season (October 1 – April 30)
- Possess shallow root systems suited for the depth of the growth media
- Require little or no irrigation after establishment
- are primarily non-deciduous to provide adequate foliage cover year-round and reduce erosion potential
- Have good regenerative qualities (i.e., perennial or self-sowing)
- Are low maintenance (i.e., no need for fertilizers, pesticides, or herbicides, little or no mowing or trimming)
- Have growth patterns allowing vegetation to thoroughly cover the soil (at least 90% surface area coverage should be achieved within 2 years).
- Are compatible with the aesthetic preferences of the owner and future building occupants who may utilize the roof as a green space

Plants of the genus *Sedum* (family Crassulaceae), which are low-growing succulents, are often used for because of their resistance to wind, frost, drought, and fire. A mix of *Sedum* and other succulent plants is recommended, because they possess many of the recommended attributes. Herbs, forbs, grasses, and other low groundcovers may also be used but typically require more irrigation and maintenance. Although the use of native vegetation is preferred when possible, some natives may not thrive in the rooftop environment. Thus, a mix of approximately 80% Sedum/succulent plants and 20% native plants generally recognized for their hardiness is recommended, particularly for extensive green roofs. (Velazquez, 2005)

Step 7 – Determine Irrigation Needs

Determine irrigation needs based on the vegetation selected; at a minimum, temporary irrigation is recommended during the first two years of plant establishment. Potable water may be used in a permanent irrigation system, but consider using recycled, non-potable water, such as air conditioning condensate. Analyze any alternative water source to make sure it doesn't contain compounds harmful to the plants.

Step 8 – Incorporate Fire Breaks

A Berlin study found that green roofs are more fire resistant than gravel roofs. The City of Portland's Fire Bureau recently converted a fire station conventional roof to a green roof. Green roofs may help slow the spread of fire to and from the building through the roof, particularly when the growth medium is saturated. Succulents such as *Sedum* offer good fire resistance due to their high water content. However, if the plants themselves are dry, they may present a fire hazard. The integration of vegetation-free "fire breaks" at regular intervals across the roof, at the roof perimeter, and around all roof protrusions is recommended. These breaks should be made of a non-combustible material such as crushed gravel, pebbles, or concrete pavers; be 12 to 36 inches wide; and be situated every 130 feet in all directions. Another option for fire prevention is a sprinkler irrigation system connected to the fire alarm. (Köhler 2004; Peck and Kuhn; Velazquez 2005)

Construction Considerations

Consider hiring an environmental/green roof specialist to oversee the construction process.

- Throughout the construction process, protect green roof components, particularly the vegetation, until established.
- Prevent erosion by covering the growth media with mulch, jute/cellulose netting, or other approved protection methods prior to seeding or planting.
- Require consultants and installers to follow appropriate safety measures for working on industrial/commercial rooftops.

Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas require execution of a maintenance agreement or permit with the property owner prior to final acceptance of a private development project that includes a green roof. Such agreements or permits will typically include requirements such as those outlined in Table GR-2. The property owner or his/her designee is responsible for compliance.

Table GR-2. Inspection and Maintenance Recommendations for Green Roofs[1]

Activity	Schedule
Irrigation	
▪ Irrigation can be accomplished by hand watering or automatic sprinkler systems (preferable). Follow the short and long-term watering regimes designed by the landscape designer, based on the selected plants and their water needs.	Irrigate plants regularly until they are established and thereafter as needed
Vegetation	
▪ Inspect and maintain vegetation to ensure at least 90% vegetative cover (visual guideline) at the end of the plant establishment period and thereafter. Replace dead plants as needed. Use fertilizers sparingly, if at all.	Inspect monthly during vegetation establishment period; thereafter, annually or as needed.
▪ Remove fallen leaves and debris from deciduous plant foliage. Repair/replace damaged or dead vegetation to maintain required cover.	As needed
▪ Employ integrated pest management (IPM) practices to minimize or eliminate use of chemical pesticides and herbicides. Remove weeds manually whenever possible.	As needed. Remove weeds during growing season.
▪ During drought conditions, apply mulch or shade cloth as needed to prevent excess solar damage and water loss.	As needed
▪ Mow grasses and remove clippings.	As needed
Component Layers	
▪ Inspect/maintain waterproof membrane for proper operation, waterproofing integrity, and structural stability.	2-3 times per year
▪ Inspect/maintain drainage layer flow paths for proper operation. Determine if drain pipes and inlets are in good condition and check drain inlets for obstructions. Clear inlet pipe of growth media, vegetation, debris or other materials. Identify and correct sources of obstructions.	At least twice per year during wet season, preferably during and after storms. Additional inspections after periods of heavy runoff are desirable.
▪ Inspect growth medium for evidence of erosion from wind or water. If erosion channels are evident, stabilize with additional growth medium and plants.	2-3 times per year. Additional inspections after periods of heavy runoff are desirable.
Other	
▪ Use spill prevention measures for rooftop mechanical systems when handling substances that can contaminate stormwater. Correct any identified releases of pollutants.	As needed
▪ Remove litter/trash from landscape area to prevent clogging of inlet drains and interference with plant growth.	As needed
▪ Manage mosquitos by eliminating any observed standing water; use integrated pest management (IPM) techniques and seek advice of local vector control district.	weekly during peak mosquito season (April-October); as needed thereafter.
▪ Maintain green roof aesthetics. Repair any damage or vandalism and remove any trash or debris.	As needed
▪ Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.

Notes:
1. Adapted from the City of Portland's Stormwater Management Manual.

Helpful Links and Resources*

Ecoroofs Everywhere: *www.ecoroofseverywhere.org*

Greenroof Directory: www.greenroofs.com

City of Portland, Oregon, Bureau of Environmental Services, Ecoroofs*: www.portlandonline.com/bes/index.cfm?c=34663 (includes the excellent publication "Portland Ecoroof Tours")

San Francisco Bay Area Stormwater Management Agencies Association (BASMAA), Site Design Guidebooks for Northern SF Bay Area, Alameda and Santa Clara Counties*: http://www.basmaa.org/documents/index.cfm?fuseaction=documents&doctypeID=3

Green Roof Plants: A Resource and Planting Guide, Edmund C. Snodgrass and Lucie L. Snodgrass, 2006. Timber Press, Portland, OR.

**These links contain project examples.*

References Used To Develop This Fact Sheet

- Bass, B., 1999: Modeling the Impact of Green Roofs on Toronto's Urban Heat Island. Environment Canada, Green Roofs for Healthy Cities. Accessible at http://www.peck.ca/grhcc/research/overview.htm.
- Coffman, L.S., R. Goo and R. Frederick. Low impact development an innovative alternative approach to stormwater management. Proceedings of the 26th Annual Water Resources Planning and Management Conference. ASCE, Tempe, Arizona, 1999.
- Delston DIY Flat Roofing Company, 1999: Green Roofs. Accessible at http://www.delston.co.uk/greenroofs.htm.
- Dramstad, W. E., J.D. Olson, and R.T. Forman. Landscape Ecology Principles in Landscape Architecture and Land-Use Planning. Harvard University Graduate School of Design, Cambridge, 1996.
- EPA, 2006: Green Roofs. Accessible at http://www.epa.gov/heatisland/strategies/greenroofs.html.
- Köhler, Manfred. 2004. In Proceedings of the Greening Rooftops for Sustainable Communities Symposium. Hosted by: Green Roofs for Healthy Cities and City of Chicago, Chicago, June 22-24, 2004.
- Miller, C, 2006: Roofscapes, Inc., Green Technology for the Urban Environment. Accessible at: www.roofmeadow.com.
- Moran, A., B. Hunt, and G. Jennings. A North Carolina Field Study to Evaluate Greenroof Runoff Quantity, Runoff Quality, and Plant Growth. Proceedings of the World Water & Environmental Resources Congress 2003 and Related Symposia. ASCE, 2003. doi 10.1061/40685(2003)335
- Ngan, Goya. Green Roof Policies: Tools for Encouraging Sustainable Design. 2004. Accessible at http://www.gnla.ca/library.htm.
- Peck, S.W. and C. Callaghan. Greenbacks from Green Roofs: Forging a New Industry in Canada. Prepared for: Canada Mortgage and Housing Corporation. Environmental Adaptation Research Group, Environment Canada, 1999.
- Peck, S. and Kuhn, M., "Design Guidelines for Greenroofs." Prepared for the Canada Mortgage and Housing Corporation (CMHC) and the Ontario Association of Architects (OAA). Accessible at: http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/loader.cfm?url=/commonspot/security/getfile.cfm&PageID=70146

- Portland, City of, 2004. *Stormwater Management Manual* and various Green roof publications.
- Scholz-Barth, K., 2001: Green Roofs, Stormwater Management from the Top Down. Environmental Design and Construction. Accessible at http://www.edcmag.com.
- Velazquez, L., 2006: Greenroofs.com: Exploring the Ecology of Organic Green Roof Architecture. Accessible at http://www.greenroofs.com.
- Velazquez, L., Organic Greenroof Architecture: Design Considerations and System Components. Wiley Periodicals, Inc., Environmental Quality Management/Summer 2005.

Table GR-3. Design Data Summary Sheet for Green Roof

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Design Water Quality Volume: WQV = __________ ft^3
2. Determine growth medium volume based on porosity of growth media with vegetation. Volume of growth medium = WQV/Porosity. V = __________ ft^3
3. Select green roof type ☐ Extensive ☐ Intensive
4. Determine Required Structural Support ______________________________

   ____

   ____

5. Check that system includes all component layers

   ☐ Waterproofing Membrane
   ☐ Insulation/Air Barrier (optional)
   ☐ Drainage/Water Storage/Aeration Layers
   ☐ Engineered Growth Media
   ☐ Protection Layer/Root Barrier
   ☐ Water Retention Mat
   ☐ Geotextile Filter Fabric
   ☐ Gravel Ballast (if needed)

6. Select Vegetation and describe

   ☐ 80% *Sedum* ______________________________

   ____

   ☐ 20% Native species ______________________________

   ____

7. Determine Irrigation Needs ______________________________

   ____

   ____

8. Incorporate Vegetation-Free Zones or Fire Breaks ______________________________

   ____

   ____

Notes: ______________________________

____

6 Treatment Control Measures

The stormwater quality treatment control measures profiled in this chapter are the more common ones being implemented throughout the state and the rest of the country. Studies have shown these measures to be effective if properly installed and maintained. Alternative technologies that provide equivalent treatment may be proposed and will be considered by the permitting agencies, but may result in additional time for agency review and approval unless coordinated well in advance with the appropriate agency staff.

Treatment Control Principles

Stormwater quality treatment control measures are engineered technologies designed to remove pollutants from site runoff. They can have a higher cost and require more space than the runoff reduction measures discussed in Chapter 5. All development and redevelopment projects meeting the size thresholds on Table 3-2 require treatment control measures, but the required treatment volume or flow can be reduced (potentially to zero) through the use of runoff reduction measures. The treatment control methods suitable for a given project depend on a number of factors including: type of pollutants to remove, amount of stormwater runoff to be treated, site conditions, and state industrial permit requirements, when applicable. Land requirements, and costs to design, construct and maintain treatment control measures vary by measure and locale.

Unlike flood control measures that are designed to handle peak flows from large storm events, stormwater quality treatment control measures are designed to treat the more frequent, lower flow storm events, or the "first flush" portions of runoff from larger storm events (sometimes referred to as "first flush events"). Small frequent storm events (0.5 inches of rain and less) on the average represent over 80% of the total average annual rainfall for the Sacramento area. The "first flush" flow and volume (referred to as the water quality flow or volume in this manual) is targeted for treatment in order to reduce pollutants to the maximum extent practicable. There is no incremental water quality benefit to size treatment facilities to handle flows or volumes greater than these values.

Selecting Treatment Control Measures

If stormwater quality treatment control measures are required for your project, the answers to the following questions will help you determine the appropriate control measure(s) for your unique conditions:

- What are **pollutants of concern** for the future land use of the development?

  See Table 3-1 in Chapter 3, which correlates project types with likely pollutants of concern. When you have identified the pollutants, you can use the pollutant removal effectiveness information on the fact sheets at the end of this chapter to find control measures that would be most appropriate for treating those pollutants.

- What **amount of stormwater runoff** will need to be treated?

  The amount of stormwater runoff that needs to be treated for a site is defined by the local permitting agencies as the water quality volume (WQV) or water quality flow (WQF), described later in this chapter. Treating this amount is presumed to remove pollutants in urban runoff from the Sacramento and South Placer regions to the maximum extent practicable. Using runoff reduction control measures (Chapter 5) will decrease the amount of runoff needing to be treated, which in turn will likely reduce costs and space requirements for the treatment control measures.

  If you are using runoff reduction measures for your project, or if you would like to determine if applying runoff reduction measures can help reduce your treatment needs, refer to Appendix D. Appendix D will lead you through the process of calculating runoff reduction credits and then determining the water quality volume or flow remaining to be treated.

  If you will not be using runoff reduction measures, refer to Appendix E to calculate the expected water quality volume or flow for your site, based on drainage area, rainfall and imperviousness.

- **How much space is available** on the project site for a stormwater quality treatment facility?

  Refer to the fact sheets at the end of this chapter to determine the space requirements for the various types of stormwater quality control measures. Consider that vegetated facilities can typically be integrated into the landscaping already required by the permitting agency for the site. Also, although underground facilities do not take up as much space, they can be more costly to construct and maintain.

- What are the **site conditions and associated limitations** on use of stormwater quality treatment control measures for this property?

  As described in the fact sheets at the end of this chapter, the selection and design of stormwater quality control measures is largely dependent on soils, topography/slope and other natural site features.

- What **level of maintenance** will the property owner agree to conduct as long as he/she owns the property?

Consider the short and long-term maintenance needs of the treatment control measures (as described on the fact sheets at the end of this chapter) and whether or not the property owner can agree to those requirements. The permitting agencies in the Sacramento and South Placer Regions require that the property owner sign a maintenance agreement or obtain a permit to ensure long-term maintenance. Such maintenance agreements require reconstruction or replacement of the feature when it fails to function properly. For informational purposes, projected lifespan information is provided for the various control measures in Appendix B.

Designing Treatment Control Measures

The treatment control measures presented in this manual are sized and configured using either a volume-based or flow-based design approach, as explained in more detail in Appendix E:

Volume-Based Design (WQV)

Treatment control measures that depend on storage and gravitational settling for pollutant removal (e.g., detention basins, vaults) are designed for the water quality volume. Volume-based design criteria call for the capture and infiltration or treatment of a certain percentage of the runoff from the project site, usually in the range of the 75th to 85th percentile average annual runoff volume.

Flow-Based Design (WQF)

Flow-through treatment control measures that do not require long detention times for pollutant removal (e.g., vegetated swales) are designed for the water quality flow. Flow-based design criteria call for the capture and treatment of the flow produced by rain events of a specified magnitude, usually the 85^{th} percentile hourly rainfall intensity multiplied by a factor of 2.

Appendix E includes instructions for calculating the expected water quality volume (WQV) or water quality flow (WQF) for your project. The procedure requires you to determine the amount of impervious surfaces that will contribute runoff to the treatment control measures. In addition, site run-on that is not diverted around the site and combines with other runoff may need to be treated, depending on the local agency requirements. Each situation will be handled on a case-by-case basis.

Operation and Maintenance

The property owner is ultimately responsible for the operation and maintenance and long-term continued performance of the treatment control measure(s). Failure to properly operate and maintain the measures could result in no treatment of site runoff, or a slug loading of pollutants to the storm drain system. Both consequences will result in violation of the local permitting agencies' municipal codes, as well as state and federal water quality regulations.

For projects using any of the treatment control measures in this chapter, verification of long-term maintenance provisions is required. This is mandated by the agencies' State-issued stormwater permits. The local permitting agencies in the Sacramento and South Placer areas require execution of a maintenance agreement, covenant or permit with the property owner. Typically maintenance agreements and covenants are recorded with the deed for the property and follow property ownership. Such maintenance agreements require reconstruction or replacement of the feature when it fails to function properly. For informational purposes, Appendix B presents projected lifespan information for the various control measures.

Check with the local permitting agency about the maintenance submittal requirements and timing for execution of the agreement. See Appendix B for additional information and a sample maintenance agreement .

Treatment Control Measure Fact Sheets

The remainder of this chapter includes fact sheets for various treatment control measures. Each fact sheets describe siting, design, construction considerations, and maintenance requirements to ensure optimal performance of the measures.

Proprietary Treatment Control Measures

Proprietary stormwater quality treatment measures are manufactured devices intended to capture and treat post-construction site runoff to remove pollutants. The permitting agencies in Sacramento County and the City of Roseville allow certain proprietary devices for treatment of runoff, under certain conditions, as described below.

Agencies in Sacramento. Since the late 1990's, the Sacramento Stormwater Quality Partnership has been conducting a study to investigate and verify the field performance of proprietary stormwater quality devices. In November 1999, the Partnership published a report that describes the protocol that must be followed in order for a particular device to be accepted for use in the Sacramento area. The protocol is based on a comparison of the performance of the proprietary device to that of widely- accepted public domain measures, such as vegetated swales. Manufacturers are invited to submit data that can be reviewed for conformance with the protocol. In addition to devices accepted using the Sacramento area protocol, the Partnership will consider technologies with the Washington State Department of Ecology's General Use Level Designation for Basic (TSS) Treatment on a case by case basis.

For an updated list of accepted devices and more details on the Sacramento proprietary study, see *www.sacramentostormwater.org (new development)*. In select cases, the local permitting agency may allow the use of other proprietary treatment measures as a "pilot study." In such cases, the property owner and/or manufacturer will be required to fund and complete a monitoring study to verify the device's performance. Since approval is not guaranteed, site designers proposing to use an alternative technique should coordinate with the permitting agency early in the site design process.

Site designers proposing to use accepted proprietary device(s) on their project need to include the following items (to scale) on the improvement plans:

- Plan view of device & appurtenances on the civil site plans
- Section view of device & appurtenances in reference to other utilities
- Detail drawings of device & appurtenances
- Specifications and installation notes.

City of Roseville. The City will develop its policy related to proprietary devices by summer 2007. Check their web site for more details: *www.roseville.ca.us/eu/stormwater_management/default.asp*.

References

The following references were used to develop this chapter.

- California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook for New Development and Redevelopment, *www.cabmphandbooks.com*.

- Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices. Urban Drainage and Flood Control District. Denver, CO. September, 1999 (Rev. October, 2005).

- Stormwater Quality Requirements for Development Applications – Stormwater C.3 Guidebook, 2nd Edition, March 2005. Contra Costa Clean Water Program. *www.cccleanwater.org/construction/index.php*

- Stormwater Management Manual, 2004. City of Portland Bureau of Environmental Services. *www.portlandonline.com/bes*

- Maintaining your Stormwater Management Facility, 2002. City of Portland Bureau of Environmental Services. *www.portlandonline.com/bes*

- Georgia Stormwater Management Manual, Volume 2 Technical Handbook. Atlanta Regional Commission. August 2001. *www.georgiastormwater.com*

- Land Development Guidelines. Ventura Countywide Stormwater Quality Management Program. August 2001.

West David Pond. Photo: Larry Walker Associates

Description

A constructed wetland basin is an earthen basin treatment system with a permanent pool of water that includes four zones: a forebay, an open-water zone, a wetland zone with aquatic plants, and an outlet zone. The basin contains an area above the permanent pool to retain runoff from the stormwater quality design storm (water quality volume or WQV) and slowly release excess water over a specified drawdown period. Constructed wetland basins provide a significant natural amenity to a community. The basin pictured is located near Village Homes in Davis.

Siting Considerations

- Tributary Drainage Area: Up to 100 acres.
- Soil Type: Most appropriate for Type C and D soils. For Type A and B soils, use an impermeable (e.g., clay) liner.
- Topography: Not appropriate on fill or steep slopes.

Vector Considerations

- Potential for mosquitoes exists due to permanent water pool. However, proper design of permanent pool zones, routine vegetation management, and introduction of mosquito fish will minimize the risk.

Advantages

- Reduces stormwater discharge to surface waters during most storm events.
- Reduces peak flows during small storm events.
- Can provide wildlife habitat, high aesthetic value and passive recreational opportunities.

POLLUTANT REMOVAL EFFECTIVENESS

Sediment	High
Nutrients	Medium
Trash	High
Metals*	High
Bacteria*	High
Oil and Grease	High
Organics*	High

*The following are target pollutants for Sacramento area: copper; lead; mercury; pathogens; diazinon; and chlorpyrifos

Source: CASQA California Stormwater BMP Handbook, January 2003

Limitations

- Supplemental water supply or perennial base flow is required to maintain the permanent pool.
- Public safety related to access must be considered; security fencing is generally required by most permitting agencies in urban settings.
- Will typically require five years to establish.

General Maintenance Recommendations (Moderate to High)

- Inspect basin annually in early spring.
- Periodically remove debris from inlet and outlet structures, and wetland basin itself.
- Regularly harvest vegetation and stock with mosquito fish for mosquito control.
- Remove accumulated sediment from forebay and other water zones as needed.
- Inspect seasonally for abnormal algae growth and address as needed.

How does a constructed wetland basin work?

> Constructed wetland basins should not be confused with wet detention basins (wet ponds), which are presented elsewhere in this manual. Constructed wetland basins are shallower and feature more vegetative coverage than wet detention basins.

Permanent pools of water are located throughout the constructed wetland basin, within: the forebay (which allows settling out of larger particles); an open water zone and a wetland zone with emergent vegetation (providing desired biodiversity); and the outlet zone (from which water is discharged to the downstream storm drain system or receiving water). An area above the permanent pool is designed to retain the stormwater quality design volume (WQV). The retained water mixes with and displaces water from the permanent pool, which drains to the downstream storm drain system or receiving water over the design drawdown period (48 hours for WQV). Much of the water discharged during and following a storm event is water displaced from the permanent pool which has previously been treated by natural processes.

Treatment of the runoff occurs through a variety of natural mechanisms that occur in the wetland, including sedimentation, filtration, adsorption, and biological uptake. The aquatic plants provide energy dissipation and pollutant removal by enhancing sedimentation and providing biological uptake.

Supplemental water or perennial baseflow is needed to maintain the permanent pool at all times.

Planning and Siting Considerations

- Integrate constructed wetland basins into open space, natural areas, and other planned landscaped areas when possible. Avoid placing features in open space and wetland preserves where future maintenance of the water quality facility will be restricted or prohibited.
- Provide aesthetic security fencing if required by the permitting agency.

Design Criteria

Design criteria for constructed wetland basins are listed in Table CWB-1. Use the Design Data Summary Sheet provided at the end of this fact sheet (Table CWB-4) to record design information for the permitting agency's review.

Design Procedure

> Use the **Design Data Summary Sheet** (Table CWB-4) to record design information for the permitting agency's review.

Step 1 – Calculate Water Quality Volume (WQV)

Using the Appendix E in this Design Manual, determine the tributary drainage area and stormwater quality design volume (WQV) for 48-hour drawdown.

Step 2 – Determine Basin Minimum Volume for Permanent Pool

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

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

Step 3 – Determine Basin Depths and Surface Areas

Distribution of the wetland area is needed to achieve desired biodiversity. Distribute component areas as indicated in Table CWB-2.

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

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

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

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

Table CWB-1. Constructed Wetland Basin Design Criteria

Design Parameter	Criteria	Notes
Design volume	WQV	See *Standard Calculation Fact Sheet*
Maximum drawdown time for WQV	48 hours	Based on WQV
Minimum permanent pool volume	75%	Percentage of WQV
Liner	Clay	Required in areas with very permeable soils (e.g., Types A, B)
Inlet/outlet erosion control	–	Provide energy dissipaters to reduce velocity, subject to the approval of the permitting agency
Forebay		
Volume	5-10%	Percentage of WQV
Area	5-10%	Percentage of permanent pool surface area
Depth	4 ft	Minimum
Liner		Concrete, to facilitate maintenance
Open-water Zone		
a. Area (including forebay)	10-50%	Percentage of permanent pool surface area
b. Depth	4 ft	Minimum
Wetland Zone		
a. Area	50-70%	Percentage of permanent pool surface area
b. Depth	0.5-1 ft	30 to 50% should be 1.0 ft deep
Outlet Zone		
a. Area	5-10%	Percentage of permanent pool surface area
b. Depth	3 ft	Minimum
Surcharge depth above permanent pool	2 ft	Maximum
Basin length to width ratio	2:1	Minimum (larger preferred)
Basin freeboard	1 ft	Minimum
Wetland zone bottom slope	10%	Maximum
Embankment side slope (H:V)	4:1 3:1	(or steeper) Inside Outside (without retaining walls)
Side slopes (H:V)	5:1	
Maintenance access ramp slope (H:V)	10:1	or flatter
Maintenance access ramp width	5-20 ft	Minimum. Paved with concrete or porous pavement, subject to approval of permitting agency

Table CWB-2. Distribution of Wetland Components

Components	% Permanent Pool Surface Area	Design Water Depth
Forebay	5-10%	4 feet (minimum)
Open-water zone	10-50%	4 feet (minimum)
Wetland zones with emergent vegetation	50-70%	6 to 12 inches (30% to 50% of this area should be 1 foot deep with bottom slope ≤ 10%)
Outlet zone	5-10%	3 feet (minimum)

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

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

a. Estimate WQV surcharge depth (D_{WQV}) based on A_{pp}.

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

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

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

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

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

$$\text{Final } D_{WQV} = WQV/((A_{WQV} + A_{pp})/2)$$

e. Calculate maximum water surface elevation in basin with WQV.

$$\text{WS Elev}_{WQV} = \text{WS Elev}_{pp} + \text{Final } D_{WQV}$$

Step 5 – Determine inflow requirement

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

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

where

Q_{inflow} = Estimated base flow (acre-ft/mo.) (Estimate by seasonal measurements and/or comparison to similar watersheds)
Q_{E-P} = Loss due to evaporation minus the gain due to precipitation (acre-ft/mo.)
$Q_{seepage}$ = Loss or gain due to seepage to groundwater (acre-ft/mo.)
Q_{ET} = Loss due to evapotranspiration (additional loss through plant area above water surface not including the water surface) (acre-ft/mo.)

Note that an impermeable liner may be required to maintain permanent pool level in areas with extremely permeable soils.

Step 6 – Design Basin 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 5 to 10% of the permanent pool water surface area and a volume comprising 5 to 10% of the WQV. The depth of permanent pool in the forebay should be a minimum of 4 feet. Provide the forebay inlet with an energy dissipation structure and/or erosion protection. Trash screens at the inlet are recommended to keep trash out of the basin.

Step 7 – Design Outlet Works

Provide outlet works that limit the maximum water surface elevation to WS $Elev_{WQV}$. The outlet works are to be designed to release the WQV over a 48-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 shown in Figure CWB-1.

a. For single orifice outlet control or single row of orifices at the permanent pool elevation (WS $Elev_{pp}$) (see Figure CWB-1), use the orifice equation based on the WQV (ft^3) and depth of water above orifice centerline D (ft) to determine orifice area (ft^2):

   Orifice Equation

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

where

Q = Flow rate, (cfs)
C = Orifice coefficient (use 0.61)
A = Area of orifice, (ft^2)
g = Acceleration due to gravity (32.2 ft/sec^2)
D = Depth of water above orifice centerline (D_{WQV})

   The equation can be solved for A based on the WQV and using a design drawdown time (t) of 48 hours.

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

$$\mathbf{Area/row\ (in^2) = WQV/K_{48}}$$

   where

$$\mathbf{K_{48} = 0.012D^2 + 0.14D - 0.06} \text{ (from Denver UDFCD, 1999)}$$

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

$$\mathbf{nr = 1 + (D \times 3)}$$

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

$$\mathbf{Total\ Orifice\ Area = area/row \times nr}$$

Step 8 – Design basin shape

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

Step 9 – Design basin side slopes

Side slopes should be stable and sufficiently gentle to limit rill erosion and 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 Access

Provide for all-weather access for maintenance vehicles to the bottom and outlet works. Maximum grades of access ramps should be 10 percent and minimum width will vary according to local permitting agency requirements, but usually between 15-20 feet. Pave ramps with concrete or porous pavement, subject to the approval of the permitting agency.

Step 11 – Design Security Fencing

To protect habitat and for safety reasons, provide aesthetic security fencing approved by the permitting agency around the basin, except when specifically waived by the permitting agency.

Step 12 – Select Vegetation

Select wetland vegetation appropriate for planting in the wetland bottom. Consider the water fluctuations that are likely to occur. Consult a qualified wetland specialist regarding selection and establishment of plants. The shallow littoral bench should have a 4- to 6-inch layer of organic topsoil. Berms and side-sloping areas should be planted with native or irrigated turf grasses.

Construction Considerations

- If possible, stabilize the entire tributary area to the basin before construction begins. If this is not possible, divert flow around the basin to protect it from sediment loads during construction. If sediment does enter the facility during construction, the contractor will be required to remove soil from the basin floor after the entire site has been stabilized, to the satisfaction of the permitting agency inspector.
- Prevent construction traffic from entering basin.
- Ensure that final grading produces a level basin bottom without low spots or depressions.
- Install seepage collars on outlet piping to prevent seepage through embankments.

Maintenance During Vegetation Establishment

- Control the permanent pool water levels as necessary to allow establishment of wetland plants (typically up to 5 years); raise it to the final operating level after plants are established.
- Inspect frequently during vegetation establishment, and identify and re-plant areas immediately as needed.

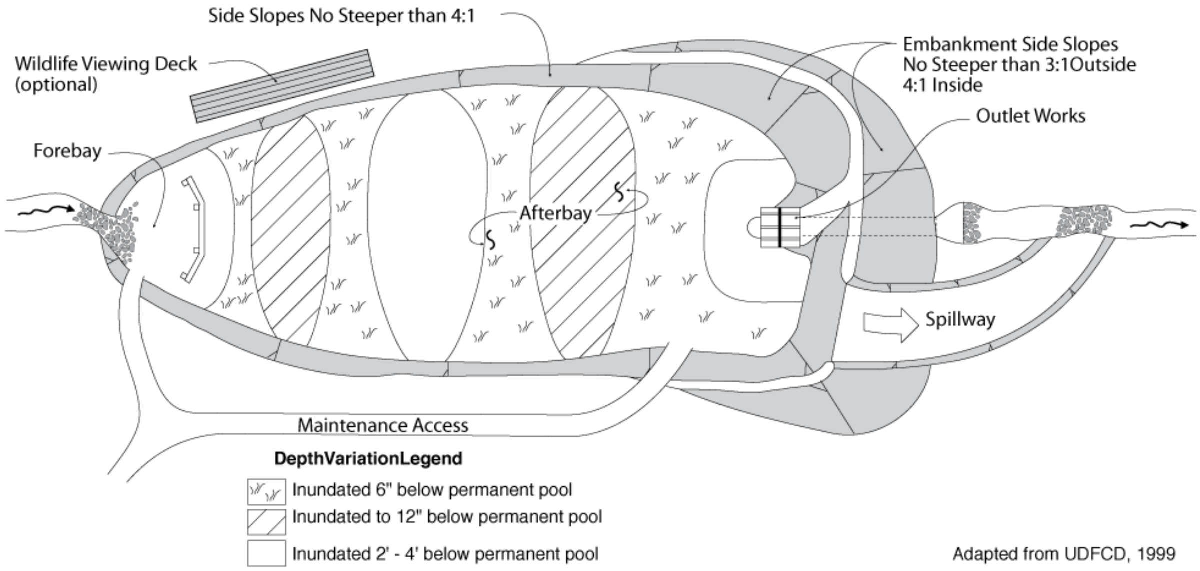
Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas will require execution of a maintenance agreement or permit with the property owner for projects including a constructed wetland basin. Check with the local permitting agency about the timing for execution of the agreement. Such agreements will typically include requirements such as those outlined in Table CWB-3. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

Table CWB-3.
Inspection and Maintenance Recommendations for Constructed Wetland Basins

Activity	Schedule
Inspect basin to identify potential problems such as trash and debris accumulation, damage from burrowing animals, and sediment accumulation.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
Remove litter and debris from constructed wetland basin area.	As required
Stock basin with mosquito fish to enhance natural mosquito and midge control. Contact the local vector control district for assistance.	As required
Harvest vegetation for vector control and to maintain open water surface area.	Annually or more frequently if required
Remove sediment from forebay and other zones when accumulation reaches 10 percent of original design depth or if resuspension is observed. (Note: Sediment removal may not be required in the main pool area for as long as 20 years.)	Clean in early spring so vegetation damaged during cleaning has time to reestablish.
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.

PLAN VIEW



SECTION VIEW

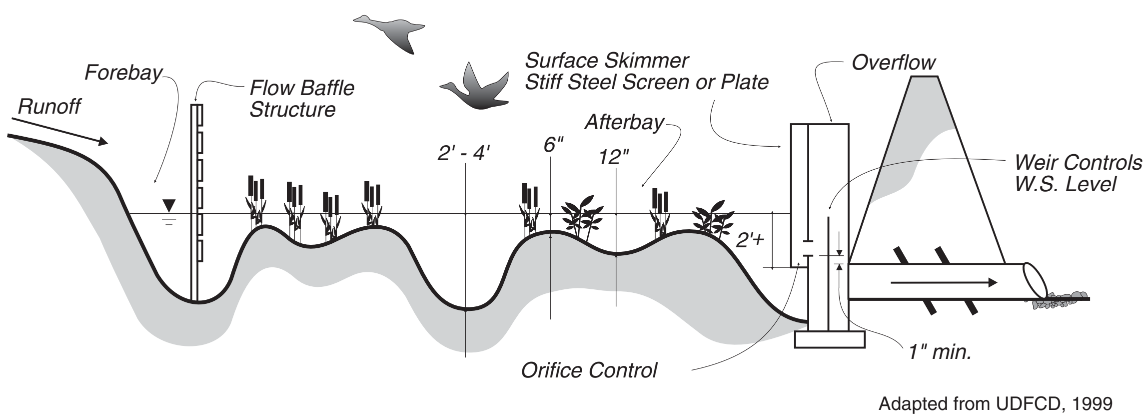


Figure CWB-1. Constructed Wetland Basin

Table CWB-4. Design Data Summary Sheet for Constructed Wetland Basin (Page 1 of 2)

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

1.	Design Water Quality Volume	
	a. Tributary drainage area	Area = ____________ ft^2
	b. Water Quality Volume	WQV = ____________ ft^3
2.	Wetland Basin Minimum Permanent Pool Volume ($Vol_{pp} \geq 0.75 \times WQV$)	$Vol_{pp} \geq$ ____________ acre-ft
3.	Wetland Basin Depths and Water Surface Areas	**ACTUAL DESIGN**
	a. Permanent pool volume (Vol_{pp})	Vol_{pp} = ____________ acre-ft
	Average depth of permanent pool (D_{avg})	D_{avg} = ____________ ft
	Water surface area of permanent pool (A_{pp})	A_{pp} = ____________ ft^2
	Water surface elevation of permanent pool (WS $Elev_{pp}$)	WS $Elev_{pp}$ = ____________ ft
	b. Forebay	
	Depth range = minimum 4 ft	Depth = ____________ ft
	Volume range = 5-10 % of WQV	Volume = ____________ acre-ft
	Water surface area range = 5-10 % of App	WS Area = ____________ ft2
	c. Open Water Zone	
	Depth Range = minimum 4 ft	Depth = ____________ ft
	Water surface area range = 30-50% of App	WS Area = ____________ ft^2
	d. Wetland Zones with Emergent Vegetation	
	Depth Range = 6-12 inches	Depth = ____________ ft
	Water surface area range = 50-70% of App	WS Area = ____________ ft^2
	e. Outlet Pool	
	Depth Range = 3 ft minimum	Depth = ____________ ft
	Water surface area range = 5-10% of App	WS Area = ____________ ft^2
4.	Surcharge Depth of WQV and Max WS Elevation	
	a. Maximum water surface area with WQV (A_{WQV})	A_{WQV} = ____________ ft2
	b. Surcharge depth of WQV ($D_{WQV} \leq 2.0$ ft)	D_{WQV} = ____________ ft.
	Final $D_{WQV} = WQV/((A_{WQV} + A_{pp})/2)$	
	c. Maximum water surface elevation with WQV (WS $Elev_{WQV}$)	WS $Elev_{WQV}$ = ____________ ft
5.	Determine Maximum Month Inflow Requirement	
	$Q_{inflow} = - Q_{E\text{-}P} + Q_{seepage} + Q_{ET}$	$Q_{E\text{-}P}$ = ____________ acre-ft/mo
		$Q_{seepage}$ = ____________ acre-ft/mo
		Q_{ET} = ____________ acre-ft/mo
		Q_{inflow} = ____________ acre-ft/mo

Design Data Summary Sheet for Constructed Wetland Basin (Page 2 of 2)

Project: ____

____

6. Outlet Works
   a. Outlet Type (check one)
      ☐ Single Orifice ☐ Multi-orifice Plate
      ☐ Perforated Pipe ☐ Other
   b. Depth of water above bottom orifice (D_{WQV}) — Depth = __________ ft
   c. Single Orifice Outlet
      1) Total Area — A = __________ in^2
      2) Diameter (or L x W) — D = __________ in
   d. Multiple Orifice Outlet
      1) Area per Row of Perforations — A = __________ in^2
      2) Perforation Diameter (2-inch max.) — Diam = __________ in
      3) No. of Perforations (columns) per Row — Perforations = __________
      4) No. of Rows (4-inch spacing) — Rows = __________
      5) Total Orifice Area (Area per Row) x (Number of Rows) — Area = __________ in^2

7. Basin Shape
   a. Length-Width Ratio (2:1 min.) — Ratio = __________ L:W

8. Embankment Side Slope
   a. Interior Side Slope (4:1 or steeper) — Int. Side Slope = ______ L:W
   b. Exterior Side Slope (3:1) — Ext. Side Slope = ______ L:W

9. Maintenance Access Ramp
   a. Slope (10% maximum) — Slope = __________ %
   b. Width (15 to 20 feet) — Width = __________ ft

10. Vegetation (describe)

Native Grasses ____

Irrigated Turf ____

Emergent Aquatic Plants (specify type / density)* ______________________________

____

Other ____

____

Notes: ____

____

____

Source: County of Sacramento, Department of Water Resources

Description

A stormwater quality detention basin (also called a water quality basin or extended detention basin) is designed to hold stormwater runoff from small storms and the initial runoff ("first flush") from larger storms for a regulated downstream release. Pollutants are removed from stormwater through gravitational settling and biological processes depending on the type of basin. There are three types of water quality detention basins:

- **Wet** stormwater quality detention basins (wet basins) that store a permanent pond of water
- **Dry extended** stormwater quality detention basins (dry-extended basins) that temporarily store stormwater runoff
- **Combination** (wet/dry) stormwater quality detention basins (combination basins) that combine the wet and dry basin treatment systems

Stormwater quality basins must incorporate features that treat dry-weather flows (such as irrigation runoff). Wet basins and combination basins treat the dry weather flows within the permanent pond (micropool); however, dry basin designs must include an additional feature such as a submerged gravel bed or other agency approved feature.

Siting Considerations

- Drainage area: typically greater than 20 acres
- Longitudinal bottom slope: At least 2% in dry basins. Can undulate in wet basins.
- Side slopes: 3:1 or flatter for basin; 3:1 or steeper for permanent ponds.
- Impermeable liners may be required in areas with high groundwater.

POLLUTANT REMOVAL EFFECTIVENESS

	Dry basin	Wet basin
Sediment	Medium	High
Nutrients	Low	Medium
Trash	High	High
Metals*	Medium	High
Bacteria*	Medium	High
Oil & Grease	Medium	High
Organics*	Medium	High

*Target Pollutant for Sacramento Area

Source: CASQA California Stormwater BMP Handbook, January 2003

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the basins and associated features are properly designed, constructed, operated and maintained.
- Permanent ponds shall be stocked with mosquito fish for vector control.

Advantages

- May provide both stormwater quality treatment and flood control if designed for flood flows.
- Mitigate increased volume and flow impacts caused by development.
- If properly designed, constructed, and maintained, have substantial aesthetic and recreational value and provide wildlife habitat.
- Viewed as a public amenity when integrated into a park or open space setting and properly designed and landscaped.

- Wet basins: Permanent ponds can provide significant water quality improvement across a broad spectrum of constituents including dissolved nutrients.
- Wet basins: Can treat dry weather flows without the need for additional features.
- Dry basins: May be easier to maintain than wet basins.

Limitations

- May pose some safety concerns where there is public access.
- Cannot be placed on steep, unstable slopes.
- Wet basins: May need a supplemental water source to replenish and maintain the permanent pond.
- Wet basins: Are typically not permitted if routine pumping of ground or surface water would be needed to maintain the pond. Check with the local permitting agency.
- Dry basins: May require more land than combination and wet ponds.

How does a water quality detention basin work?

Stormwater quality detention basins allow particles and associated pollutants to settle out. Permanent ponds (micropools) may enhance pollutant removal through biological and chemical processes. The volume of runoff may also be reduced through infiltration and evaporation. Dry basins fill up during a storm event and detain the water quality volume for a period of 48 hours. Wet basins allow stormwater runoff to slowly pass through the pond displacing water from the permanent pond. Combination basins include both a permanent pond and additional storage for detaining a portion of the water quality volume for a period of 48 hours.

Other Names: water quality basin, extended detention basin, dry extended basin, wet ponds, wet extended-detention basins, dry ponds

Planning and Siting Considerations

- Plan water quality basins to be aesthetically-pleasing public amenities (see Figure DB-1).
- Where possible, design water quality basins as a joint use with parks (passive recreation), open space, wildlife habitat, aesthetic amenities and/or flood control detention facilities (see Figures DB-1 and DB-2). Generally, the area within the water quality volume (WQV) is not well suited for recreation facilities such as ballparks, picnic areas and restrooms.
- Ponds present special design considerations such as the selection of appropriate vegetation and nuisance abatement in order to function properly as both a water quality control measure and a public amenity.
- Use dry basins if dry weather flows are not sufficient to maintain the permanent pond of wet and combination ponds. See Figure DB-4.
- Wet and combination basins may require a supplemental water source to maintain the permanent pond until the entire drainage shed is built out.
- Wet and combination basins require submitting water balancing calculations to ensure that the permanent pond volume will be maintained in the dry season. Use an evaporation rate of 0.45 in/day for the Sacramento area.
- May be required to include aeration and/or fountains for permanent ponds with depths greater than 6 feet.
- Place top soil within the top 12” of the basin to support plant growth.
- Refer to the local agency drainage criteria for flood control design.
- Consider re-circulating dry-weather flows in a water feature or as irrigation water to conserve water and benefit water quality.

- Provide vehicle/equipment access for maintenance of the basins and inlet/outlet structures. May be required to include a boat ramp for harvesting of aquatic plants. Refer to the local agency for specific design criteria. Access could be combined with other uses such as walking or bicycle paths.
- Impermeable liners may be required in areas with high groundwater.
- May require approval from State Division of Safety of Dams.

Figure DB-1. Park Incorporating Water Quality Detention With Wet Pond

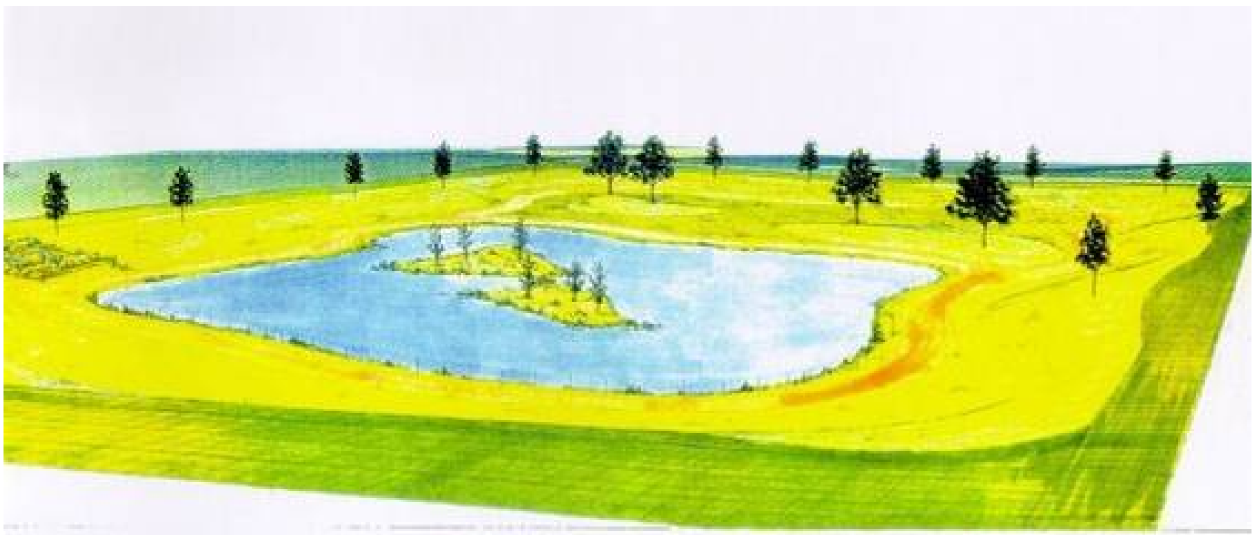


Figure DB-2. Water Quality Detention Pond Incorporating Wet Pond and Natural Contours

Design Criteria

Design criteria for stormwater detention basins are listed in Table DB-1.

Table DB-1. Water Quality Detention Basin Design Criteria

Design Parameter	Criteria for Basin Type			Notes
	Dry	Wet	Combo	
Drainage area	Typically >20 acres			
Design volume	WQV	1.25 WQV	1.125 WQV	See Figure DB-3 and Appendix E in this manual for details.
Max Drawdown Time	48 hrs			See Appendix E.
Depth of Basin/ Permanent Pond	NA	4 ft. – 8 ft	4 ft. – 8 ft	A 4 ft pond depth ensures an open water area, retards cattail growth, reduces stagnation, & allows for mosquito fish. Water deeper than 4 ft increases the residence time and results in less heating/stagnation in summer.
Basin Shape	Length 3X width (min.)			Always maximize the distance between the inlet and outlet. Whenever possible, shape the basin to gradually expand from the inlet then gradually contract toward the outlet (e.g., teardrop.)
Side slopes (H:V)	3:1 or flatter 3:1 or steeper			Basin side slopes Permanent ponds side slopes
Embankment side slope (H:V)	4:1 or flatter 3:1 or flatter			Inside Outside (without retaining wall)
Longitudinal slope/ bottom surface	Slope at least 2%	Undulate the bottom depth	Undulate the bottom depth	
Basin freeboard	1 ft.			
Treatment for dry-weather flows	submerged gravel bed	permanent pond	permanent pond	Other dry weather treatment features for dry basins may be approved by the permitting agency on a case by case basis.
Sediment Forebay Volume	5% to 10% max of the total design volume			Sediment forebays may not be required; check with the local permitting agency.

Step 1 – Calculate Water Quality Volume (WQV)

Using Appendix E in this manual, determine the stormwater quality design volume, WQV, for the contributing area. See Figure DB-3 and table DB-1 for the volume requirements for dry, combination and wet basins.

Step 2 – Design the Basin

Design the basin to:

- Provide the required volume as determined in step 1.
- Meet criteria on Table DB-1 regarding depth, shape, side slope and longitudinal slope
- Incorporate a sediment forebay if required by the local agency. See step 3.

- Maximize residence time by placing the inlet and outlet on opposite ends of the basin. Ensuring the length is at least three times the width, as measured down the center of the flow path. For permanent ponds, incorporate additional features to maximize residence time, such as:
    - Contouring the basin bottom to baffle flows and promote mixing.
    - Using islands or peninsulas.
    - If possible, designing the deepest point to be at least 8 ft. deep.
- Incorporate access. See step 5.
- Incorporate a concrete low flow channel in dry basins (see Figures DB-4 and DB-5).
- Consider an aquatic bench with emergent vegetation around the perimeter of wet ponds and permanent pools to help with water quality and to provide a safety feature.

See Figure DB-4 for an example of a dry extended detention basin.

Figure DB-3. Basin Criteria to Control Stormwater Pollution

Dry-Extended Detention Basin

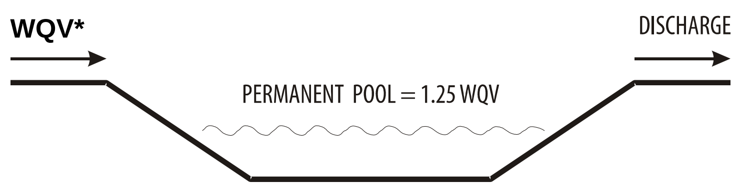
Storm discharge: release 75% of WQV in a minimum of 24 hours, 100% of WQV within 48 hours total.

Dry weather treatment: vegetated gravel bed or other approved feature.

Wet Basin

Storm discharge: based on the downstream drainage systems capacity

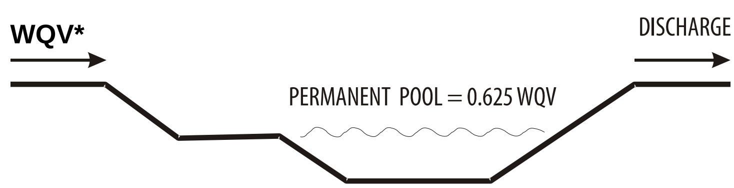
Dry weather treatment included in permanent pool



Combination Basin

Storm discharge: release 75% of the 0.5 WQV in a minimum of 24 hours, 100% of the 0.5 WQV within 48 hours total.

Dry weather treatment included in permanent pool



*WQV is the Water Quality Volume per Appendix E

Step 3 – Sediment Forebay

A sediment forebay may be required (check with local permitting agency) at each inflow point in order to trap sediment where it can be easily cleaned out. The forebay size should be about 5% to 10% maximum of the total design volume and designed to release in 3-5 minutes.

For easy-maintenance, design the sediment forebay(s) to include:

- An access road. See step 5 for detailed information.
- Concrete lining to prevent equipment from sinking during cleaning.
- A concrete wall to separate the forebay from the rest of the water quality basin. The concrete wall should include overflow weir allowing flows to exit at non-erosive velocities during the 2-year and 10-year frequency design storms.

Step 4 - Design the Inlet and Outlet

Inlet Design

Design the inlet structure to:

- Dissipate energy of incoming flows to prevent erosion and prevent resuspension of previously deposited sediment.
- For permanent ponds, set pipe invert approximately two (2) feet from pond bottom above sediment storage.
- Install trash/access control rack. Check with the local agencies details.
- Provide access per Step 5.

Outlet Design

The goal of the outlet design criteria is to detain flows for a sufficient period of time to permit the settling of smaller sized sediments while meeting the release criteria so that storage is available for subsequent storm events. Outlets should be designed in accordance to Figure DB-6 or equal design as approved by the local agency and shall include trash racks to keep debris from clogging the outlet without interfering with the hydraulic capacity. In addition, flap gates should be installed to avoid the effects of backwater in the downstream creek or channel. The release criteria for the basins are as follows:

- **Dry Basin** - A dry basin is required to release 75 percent of the water quality volume in a minimum of 24 hours and the total design volume over an additional 24 hours for a total release time of 48 hours. The WQV should not be discharged too quickly or pollutant removal will be compromised.
- **Wet basins** - A wet basin is required to maintain the permanent pond volume while discharging based on the downstream drainage systems capacity.
- **Combination basins** - A combination basin is required to maintain the permanent pond volume while releasing 75 percent of the 0.5 WQV in a minimum of 24 hours and the remainder 25 percent of the 0.5 WQV over an additional 24 hours for a total release time of 48 hours.

Step 5 – Access Design

Provide a way for maintenance vehicles to access all structures and cells within the basin such as the basin bottom, sediment forebay, inlets and outlets, low flow channels and submerged gravel beds.

Design access roads to have an all weather access surface, a width of 15’ to 20’ (check with the local permitting agency for required width) and a minimum turning radius of 40 feet. Design access ramps to be concrete or other impervious surface (check with local permitting agency) to the basin bottom with a maximum slope of 10% and a width of 15 feet. Place gates across all access ramps to discourage access.

Step 6 – Design for Safety

Incorporate features for safety

- Consider fencing the facility with post and cable (6” x 6” post minimum) or other approved fencing material to discourage access.
- Hinge and lock gates on structures.
- Provide gates or removable bollards across access roads.

If applicable, design the dam embankment for safety

- Obtain approval from State Division of Safety of Dams, if required based on the size of the dam/ storage volume. If that is not required, nonetheless design the embankment-spillway-outlet system to prevent catastrophic failure.
- Design the embankment not to fail during 100-year and larger storms.
- Create embankment slopes to be 3:1 or flatter for outside slopes and 4:1 or flatter for inside slopes and plant them with turf forming grasses.
- Compact embankment soils in accordance to geotechnical engineer’s specifications.
- Design spillway structures and overflows in accordance with local drainage criteria.

Step 7- Incorporate Treatment for Dry-Weather Flows

For wet and combination basins, the permanent pond provides treatment for dry-weather flows. For dry basins, it is necessary to provide dry-weather flow treatment such as a vegetated submerged gravel bed or other equal treatment that is approved by the local permitting agency. See Figure DB-4.

Dry weather flows vary by land use, drainage basin size, soil types and other factors. Determine dry weather design flows, Q, using the values in Table DB-2 or other criteria acceptable to the local agency.

Vegetated Submerged Gravel Beds

Vegetated submerged gravel beds can be used to reduce contaminants in dry weather flows within or outside of a dry basin (See Figure DB-4). Design vegetated submerged gravel beds so that:

- Anticipated dry weather flows pass through the gravel bed without overland flow or flooding.
- Anticipated dry weather flows pass through the gravel bed without dry out (excessive dry headspace) at the inlet zone of the bed.
- The bed remains functional in the likely event of changing hydraulic conductivity (As the bed clogs with roots and sediment, it should not flood.)
- Water levels are fully controllable through the use of inlet and outlet structures.
- The system achieves desired removal of contaminants.
- The gravel bed shall be planted with emergent plants (See Table DB-3).
- The top 3” of the gravel bed shall be above the outlet flow line.
- Gravel shall be held to 2” below the outfall flow line within a 4 foot radius of the outfall pipe.

Basin geometry: Choose a length-to-width ratio that results in a sufficient hydraulic gradient to push the water through the gravel bed. A length-to-width ratio of 5 to 10 is common, but other length-to width ratios can be used provided the hydraulic gradient is adequate. (As the length-to-width ratio is increased, the linear velocity of the water passing through the gravel bed increases, the pressure drop increases, and the hydraulic gradient decreases. At some point, the hydraulic gradient is not sufficient to push the water through the gravel bed, resulting in overland flow.)

Table DB-2. Dry Weather Design Flows

BASIN	AREA (ACRES)	DRY WEATHER FLOW (MGAL/WK)	LAND USE	MGAL/WK (PER AC SHED)	CFS (PER AC SHED)	AC-FT/DAY (PER AC SHED)
Summary of City of Sacramento Drainage Sump Stations Used						
33	684	1.07	Residential/Commercial	0.0016	0.000354	0.0007
34	687	1.25	Residential	0.0018	0.000398	0.0008
63	481	1.71	Residential	0.0036	0.000796	0.0016
66	443	1.72	Industrial	0.0039	0.000862	0.0017
67	896	3.10	Residential/Commercial	0.0035	0.000774	0.0015
69	1,115	4.50	Residential	0.0040	0.000884	0.0018
96	1,308	1.33	Mix	0.0010	0.000221	0.0004
116	197	0.30	Industrial	0.0015	0.000332	0.0007
129	1,356	3.53	Mix (mostly residential)	0.0026	0.000575	0.0011
132	2,044	8.83	Residential	0.0043	0.000950	0.0019
151	1,058	3.24	Mix	0.0031	0.000685	0.0013
152	1,479	13.60	Mix	0.0092	0.002034	0.0040
154	662	0.92	Commercial/Industrial	0.0014	0.000309	0.0006
159	573	1.48	Residential/Industrial	0.0026	0.000575	0.0011

Source of information for basins 33, 66, 67, 69, 116, 151, 152, and 159 is from the City of Sacramento Illicit Connection Program Field Screening Report Phase 2, January 1997. Flow data from 1993, 1994, 1995, and 1996.

Source of information for basins 34, 63, 96, 129, 132, and 154 is from the City of Sacramento Illicit Connection Program Field Screening Report, July 1995. Flow data from 1994.

BASIN	AREA (ACRES)	DRY WEATHER FLOW (MGAL/WK)	LAND USE	MGAL/WK (PER AC SHED)	CFS (PER AC SHED)	AC-FT/DAY (PER AC SHED)
Residential and Residential/Other						
33	684	1.07	Residential / Commercial	0.0016	0.000354	0.0007
34	687	1.25	Residential	0.0018	0.000398	0.0008
63	481	1.71	Residential	0.0036	0.000796	0.0016
67	896	3.10	Residential/Commercial	0.0035	0.000774	0.0015
69	1,115	4.50	Residential	0.0040	0.000884	0.0018
129	1,356	3.53	Mix (Mostly residential)	0.0026	0.000575	0.0011
132	2,044	8.83	Residential	0.0043	0.000950	0.0019
159	573	1.48	Residential/Industrial	0.0026	0.000575	0.0011
			Average	0.003000	0.000663	0.001313
			Median	0.003050	0.000674	0.001300
Commercial / Industrial / Mix						
66	443	1.72	Industrial	0.0039	0.00086	0.0017
96	1,308	1.33	Mix	0.0010	0.00022	0.0004
116	197	0.30	Industrial	0.0015	0.00033	0.0007
151	1,058	3.24	Mix	0.0031	0.00069	0.0013
152	1,479	13.60	Mix	0.0092	0.00203	0.0040
154	662	0.92	Commercial/Industrial	0.0014	0.00031	0.0006
			Average	0.003350	0.000740	0.001450
			Median	0.002300	0.000508	0.001000
Residential						
34	687	1.25	Residential	0.0018	0.000398	0.0008
63	481	1.71	Residential	0.0036	0.000796	0.0016
69	1,115	4.50	Residential	0.0040	0.000884	0.0018
132	2,044	8.83	Residential	0.0043	0.000950	0.0019
			Average	0.003425	0.000757	0.001525
			Median	0.003800	0.000839	0.001700

Design Criteria: Design using the following criteria:

- The gravel media - 1” to 1-1/2” in size. The porosity of the gravel bed is approximately 0.4
- The bed depth – d = 2 feet (The depth of media is selected by allowing consideration for bottom sediment buildup and rooting requirements of desired vegetation.)
- The design porosity of the gravel bed - $\varepsilon = 0.3$
- The effective hydraulic conductivity shall be less than 95,000 ft/day.
- Nominal hydraulic detention time through the gravel bed, $\tau = 2$ days.

Surface Area = SA = L W = (τ Q) / (d ε) = (2 days)Q/(2 feet)(0.3)(86400 sec/day)

where Q= dry weather design flow rate (cfs)

Step 8 - Prepare a Landscaping Plan

Retain a certified landscape architect or wetland specialist to prepare a landscaping plan that includes:

- a planting layout showing what species to plant where
- plant sizes (e.g. seed, plug, 1-gallon container, etc.)
- planting techniques
- plant spacing
- soil amendments
- hydroseed specifications
- Irrigation specifications (which must conform to applicable local regulations)

Consider the following when choosing plants:

- Do not plant trees at the base of any access ramps, around any inlet, outlet or culvert, or within 5 to 10 feet of a concrete structure or channel.
- Cluster trees and shrubs when possible to make mowing of basin easier.
- Trees may not be allowed on the basin floor (check with local permitting agency).
- Use native plants.
- Choose plants that are adapted to the site conditions, including the expected degree of inundation/soil moisture.
- Incorporate plants known to improve water quality.
- Where possible, specify an array of plant types, including emergent species (in channels/ponds), herbaceous species, and trees and shrubs (along the outer borders). This results in a more natural system and enhances the aesthetic and wildlife value. However, shrubs and trees should not be used for clay-lined permanent ponds or basins.

See Tables DB-3 and DB-4 for a list of suitable plants for different degrees of inundation/soil saturation.

Table DB-3: Plants for Areas that are Periodically Inundated

Scientific name	Common name	Propagation method: Plug	Propagation method: Container stock	Propagation method: Seed	Notes
Emergent species					
Carex densa	Dense sedge	✓	✓		Best where soil is saturated for greater duration
Carex barbarae	Santa Barbara sedge	✓	✓		
Cyperus eragrostis	Tall faltsedge	✓	✓		
Eleocharis macrostachya	Creeping spikerush	✓	✓		
Juncus balitcus	Baltic rush	✓	✓		
Juncus xiphioides	Irish-leaved rush	✓	✓		
Grasses					
Hordeum brachyantherum	Meadow barley			✓	
Leptochloa fascicularis	Bearded sprangle-top			✓	
Muhlenbergia rigens	Deergrass			✓	
Paspalum distichum	Paspalum			✓	
Phalaris arundinaceae	Reed canary grass			✓	
Phalaris lemmonii	Lemmon's canary grassseed			✓	
Herbaceous species					
Polygonum lapathifolium	Willow weed	✓	✓		Locate where soil is most apt to be saturated
Polygonum punctatum	Dotted smartweed	✓	✓		
Verbena hastate	Blue vervain		✓	✓	Locate near borders where soil dries out first

Construction Considerations

- Before acceptance of the basin by the local agency, the accumulated sediment most be removed.
- See "Recommended Planting Guidelines" later in this fact sheet for information on planting techniques and recommended planting times.
- Take steps to ensure plants become established:
  - Plant emergent species bordering the permanent pond in saturated soil, so the plants will become established. Maintain the water level in the pond to allow for soil saturation or shallow inundation around the base of the plants, but avoid significant flooding and inundation of stems and leaves during the first year. Tall plugs and plantings can tolerate greater depths of inundation as long as a significant portion of the stems and leaves of the plantings remain above the water surface.
  - Provide drip irrigation for plantings in areas that will not be saturated to the surface or inundated. Irrigate as needed at least during the first two years--until the plants can survive on annual rainfall and/or groundwater.
  - Irrigate hydroseeded areas only if needed for plant establishment. Hydroseeded portions of the bank do not need irrigation in years of normal rainfall. If a period of drought occurs after hydroseeding, supplemental watering may be needed to establish germination in the first year.

Table DB-4. Plants to Use In/Adjacent to a Permanent Pond

Scientific name	Common name	PROPAGATION METHOD: Plug	Container stock	Pole cuttings	Tuber	Seed	Notes
Aquatic species							
Ceratophyllum demersum	Hornwort	✓	✓				
Elodea canadensis	Common waterweed	✓	✓				
Potomogeton pectinatus	Sago pondweed				✓		
Emergent species							
Carex barbarae	Santa Barbara sedge	✓	✓				Best at pond border where soil saturated/periodically inundated
Juncus balitcus	Baltic rush	✓	✓				
Juncus effusus	Soft rush	✓	✓				
Scirpus acutus var. *Occidentalis*	Hard-stem bulrush	✓	✓				Adapted to water levels up to three feet
Scirpus americanus	Three square	✓	✓				Best at pond border
Grasses							
Hordeum brachyantherum	Meadow barley					✓	Adjacent to pond, where soils are saturated to the surface but not inundated
Leptochloa fascicularis	Bearded sprangle-top					✓	
Paspalum distichum	Paspalum					✓	
Herbaceous species							
Baccharis douglasii	Marsh baccharis	✓	✓				
Euthamia occidentalis	Western goldenrod	✓	✓				
Polygonum lapathifolium	Willow weed	✓	✓				Can be grown along the pond borders where soils are saturated to the surface
Polygonum punctatum	Dotted smartweed	✓	✓				
Sagittaria latifolia	Broad-leaf arrowhead	✓	✓				
Shrubs (may not be appropriate if pond is clay-lined)							
Baccharis salicifolia	Mule fat		✓				
Cephalanthus occidentalis	Common buttonbush		✓				Can be grown on the pond banks; accepts greater soil saturation than the California rose
Rosa californica	California rose		✓				Can be grown on the pond banks, ideally where there is minimal surface soil saturation
Trees (should not to be used for clay lined permanent ponds)							
Alnus rhombifolia	White alder		✓				Can be grown on pond berms/borders
Populus fremontii	Fremont's cottonwood		✓	✓			
Salix exigua	Sandbar willow		✓	✓			
Salix gooddingii	Goodding's black willow		✓	✓			
Salix lasiolepis	Arroyo willow		✓	✓			
Salix laevigata	Red willow		✓	✓			
Salix lucida var. *lasiandra*	Shining willow		✓	✓			

Long-Term Maintenance

Regional detention basins usually will be maintained by the local agency. A long-term maintenance plan (i.e., adaptive management plan) shall be prepared by the developer/owner and approved by the local agency prior to acceptance of the basin.

If the basin will be privately maintained, the local agencies will require execution of a maintenance agreement with the property owner prior to final acceptance of a private development project, including acceptance of the water quality basin. Check with the local permitting agency about the timing for execution of the agreement. The maintenance agreement will typically include requirements such as those in Table DB-5. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

Table DB-5.
Inspection and Maintenance Recommendations for Water Quality Detention Basins

Activity	Schedule
Inspect the facility for needed maintenance.	Twice a year.
Remove trash and debris.	At least twice a year.
Remove sediment, debris and litter that accumulates in the sediment forebay (To clean the sediment-collection area for a wet basin, it may be necessary to drain, pump or partially drawdown the pond area.)	Every 3 to 5 years or when 6 to 12 inches have accumulated, whichever comes first.
Remove sediment that accumulates in the concrete low flow channel.	Annually
Control weeds and invasive plant species.. Carefully weed areas to avoid removing the native species .	Regularly during the first 2 years and then as needed
Use integrated pest management (IPM)	As needed
Irrigate plants	As needed during the establishment period (see construction considerations) and during periods of drought
Replant any bare areas. Investigate why the die-off occurred and take remedial action to correct the problem	In the event of extensive die-off
Harvest vegetation around the perimeter of permanent ponds so that mosquito fish are not impeded by thick vegetation.	Each summer. More frequently if required by local vector control agencies.
Harvest vegetation in channels	As needed
Where permitted by the Department of Fish and Game or other agency regulations, stock wet ponds with mosquito fish (Gambusia spp.) to enhance natural mosquito and midge control.	As needed
Control any erosion by redirecting or dissipating the water source. If necessary, recontour, mulch, and/or reseed.	When there are signs of erosion, including gullies, rills and evidence of sheet erosion.
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.

Recommended Planting Guidelines

Propagation Methods

Plugs. Plugs are clumps of plant roots, rhizomes or tubers combined with associated soil. To propagate plants with plugs, follow these guidelines:

- Plant plugs during the fall dormant period, preferably between October 1 and November 15.
- Collect plugs from a suitable collection site in the vicinity of the constructed basins, using a qualified botanist or nursery staff. Plugs can be removed manually or salvaged with an excavator or backhoe. Collect plugs from healthy specimens free of insects, weeds and disease. Use either whole plants or plant divisions. The minimum recommended size is 1 foot x 1 foot.
- When possible, plant plugs immediately after collection. When necessary, plugs can be stored in a cool, moist, shaded location for a maximum of one day.
- Space plugs 1 foot to 6 feet apart, depending on the size of the plug. Smaller plugs can be planted at the minimum distance to promote faster spreading and cover. Plant larger plugs from cattail and bulrush species at 3 foot to 6 foot intervals.
- Prepare a hole slightly larger than the diameter of each plug and place the root system of the plug into the hole. Use a breaking bar or similar technique to create the planting hole. Manual planting with a spade is recommended for wet soils. Power augers can be used to create holes in dry soils. Alternatively, in lieu of individual holes, create a trench along the narrow axis of the pond; manually place plants at specified elevations in relation to the proximity of permanently saturated soils as shown on the planting plan.
- If the plug has an established root system, make sure the base of the stem and top of the root collar are level with the ground surface. Secure tubers to prevent floating. Place rhizomes in the soil with a slight upward angle.
- Backfill the hole or trench containing the plug(s) with soil and tamp it down to assure good soil contact and secure the plug.
- Cut back the vegetative portion of the plant to prevent water loss and wilting, and encourage the growth of roots and new shoots. Plugs of wetland plants should be grown in saturated soil.
- For wetland plants, the soil should not be allowed to dry out after planting.

Container Stock. When planting using container stock, follow these guidelines:

- Dig planting holes twice as wide and deep as the container size. It is recommended that container plantings receive a balanced time released fertilizer tablet that is placed at the bottom of the planting hole prior to installation of the plant.
- Space plants as shown on the planting plan.
- When planting, make sure the root collar and base of the stem are level with the adjacent soil surface. Berms for water retention and mulch can be used enhance plant establishment.
- Backfill the soil and tamp it down to assure contact with the roots. Promptly water to promote the settling of soil.

Pole Cuttings. Follow these guidelines when using pole cuttings:

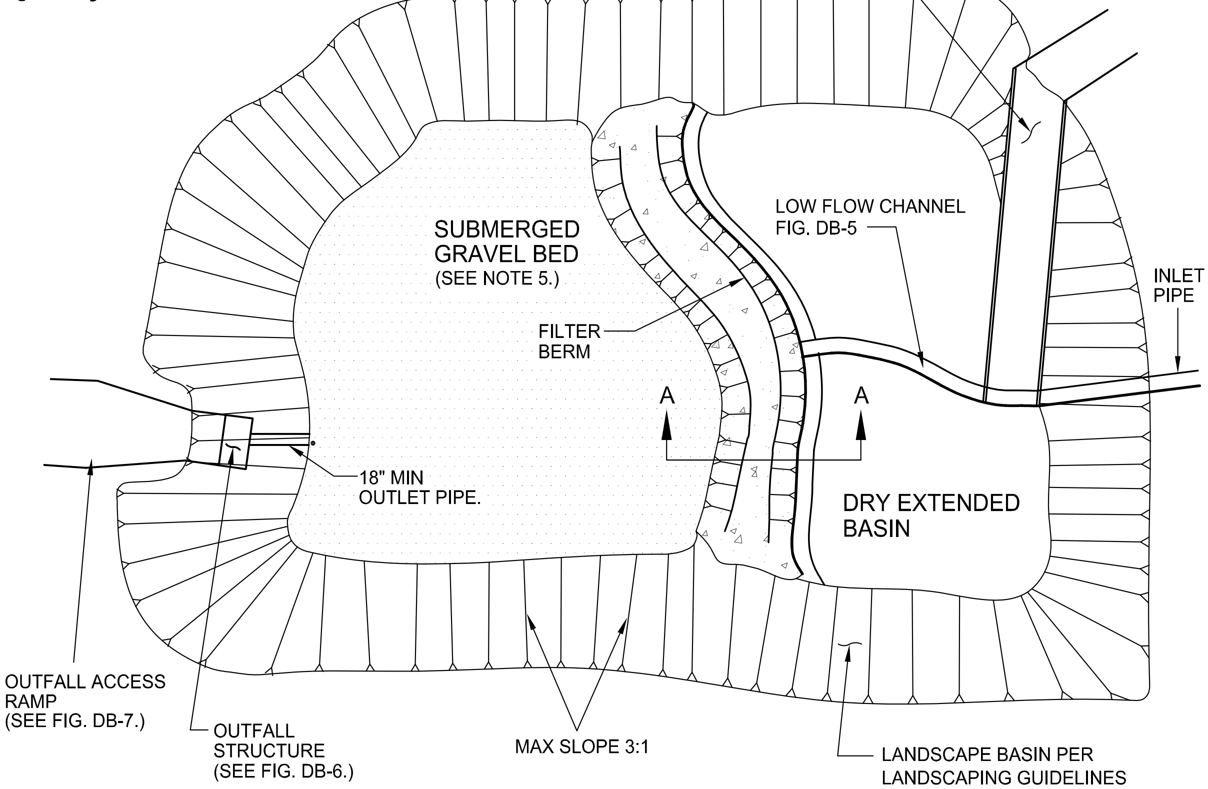
- Collect pole cuttings from the young wood of dormant trees that are healthy and free of diseases.
- Size pole cuttings to have at least five viable nodes; to have a diameter at the base between 1/2 and 2 inches (1 inch is optimum); and to be between 2 and 4 feet long.
- Collect pole cuttings no more than 10 days prior to planting. Place them in cool water to promote swelling of the nodes, and keep the water fresh by aeration and/or by daily replacement.

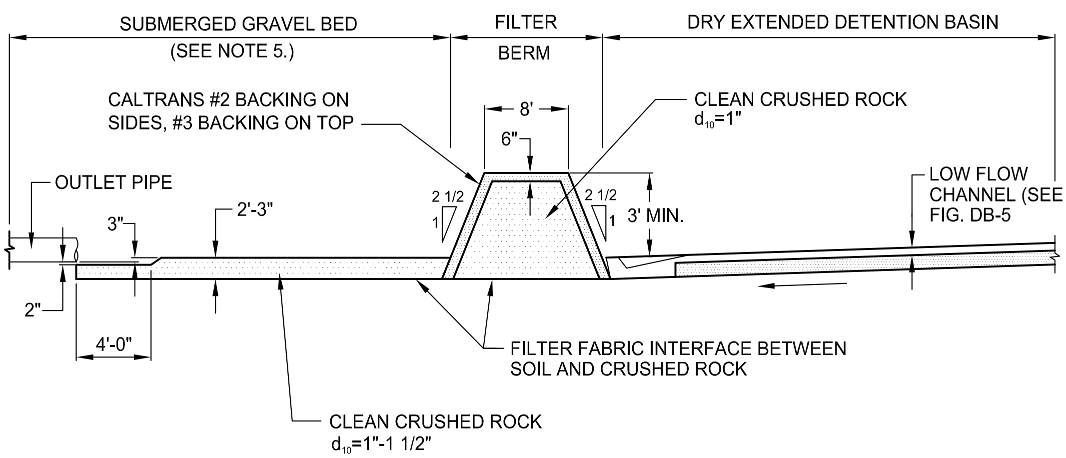
- Following the production of the nodes (2-5 days), plant the pole cuttings in a rich organic medium mixed with native soil to encourage the production of a fibrous root system.
- Place pole cuttings in a hole approximately 3 feet deep (as determined by the length of the cutting--generally 75 percent of the length of the cutting should be planted beneath the soil surface). Backfill with native soil, or a rich organic medium mixed with native soil. Tamp down the soil to remove air pockets and assure soil contact with the cutting.

Seeds. Follow these guidelines when seeding:

- Plant seeds in the fall, preferably during the early portion of the dormant season. Time seeding to occur after plugs, container stock and pole cuttings are installed.
- Scarify the soil surface with a rake prior to seeding, taking care not to damage previously planted vegetation.
- Plant seeds at the ratios and rates specified by the supplier. The certified germination percentage should be provided by the supplier. Use seeds free of weeds and diseases.
- Broadcast seeds over the scarified planting area, using a hand-held spreader. Seed can be mixed with a slow-released fertilizer (16-20-0).
- Rake the surface to cover the seeds with about one eighth to one quarter inch of soil.

Figure DB-4. Dry Extended Stormwater Quality Detention Basin





SECTION A-A

NOTES:

1.- ALL GRAVEL-SOIL INTERFACES MUST BE LINED WITH MIRAFI 400 GEOFILTER OR APPROVED EQUAL.
2.- TOP 3" OF SUBMERGED GRAVEL BED SHALL BE ABOVE THE OUTLET FLOW LINE.
3.- WITHIN A 4' RADIUS OF THE OUTFALL PIPE, GRAVEL SHALL BE HELD TO 2" BELOW OUTFALL FLOW LINE.
4.- CLEAN CRUSHED ROCK TO BE PLACE NO SOONER THAN 2 WEEKS PRIOR TO ACCEPTANCE BY LOCAL AGENCY.
5.- DRY BASINS SHALL INCLUDE AN ADDITIONAL FEATURE TO TREAT DRY WEATHER FLOWS SUCH AS A SUBMERGED GRAVEL BED. CHECK WITH YOUR LOCAL PERMITTING AGENCY FOR ALLOWED DRY WEATHER TREATMENT FEATURES.

DATE: MAY 2007

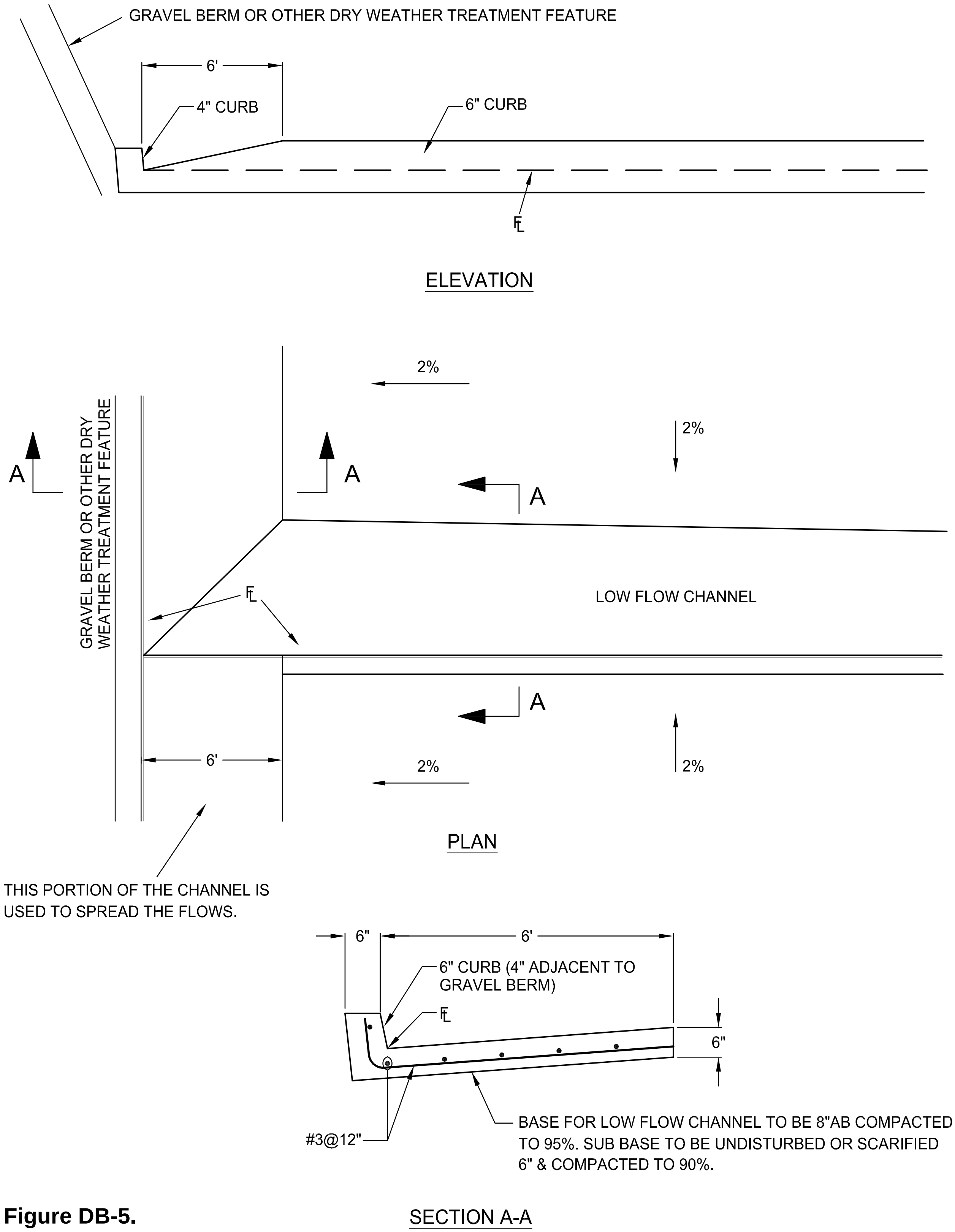


Figure DB-5.
Low Flow Channel

DATE: MAY 2007

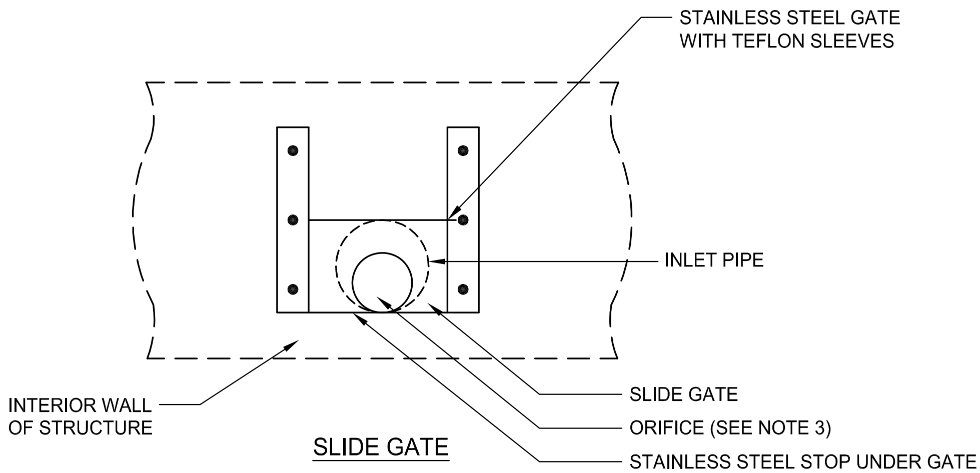
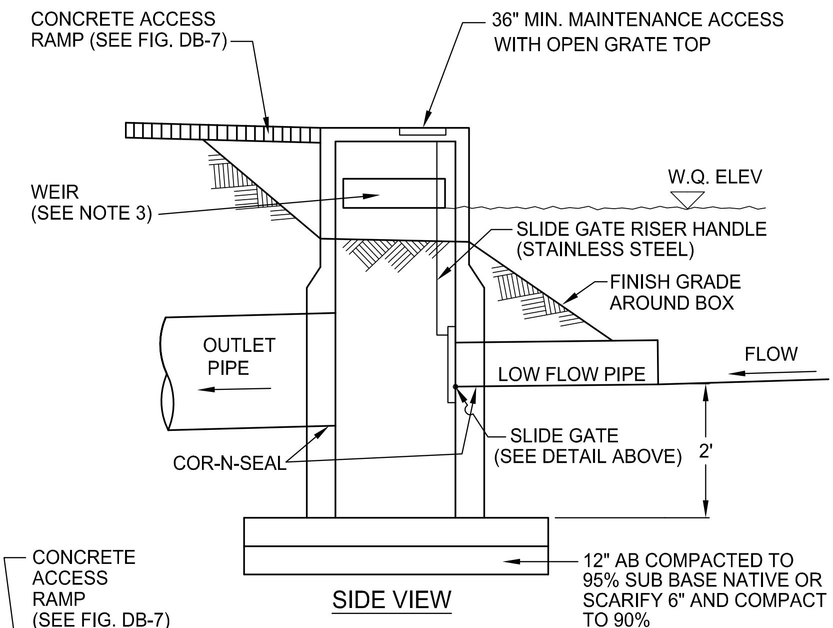
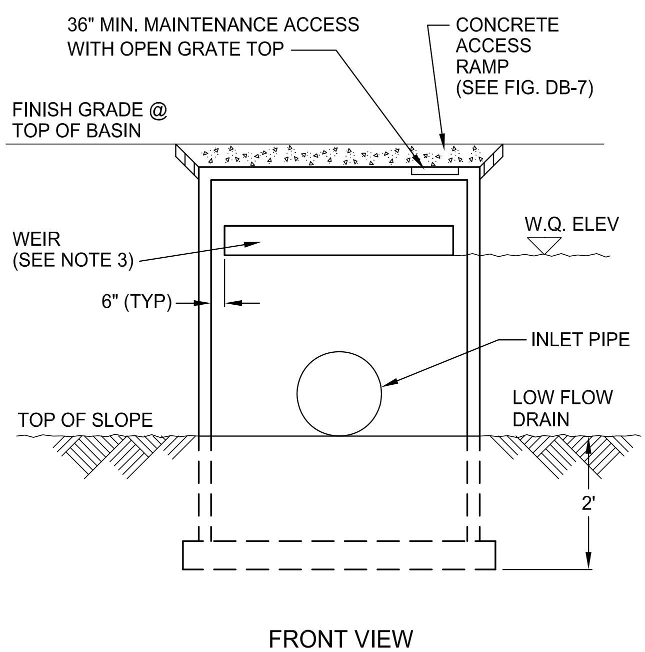


Figure DB-6.
Outfall structure



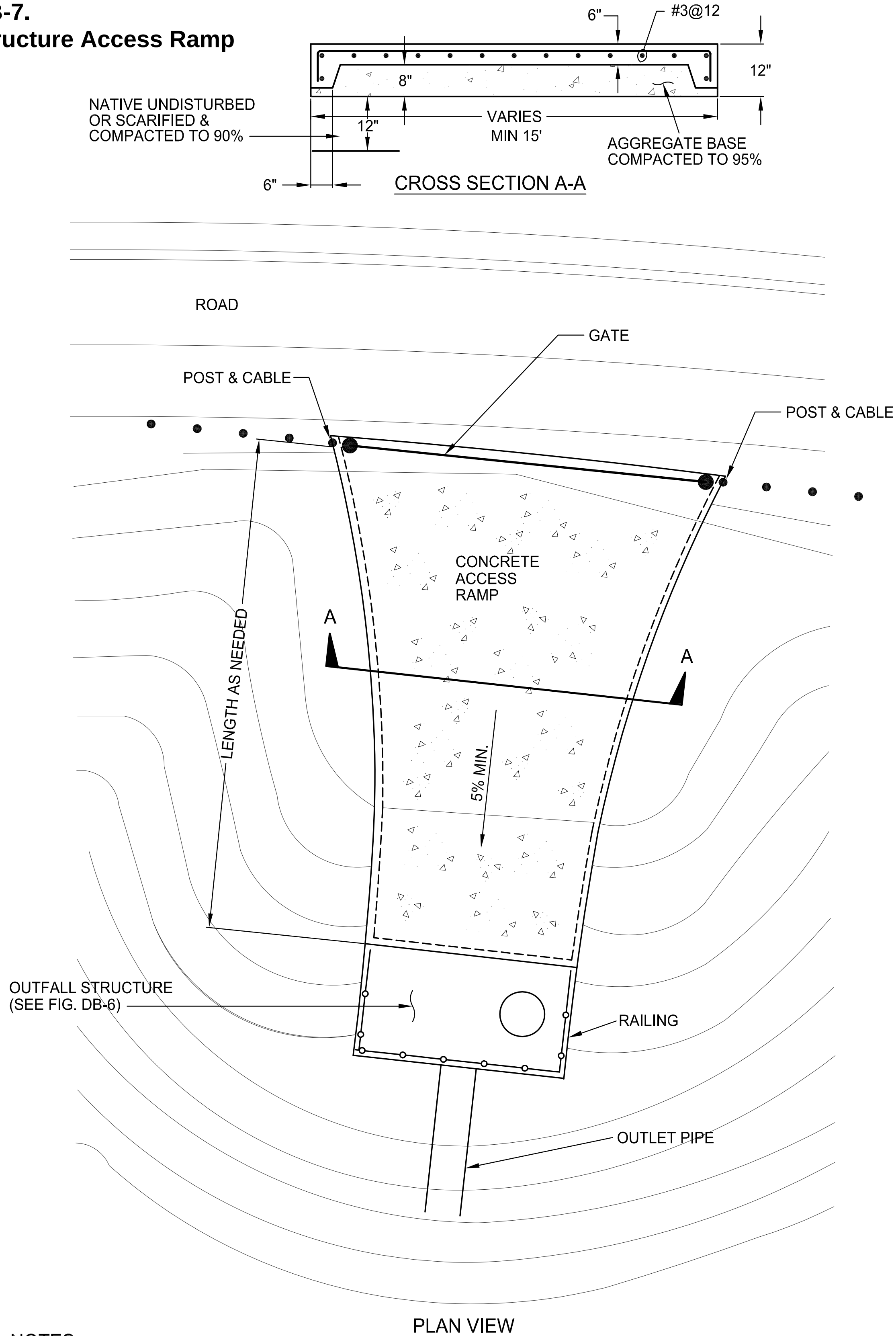


NOTE:

1) OUTFALL STRUCTURE SHOWN MAY BE SUBSTITUTED WITH AN APPROPIATE SIZE CIRCULAR PRECAST MANHOLE.
2) RECTANGULAR STRUCTURE MUST BE DESIGNED AND STAMPED BY REGISTERED CIVIL ENGINEER.
3) OUTLET WEIR AND ORIFICE MUST BE SIZED PER BASIN DISCHARGE RELEASE SCHEDULE.

DATE: MAY 2007

Figure DB-7.
Outfall structure Access Ramp



NOTES:

1.- RETAINING WALLS MAY BE NECESSARY FOR RAMP STABILITY.

DATE: MAY 2007

Table DB-6. Design Data Summary Sheet for Water Quality Detention Basin

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

---

1. Design Water Quality Volume

a. Tributary drainage area	Area = ____________ acre
b. Water Quality Volume	WQV = ____________ acre-ft

2. Basin Depths and Water Surface Areas — **ACTUAL DESIGN**

a. For Wet and Combination Basins:

Permanent pool volume (Vol_{pp})	Vol_{pp} = ____________ acre-ft
Average depth of permanent pool (D_{avg}) (4-8 ft)	D_{avg} = ____________ ft
Water surface area of permanent pool (A_{pp})	A_{pp} = ____________ ft^2
Water surface elevation of permanent pool (WS $Elev_{pp}$)	WS $Elev_{pp}$ = ____________ ft

b. Forebay

Depth range = 2-4 ft	Depth = ____________ ft
Volume range = 5-10 % of WQV	Volume = ____________ acre-ft
Water surface area range	WS Area = ____________ ft^2

4. Depth of WQV and Max WS Elevation

a. Maximum water surface area with WQV (A_{WQV})	A_{WQV} = ____________ ft^2
c. Maximum water surface elevation with WQV (WS $Elev_{WQV}$)	WS $Elev_{WQV}$ = ____________ ft

5. For Wet and Combo Basins: Determine Maximum dry season inflow to maintain permanent pond in the dry season. Use table DB-2 and an evaporation rate of 0.45 in/day for the Sacramento area.

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

$Q_{E\text{-}P}$ = ____________ acre-ft/mo

$Q_{seepage}$ = ____________ acre-ft/mo

Q_{inflow} = ____________ acre-ft/mo

Design Data Summary Sheet for Water Quality Detention Basin

Project: ____

6. Outlet
   a. Outlet Type:

   b. Drawdown Time: Time = ____________ Hours

7. Basin Shape
   a. Length-Width Ratio (2:1 min.) Ratio = ____________ L:W

8. Embankment Side Slope
   a. Interior Side Slope (4:1or flatter) Int. Side Slope = ______ L:W
   b. Exterior Side Slope (3:1or flatter) Ext. Side Slope = ______ L:W

9. Maintenance Access Ramp
   a. Slope (10% maximum) Slope = ____________ %
   b. Width (15 to 20 feet) Width = ____________ ft

10. Vegetation (describe)

Native Grasses ____

Irrigated Turf ____

Emergent Aquatic Plants (specify type / density)* ______________________________

____

Other ____

____

Notes: ____

____

____

Photo credit: Wisconsin DNR

Description

An infiltration basin is a shallow earthen basin constructed in naturally pervious soils (usually Type A or B) and designed for infiltrating stormwater. An infiltration basin functions by retaining runoff and allowing it to percolate into the underlying native soils and into the groundwater table over a specified drawdown period. The bottoms and side slopes of infiltration basins are typically vegetated with dryland grasses or irrigated turf grass.

Siting Considerations

- Tributary drainage area: Up to 50 acres.
- Soil Infiltration Rate: 0.5-2.0 in/hr (permeability test required). Soils with higher infiltration rates require pretreatment device.
- Depth to groundwater: ≥10 ft from basin bottom.
- Existing groundwater contamination.
- Setback requirements: 100 ft from wells; 20 ft downslope and 100 ft upslope from foundations.
- Topography: Not appropriate on fill or steep slopes.

POLLUTANT REMOVAL EFFECTIVENESS

Sediment	High
Nutrients	High
Trash	High
Metals*	High
Bacteria*	High
Oil and Grease	High
Organics*	High

*The following are target pollutants for Sacramento area: copper; lead; mercury; pathogens; diazinon; and chlorpyrifos

Source: CASQA California Stormwater BMP Handbook, January 2003

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the basin is properly designed, constructed, and operated to maintain its infiltration capacity and drawdown time.

Advantages

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

Limitations

- Not appropriate for areas with slowly permeable soils, high groundwater or existing groundwater contamination.
- Not appropriate for industrial sites or locations where spills may occur.
- Must be protected from high sediment loads. Once clogged with sediment, restoration of basin infiltration capacity may be difficult.

General Maintenance Recommendations (Low to Moderate)

- Maintain vegetation as in any landscaped area.
- Periodically remove debris and sediment from basin floor.
- Repair/replace vegetation as necessary to maintain desired cover.
- Check and record drawdown time during and after major storm events to document infiltration rates.
- Remove sediment and/or scarify basin bottom to restore infiltration capacity when maximum drawdown time for WQV is exceeded.

How does an Infiltration Basin work?

> Do not confuse an Infiltration Basin with an *Extended Dry Detention Basin*, which is designed to infiltrate some runoff and release the rest, as described elsewhere in this chapter.

An infiltration basin is designed to retain the stormwater quality design volume (WQV) within a basin and to allow that volume to infiltrate into the native soil profile over the design drawdown period. Infiltrated water typically reaches and recharges the underlying groundwater. Treatment of the runoff occurs through a variety of natural mechanisms as the water flows through the soil profile. To ensure adequate treatment, the depth of unsaturated soil between the infiltration basin bottom and the seasonal maximum groundwater surface level should be at least 10 feet. See Figure IB-1 for a typical infiltration basin configuration.

Other Names: *retention basin, p*ercolation basin

Planning and Siting 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 IB-1. A soil permeability test will be required by permitting agency to confirm acceptable saturated permeability. Number of soil borings will depend on size of facility.
- Not suitable for areas with existing groundwater contamination.
- Integrate infiltration basins into open space buffers, undisturbed natural areas, and other landscape areas when possible. Avoid placing features in open space and wetland preserves where future maintenance of the water quality facility will be restricted or prohibited.
- Not suitable for active parkland/recreation use.
- Irrigation may be required to maintain vegetation on the slopes and bottom of the basin. If irrigation is needed, coordinate its design with that of the general landscape irrigation system for the project.
- Plan for setback requirements (see Table IB-1).

Design Criteria

Design criteria for infiltration basins are listed in Table IB-1. Use the Design Data Summary Sheet provided at the end of this fact sheet (Table IB-3) to record design information for the permitting agency's review.

Table IB-1. Infiltration Basin Design Criteria

Design Parameter	Criteria	Notes
Tributary Drainage Area	≤ 50 acres	
Design volume	WQV	See Appendix E in this Design Manual
Soil infiltration rate	0.5-2.0 in/hr	To be confirmed by permeability test. Higher permeability allowed if pretreatment provided.
Maximum drawdown time	48 hrs.	Based on WQV (see Appendix E)
Minimum groundwater separation	10 ft	Between basin bottom and top of seasonally high groundwater
Freeboard (minimum)	1 ft	

Design Parameter	Criteria	Notes
Setbacks	100 ft 20 ft 100 ft	From wells, tanks, fields, springs Downslope from foundations Up slope from foundations
Inlet/outlet erosion control	–	Use energy dissipater to reduce inlet/outlet velocity
Forebay setting basin volume/drain time	5-10%/45 min.	Based on WQV
Embankment side slope (H:V)	≥ 4:1 ≥ 3:1	Inside Outside (without retaining walls)
Maintenance access ramp slope (H:V)	10:1	Or flatter
Maintenance access ramp width	15 to 20 ft	Check with permitting agency for their minimum width. Pave approach with concrete or porous pavement materials, subject to approval of permitting agency.
Relief underdrain pipe diameter	4 in.	Perforated plastic pipe
Vegetation	–	Side slopes and bottom (may require irrigation)

Design Procedure

Use the **Design Data Summary Sheet** (Table IB-3) to record design information for the permitting agency's review.

Step 1 – Calculate Water Quality Volume (WQV)

Using the Appendix E in this Design Manual, determine the tributary drainage area and stormwater quality design volume (WQV) for 48-hour drawdown.

Step 2 – Calculate design depth of water surcharge in infiltration basin (D_{max})

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

where

t_{max} = Maximum drawdown time = 48 hrs
I = Site infiltration rate (soil permeability) (in/hr)
s = Safety factor

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

Step 3 – Calculate minimum surface area of Infiltration Basin bottom (Amin)

$$A_{min} = WQV/D_{max}$$

where

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

Step 4 – Design forebay settling basin

The forebay provides a zone for removal of course sediment by sedimentation. Design the forebaye volumeto be five (5) to ten (10) percent of the WQV. Separate the forebay from the basin by a berm or similar feature. Provide an outlet pipe connecting the bottom of the forebay and the basin and size it to allow the forebay volume to drain within 45 minutes.

Step 5 – Design embankments

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

Step 6 – Design Maintenance Access

Provide 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 will vary according to local permitting agency requirements, but usually between 15-20 feet. Pave ramps with concrete that is colored to blend with surroundings.

Step 7 – Design Security Fencing

To protect habitat and for safety reasons, provide aesthetic security fencing approved by the permitting agency around the infiltration basin, except when specifically waived by the permitting agency.

Step 8 – Design Bypass

Provide for bypass or overflow of runoff volumes in excess of the WQV. Provide spillway or overflow structures, as applicable (see Figure IB-1).

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. Cutoff collars are recommended along drain pipes running under the embankment at 10 to 20 feet intervals to prevent the water from piping through the fill. The portion of the relief drain that is under the embankement should not be permeable.

Step 10 – Select Vegetation

Plant basin bottoms, berms, and side slopes with native grasses or with irrigated turf. Vegetation provides erosion protection and filters sediment out of the runoff..

Step 11 – Design irrigation system

Provide an irrigation system to maintain viability of vegetation (short-term establishment and long-term needs).

Construction Considerations

- If possible, stabilize the entire tributary area to the infiltration basin before construction begins. If this is not possible, divert flow around the basin to protect it from sediment loads during construction. If sediment does enter the facility during construction, the contractor will be required to remove soil from the basin floor after the entire site has been stabilized, to the satisfaction of the permitting agency inspector.
- Construct basin using equipment with extra wide, low-pressure tires. Prevent construction traffic from entering basin.
- Ensure that final grading produces a level basin bottom without low spots or depressions.
- After final grading, deep till the basin bottom.
- Once construction is complete, stabilize the entire tributary area to the basin and the vegetation within the basin itself, before allowing runoff to enter the infiltration facility.
- Divert runoff (other than necessary irrigation) during the period of basin vegetation establishment.
- Inspect frequently during vegetation establishment, and repair, seed, or re-plant damaged areas immediately.

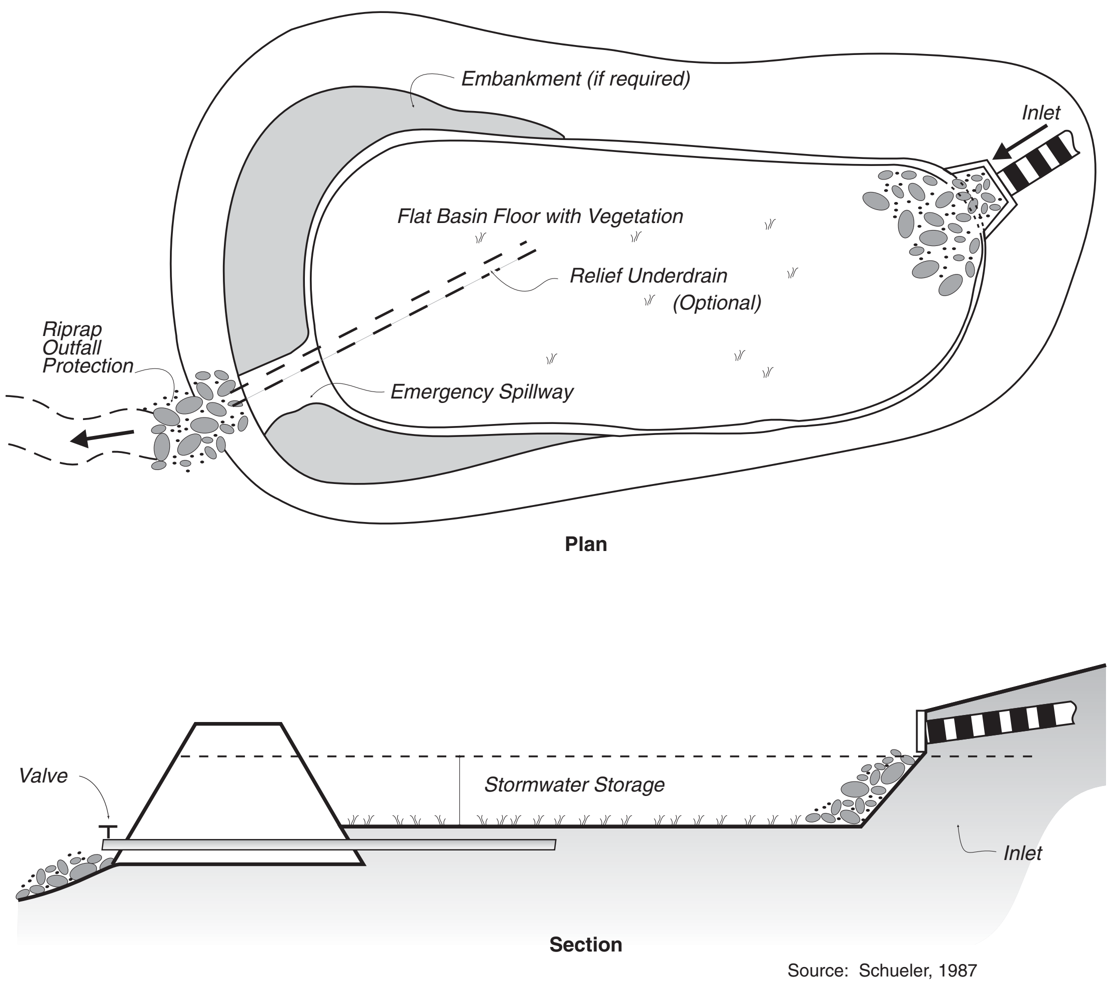


Figure IB-1. Infiltration Basin

Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas require execution of a maintenance agreement or permit with the property owner for projects including an infiltration basin. Check with the local permitting agency about the timing for execution of the agreement. Such agreements will typically include requirements such as those outlined in Table IB-2. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

Table IB-2. Inspection and Maintenance Recommendations for Infiltration Basins

Activity	Schedule
Monitor infiltration rate in basin after storm events by recording the drop in water depth versus time using a calibrated rod or staff gauge.	Several times during first year. Thereafter at the beginning and end of the wet season. Additional monitoring after periods of heavy runoff is recommended.
If drawdown time is observed to have increased significantly over the design drawdown time, clean, re-grade, and till basin bottom to restore infiltrative capacity. This maintenance activity is expensive and the need for it can be minimized by preventing upstream erosion.	As needed
Inspect basin to identify potential problems such as erosion of the basin side slopes and invert, standing water, trash and debris, and sediment accumulation.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If erosion is occurring within the basin, stabilize with erosion control mulch or mat and seed or re-vegetate immediately.	As needed
Monitor health of vegetation and replace as needed.	Routinely monitor vegetation
Trim vegetation to prevent the establishment of woody vegetation and for aesthetic and vector control reasons.	At the beginning and end of the wet season
Remove litter and debris from infiltration basin area.	As needed
Remove accumulated sediment and re-grade when the accumulated sediment volume exceeds ten (10) percent of the basin volume. Note: scarification or other activities creating disturbance should only be performed when there are actual signs of clogging, rather than on a routine basis.	As required for both forebay and basin
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.

Table IB-3. Design Data Summary Sheet for Infiltration Basin

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

---

1. Determine Design Water Quality Volume

   a. Tributary drainage area — Area = ____________ ft^2

   b. Water Quality Volume — WQV = ____________ ft^3

---

2. Determine Maximum Allowable Depth ($D_{max} \leq 10$ ft)

   a. Maximum drawdown time (t = 48 hrs) — t = 48 hr

   b. Site infiltration rate (I) — I = ____________ in/hr

   c. Safety factor (s) — s = ____________

   d. $D_{max} = \frac{t_{max} \times I}{12 \times s}$ — D_{max} = ____________ ft

---

3. Determine Minimum Allowable Basin Bottom Area ($A_{min} = WQV/D_{max}$) — A_{min} = ____________ in/hr

---

4. Forebay Volume (VFB) — VFB = ____________ ft^3

---

5. Bypass/Outlet Control Structure (Check type)

   ☐ Overflow Structure ☐ Spillway

---

6. Vegetation (Check type used or describe "Other")

   ☐ Native grasses ☐ Irrigated turf grass

   ☐ Other ______________________________

   ____

Notes: ______________________________

____

____

____

Photo credit: CASQA, 2003

Description

An infiltration trench is a long, narrow trench constructed in naturally pervious soils (types A or B) and filled with gravel (and sand if desired). Runoff is stored in the trench until it infiltrates into the soil profile over a specified drawdown period. Overflow drains are often provided to allow drainage if the infiltration trench becomes clogged. Infiltration vaults and infiltration leach fields are subsurface variations of the infiltration trench concept; runoff is distributed to the upper zone of a subsurface gravel bed by means of perforated pipes.

Siting Considerations

- Tributary Drainage area: Up to 5 acres. Tributary areas should have a low potential for erosion.
- Soil Infiltration Rate: 0.5-2.0 in/hr (permeability test required). Soils with higher permeability will require pretreatment device.
- Depth to groundwater: ≥10 ft from trench bottom required
- Setback requirements: 100 ft from wells; 20 ft downslope and 100 ft upslope from foundations.
- Maximum contributing area slope: 5%, maximum downstream slope: 20%

POLLUTANT REMOVAL EFFECTIVENESS

Sediment	High
Nutrients	High
Trash	High
Metals*	High
Bacteria*	High
Oil and Grease	High
Organics*	High

*The following are target pollutants for Sacramento area: copper; lead; mercury; pathogens; diazinon; and chlorpyrifos

Source: CASQA California Stormwater BMP Handbook, January 2003

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the trench is properly designed, constructed, and operated to maintain its infiltration capacity and drawdown time.

Advantages

- Reduces or eliminates stormwater discharge to surface waters during most storm events.
- Reduces peak flows during small storm events.
- Can be incorporated into site landscaping.

Limitations

- Not appropriate for areas with slowly permeable soil or high groundwater.
- Must be protected from high sediment loads; difficult to restore functionality when clogged.
- Not appropriate for industrial sites or locations where spills may occur.

General Maintenance Recommendations (Low to Moderate)

- Repair/replace vegetation buffer as necessary to maintain full cover and prevent erosion.
- Periodically remove debris from trench surface.
- Check and record infiltration rate during and after major storm events to document infiltration rates.
- Repair or replace trench material to restore infiltration capacity when infiltration rate falls below design rate.

How does an Infiltration Trench work?

An infiltration trench is designed to retain the stormwater quality design volume (or WQV) in the trench and allow that volume to infiltrate into the native soil profile over the design drawdown period. Infiltrated water typically reaches and can recharge the underlying groundwater. Treatment of the runoff occurs through a variety of natural mechanisms as the water flows through the trench media and the soil profile. To ensure adequate treatment and protect groundwater, the depth of unsaturated soil between the trench bottom and the highest seasonal groundwater surface level should be at least 10 feet. See Figure IT-1 for a typical infiltration trench configuration.

Infiltration vaults (Figure IT-2) and infiltration leach fields (Figure IT-3) are similar to infiltration trenches except they are entirely below ground; runoff is conveyed to the upper zone of the gravel bed media via perforated pipes.

Other Names: Percolation trench

Prevent Clogging!

Infiltration trenches need to be protected from sediment loads to prevent clogging; a grass buffer is required. If sediment deposition significantly reduces soil infiltration rates, the cost of restoring the trench can be high.

Planning and Siting Considerations

- Conduct an on-site permeability test to confirm suitable infiltration rate prior to beginning design. At least one soil boring under in proposed trench location is recommended. Local permitting agency will require results before accepting design.
- Integrate infiltration trenches into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- Plan for setback requirements as listed in Table IT-1.
- Do not locate trenches under tree drip lines.
- Install a pretreatment grass buffer strip to filter out sediment and protect the trench from high sediment loads (see Figure IT-1).

Design Criteria

Design criteria for infiltration trenches are listed in Table IT-1. Use the Design Data Summary Sheet provided at the end of this fact sheet (Table IT-3) to record design information for the permitting agency's review.

Table IT-1. Infiltration Trench Design Criteria

Design Parameter	Criteria	Notes
Tributary Drainage Area	≤ 5 acres	
Design volume	WQV	See Appendix E in this Design Manual.
Maximum drawdown time for WQV	48 hrs	Based on WQV
Soil infiltration rate	0.5-2 in./hr	(soil permeability test required)
Minimum groundwater separation	10 ft	Between trench bottom and top of seasonally high groundwater table
Maximum trench surcharge depth (D_{max})	10 ft	
Setbacks	100 ft 20 ft 100 ft –	From wells, tanks, fields, springs Downslope from foundations Upslope from foundations Do not locate under tree drip-lines
Trench media material size/type	·3 in. diameter	Washed gravel 6-12 in. deep sand (if desired)
Trench lining material	–	Geotextile fabric prevents clogging
Observation well size	4-6 in.	Perforated PVC pipe with removable cap
Pretreatment grass buffer strip length/slope	10 ft/4%	Minimum length/maximum slope in flow direction

Design Procedure

Use the **Design Data Summary Sheet** (Table IT-3) to record design information for the permitting agency's review.

Step 1 – Calculate Water Quality Volume (WQV)

Using the Appendix E in this Design Manual, determine the tributary drainage area and stormwater quality design volume (WQV) for 48-hour drawdown.

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

Maximum depth should not exceed ten (10) feet.

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

where

t_{max}	=	Maximum drawdown time = 48 hrs
I	=	Site infiltration rate (soil permeability) (in/hr)
s	=	Safety factor
P	=	Porosity of Infiltration Trench gravel material (use 0.30)

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

Step 3 – Calculate minimum surface area of infiltration trench bottom (A_{min})

$A_{min} = WQV/D_{max}$

where

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

Step 4 – Design Observation Well

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

Step 5 – Design Bypass

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

Construction Considerations

- If possible, stabilize the entire tributary area to the infiltration trench before construction begins. If this is not possible, divert flow around the trench site to protect it from sediment loads during construction.
- Once construction is complete, stabilize the entire tributary area to the trench before allowing runoff to enter the trench facility.
- Install filter fabric on sides, bottom, and one foot below the surface of the trench (see Figure IT-1). Provide generous overlap at all seams.
- Store excavated material at least 10 feet from the trench to avoid backsliding and cave-ins.
- Place clean, washed 1-3 inch gravel in the excavated trench in lifts and lightly compact it with a plate compactor. Using unwashed gravel can result in clogging.

Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas will require execution of a maintenance agreement or permit with the property owner for projects including an infiltration trench. Check with the local permitting agency about the timing for execution of the agreement. Such agreements will typically include requirements such as those outlined in Table IT-2. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

Table IT-2. Inspection and Maintenance Recommendations for Infiltration Trenches

Activity	Schedule
Monitor the infiltration rate in the trench during and after storms by recording the drop in water depth versus time using a calibrated rod or staff gauge.	Several times during first year then near the beginning and end of each wet season. Additional monitoring after periods of heavy runoff is desirable.
Clean the trench when the infiltration rate decreases significantly over the design rate. To clean it, remove the top layer of gravel and clogged filter fabric, install a new layer of filter fabric, wash the removed gravel, and place the washed gravel back into the trench. This maintenance activity is expensive and can be avoided by preventing upstream erosion and maintaining the pretreatment buffer strip.	As required
Inspect grass buffer strip to identify potential channelization and erosion problems.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
If channels are forming or erosion is occurring within the grass buffer strip, add soil as needed and stabilize with erosion control mulch or mat and re-seed or re-vegetate immediately. See the Vegetated Filter Strip fact sheet elsewhere in this chapter for more information.	As needed
Inspect trench to identify potential problems such as standing water, trash and debris, and sediment accumulation.	At beginning and end of the wet season. Additional inspections after periods of heavy runoff are desirable.
Remove pioneer trees that sprout in the trench vicinity so that roots don't puncture the filter fabric, allowing sediment to enter the trench.	As needed
Trim adjacent trees so the canopy doesn't extend over the trench surface.	As needed
Remove litter and debris from trench area.	As needed
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.

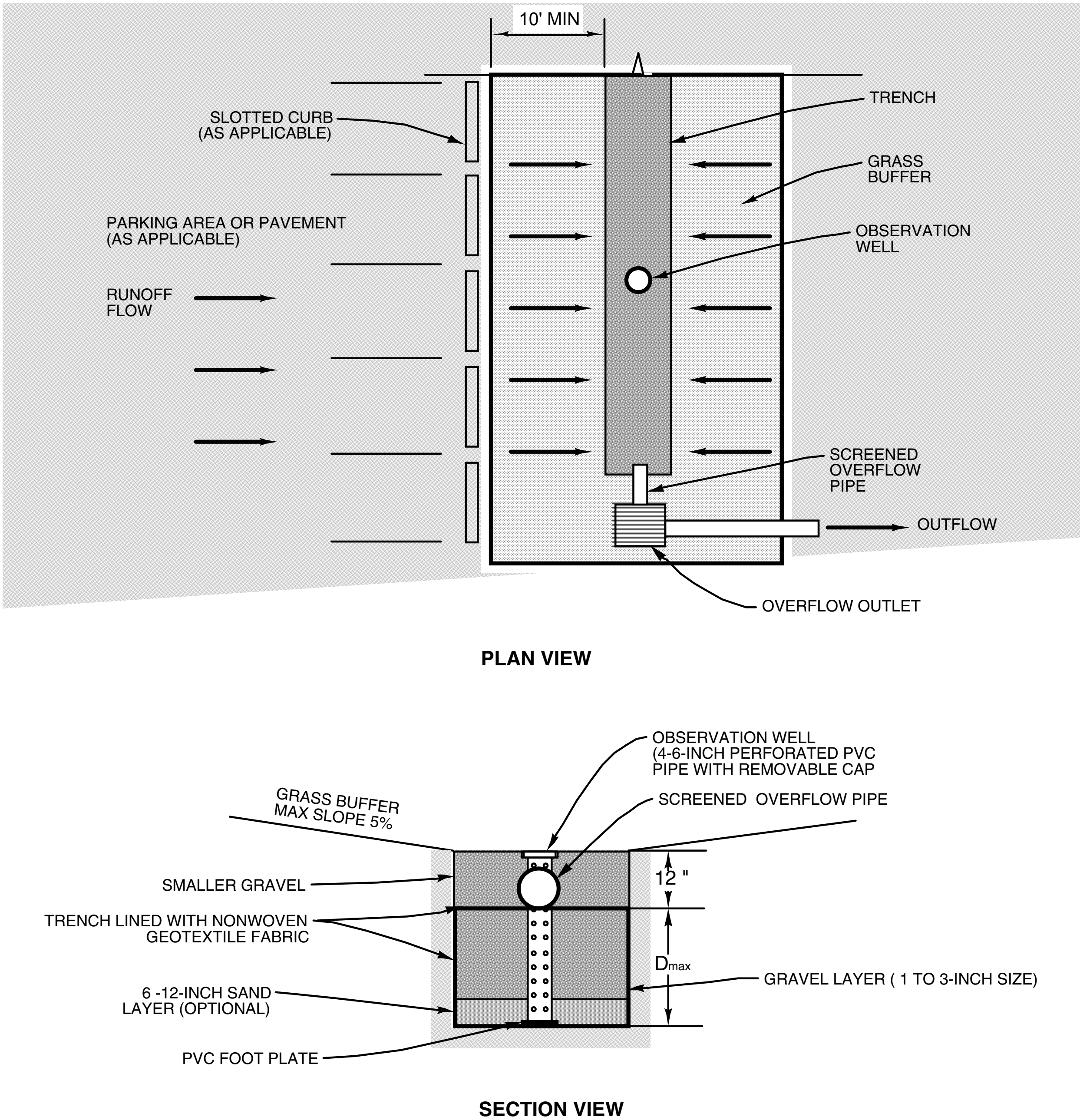


Figure IT-1. Infiltration Trench

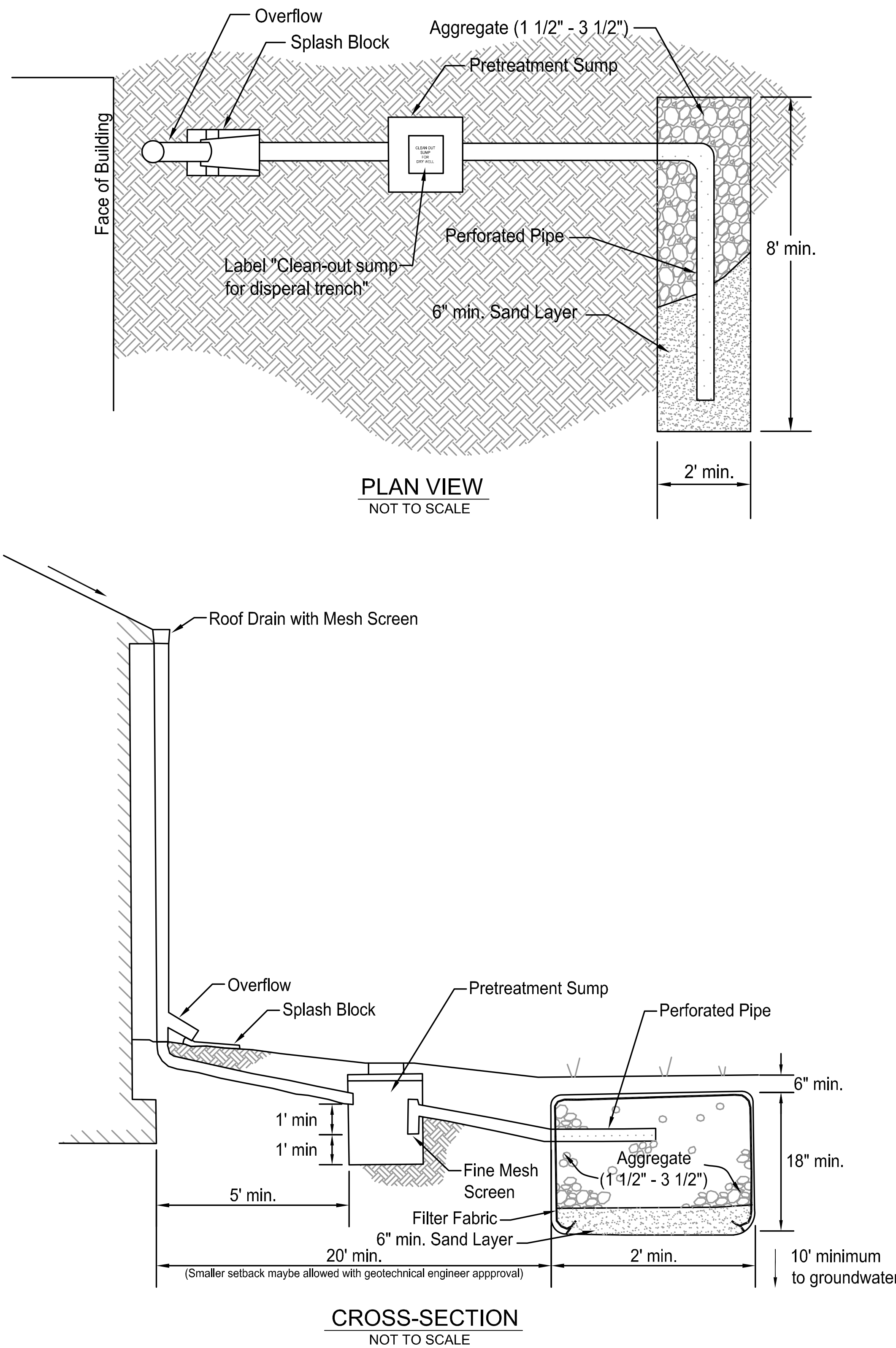


Figure IT-2. Infiltration Vault

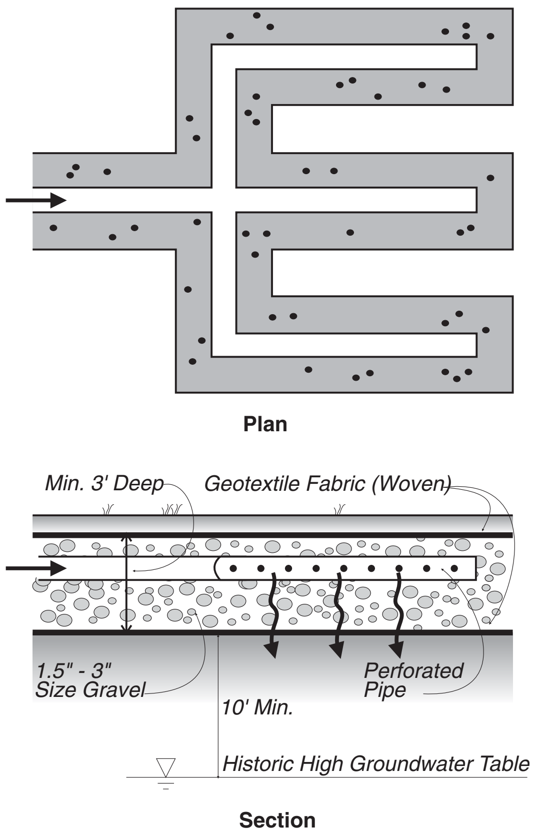


Figure IT-3. Infiltration Leach Field

Table IT-3. Design Data Summary Sheet for Infiltration Trench

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Design Water Quality Volume		
a. Tributary drainage area	Area = ________	ft^2
b. Water Quality Volume	WQV = ________	ft^3
2. Determine Maximum Allowable Depth ($D_{max} \leq 10$ ft)		
a. Maximum drawdown time (t = 48 hrs)	t = 48	hr
b. Site infiltration rate (I)	I = ________	in/hr
c. Safety factor (s)	s = ________	
d. Gravel porosity (P)	P = 0.30	
e. $D_{max} = \dfrac{t_{max} \times I}{12 \times s \times P}$	D_{max} = ________	ft
3. Determine Minimum Trench Bottom Surface Area (A_{min} = WQV/D_{max})	A_{min} = ________	ft^2
4. Final Design Trench Dimensions		
a. Trench length (L)	L = ________	ft
b. Trench width (W)	W = ________	ft
c. Trench depth (D)	D = ________	ft
5. Observation well diameter	Diam. = ________	in.

Notes: ______________________________

Sand filter in parking lot, City of Sacramento Dept. of Utilities

Description

A sand filter is a two-stage constructed treatment system including a pretreatment sedimentation basin and a filtration basin containing sand[1]. The filter bed is supported by a gravel base which includes an underdrain. As stormwater flows into and through the system, large particles settle out in the first basin and finer particles and other pollutants are removed in the second basin. Runoff from large storm events in excess of the water quality design volume (WQV) are bypassed around the system. There are several variations of sand filters; this fact sheet discusses the Austin Sand Filter.

Siting Considerations

- Tributary drainage area: Up to 50 acres.
- Sizing basis: Water quality volume (WQV) with 48-hour drawdown. Storm volumes in excess of the WQV must be bypassed.
- Hydraulic head: about four feet of hydraulic head is required to achieve design flow through the Austin Sand Filter.
- Total filtration basin depth (minimum): 36 inches.

POLLUTANT REMOVAL EFFECTIVENESS

Sediment	High
Nutrients	Low
Trash	High
Metals*	High
Bacteria*	Medium
Oil and Grease	High
Organics*	High

*The following are target pollutants for Sacramento area: copper; lead; mercury; pathogens; dia zinon; and chlorpyrifos

Source: CASQA California Stormwater BMP Handbook, January 2003

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the sand filter is properly designed, constructed, and maintained.

Advantages

- Provides effective water quality enhancement through settling and filtering while requiring relatively small space.
- Can be placed above or below ground.
- Does not require irrigation or base flow.
- Suited for most soil conditions; permeable soils are not needed.
- Reduces peak flows during small storm events.

Limitations

- Upstream treatment controls may be needed to pretreat and remove sediment from runoff before it enters the sand filter. This will prevent or minimize clogging.
- Significant head loss through treatment units may limit use on flat sites.
- More expensive to construct than other types of treatment control measures.

General Maintenance Recommendations (Moderate to High)

- Periodically remove debris and sediment from sedimentation basin and surface of filtration basin.
- Periodically replace sand layer in filtration basin when filtration capacity is diminished.

[1] Other absorptive filtering media, such as peat, may be used, but this fact sheet focuses on sand.

How does a sand filter work?

A typical configuration of an Austin Sand Filter is shown in Figure SF-1. The principal components of the unit include a sedimentation basin and a filtration basin. The sedimentation basin is designed to hold the entire WQV and to release that volume to the filtration basin over the design drawdown time of 40 hours. Large sediment is removed from the runoff through this process. Fine particles and other pollutants are removed in the filtration basin as the runoff passes through the sand filter. Runoff in excess of the WQV is bypassed around the treatment unit.

Variations of Sand Filters

This fact sheet focuses on the Austin Sand Filter. Other variations (also named after the area of the country where they were developed) include the underground (DC) sand filter and the linear or perimeter (Delaware) sand filter. The size of the drainage area and the facility location typically dictate what type of filter is best. For large watersheds (i.e., up to 50 acres), an Austin Sand Filter is recommended. For small catchments up to 1.5 acres requiring underground facilities, a DC Underground Sand Filter is recommended. Delaware Linear Sand Filters are especially suitable for paved sites and industrial sites (catchments up to five acres in size) because they can be situated to accept sheet flow from adjacent pavement. The units also differ in hydraulic head requirements. Approximately four feet of hydraulic head is required to achieve design flow through the Austin and DC Underground Sand Filters, whereas Delaware Linear Sand Filters can operate with as little as two feet of head.

Planning and Siting Considerations

- Sand filters are generally suited for sites where there is no base flow and the influent sediment load is relatively low.
- Sand filters are well suited for drier areas and/or urban areas because they do not require vegetation or irrigation and require less space than most other treatment controls.
- Because the filter media is imported sand or engineered adsorptive material, sand filters are suited for most soil conditions, and the presence of permeable soils is not a requirement.
- The Austin Sand Filter may be constructed inside a concrete shell, or built directly into the terrain over an impermeable liner (e.g., clay), if site conditions allow. Figure SF-1 shows a unit within a concrete shell, with an enclosed sedimentation basin and the filtration basin open at the surface.

Design Criteria

Design criteria for the Austin Sand Filter are listed in Table SF-1. Use the Design Data Summary Sheet provided at the end of this fact sheet (Table SF-3) to record design information for the permitting agency's review.

Table SF-1. Austin Sand Filter Design Criteria

Design Parameter	Criteria	Notes
Sedimentation Basin		
Maximum tributary drainage area	50 acres	The larger the tributary area, the larger the surface area of filter required.
Minimum basin volume	WQV	See Appendix E in this Design Manual
Minimum/Maximum basin water depth (d_{SB})	3ft/10 ft	
Minimum length/width ratio	2:1	
Maximum drawdown time	48 hrs	Based on WQV (See Appendix E)
Freeboard	1 ft	Above maximum water surface elevation
Maximum inlet velocity	3 ft/sec	Provide inlet energy dissipater as required to limit inlet velocity to 3 ft/sec
Filtration Basin		
Minimum gravel depth over sand filter (if applicable)	2 in.	See Figures SF-3 and 4
Minimum storage volume above filter bed	20%	Based on WQV
Minimum storage depth above filter bed (d_s)	3 ft	
Minimum sand depth in filter bed (d_f)	18 in.	Place geotextile fabric between sand and gravel layers
Coefficient of permeability for sand filter (k)	3.5 ft/day	0.146 ft/hour
Sand size, diameter	0.02-0.04 in.	
Slope of sand filter surface	0%	flat
Minimum gravel cover over underdrain	2 in.	Gravel not required under the drain pipe
Underdrain gravel size, diameter	0.5-2 in.	
Minimum inside diameter of underdrain	6 in.	
Underdrain pipe type	PVC	Schedule 40 (or heavier)
Minimum slope of underdrain	1%	
Minimum underdrain perforation, diameter	0.375 in.	3/8 inch
Minimum perforations per row	6	
Minimum space between perforation rows	6 in.	
Maximum drawdown time (t_f)	48 hrs	
Minimum gravel bed depth, (d_g)	16 in.	
Liner (if required)	Clay	

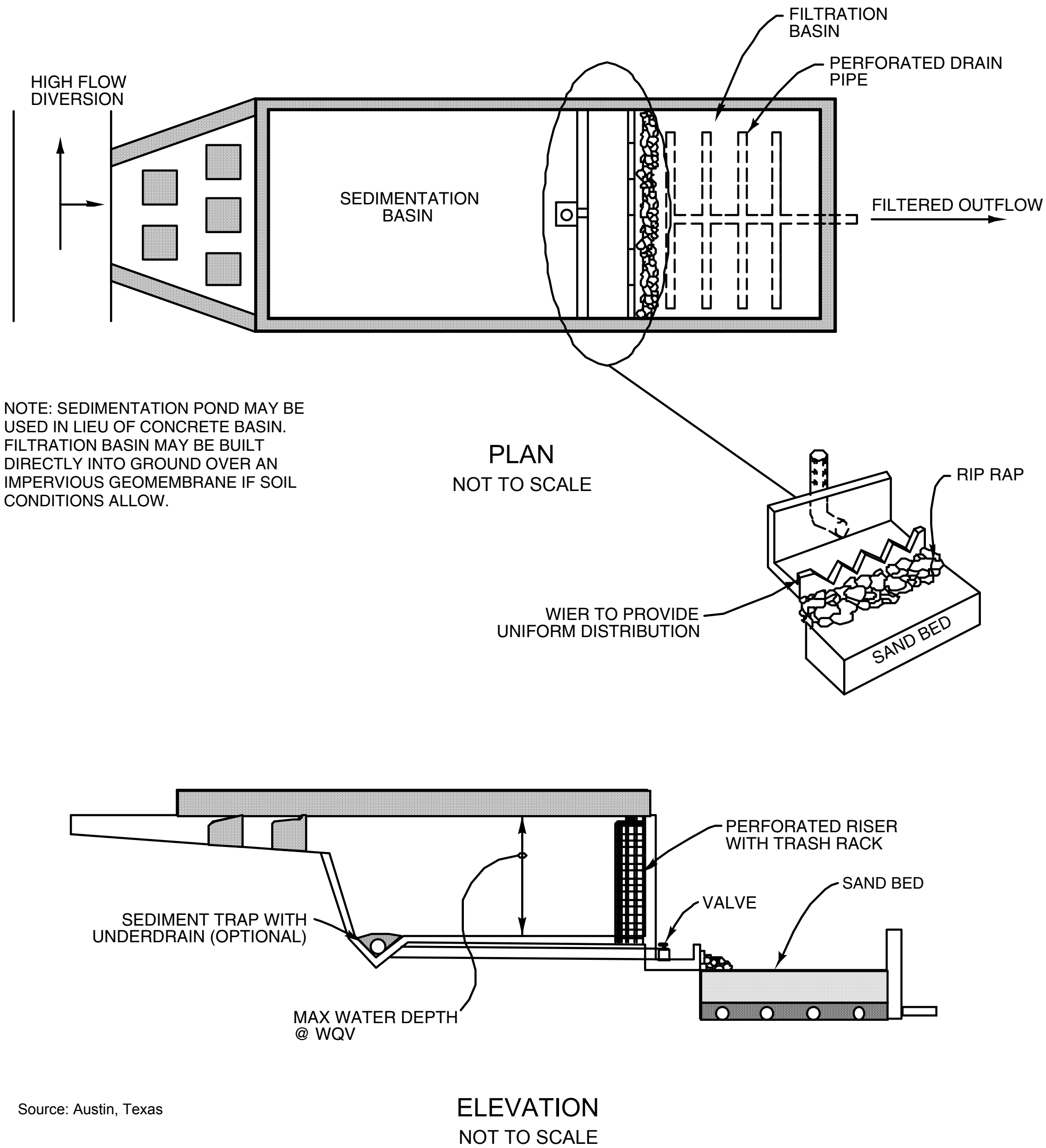


Figure SF-1. Sand Filter Configuration (Austin Sand Filter)

Design Procedure – Sedimentation Basin

The design procedure and application of design criteria for the Austin Sand Filter sedimentation basin are outlined in the following steps. This procedure is for full sedimentation design. Partial sedimentation devices are not recommended due to high maintenance concerns.

> Use the **Design Data Summary Sheet** (Table SF-5) to record design information for the permitting agency's review.

Step 1 – Determine Water Quality Volume (WQV)

Using the Appendix E in this Design Manual, determine the tributary drainage area and stormwater quality design volume (WQV) for 48-hour drawdown.

Step 2 – Determine Sedimentation Basin Volume (Vsb)

The volume of the sedimentation basin must be ≥ WQV

$$V_{sb} = WQV \text{ (minimum)}$$

Step 3 – Determine Sedimentation Basin Water Depth (d_{sb})

The allowable water depth in the sedimentation basin will be governed by the available hydraulic head, which will be based on the difference in elevation between the sedimentation basin inlet and the filltration basin outlet. The design d_{sb} value should be ≥ 3 ft and ≤ 10 ft. Select a design depth in the allowable range that yields the required V_{sb} given any footprint area constraints.

Step 4 – Determine Sedimentation Basin Area (Asb)

$$A_{sb} = V_{sb} / d_{sb}$$

Step 5 – Determine Sedimentation Basin Shape

Determine overall length (L_{sb}) and width (W_{sb}) dimensions to yield the A_{sb} for the basin, given any footprint area constraints.

$$A_{sb} = L_{sb} \times W_{sb}$$

The length-to-width ratio should be at least 2:1. If necessary, provide internal baffling to achieve this ratio and to mitigate short-circuiting and/or dead storage problems

If the basin is not rectangular, shape the basin with a gradual expansion from the inlet and a gradual contraction toward the outlet. Design the basin to maximize the distance from the inlet (near where heavier sediment will be deposited) to the outlet structure. This configuration improves basin performance and reduces maintenance requirements.

Step 6 – Determine Inlet/Outlet Design

Design the inlet structure to convey the water quality volume to the unit and bypass flows in excess of this volume directly to the downstream storm drain system. Provide energy dissipation at the inlet to maintain quiescent conditions needed for effective sedimentation; keep inlet velocities at three (3) feet per second or less.

The outlet structure conveys the water quality volume from the sedimentation basin to the filtration basin and should be a perforated riser pipe equipped with a trash rack to prevent clogging. Trash racks allow easy access for inspecting and cleaning outlet orifices. Size trash racks to prevent clogging of the outlet without restricting the hydraulic capacity of the outlet control orifices.

A trash rack shall be provided for the outlet. Opening in the rack should not exceed 1/3 the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. The bottom rows of perforations of the riser pipe should be protected from clogging. To prevent clogging of the bottom perforations, it is recommended that geotextile fabric be wrapped over the pipe's bottom rows and that a cone of one (1) to three (3) inch diameter gravel be placed around the pipe. If a geotextile fabric wrap is not used, the gravel must be large enough not to enter the riser piper perforations. An alternative design, such as geocomposite drain, may also be approved by the local permitting agency.

Step 7 – Design the Basin to Avoid Short-Circuiting

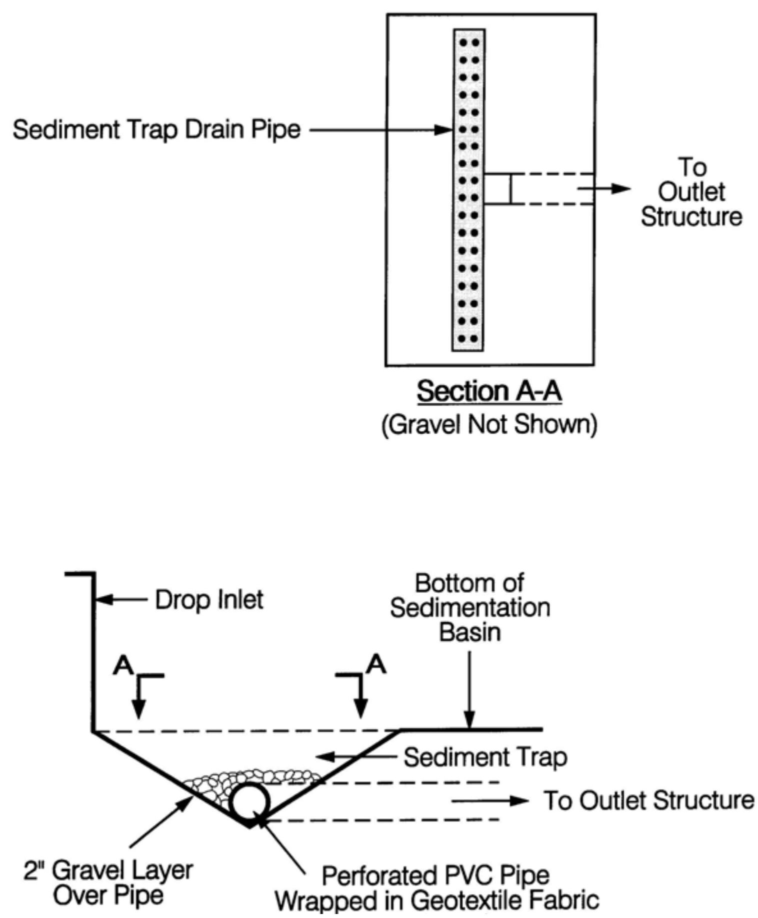
Design the sedimentation basin with baffles as needed to avoid short-circuiting (i.e., flow reaching the outlet before it passes through the sedimentation basin volume).

Step 8 – Design the Sediment Trap (Optional)

A sediment trap is a storage area that captures sediment and removes it from the basin flow regime, thereby inhibiting resuspension of solids during subsequent runoff events and improving long-term removal efficiency. The trap also helps the basin maintain adequate storage volume by reducing sediment that would otherwise accumulate within it; this, in turn, can reduce maintenance needs. If a sediment trap is provided, size the volume to be equal to 10 percent of the sedimentation basin volume and design it to completely drain within 48 hours. Place the invert of the drain pipe above the surface of the sand bed of the filtration basin and make sure the grading of the piping to the filtration basin is at least 1/4 inch per foot (two percent slope). Provide access for cleaning the sediment trap drain system.

Figure SF-2.

Example Sediment Trap Details



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 liner shall provide a maximum permeability of 1×10^{-6} cm/sec (ASTM Method D-2434). If an impermeable liner is not required, then install a geotextile fabric liner that meets the specifications listed in Table SF-3 unless the basin has been excavated to bedrock.

Design Procedure – Filtration Basin

The design procedure and application of design criteria for the Austin Sand Filter Filtration Basin are outlined in the following steps.

Step 1 – Determine Minimum Filtration Basin Storage Volume

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

$$\mathbf{V_{fbs} \geq 0.2 \times WQV}$$

Step 2 – Determine Filter Bed Surface Area

Surface area is the primary design parameter for the filtration basin and is a function of sand permeability, filter bed depth, hydraulic head, and filtration rate. The design filter bed area should be the larger of the minimum area required for storage and the minimum area required for flow.

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

$$\mathbf{A_{fbs} = V_{fbs} / d_{fbs}}$$

where
V_{fbs} = Storage volume above filter bed
A_{fbs} = Filter bed surface area based on storage, ft^2
d_{fbs} = Depth of storage above filter bed, ft (3 ft minimum)

b. Determine minimum filter surface area required for flow (Aff)

$$\mathbf{A_{ff} = \frac{(WQV)(d_f)}{(k)(d_{fbs} + d_f)(t_f)}}$$

where
WQV = Design Water Quality Volume, ft^3
A_{ff} = Filter surface area based on flow, ft^2
d_f = Filter bed depth, ft
k = Coefficient of permeability for sand filter, ft/h (0.146 ft/h)
d_{fbs} = Depth of storage above filter bed, ft
t_f = Time required for runoff volume to pass through filter, hrs (48 hrs)

c. Use the larger of Afbs and Aff as design value for sand filter bed area

Step 3 – Design Inlet Structure

The inlet structure should spread the flow uniformly across the surface of the sand filter. Flow spreaders, weirs, or multiple orifice openings are recommended. See Figure SF-1 for an example inlet structure design.

Step 4 – Design Filter Bed

The sand filter bed may be either of the two configurations given below. Sand bed depths are final, consolidated depths, so consolidation effects must be taken into account.

a. Sand Bed with Gravel Underdrain (Figure SF-3)

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

Drainage matting meeting the specifications in Table SF-2 should be placed under the laterals to provide for adequate vertical and horizontal hydraulic conductivity to the laterals.

In areas with expected high sediment loads (total suspended solids concentration ≥ 200 mg/L), the two-inch layer of gravel on top of the sand filter should be underlain with Enkadrain 9120™ filter fabric or equivalent meeting the specifications in Table SF-2.

b. Sand Bed with Trench Underdrain (Figure SF-4)

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

In areas with expected high sediment loads, see the note above about use of Enkadrain filter fabric or equivalent.

Step 5 – Design Underdrain Piping

The underdrain piping consists of the main collector pipe(s) and perforated lateral branch pipes (see plan view in Figure SF-1). The piping should be reinforced to withstand the weight of the overburden. Internal diameters of lateral branch pipes should be six inches or greater and perforations should be 3/8 inch. Each row of perforations should contain at least six holes and the maximum spacing between rows of perforations should not exceed six inches. All piping is to be Schedule 40 polyvinyl chloride (PVC) or greater strength. The minimum slope of piping shall be 1/8 inch per foot (one (1) percent; slopes down to one-half (0.5) percent may be acceptable to the permitting agency). Access for cleaning all underdrain piping is needed.

Note: Unlike the sedimentation basin, the filtration basin does not require a drawdown time for release. Thus, it is not necessary to have a specifically-designed orifice for the filtration basin outlet structure.

Step 6 – 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 1×10^{-6} cm/sec (ASTM Method D-2434). If an impermeable liner is not required, then install a geotextile fabric liner that meets the specifications listed in Table SF-3 unless the basin has been excavated to bedrock.

Table SF-2. Geotextile Fabric and Drainage Matting Specifications for Sand Filters

Property	Test Method	Specifications
Geotextile Fabric		
Material		Non-woven geotextile fabric
Unit Weight		8 oz./yd (minimum)
Filtration Rate		0.08 in./sec (minimum)
Puncture Strength	ASTM D-751 (Modified)	125 lbs (minimum)
Mullen Burst Strength	ASTM D-751	400 psi (minimum)
Tensile Strength	ASTM-D-1682	300 lbs (minimum)
Equivalent Opening Size	US Standard Sieve	No. 80 (minimum)
Drainage Matting		
Material		Non-woven geotextile fabric
Unit Weight		20 oz./yd (minimum)
Flow Rate (fabric)		180 gpm/ft^2 (minimum)
Permeability	ASTM D-2434	12.4 x 10^{-2} cm/sec
Grab Strength	ASTM D-1682	Dry: Lg 90/Wd 70; Wet: Lg 95/Wd 70
Puncture Strength	COE CW-02215	42 lbs (minimum)
Mullen Burst Strength	ASTM-D-1117	400 psi (minimum)
Equivalent Opening Size	ASTM-D-1682	No. 100 (70-120)
Flow Rate (Drainage Core)	Drexel University	14 gpm/ft width
Filter Fabric		
Material		Non-woven geotextile fabric
Unit Weight		4.3 oz./yd (minimum)
Filtration Rate		120 gpm/ft^2 (minimum)
Puncture Strength	ASTM D-751 (Modified)	60 lbs (minimum)
Thickness		0.8 in. (minimum)

Construction Considerations

- Divert flow around the sand filter to protect it from sediment loads during construction. If sediment does enter the facility during construction, the contractor will be required to remove soil from the unit after the entire site has been stabilized, to the satisfaction of the permitting agency inspector.
- Where underdrains are used, ensure that the minimum slope of the pipe is 0.5 (1/2) percent. Where only gravel filtered water conveyance is provided, slope the filter floor towards the weepholes at a minimum of 0.5 (1/2) percent.
- Ensure that the inverts of the notches, multiple orifices, or weirs dividing the sedimentation chamber from the filtration basin are completely level. Otherwise, water will not arrive at the filtration basin as sheet flow, and only the downgradient end of the filtration basin 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.
- Level the top of the sand filter bed in the filtration basin; no slope is allowed.

- If precast concrete lids are used, provide lifting rings or threaded sockets to allow easy removal with standard lifting equipment, considering the party that will be responsible for maintenance.
- Once construction is complete, stabilize the entire tributary area to the filter before allowing runoff to enter the unit.

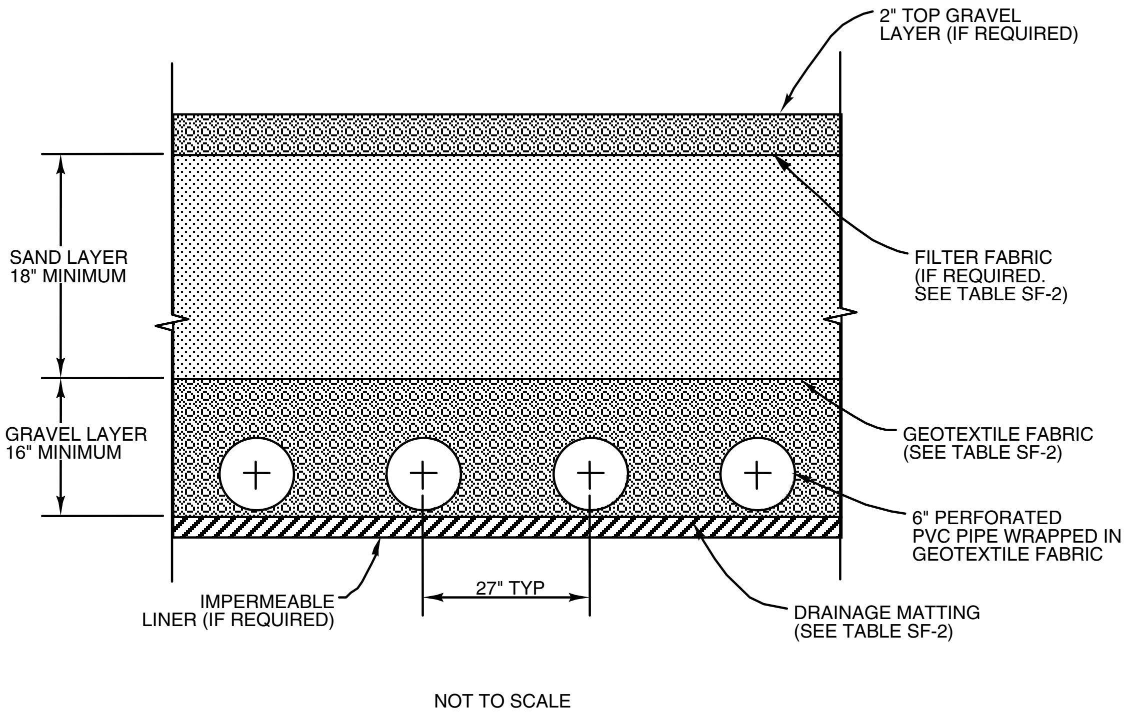


Figure SF-3. Filter Bed with Gravel Underdrain

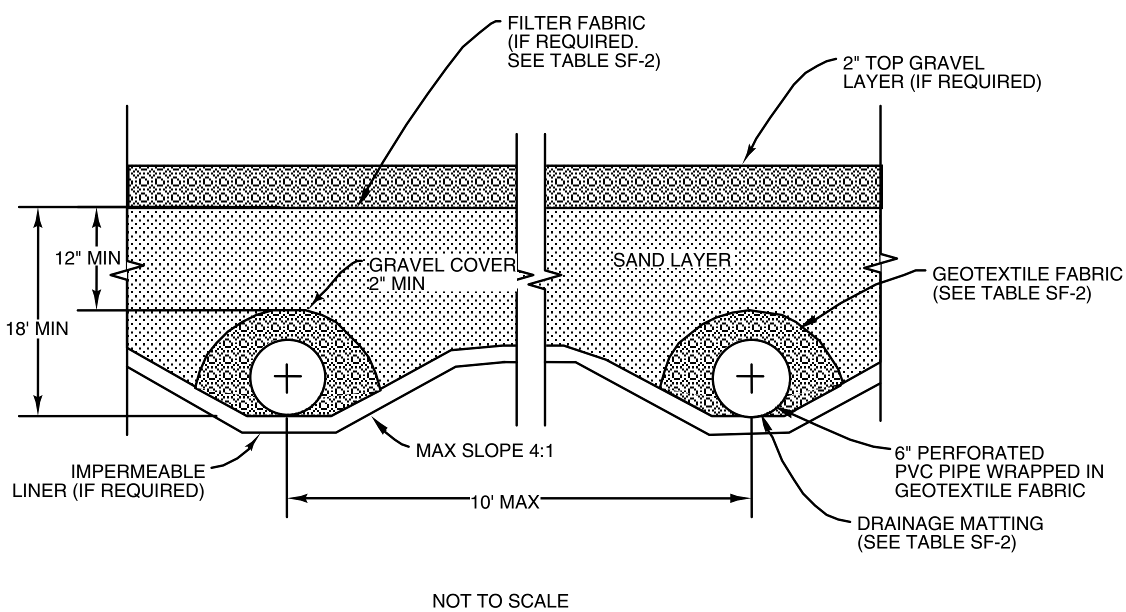


Figure SF-4. Filter Bed with Trench Underdrain

Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas will require execution of a maintenance agreement or permit with the property owner for projects including a sand filter. Check with the local permitting agency about the timing for execution of the agreement. Such agreements will typically include requirements such as those outlined in Table SF-3. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

Table SF-3. Inspection and Maintenance Recommendations for Sand Filters

Activity	Schedule
Remove trash and debris collected in the sedimentation basin inlet area to maintain the inflow capacity of the sand filter and avoid bypassing of the unit.	Before significant storm events during wet season (October 1 – April 30)
Remove cover grates or precast lids on the sedimentation basin and inspect to determine if the system is functioning properly. Inspect for standing water, sediment, grass/vegetative debris, and trash on the trash racks at the outlet pipe or elsewhere in the unit. Schedule removal of observed materials and correct any other observed problems. Sediment removal should be scheduled when the sediment occupies 10 percent of the basin volume.	Inspect quarterly during first year of operation; semiannually after first year of operation Maintain as needed based on observations
Inspect sediment trap (if applicable) and clean when full.	Same as above
Inspect the facility after large rain events to determine whether the facility is draining completely within 48 hours. Look for discoloration of the filter, which may be an indication of clogging.	At least once during the wet season (October 1 – April 30)
If drawdown time exceeds 40 hours, remove top two inches of sand. Restore sand layer depth to 18 inches when overall depth drops to 12 inches.	As required.
Add maintenance recommendations/methods for geotextile fabric, gravel bed, underdrains, as needed.	
Dispose of sand, gravel, or filter fabric contaminated with petroleum hydrocarbons in accordance with all applicable laws.	As required
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.

References

- California Stormwater Quality Association (CASQA). Stormwater Best Management Practice Handbook – New Development and Redevelopment. January 2003.
- Urban Drainage and Flood Control District (UDFCD), Denver, Colorado. Urban Drainage Criteria Manual, Volume 3 – Best Management Practices. 1999.

Table SF-4. Design Data Summary Sheet for Sand Filter

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Design Water Quality Volume
   a. Tributary drainage area — Area = ____________ ft^2
   b. Water Quality Volume (based on 48 h drawdown) — WQV = ____________ ft^3

2. Sedimentation Basin Volume ($V_{sb} \geq$ WQV) — V_{sb} = ____________ ft^3

3. Sedimentation Basin Depth (3 ft $\leq d_{sb} \leq$ 10 ft) — d_{sb} = ____________ ft

4. Sedimentation Basin Area ($A_{sb} = V_{sb} / d_{sb}$) — A_{sb} = ____________ ft^2

5. Sedimentation Basin Shape
   a. Sedimentation Basin Length (L_{sb}) — L_{sb} = ____________ ft
   b. Sedimentation Basin Width (W_{sb}) — W_{sb} = ____________ ft
   c. Sedimentation Basin L:W Ratio (2:1 minimum) — L:W = ____________

6. Filtration Basin Storage Volume ($V_{fbs} \geq 0.2$ x WQV) — V_{fbs} = ____________ ft^3

7. Filter Bed Surface Area
   a. Minimum filter surface area for storage (A_{fbs})
      $A_{fbs} = V_{fbs} / d_{fbs}$ — A_{fbs} = ____________ ft^2
      where d_{fbs} = Depth of storage above filter bed (3 ft min.)
   b. Minimum filter surface area for flow (A_{ff}) — d_{fbs} = ____________ ft
      Sand Bed Depth ($d_f \geq 1.5$ ft) — d_f = ____________ ft
      Coefficient of permeability for sand (k = 0.146 ft/h) — k = ____________ ft/hr
      Time required pass through filter (t_f = 40 h) — t_f = ____________ hr

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

   A_{ff} = ____________ ft^2

   c. Final design filter bed surface area (A_{fb}) — A_{fb} = ____________ ft^2

8. Filter Bed Design (Check Type Used)
   ☐ Sand Bed with Gravel Underdrain ☐ Sand Bed with Trench Underdrain

Photo Credit: City of Portland

Description

A stormwater planter is a low-lying vegetated planter that receives runoff from roof drains or adjoining paved areas. A shallow surcharge zone above the vegetated surface temporarily stores stormwater (the water quality volume, WQV). The accumulated runoff gradually infiltrates into an underlying sand/peat bed and then into a gravel layer. If the planter is a flow-through stormwater planter, it has an impermeable bottom liner and an underdrain pipe to collect the treated water and discharge it to the municipal storm drain. Planters without an impermeable bottom liner (infiltration planters) will also require an underdrain when the underlying soils are less permeable than the planter's sand/peat layer.

POLLUTANT REMOVAL EFFECTIVENESS

Sediment	High
Nutrients	Low
Trash	Medium
Metals*	High
Bacteria*	Medium
Oil and Grease	High
Organics*	High

*The following are target pollutants for Sacramento area: copper; lead; mercury; pathogens; diazinon; and chlorpyrifos.

Source: CASQA California Stormwater BMP Handbook, January 2003

Siting Considerations

- Tributary Drainage area: Typically ≤ 1 acre.
- Depth to Groundwater: > 10 ft from planter soil surface (only applies to infiltration planter without underdrain).
- Slope: Relatively flat.
- Soils: For soil types C and D, use a flow-through planter with a bottom liner and underdrain. For soil types A and B, an infiltration-type planter may be used, but an underdrain may be required if the underlying soils have lower permeability than the planter's sand/peat layer.
- Setback: Flow-through planter is required if within 10 ft. of building foundation unless otherwise specified by local permitting agency.

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the planter is properly designed, constructed, and maintained.

Advantages

- Relatively inexpensive when integrated into site landscaping.
- Suitable for parking lots and sites with limited space.
- Reduces peak flows during small storm events.
- Attractive and relatively easy to maintain.

Limitations

- Not appropriate for industrial sites or locations where spills may occur, unless infiltration is prevented.
- Not suitable for steeply sloping areas.

General Maintenance Recommendations (Low to Moderate)

- Periodically remove debris and sediment from planter.
- Repair/replace vegetation as necessary to maintain full cover.
- See table SP-2 for additional vegetation maintenance recommendation.

How does a Stormwater Planter work?

A stormwater planter is designed to receive runoff from downspouts, piped inlets or sheet flow from adjoining paved areas. A shallow surcharge zone above the vegetated surface temporarily stores runoff (the water quality volume or WQV). The runoff gradually infiltrates through the root zone of the vegetation and into the underlying sand/peat bed where it fills the pore spaces. A variety of natural mechanisms remove pollutants from the runoff as it infiltrates through the root zone and is detained in the sand/peat bed before reaching a base layer of gravel.

If infiltration to the underlying soil is not possible or desired, a flow-through stormwater planter with an impermeable bottom liner and underdrain should be used. The underdrain gradually dewaters the sand/peat bed over the drawdown period and discharges the runoff to the downstream storm drain system. If an infiltration planter is used, there is no impermeable bottom liner, and runoff percolates into the ground. An underdrain may still be needed if the permeability of the underlying soils is lower than the sand/peat layer, but at least a portion of the treated runoff will infiltrate into the underlying soil. See Figures SP-1 and SP-2 for typical stormwater planter configurations.

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

Planning and Siting Considerations

- For infiltration type planters, consult a geotechnical engineer about site suitability.
- Select location where site topography is relatively flat and allows runoff drainage to the stormwater planter.
- Integrate stormwater planters into other landscape areas when possible.
- Stormwater planters may be located within landscape areas as “rain gardens” and may have a non-rectangular footprint to fit the site landscape design.
- In expansive (C, D) soils, locate stormwater planters far enough from structures to avoid damage to foundations (as determined by a structural or geotechnical engineer). 10 feet is given as a rule-of-thumb on the first page of this fact sheet. Alternatively, use a flow-through stormwater planter.

Early Design Is Critical!

Stormwater planters must be located on the site plan at the earliest possible design phase when laying out the building and parking footprints and before the site grading plan is prepared.

Parking lot rain garden, Kansas City, MO

Residential rain garden, Minnesota

Design Criteria

Design criteria for stormwater planters are listed in Table SP-1. A Design Data Summary Sheet (Table SP-3) is provided at the end of this fact sheet.

Table SP-1. Stormwater Planter Design Criteria

Design Parameter	Criteria	Notes
Tributary drainage area	≤ 1 acre	Ideally suited for small areas such as parking lot islands, perimeter building planters, street medians, roadside swale features, and site entrance or buffer features. Can be implemented on a larger scale, provided the WQV and average depth requirements are met.
Design volume	WQV	See Appendix E in this Design Manual
Design drawdown time	12 hrs	Period of time over which WQV drains from planter.
Design average surcharge depth (d_s)	6-12 in.	
Containment curb (if applicable)	height >6 in.	Design to deter skateboarding and satisfy ADA requirements
Inlet curb cuts (if applicable)	≥ 12 in. wide	To prevent clogging and promote flow spreading. Pavement should be slightly higher than swale. Include energy dissipaters.
Topsoil layer	6 in. (minimum)	Sandy loam topsoil. Deeper layer recommended for better vegetation establishment
Sand-peat layer	18 in. (minimum)	Design mix to achieve approx. 3-4 inches/hr infiltration rate and provide 12 hour drawdown; check with permitting agency for verification.
Gravel layer	9 in.	ASSHTO #8 Coarse Aggregate
Filter fabric		Between sand/peat and gravel layers
Minimum width	30 in.	
Underdrain (as required)	3-4-inch perforated pipe	For all flow-through planters, planters within 10 ft. of a building foundation, and infiltration planters where underlying soils have lower permeability than the planter's sand/peat media layer
Overflow device	Varies	Connect to storm drain system. See Figures SP-1 and SP-2 for recommended designs. Alternative designs may be allowed; check with permitting agency.
Waterproofing membrane		Required for planters adjacent to building foundations.

Design Procedure

Step 1 – Calculate Water Quality Volume (WQV)

Using the calculations given in Appendix E, determine the contributing area and stormwater quality design volume, WQV, based on a 12-hour drawdown period.

Step 2 – Design average surcharge depth (d_s)

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 planter.

Step 3 – Calculate planter surface area (A_S)

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

$$A_S = WQV/d_s \text{ (see Figures SP-1 and SP-2)}$$

Step 4 – Design base courses

Bottom Gravel layer – Provide a 9-inch gravel layer (ASSHTO #8 Coarse Aggregate)

Sand/Peat layer – Provide an 18-inch (minimum) sand and peat layer over the gravel layer as shown in Figures SP-1 and SP-2. Place filter fabric between sand/peat mixture and gravel layer.

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.

Step 5 – Select subbase liner

If expansive soils or rocks are a concern, chemical or petroleum products are handled or stored within the tributary catchment, or infiltration is not desired for any reason, use a flow-through stormwater planter with an impermeable liner (see Figure SP-2). Otherwise, use an infiltration stormwater planter and install a non-woven geotextile membrane below the gravel layer to allow infiltration.

Step 6 – Provide underdrain if needed

Provide a perforated underdrain pipe if the planter has an impermeable bottom liner or if the underlying soils are less permeable than the sand/peat layer. Size the underdrain to ensure a 12-hour drawdown and connect it to the downstream storm drain system.

Step 7 – Select vegetation

Select vegetation that:

- Is suited to well-drained soil but will withstand being inundated for periods of time;
- 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 which promote less use of chemical pesticides; and
- Is consistent with local water conservation requirements.

Avoid the use of bark or similar buoyant material that will tend to float when the vegetated area is inundated. Check with the local agency's Ordinance if the planter will be used to satisfy landscaping requirements.

Step 8 – 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 opening are appropriate overflow devices (see Figures SP-1 and SP-2).

Construction Considerations

- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded, seeded, and/or planted areas with suitable erosion control materials.
- For planters flush with the surrounding landscape, install sediment controls (e.g., staked straw wattles) around the planter to prevent high sediment loads from entering the planter during construction activities.
- Repair, seed, or re-plant damaged areas immediately.

Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas will require execution of a maintenance agreement or permit with the property owner for projects including a stormwater planter. Check with the local permitting agency about the timing for execution of the agreement. Such agreements will typically include requirements such as those outlined in Table SP-2. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

Table SP-2. Inspection and Maintenance Recommendations for Stormwater Planter

Activity	Schedule
Trim vegetation (as applicable) and remove weeds to limit unwanted vegetation.	As needed
Remove litter and debris from landscape area.	As needed
Use integrated pest management (IPM) techniques to reduce use of chemical pesticides and herbicides.	Monitor for pests regularly and take other action as needed
Inspect the planter to determine if runoff is infiltrating properly.	At least twice per year during storm events. Additional inspections after periods of heavy runoff are desirable.
If infiltration is significantly reduced, remove and replace topsoil and sand/peat layer.	May be required every 5 to 10 years or more frequently, depending on sediment loads
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.

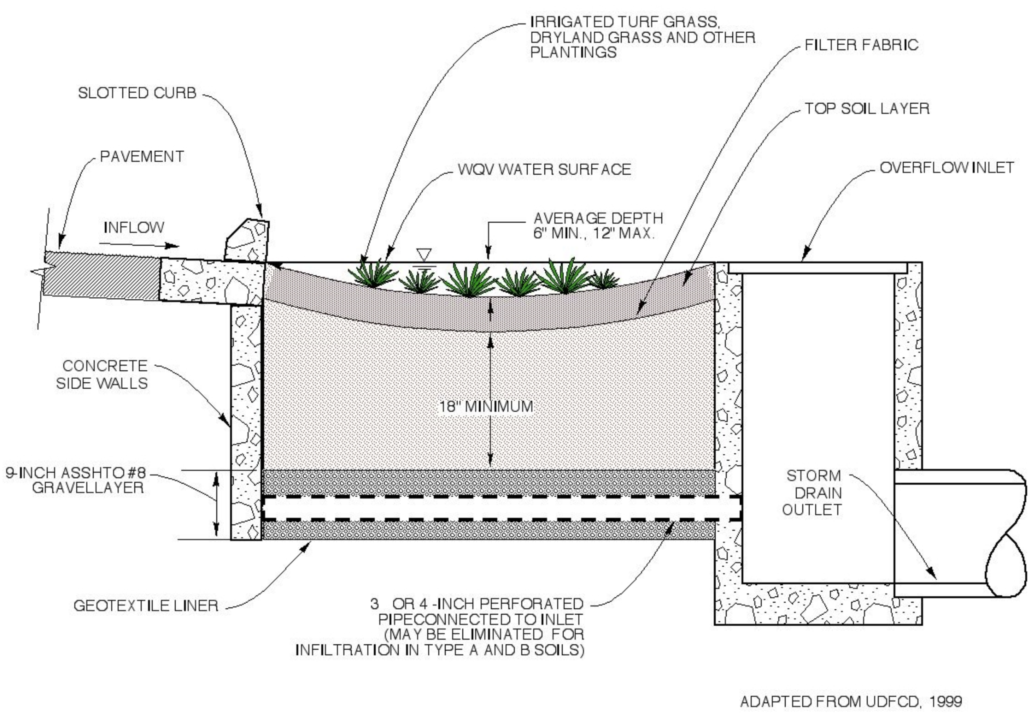


Figure SP-1. Infiltration Stormwater Planter Configuration

(other media mix and overflow design options may be allowed; check with permitting agency for verification)

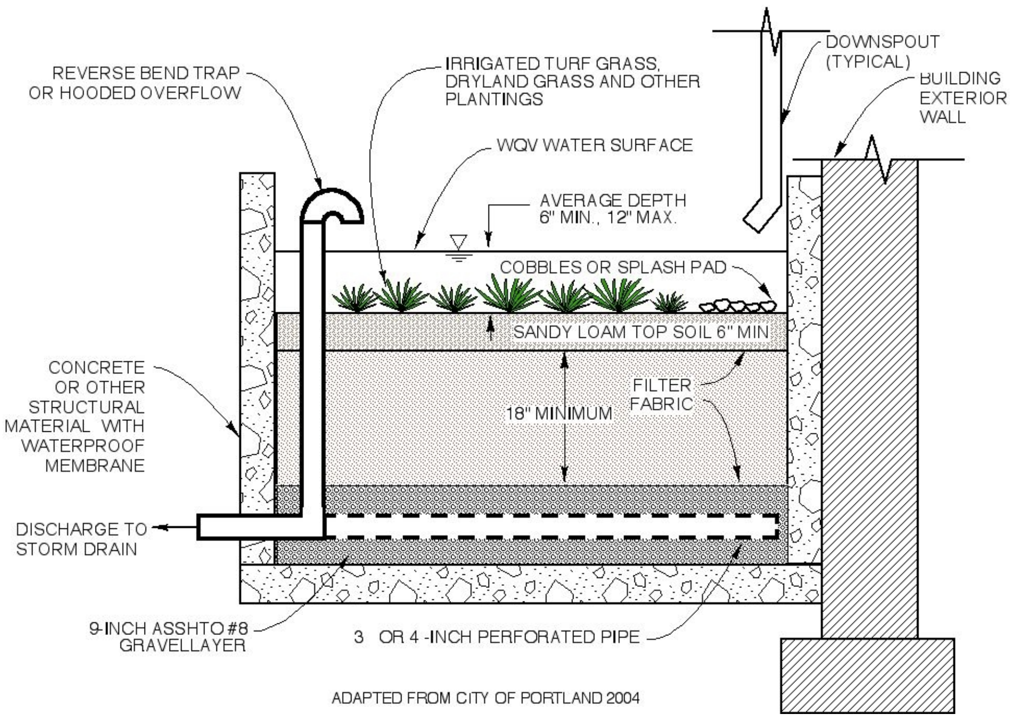


Figure SP-2. Flow-through Stormwater Planter Configuration

(other media mix and overflow design options may be allowed; check with permitting agency for verification)

Table SP-3. Design Data Summary Sheet for Stormwater Planter

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

1. Determine Design Water Quality Volume
   a. Tributary drainage area — Area = ____________ ft^2
   b. Water Quality Volume — WQV = ____________ ft^3

2. Design average surcharge depth (d_s)
   d_s = 6–12 inches (0.5–1 foot) — d_s = ____________ ft

3. Design Planter Surface Area (A_s)
   $A_s = WQV/d_s$ — A_s = ____________ ft^2

4. Base Course Layers
   a. Topsoil (6 in. minimum) ____________ in.
   b. Sand/Peat Layer (18 in. minimum) ____________ in.
   c. Gravel Layer (9 in. minimum) ____________ in.

5. Planter Type (check type used)
   ☐ Infiltration without underdrain ☐ Infiltration with underdrain
   ☐ Flow-through with impermeable liner

6. Vegetation (describe) ______________________________

____

____

7. Overflow Device (check type used or describe "Other")
   ☐ Drop inlet ☐ Standpipe
   ☐ Other ______________________________

____

Notes: ______________________________

____

____

Description

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

Siting Considerations

- Drainage area: 10 acres maximum per swale.
- Longitudinal Bottom Slope: 0.5%-2.5%
- Underdrains required for slopes less than 1%. For slopes up to 5%, check dams can be used to reduce slopes to 2.5%.
- Minimum Bottom width: 2 ft.
- Side slopes: 3:1 or flatter.
- Liners may be required in areas where swales may be impacted by hazardous materials or where spills may occur (e.g., retail gasoline outlets, auto maintenance businesses, processing/manufacturing areas).
- Surface flow into swale preferred instead of underground conveyance.

POLLUTANT REMOVAL EFFECTIVENESS

Sediment	Medium
Nutrients	Low
Trash	Low
Metals*	Medium
Bacteria*	Low
Oil and Grease	Medium
Organics*	Medium

*The following are target pollutants for Sacramento area: copper; lead; mercury; pathogens; diazinon; and chlorpyrifos

Source: CASQA California Stormwater BMP Handbook, January 2003

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly.
  reduced or eliminated if the swale is properly designed, constructed, and maintained.

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping.
- Provides both stormwater treatment and conveyance.
- Reduces peak flows during small storm events.
- Attractive and easy to maintain.

Limitations

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

General Maintenance Recommendations (Low to Moderate)

- Periodically remove debris and sediment from inlets and swale.
- Repair/replace vegetation as necessary to maintain full cover and prevent erosion.
- See table VS-2 for additional vegetation maintenance recommendation.

How does a Vegetated Swale work?

A vegetated swale differs from a conventional drainage channel or roadside ditch due to the incorporation of specific features that enhance stormwater pollutant removal. A vegetated swale is designed to control flow velocities through the vegetation in the swale and to provide sufficient contact time to promote settling and filtering of the runoff flowing through it. Greater surface area and contact time promote greater runoff treatment efficiencies. The volume of runoff can also be reduced through infiltration into underlying soils.

Runoff is treated as it flows through, not over, the vegetation in a vegetated swale. Vegetation can cause considerable turbulence, resulting in energy loss and retardance of flow. To provide adequate treatment, the vegetation must be dense and strong.

Other Names: Grassy swale, bioswale

Alternative vegetation is encouraged but is subject to approval of local permitting agency. Parking lot swale at Elk Grove Marketplace, Elk Grove, CA. Photo: CKB Environmental

Planning and Siting Considerations

- Select location where site topography allows for the design of a channel with sufficiently mild slope (unless small drop structures are used) and enough surface area to maintain non-erosive velocities in the channel.
- Integrate swales into open space buffers, undisturbed natural areas, and other landscape areas when possible. Do not place in open space or wetland preserve areas where future maintenance could be prohibited.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the swale and cars are allowed to overhang the swale (see Farm Bureau photo).

Vegetated Swale Planted with Native Clump Grasses (note that trees as shown are now discouraged; locate outside of flowline), U.S. Farm Bureau, Sacramento. Photo: City of Sacramento

Roadside Swale. Photo: City of Spokane

- In parking lots, plan areas for pedestrians to cross swales without damaging vegetation.
- The required swale length to meet treatment criteria for a 1-acre project site is typically in the range of 75 to 100 feet. The length will vary depending on several variables, including the geometry of the swale and the runoff coefficient for the site.

Early Design Is Critical!

Vegetated swales must be located on the site plan at the earliest possible design phase when laying out the building and parking footprints and before the site grading plan is prepared.

Design Criteria

Design criteria for vegetated swales are listed in Table VS-1. Use the Design Data Summary Sheet provided at the end of this fact sheet (Table VS-3) to record design information for the permitting agency's review.

Table VS-1. Vegetated Swale Design Criteria

Design Parameter	Criteria	Notes
Tributary drainage area	≤ 10 acres	For larger areas, break up into sub-sheds of 10 acres or less, with a swale for each
Water Quality design flow	WQF	See Appendix E in this Design Manual.
Roughness coefficient (n) for treatment design	0.2	Reflects the roughness associated with shallow flow through dense vegetation.
Roughness coefficient (n) for conveyance design	0.1	Reflects the roughness of swale when depth of flow is above the height of the grass. To be used to determine capacity of swale to convey peak hydraulic flows
Minimum contact time for treatment of the WQF	7 minutes	Provide sufficient length to yield minimum contact time for the WQF
Minimum bottom width	2 ft	
Maximum bottom width	10 ft	Swales wider than 10 feet must meet additional flow spreading requirements.
Maximum side slopes	3:1	Side slopes must allow for ease of mowing. Steeper slopes may be allowed with adequate slope stabilization.
Longitudinal slope	0.5-2.5%	
Check dams	As required	For longitudinal slope > 2.5% but less than 5%, and as a means of promoting more infiltration. Spacing as required to maintain maximum longitudinal bottom slope ≤ 2.5%.
Underdrains	As required	For longitudinal slope < 1.0%
Maximum depth of flow (treatment)	3-5 in.	1 inch below top of vegetation
Maximum flow velocity (treatment)	1 ft/sec	Based on Manning's n = 0.20. Concentrated inlet flow must be spread
Inlet Design/Curb cuts	≥ 12 in. wide	To prevent clogging and promote flow spreading, pavement should be slightly higher than swale. Include energy dissipaters/flow spreaders such as cobble, porous concrete, or gravel at inlet.

Design Procedure

Step 1 – Determine the vegetated swale's function

The vegetated swale can be designed to function as both a treatment control measure for the stormwater quality design flow and as a conveyance system to pass the peak hydraulic design flows, if the swale is located "on-line".

Step 2 – Calculate Water Quality Flow (WQF)

Using Appendix E in this Design Manual, determine the contributing area and stormwater quality design flow, WQF.

Step 3 – Provide for peak hydraulic design flows

Using local hydrologic design criteria, calculate flows greater than WQF to be diverted around or flow through the swale. Design the diversion structure, if needed.

Step 4 – Design the vegetated swale using Manning's Equation

Swales can be trapezoidal or parabolic in shape, as illustrated in Figure VS-1. While trapezoidal channels are the most efficient for conveying flows, parabolic configurations provide good water quality treatment and may be easier to mow since they don't have sharp breaks in slope.

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

Manning's Equation

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

where

Q = WQF, (cfs)
A = Cross sectional area of flow, (ft^2)
P = Wetted perimeter of flow, (ft)
s = Bottom slope in flow direction, (ft/ft)
n = Manning's n (roughness coefficient)

Record all of your calculations on the ***Vegetated Swale Design Data Summary Sheet*** (Table VS-3) at the end of this section. The data sheet will be checked by the agency plan review staff.

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

Step 5 – Design Inlet Controls

- For flow introduced along the length of the swale through curb cuts, provide minimum curb cut widths of 12 inches and avoid short-circuiting the swale by providing the minimum contact time of 7 minutes.
- For swales that receive direct concentrated runoff at the upstream end, provide an energy dissipater, as appropriate, and a flow spreader such as a pea gravel diaphragm flow spreader at the upstream end of the swale.

Step 6 – Select Vegetation

A full, dense cover of sod-forming vegetation is typically recommended for vegetated swales, since most pollutant removal performance studies are based on use of grass. Alternative vegetation such as shrubs and groundcovers may also be allowed; check with the local permitting agency.

Select vegetation that:

- Will be dense and strong enough to stay upright, even in flowing water and steep slopes;
- Has minimum need for fertilizers;
- Is not prone to pests and will not require a lot of pesticide/herbicide application, consistent with any integrated pest management (IPM) practices or policies of the local permitting agency;
- Will withstand being inundated for periods of time; and
- Needs little supplemental water, consistent with local water conservation ordinances. Bunch-type grasses or grass mixes are preferred.

Check with the permitting agency for approved plant and tree lists. Do not use bark or similar buoyant material in the swale or around drain inlets or outlets.

Construction Considerations

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

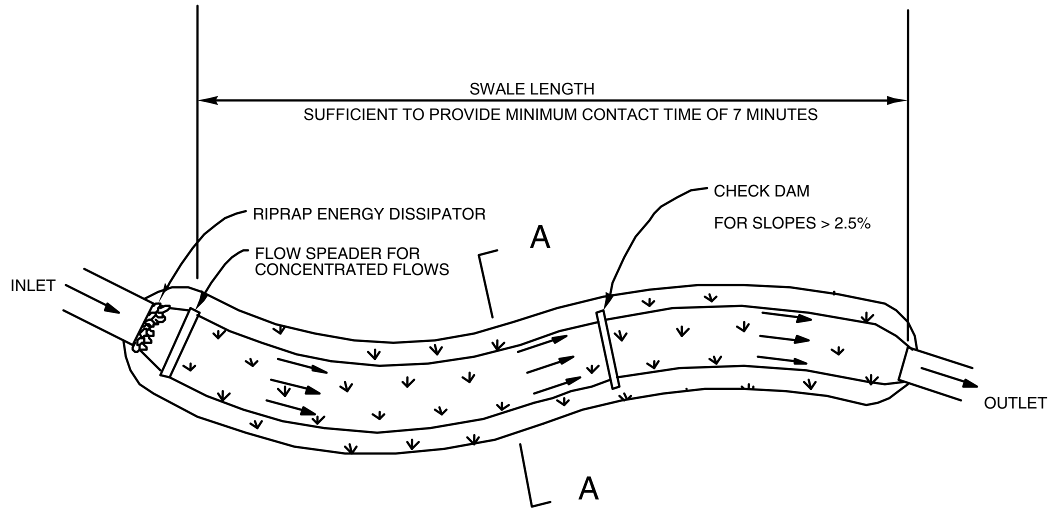
Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas will require execution of a maintenance agreement or permit with the property owner for projects including a vegetated swale. Check with the local permitting agency about the timing for execution of the agreement. Such agreements will typically include requirements such as those outlined in Table VS-2. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

Swales with rock in the flowline are *discouraged* due to high maintenance needs (including use of weed killers) and potential for mosquito breeding.

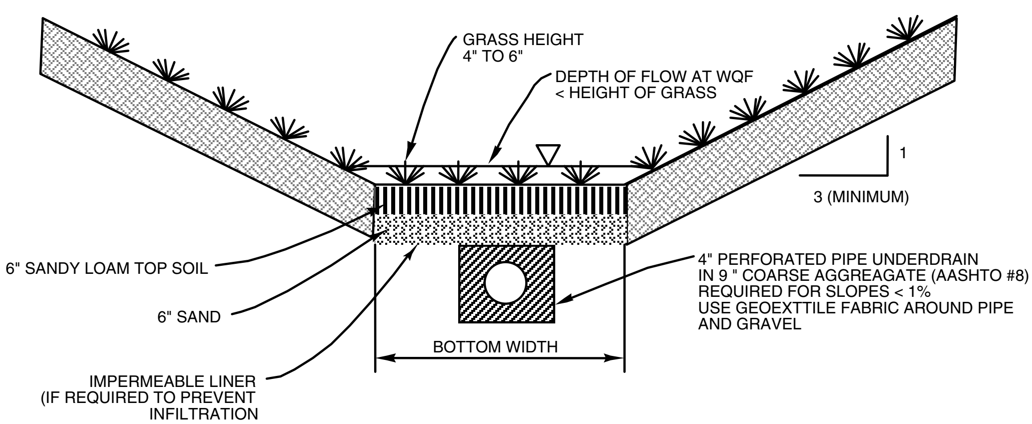
Table VS-2. Inspection and Maintenance Recommendations for Vegetated Swales

Activity	Schedule
Mow grass to maintain a height of 4 to 6 inches or above depth of flow at WQF.	As needed to maintain optimum grass height
Use integrated pest management (IPM) techniques to minimize use of fertilizers, pesticides and herbicides.	As needed
Remove trash and debris from the swale (especially the outlet)	As needed
Inspect swale for signs of erosion, vegetation damage/coverage, channelization problems, debris build-up and excessive sedimentation in bottom of channel. Correct problems (e.g., remove sediment or stabilize, re-seed eroded areas) as soon as possible.	At least twice annually. Schedule one inspection at the end of the wet season so that summer maintenance can be scheduled to prepare swale for wet season. Additional inspections after periods of heavy runoff are desirable.
Remove sediment in inlet areas, channel, culverts, and outlets whenever flow into the swale is retarded or blocked.	As needed
Repair ruts or holes in the channel by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.	As needed
Inspect swale for obstructions (e.g., debris accumulation, invasive vegetation) and pools of standing water that can provide mosquito-breeding habitat. Correct observed problems as soon as possible.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.



TRAPEZOIDAL VEGETATED SWALE – PLAN

NOT TO SCALE



TRAPEZOIDAL VEGETATED SWALE – SECTION

NOT TO SCALE

ADAPTED FROM URBAN STORM DRAIN CRITERIA MANUAL VOL. 3 - BEST MANAGEMENT PRACTICES, URBAN DRAINAGE AND FLOOD CONTROL DISTRICT,11/99

Figure VS-1. Vegetated Swale

Table VS-3. Design Data Summary Sheet for Vegetated Swale

Designer: ______________________________ Date: ____________

Company: ______________________________

Project: ______________________________

Location: ______________________________

1. Design Flow: WQF = I x C x A	WQF = ____________	cfs
a. I = Design Intensity = 0.18 in/hr	I = ____________	in/hr
b. C = Runoff Coefficient	C = ____________	
c. A = Tributary area	A = ____________	acres
2. Swale Geometry		
a. Swale Bottom Width (b)	b = ____________	ft
b. Side slope (Z)	Z = ____________	
3. Depth of flow (d) at WQF (3”-5” with Manning’s n= 0.20)	d = ____________	in
4. Design Slope		
a. s = 1% minimum without underdrains; 4% maximum without grade controls	s = ____________	%
b. Number of grade controls required	____________	(number)
5. Design flow velocity (Manning’s n= 0.20)	V = _ ft/sec	
6. Contact Time (t_c = 7 minutes minimum)	t_c = ____________	minutes
7. Design Length		
L = (t_c) x (flow velocity) x 60	L = ____________	ft

8. Vegetation (describe) ______________________________

____

____

9. Outflow Collection (Check type used or describe “Other”)

☐ Grated Inlet ☐ Infiltration Trench ☐ Underdrain Used

☐ Other ______________________________

Notes: ______________________________

____

____

Caltrans

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 runoff from adjacent surfaces. As the runoff flows through the vegetation and over the soil surface at a shallow depth, pollutants are removed by a variety of physical, chemical, and biological mechanisms, including sedimentation, filtration, adsorption, precipitation, and microbial degradation and conversion.

Siting Considerations

- Drainage area: 5 acres maximum per filter strip.
- Longitudinal Slope: 1% - 4%
- Terracing may be used for slopes > 4%
- Minimum length in flow direction: 25 ft.
- Minimum depth to groundwater table: 2 ft.
- Maximum ponding depth: 1 ft.
- Type A & B soils only.

POLLUTANT REMOVAL EFFECTIVENESS

Sediment	Medium
Nutrients	Low
Trash	Low
Metals*	Medium
Bacteria*	Low
Oil and Grease	Medium
Organics*	Medium

*The following are target pollutants for Sacramento area: copper; lead; mercury; pathogens; diazinon; and chlorpyrifos

Source: CASQA California Stormwater BMP Handbook, January 2003

Vector Considerations

- Potential for mosquitoes due to standing water will be greatly reduced or eliminated if the strip is properly designed, constructed, and operated.

Advantages

- Relatively inexpensive when used to replace part of a conventional storm drainage system and integrated into site landscaping.
- Attractive.
- Easy to maintain.

Limitations

- Possible conflicts with water conservation ordinances for landscape irrigation requirements.
- Not appropriate for industrial sites or locations where spills may occur.
- Removes high percentage of particulate pollutants, but not soluble pollutants.

General Maintenance Recommendations (Low to Moderate)

- Periodically remove debris and sediment from filter strip surface.
- Repair/replace vegetation as necessary to maintain full cover and prevent erosion.
- See table VFS-2 for additional vegetation maintenance recommendation.

How does a Vegetated Filter Strip work?

A Vegetated Filter Strip is designed to create shallow sheet flow of runoff over a gently sloping, densely vegetated surface. Treatment of the runoff occurs through a variety of natural mechanisms as the runoff flows through the vegetation and over the soil surface. To ensure adequate treatment, the vegetation must be dense and strong. Greater surface area and contact time promote greater runoff treatment efficiencies. The volume of runoff can be reduced through infiltration into underlying soils. See Figure VFS-1 for a typical Vegetated Filter Strip configuration.

Other Names: Grass filter strips, Biofilter

Do not confuse a Vegetated Filter Strip with a *Vegetated Swale*, described elsewhere in this manual, or a *grass buffer strip*, which is used as a low impact design strategy or for pretreatment. The latter provides only limited pollutant removal because of higher application rates, and it requires downstream treatment controls.

Planning and Siting Considerations

- Select location where site topography allows for the design of filter strips with proper slopes in flow direction.
- Integrate Vegetated Filter Strips into open space buffers, undisturbed natural areas, and other landscape areas when possible.
- For parking lot design, stalls can be shortened if tire curbs are provided around the perimeter of the filter strip and cars are allowed to overhang the filter strip.
- Irrigation is typically required to maintain viability of the filter strip vegetation. Coordinate design of general landscape irrigation system with that of the Vegetated Filter Strip, as applicable.

Design Criteria

Design criteria for Vegetated Filter Strips are listed in Table VFS-1. Use the design data summary sheet (Table VFS-3) provided at the end of this fact sheet to record design information for review by the agency plan reviewer.

Table VFS-1. Vegetated Filter Strip Design Criteria

Design Parameter	Criteria	Notes
Drainage area	≤ 5 acres	For larger areas, break up into sub-sheds of 5 acres or less with a filter strip for each.
Design flow	WQF	See Appendix E in this Design Manual.
Maximum linear application rate (q_a)	0.005 cfs/ft of width	Rate at which runoff is applied across the top width of filter strip. This rate, combined with the design flow, will define the design width of filter strip.
Minimum slope in flow direction	1%	Gentler slopes are prone to ponding of water on surface
Maximum slope in flow direction	4%	Steeper slopes are prone to channeling
Minimum length in flow direction	25 ft	Most treatment occurs in the first 25 feet of flow. Longer lengths will typically provide somewhat higher levels of treatment
Vegetation height (typical)	2 – 4 in.	Vegetation should be maintained at a height greater than the depth of flow at design flow rate but sufficiently low to prevent lodging or shading.

Design Procedure

Step 1 – Calculate Water Quality Flow (WQF) (Flow-Based Control Measure)

Using the Appendix E in this Design Manual, determine the contributing area and water quality design flow, WQF.

Step 2 – Calculate minimum width of Vegetated Filter Strip (W_{VFS})

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

$$W_{VFS} = (WQF)/(q_a)$$

$$W_{VFS} = (WQF)/0.005 \text{ cfs/ft (minimum)}$$

Early Design Is Critical!

Vegetated Filter Strips must be located on the site plan at the earliest possible design phase when laying out the building and parking footprints and before the site grading plan is prepared.

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

The length of the filter strip in the flow direction must be a minimum of 25 feet. Greater lengths are desirable, as somewhat better treatment performance can typically be expected.

Step 4 – Determine design slope

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

Step 5 – Design inlet flow distribution

Incorporate a device such as slotted curbing, modular block porous pavement, or other spreader devices at the upstream end of the filter strip to evenly distribute flow along the top width. Concentrated flow delivered to the filter strip must be distributed evenly by means of a level spreader as shown in Figure VFS-1.

Step 6 – Select vegetation

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

Select vegetation that:

- Will be dense and strong enough to stay upright, even in flowing water;
- Has 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.

Use the design data summary sheet (Table VFS-3) provided at the end of this fact sheet to record design information for review by the agency plan reviewer.

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., grass channel/swale, storm drain, gutter).

Step 8 – Design irrigation system

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

Construction Considerations

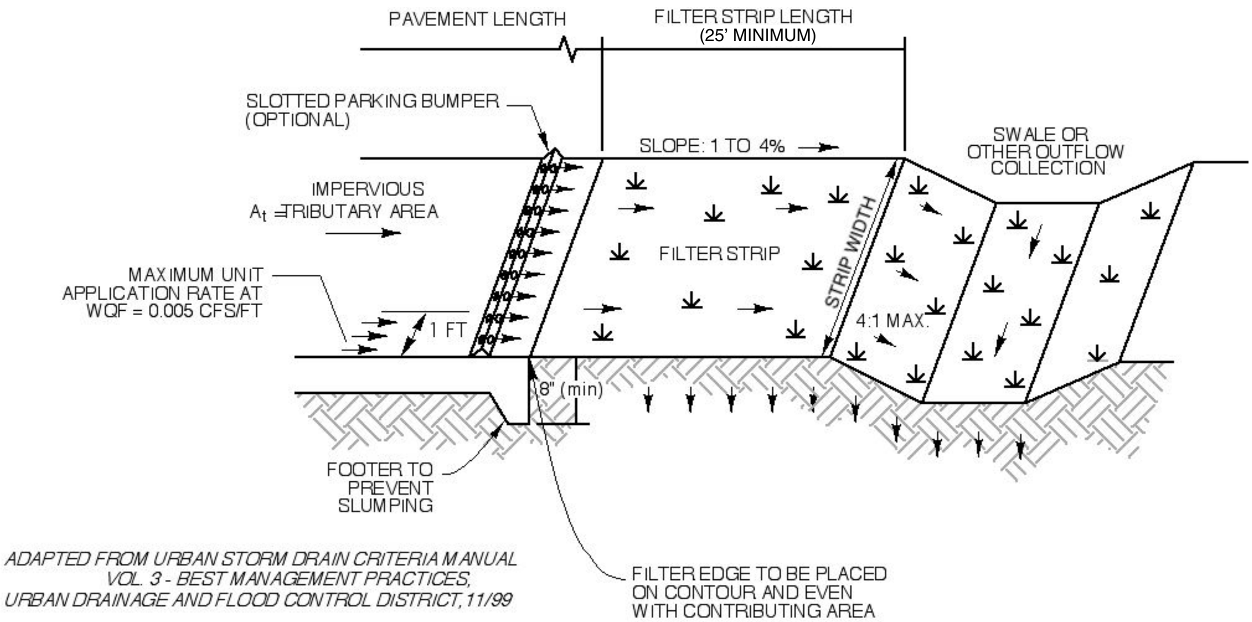
- Divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.
- Install sediment controls (e.g., staked straw wattles) around the filter strip to prevent high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

Long-Term Maintenance

The local permitting agencies in the Sacramento and South Placer areas will require execution of a maintenance agreement or permit with the property owner for projects including a vegetated filter strip. Check with the local permitting agency about the timing for execution of the agreement. Such agreements will typically include requirements such as those outlined in Table VFS-2. The property owner or his/her designee will be responsible for compliance. See Appendix B for additional information about maintenance requirements and sample agreement language.

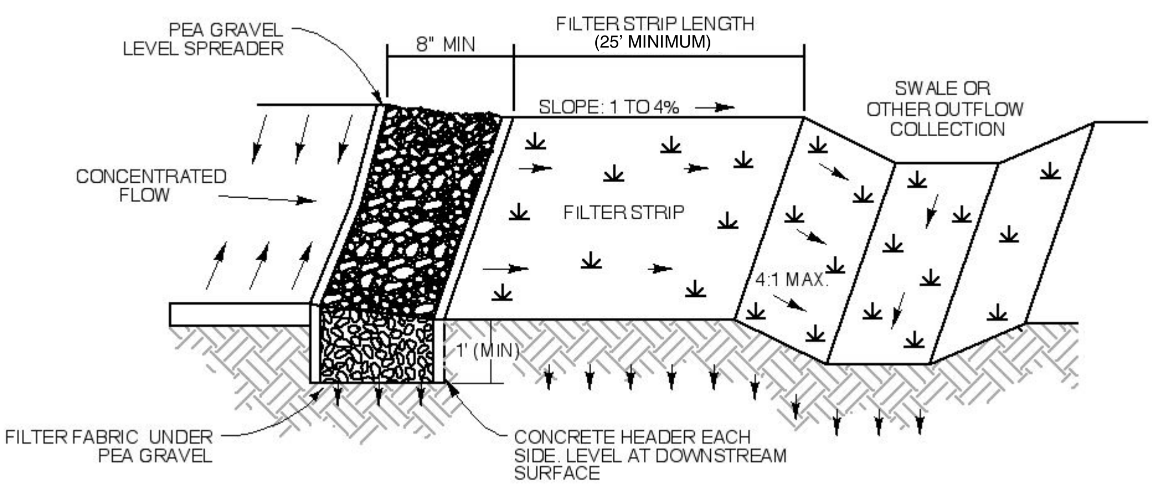
Table VFS-2. Inspection and Maintenance Recommendations for Vegetated Filter Strips

Activity	Schedule
Mow grass to maintain a height of 2 to 4 inches (typical).	As required
Use integrated pest management (IPM) techniques to minimize use of fertilizers, pesticides and herbicides.	As required
Remove trash and debris from the filter strip.	As required
Inspect filter strip for signs of erosion, vegetation damage/coverage, channel formation problems, debris build-up, and excessive sedimentation on the surface of the strip. Correct problems or remove debris and sediment as soon as possible.	At least twice annually. Schedule one inspection at the end of the wet season so that summer maintenance can be scheduled to prepare filter strip for wet season. Additional inspections after periods of heavy runoff are desirable.
Remove sediment in inlet areas, the channel, culverts, and outlets whenever flow into the filter strip is retarded or blocked.	As required
Repair ruts or holes in the strip by removing vegetation, adding and tamping suitable soil, and reseeding. Replace damaged vegetation.	As required
Inspect filter strip for obstructions (e.g., debris accumulation, invasive vegetation) and pools of standing water that can provide mosquito-breeding habitat. Correct observed problems as soon as possible.	At least twice during the wet season after significant storms. Additional inspections after periods of heavy runoff are desirable.
Reconstruct or replace the control measure when it is no longer functioning properly.	See projected lifespan in Appendix B for informational purposes.



SHEET FLOW CONTROL

NOT TO SCALE



CONCENTRATED FLOW CONTROL

NOT TO SCALE

Figure VFS-1. Vegetated Filter Strip

Table VFS-3. Design Data Sheet for Vegetated Filter Strip

Designer: ______________________________ Date: __________

Company: ______________________________

Project: ______________________________

Location: ______________________________

1. Design Flow: WQF = I x C x A	WQF = __________ cfs	
a. I = Design Intensity = 0.18 in/hr	I = __________ in/hr	
b. C = Runoff Coefficient	C = __________	
c. A = Tributary area	A = __________ acres	
2. Design Width		
W_{VFS} = (WQF)/0.005 cfs/ft	W_{VFS} = __________ ft	
3. Design Length (25 ft minimum)	L_{VFS} = __________ ft	
4. Design Slope (1% minimum; 4% maximum)	S_{VFS} = __________ %	

5. Flow Distribution (Check type used or describe "Other")

☐ Slotted Curbing ☐ Level Spreader ☐ Modular Block Porous Pavement

☐ Other ______________________________

6. Vegetation (describe) ______________________________

____

____

7. Outflow Collection (Check type used or describe "Other")

☐ Grass Swale ☐ Street Gutter ☐ Storm Sewer

☐ Underdrain Used ☐ Other ______________________________

Notes: ______________________________

____

____

Glossary

The following are the terms and acronyms used frequently in this Manual. This list is not intended to be exhaustive.

Best Management Practices (BMPs) means methods, measures, or practices designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and non-point source discharges including stormwater. BMPs include structural and nonstructural controls, and operation and maintenance procedures, which can be applied before, during, and/or after pollution producing activities.

In the stormwater field, terms are frequently used interchangeably; therefore, it is important to understand the meaning of various terms as presented in this Manual.

California Stormwater Quality Association (CASQA) — Statewide Association of stormwater quality managers and other interested parties. Publisher of the California Stormwater Best Management Practices Handbooks, available at *www.cabmphandbooks.com*. Successor to the Storm Water Quality Task Force (SWQTF).

Cluster Development — The principle of cluster development incorporates grouping new homes onto part of a development parcel so that the remaining land can be preserved as open space. This approach can save a significant portion of the land and provide an attractive living environment for homeowners. *Source: National Assoc. of Homebuilders www.nahb.org (search "cluster development")*

Commercial Development means any development on private land that is not heavy industrial or residential. The category includes, but is not limited to hospitals, laboratories and other medical facilities, educational institutions, recreational facilities, plant nurseries, car wash facilities, mini-malls, business complexes, shopping malls, hotels, office buildings, public warehouses, and light industrial complexes.

Commercial/Industrial Facility means any facility involved and/or used in the production, manufacture, storage, transportation, distribution, exchange or sale of goods and/or commodities, and any facility involved and/or used in providing professional and non-professional services. This category of facilities includes, but is not limited to, any facility defined by the SIC Code. Facility ownership (federal, state, municipal, private) and profit motive of the facility are not factors in this definition.

Construction means clearing, grading, excavating, building and related activities that result in soil disturbance. Construction includes structure teardown. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility; emergency construction activities required to immediately protect public health and safety; interior remodeling with no outside exposure of construction material or construction waste to stormwater; mechanical permit work; or sign permit work.

Control means to minimize, reduce, eliminate, or prohibit by technological, legal, contractual or other means, the discharge of pollutants from an activity or activities.

Design Storm — A synthetic rainstorm defined by rainfall intensities and durations.

Detention — The practice of holding stormwater runoff in ponds, vaults, within berms, or in depressed areas and letting it discharge slowly to the storm drain system or receiving water. The detention process allows sediment and associated pollutants to settle out of the runoff.

Development means any construction, rehabilitation, redevelopment or reconstruction of any public or private residential project (whether single-family, multi-unit or planned unit development); industrial, commercial, retail and other non-residential projects, including public agency projects; or mass grading for future construction. It does not include routine maintenance to maintain original line and grade, hydraulic capacity, or original purpose of facility, nor does it include emergency construction activities required to immediately protect public health and safety.

Development Standards means standards that the Permittees must develop and implement for new development and significant redevelopment projects to control the discharge of stormwater pollutants in post-construction stormwater.

Directly Connected Impervious Area (DCIA) or Surface — Any impervious surface which drains directly into the storm drain system without first allowing flow across a pervious area (e.g. lawn).

Disconnected Pavement (also known as disconnected impervious area, or surface, or not directly connected pavement)— an impervious area that drains across a pervious area prior to discharge to the storm drain system.

Drawdown — see Drawdown Time

Drawdown Time — The time required for a stormwater detention or infiltration BMP to drain and return to the dry-weather condition. For detention BMPs, drawdown time is a function of basin volume and outlet orifice size. For infiltration BMPs, drawdown time is a function of basin volume and infiltration rate.

Flow-Based Treatment Control Measures — Stormwater quality treatment measures that rely on flow capacity to treat stormwater. These measures remove pollutants from a moving stream of water through filtration, infiltration, adsorption, and/or biological processes. Examples: vegetated swales and filter strips.

General Construction Activities Storm Water Permit (Construction General Permit) — the general NPDES permit adopted by the State Board, which authorizes the discharge of stormwater from construction activities under certain conditions.

General Industrial Activities Storm Water Permit (Industrial General Permit) — the general NPDES permit adopted by the State Board which authorizes the discharge of stormwater from certain industrial activities under certain conditions.

Head (hydraulic head) — In hydraulics, energy represented as a difference in elevation. In slow-flowing open systems, the difference in water surface elevation, e.g., between an inlet and outlet.

Hydrograph — Runoff flow rate plotted as a function of time.

Hydrologic Soil Group —

TYPICAL INFILTRATION RATES

Soil Type (Hydrologic Soil Group)	Infiltration Rate (in/hr)
A	1.00 – 8.3
B	0.5 – 1.00
C	0.17 – 0.27
D	0.02 – 0.10

Infiltration rates shown represent the range covered by multiple sources, e.g. ASCE, BASMAA, etc.

Source: Venture County Technical Guidance Manual for Stormwater Quality Control Measures, July 2002.

Illicit Connection means any man-made conveyance that is connected to the storm drain system without a permit, excluding roof drains and other similar type connections. Examples include channels, pipelines, conduits, inlets, or outlets that are connected directly to the storm drain system.

Illicit Discharge means any discharge to the storm drain system that is prohibited under local, state, or federal statutes, ordinances, codes, or regulations. The term illicit discharge includes all non storm-water discharges except discharges pursuant to an NPDES permit, discharges that are identified as "allowable" in NPDES Municipal Stormwater Permits, and discharges authorized by the Regional Board.

Impervious Surface — Any material that prevents or substantially reduces infiltration of water into the soil.

Infiltration means the downward entry of water into the surface of the soil. Infiltration rate (or infiltration capacity) is the maximum rate at which a soil in a given condition will absorb water.

Inspection means entry and the conduct of an on-site review of a facility and its operations, at reasonable times, to determine compliance with specific municipal or other legal requirements.

Low Impact Development (LID) is a stormwater management strategy that emphasizes conservation and use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns in residential, commercial, and industrial settings.
—Source: Puget Sound Action Team 2005

Maximum Extent Practicable (MEP) — Section 402(p)(3)(B) of the Clean Water Act (CWA) directs the Regional Board to issue NPDES Municipal Stormwater Permits which require the dischargers to develop and implement programs with the goal of reducing the discharge of pollutants in stormwater runoff to the maximum extent practicable (MEP). Originally, the term was not clearly defined by the CWA or subsequent regulations, in order to allow dischargers the flexibility to design programs tailored to unique conditions and needs of the community. However, the SWRCB has since attempted to define the term. The State Board's Office of Chief Counsel (OCC) issued a memorandum interpreting the meaning of MEP to include *technical feasibility, cost, and benefit derived with the burden being on the municipality to demonstrate compliance with MEP by showing that a BMP is not technically feasible in the locality or that BMP costs would exceed any benefit to be derived* (dated 11 February 1993). For a more detailed discussion of this standard, see State Board Orders WQ 1000-11 and 91-03. Finding 38 of the Sacramento Areawide NPDES Stormwater Permit No. CAS082597 states: *Implementation of BMPs and compliance with performance standards in accordance with the Permittees' Stormwater Quality Improvement Plans and their schedules constitutes compliance with the MEP standard.*

Municipal Separate Storm Sewer System (MS4) means 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, 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) means the national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits under Clean Water Act §307, 402, 318, and 405.

Natural Drainage System means an unlined or unimproved (not engineered) creek, stream, river or similar waterway.

New Development means land disturbing activities; structural development, including construction or installation of a building or structure, creation of impervious surfaces; and land subdivision.

Non-Stormwater Discharge means any discharge to a storm drain that is not composed entirely of stormwater. Certain non-stormwater discharges are authorized per the NPDES Municipal Stormwater Permits.

Not Directly Connected Pavement — see Disconnected Pavement

NPDES — see National Pollutant Discharge Elimination System

NPDES Municipal Stormwater Permit — A permit issued by a Regional Water Quality Control Board to local government agencies (Dischargers) placing provisions on allowable discharges of municipal stormwater to waters of the state.

Performance Standard means a narrative or measurable number specifying the minimum acceptable outcome for a pollution control practice.

Permittees means agencies named in the NPDES Municipal Stormwater Permits as being responsible for permit conditions within their jurisdictions. For the Sacramento Areawide NPDES Municipal Stormwater Permit, the permittees are the County of Sacramento and the Cities of Citrus Heights, Elk Grove, Folsom, Galt, Rancho Cordova and Sacramento. The City of Roseville is the sole permittee for the Roseville Phase II NPDES Municipal Stormwater General Permit.

Permitting Agency — The City or County responsible for issuing grading, building and encroachment permits for new and redevelopment projects. In this Manual, "permitting agency" does not refer to the regulatory agencies responsible for issuing environmental permits.

Pervious Pavement — see Porous Pavement.

Pollutants means those substances defined in CWA §502(6) (33.U.S.C.§1362(6)), and incorporated by reference into California Water Code §13373.

Porous Pavements (Pervious pavements) — Pavements for roadways, sidewalks, or plazas that are designed to infiltrate runoff, such as: pervious concrete, pervious asphalt, unit pavers- on-sand, and crushed gravel.

Post-Construction Stormwater Quality Plan — A plan specifying and documenting permanent site features and control measures that are designed to control pollutants for the life of the project. The plan should include sufficient design detail and calculations to demonstrate the adequacy of the stormwater quality control measures to control pollution from the developed site. This plan may be required prior to issuance of certain development permits; check with your local permitting agency.

Rain Event or Storm Event means any rain event greater than 0.1 inch in 24 hours except where specifically stated otherwise.

Rational Method — A method of calculating runoff flows based on rainfall intensity, and tributary area, and a factor representing the proportion of rainfall that runs off.

Receiving Waters means all surface water bodies in the Central Valley Region that are identified in the Basin Plan.

Redevelopment — see Significant Redevelopment.

Regional Stormwater Quality Treatment Facility (Regional Facility) — A facility that treats runoff from more than one project or parcel (typically a large drainage catchment of 100 acres or more). A regional facility may be in lieu of on-site treatment controls to treat urban runoff prior to discharge to Waters of the State, subject to the approval of the applicable permitting agency.

Regional Water Quality Control Board (RWQCB) — California RWQCBs are responsible for implementing pollution control provisions of the Clean Water Act and California Water Code within their jurisdiction. There are nine California RWQCBs. Sacramento and South Placer County areas are under the jurisdiction of the Central Valley RWQCB (Region 5).

Restaurant means a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC Code 5812).

Retail Gasoline Outlet means any facility engaged in selling gasoline and lubricating oils.

Retention — The practice of holding stormwater in ponds or basins and allowing it to slowly infiltrate to groundwater. Some portion will evaporate. Also see infiltration.

Runoff — see Urban Runoff

Sacramento Stormwater Quality Partnership — A collaborative of public agencies in Sacramento County that protects and improves water quality in local waterways for the benefit of the community and the environment. Participating agencies include the County of Sacramento and the Cities of Citrus Heights, Elk Grove, Folsom, Galt, Rancho Cordova and Sacramento.

Significant Redevelopment includes, but is not limited to: expansion of a building footprint; replacement of a structure; replacement of impervious surface that is not part of routine maintenance activity; and land-disturbing activities related to structural or impervious surfaces. For redevelopment projects subject to this manual, the applicable design standards apply only to the redeveloped area, and not to the entire site, except in cases where untreated drainage from the existing developed portion is allowed to enter/flow through the redeveloped portion. In such cases, any new required treatment control measures must be designed for the entire contributing drainage area. Redevelopment and infill project applicants should check with the local permitting agency at the start of project design to verify whether or not the manual requirements apply.

Source Control Measure means any schedules of activities, 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.

Stormwater means stormwater runoff, snowmelt runoff, and surface runoff and drainage.

Stormwater Quality Plan — See Post-Construction Stormwater Quality Plan

Structural Control Measure means 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 source and treatment control measures.

Target Pollutants — Pollutants identified by the permittees as most likely to impair local receiving waters, based on evaluation of available monitoring data and other information.

Treatment means 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 absorption, biodegradation, biological uptake, chemical oxidation, and UV radiation.

Treatment Control Measure means any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media absorption or any other physical, biological, or chemical process.

Urban Runoff means any runoff from urbanized areas including stormwater and dry weather flows from a drainage area that reaches a receiving water body or subsurface. During dry weather, urban runoff may be comprised of groundwater base flow and/or nuisance flows, such as excess irrigation water.

Volume-Based Treatment Control Measures — Stormwater quality treatment measures that rely on volume capacity to treat stormwater. These measures detain or retain runoff and treat it primarily through settling or infiltration. Examples: detention and infiltration basins, porous pavement and stormwater planters (bioretention).

Water Board(s) — Generic reference to the State Water Resources Control Board (SWRCB) and/or the nine Regional Water Quality Control Boards (RWQCBs).

Water Quality Volume (WQV) — For stormwater treatment BMPs that depend on detention to work, the volume of water that must be detained to achieve maximum extent practicable pollutant removal. This volume of water must be detained for a specified drawdown time.

Wet Season (Rainy Season) — for the Sacramento region, the calendar period beginning October 1 and ending April 30. *Note: This differs from the Dept. of Fish and Game's wet weather definition, which is October 15 – April 15.*

Appendix A
Submittal Requirements

The submittal related to post-construction stormwater quality control measures for the project shall be made in the format specified by the permitting agency. The submittal shall include sufficient design detail and calculations to demonstrate the adequacy of the design to meet the agency requirements, and shall consist of the following information, at a minimum:

- Total site acreage
- Project density (residential projects only)
- Impervious areas: existing & proposed buildings and other structures; pavement
- Pervious areas: landscaped, open space, other areas
- Grades/contours *(agency may specify contour interval)*
- Drainage systems, including pipe materials, sizes, slopes and invert elevations
- Contributing drainage shed(s) – delineate and give acreage of the sheds contributing runon and runoff to and from the project; identify those sheds associated with the proposed stormwater quality control measures
- Location(s) where site discharges to municipal storm drain system and/or receiving waters
- Existing tree canopies and locations of proposed new evergreen/deciduous trees (if interceptor tree control measure is being proposed)
- Type and location of proposed post-construction stormwater quality control measures*, indicating for each measure: size/label of contributing shed(s); amount of contributing impervious and pervious area; and WQV or WQF to be treated.
- Design parameters used to determine size of proposed control measures, including runoff reduction worksheets, if applicable. Include calculations where appropriate/required (permitting agency may allow cross-reference to Drainage Study). Record this information on the "Design Data Summary Sheet" provided at the end of each fact sheet in Chapter 6.
- Details for post-construction control measures, including the following information, where applicable:
    - Dimensions and setbacks from property lines and structures
    - Profile view, including typical cross-sections with dimensions
    - Water surface elevations/freeboard
    - Inlets, outlet structures, and release points
    - Vegetation & growing medium specifications, incl. provisions for temporary irrigation if needed
    - Specifications for construction materials, such as filter fabric and infiltration materials
    - Installation requirements
- Maintenance requirements shall be submitted separately. See Appendix B in Design Manual.

*Control measures may be those included in the *Stormwater Quality Design Manual for Sacramento and South Placer Regions* or alternative measures. For projects proposing use of control measures not specified in the Design Manual, the review and approval process may take longer. Also, slight variations to design criteria stated in the manual may be approved on occasion, provided the agency determines that performance of the facility itself or other site structures/features is not compromised. For agencies in Sacramento County, proposals of alternative proprietary structural devices may be accepted if the manufacturer can satisfy the agencies' protocol or the property owner agrees to conduct a pilot scale monitoring study.

To avoid delays, all alternative proposals should be discussed with the stormwater quality staff at the permitting agency as early as possible in the planning stages of the project, preferably at the pre-application meeting.

Example Preliminary Stormwater Quality Compliance Form (Sacramento County)

The following information is presented for example purposes only and may not be the current version. The other permitting agencies in the region may use different forms. Contact the local permitting agency for their submittal requirements.

Sacramento County Supplemental Application:
Preliminary Stormwater Quality Compliance Form

This form is provided for example purposes only.
Check with your local permitting agency for copies of forms and procedures appropriate for your project site.

---

1) Project Information

Applicant Name:_____________________ Phone Number: ______________________

Address:____

Project Contact:______________________ Phone Number:_______________________

Project name:________________________ Assessor Parcel Number(s):____________

Site Address:____

Project Category (check all that apply): *Refer to Design Manual Table 3-2 for Priority Project Categories*

- ☐ *Residential (Single Family)*
- ☐ *Residential (Multi-Family)*
- ☐ *Commercial Development*
- ☐ *Automotive Repair Shop*
- ☐ *Retail Gasoline Outlet*
- ☐ *Restaurant*
- ☐ *Industrial Development*
- ☐ *Street/Road*
- ☐ *Hillside Development*
- ☐ *Parking Lot*

Project Gross Acres:_____________________ Project Net Acres:_____________________

Existing Impervious Surface Area:________ Proposed Impervious Surface Area:__________

Watershed or receiving water:______________

---

2) Source Controls (check source control measure or applicable pollutant sources, check Design Manual Chapter 4 for more information on source control measures)

Refer to Design Manual Table 3-2 for Requirements

- ☐ *Storm Drain Message and Signage*
- ☐ *Fueling Areas*
- ☐ *Loading/Unloading Areas*
- ☐ *Outdoor Storage Areas*
- ☐ *Outdoor Work Areas*
- ☐ *Vehicle/Equipment Wash Areas*
- ☐ *Waste Management Areas*
- ☐ *Other Describe*___________________________________

---

3) Runoff Reduction Measures

Refer to Design Manual Table 3-2 for Requirements

Will runoff reduction measures be utilized for this project? ☐Yes ☐No

If yes, check selectec runoff reduction measures below; attach completed Runoff Reduction worksheets (Design Manual Appendix D).

- ☐ *Alternative Driveway Design*
- ☐ *Disconnected Roof Drains*
- ☐ *Disconnected Pavement*
- ☐ *Green Roof*
- ☐ *Interceptor Trees*
- ☐ *Porous Pavement*
- ☐ *Other Describe*________________________________

---

4) Stormwater Quality Treatment Requirements

Refer to Design Manual Table 3-2 for Requirements

Is treatment required? ☐Yes ☐No If no, form is complete with signature. If yes, complete this section.

Indicate No. of drainage sheds for the site: _________

Early consideration of stormwater quality during site planning may reduce the overall cost of treatment controls. Runoff reduction methods and innovative design options can reduce the size of treatment options. In addition, early consideration allows for non-proprietary treatment options that can significantly reduce construction and maintenance costs.

---

5) Attach Project Overview and Stormwater Quality Narrative

☐Include Project description indicating nature of project (e.g. is it a newly developing site, replacement of previously developed site, is it an infill site). Describe activities planned for site that may impact water quality such as a retail gasoline outlet as part of a development. Describe selected treatment options. Developers should keep in mind that proprietary devices require extensive maintenance by the owners of the property and should consider alternative treatment measures first. Project description should be no more than 1 page relating to stormwater quality.

---

6) Attach Site Plans* and/or Drawings Showing:

☐Existing and natural hydrologic features
☐Existing and proposed drainage system
☐Proposed drainage sheds including **(Refer to item #4, if treatment is required)**

- Name of shed
- Existing amount of pervious and impervious areas
- Proposed amount of pervious and impervious areas
- Proposed treatment option(s) for each shed

☐Pollutant source areas including loading docks, food service areas, refuse areas, outdoor processes and storage, vehicle cleaning, repair or maintenance, fuel dispensing, equipment washing, etc.
☐Proposed design features to minimize impervious areas, applicable runoff reduction techniques, innovative design, and all treatment options selected

*Note: Plans will not be checked for adequacy of treatment options until design review of drainage system. For information related to correct sizing and other requirements refer to *Stormwater Quality Design Manual for Sacramento and South Placer Regions.*

---

7) List Sheds and Selected Stormwater Quality Treatment Controls (if treatment is required)

Shed Name	Total Shed Area		Flow (cfs) or Volume (ft^3)	Treatment Controls Selected
	Impervious Area	Pervious Area		

Attach more sheets as necessary

---

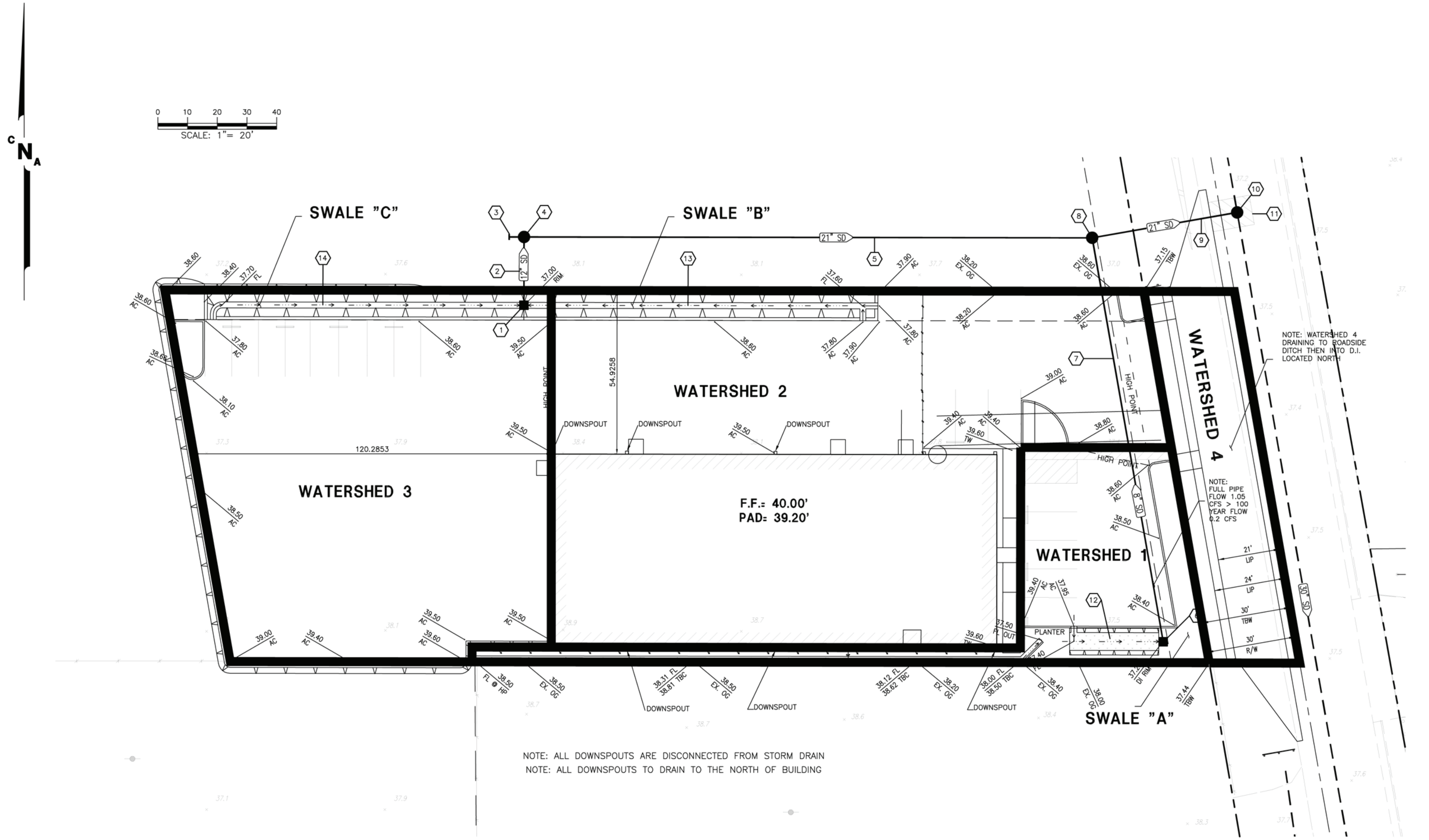
7) Signature

Print Name:___________________________ Indicate Owner or Title _____________________________

Signature:____________________________ Date:__________________

Example Post Construction Stormwater Quality Control Plan
(Sacramento County)

The following information is presented for example purposes only and may not be the current version. The other permitting agencies in the region may have different requirements. Contact the local permitting agency for their submittal requirements.



NOTE: ALL DOWNSPOUTS ARE DISCONNECTED FROM STORM DRAIN
NOTE: ALL DOWNSPOUTS TO DRAIN TO THE NORTH OF BUILDING

GRASSY SWALE FLOW CALCULATIONS

	SWALE "A"	SWALE "B"	SWALE "C"
WATERSHED AREA	0.10 AC	0.51 AC	0.34 AC
NOLTE FLOW	0.05 CFS	0.26 CFS	0.17 CFS
NOLTE DEPTH	0.05 FT	0.27 FT	0.19 FT
100 YR FLOW	0.20 CFS	1.02 CFS	0.68 CFS
100 YR DEPTH	0.12 FT	0.54 FT	0.40 FT

GRASSY SWALE DESIGN CALCULATIONS

WQF = 2 YR, 6 HR STORM PER 4–1, "STORM QUALITY MANUAL."
WQF = CLA
WHERE: C = COEFICIENT OF RUNOFF ~ 0.95
L = RAINFALL INTENSITY – 2 YR, 6 HR = 0.18
A = WATERSHED AREA

WATERSHED 1 AREA = 0.10 AC = A_1 - SWALE "A"
WATERSHED 2 AREA = 0.85 AC–2 SWALES
SWALE "B" A_2 = 0.51 AC, SWALE "C" A_2 = 0.34 AC

TREATMENT TO BE GRASSY SWALE:
ALL SWALES 3:1 SIDE SLOPES
SWALES BOTTOM GRASS HEIGHT BETWEEN 4 TO 6 INCHES

SWALE "A"

WQF = CLA_1 = .95(.18)(0.1) = 0.017 CSF
LENGTH OF: SWALE "A" = 30 FT.
WATER QUALITY DEPTH = 0.04 FT
BOTTOM WIDTH =6 FT
CHANNEL SLOPE =0.005

CONTACT TIME FOR SWALE "A":
T_c = L/V (1 MIN/ 60SEC)
WHERE: L = SWALE LENGTH 55 FT., V = VELOCITY IN SWALE
V = Q/A
WHERE: A = SWALE CROSS SECTION AREA = 0.264 SQ FT., Q= WQF = 0.017 CSF
V = (0.017/0.264)= 0.064
T_c = (30/0.064)(1 MIN/ 60 SEC) = ***7.8 MIN > 7 MIN***

SWALE "B"

WQF = CLA_2 = .95(.18)(0.51) = 0.087 CSF
LENGTH OF: SWALE "B" = 114 FT.
BOTTOM WIDTH = 2 FT
WATER QUALITY DEPTH = 0.21 FT
CHANNEL SLOPE = 0.5 %

CONTACT TIME FOR SWALE "B":
T_c = L/V (1 MIN/ 60SEC)
WHERE: L = SWALE LENGTH 114 FT., V = VELOCITY IN SWALE
V = Q/A
WHERE: A = SWALE CROSS SECTION AREA = 0.548 SQ FT., Q= WQF = 0.087 CSF
V = (0.087/0.548) = 0.159
T_c = (114/0.159)(1 MIN/ 60 SEC) = ***11.9 > 7 MIN***

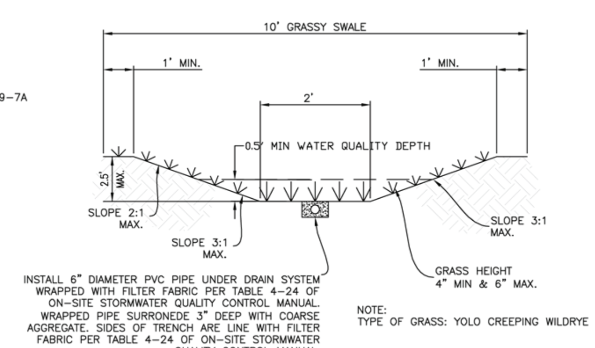
SWALE "C"

WQF = CLA_2 = .95(.18)(0.34) = 0.058 CSF
LENGTH OF: SWALE "C" = 102 FT.
BOTTOM WIDTH = 2 FT
CHANNEL SLOPE = 0.7 %
WATER QUALITY DEPTH = 0.15 FT

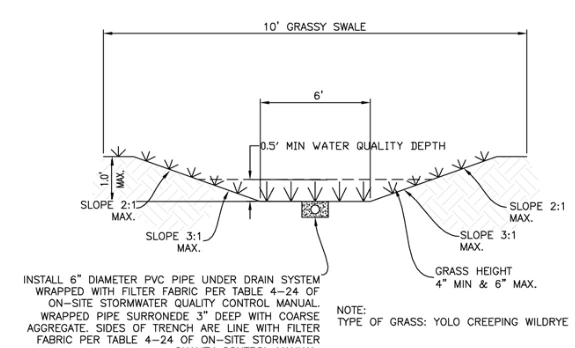
CONTACT TIME FOR SWALE "C":
T_c = L/V (1 MIN/ 60SEC)
WHERE: L = SWALE LENGTH 102 FT., V = VELOCITY IN SWALE
V = Q/A
WHERE: A = SWALE CROSS SECTION AREA = 0.372 SQ FT., Q= WQF = 0.058 CSF
V = (0.058/0.372) = 0.156
T_c = (102/0.156)(1 MIN/ 60 SEC) = 1***10.9 > 7 MIN***

CONSTRUCTION KEYNOTES

1. CONST. TYPE "F" D.I.
   RIM= 38.00'
   FL IN= 37.00'
   FL OUT= 3400'
2. PLACE 23 L.F. OF 12" SDR–35 P.V.C.
   SLOPE= 0.010
3. PLACE 5 L.F. OF 21" SDR–35 P.V.C. PLUG
   S= 0.0020
   FL OUT= 30.51'
4. CONST. 48" SDMH PER SAC. CO. DWG. 9–7A
   RIM= 38.50'
   FL OUT= 30.50'
   12" FL IN= 33.77'
5. PLACE 191 L.F. OF 21" SDR–35 P.V.C.
   SLOPE= 0.0020
6. CONST. TYPE "F" D.I.
   RIM= 38.25'
   FL IN= 37.25'
   FL OUT= 34.25'
7. PLACE 138 L.F. OF 8" SDR–35 P.V.C.
   SLOPE= 0.010
8. CONST. 48" SDMH W/ 12" SUMP PER SAC. CO. DWG. 9–7A
   RIM= 37.20'
   FL OUT= 30.12'
   FL SUMP= 29.12'
   8" FL IN= 32.87'
9. PLACE 49 L.F. OF 21" SDR–35 P.V.C.
   SLOPE= 0.0020
10. CONST. 48" SDMH PER SAC. CO. DWG. 9–7A
    RIM= MEET EX. GRADE (VERIFY IN FIELD)
    FL OUT= 30.02' = EX. FL (VERIFY IN FIELD)
11. CUT AND REPLACE EXIST. PAVEMENT TO CONST. 21" STORM DRAIN PER SAC. CO. DETAIL 4–31
12. CONST. 30 L.F. OF GRASSY SWALE
    SLOPE= 0.005
13. CONST. 114 L.F. OF GRASSY SWALE
    SLOPE= 0.005
14. CONST. 102 L.F. OF GRASSY SWALE
    SLOPE= 0.007



GRASSY SWALE DETAIL SWALE "B", "C"
NTS



GRASSY SWALE DETAIL SWALE "A"
NTS

POST CONSTRUCTION MEASURES

TYPE	IMPERVIOUS AREA	PERVIOUS AREA	WATER QUALITY FLOWS
DRAINAGE SWALE			
SWALE A	0.10 AC	0.01 AC	0.017 CFS
SWALE B	0.48 AC	0.03 AC	0.087 CFS
SWALE C	0.31 AC	0.03 AC	0.058 CFS
DRAIN INLET MESSAGE	N/A	N/A	N/A

CERTIFICATE OF CONTROL MEASURE COMPLIANCE

THE REQUIREMENTS OF THE COUNTY POST CONSTRUCTION CONTROL MEASURES REGULATION WERE MET BY THE METHOD CHECKED BELOW:

____ ALL POST CONSTRUCTION CONTROL MEASURES HAVE BEEN INSTALLED AS INDICATED ON THE APPROVED PLANS

BENCHMARK ELEV.: 39.48'
SACTO CO. B.M. NO.: 25–27
7/8" METAL DISC STAMPED "CO. B.M. 25–27" LOCATED IN TOP OF VERTICAL CURB, NEAR CHISELED CROSS, 15" WEST OF EAST END OF CURB ON THE NORTH SIDE OF GERBER ROAD AND 25 PACES WEST OF CENTER OF RAILS OF THE SPRR @ X–ING NO. D–128.2.

REVISIONS

NO.	DESCRIPTION	COUNTY APPROVAL APPROVED BY	DATE
1			
2			
3			
4			

SCALE	DRAFTED BY:
HORIZ. 1"= 20'	DESIGNED BY:
VERT. 1"= N/A	CHECKED BY:
FLD BK.:	DATE: 1/11/2007
ASSESSOR'S PARCEL NO.:	

POST-CONSTRUCTION STORM WATER QUALITY PLAN FOR:

COUNTY OF SACRAMENTO STATE OF CALIFORNIA

PLOT DATE: 1/11/2007
Fn.:

SHEET 6 OF 7 SHEETS
FILE NO.:

Appendix B

Maintenance Requirements

State Mandated Requirement

Verification of long-term maintenance provisions for post-construction structural and treatment control measures is mandated by the agencies' State-issued stormwater permits. For example, the Sacramento Areawide NPDES Municipal Stormwater Permit (No. CAS082597) specifies:

> *22. Maintenance Agreement and Transfer: Each Permittee shall require that all developments subject to Development Standards and site specific plan requirements provide verification of maintenance provisions for post-construction structural and treatment control BMPs. Verification shall include one or more of the following as applicable:*
>
> *a. The developer's signed statement accepting responsibility for maintenance until the maintenance responsibility is legally transferred to another party; or*
>
> *b. Written conditions in the sales or lease agreement that require the recipient to assume responsibility for maintenance; or*
>
> *c. Written text in project conditions, covenants and restrictions for residential properties assigning maintenance responsibilities to a home owner's association, or other appropriate group, for maintenance of structural and treatment control BMPs; or*
>
> *d. Any other legally enforceable agreement that assigns responsibility for maintenance of structural or treatment control BMPs.*

Maintenance Agreements, Covenants or Permits

In compliance with this regulation, the local permitting agencies in the Sacramento and South Placer areas have decided that they will require execution of a maintenance agreement, covenant or permit with the property owner for projects using any of the following control measures:

Chapter 5 — Runoff Reduction Control Measures:

- Porous Pavement
- Green Roof

Chapter 6 — Treatment Control Measures:

- Constructed Wetland Basin
- Detention Basin
- Infiltration Basin
- Infiltration Trench
- Stormwater Planter
- Vegetated Swale
- Vegetated Filter Strip

Typically maintenance agreements and covenants are recorded with the deed for the property and follow property ownership. The agreements generally include provisions for the permitting agency to recover costs for maintenance in the event that the property owner fails to fulfill their obligations. Check with the local permitting agency about the timing for execution of the agreement.

Recommended Inspection and Maintenance Procedures

A stand-alone table listing recommended inspection and maintenance procedures is provided at the end of the fact sheet for each of the above control measures. The intent is for the applicable table(s) to be incorporated into the maintenance agreement for the project with amendments as needed by the project designer and property owner to pertain to the unique project conditions. It is the responsibility of the project designer to inform the permitting agency of the complete set of necessary inspection and maintenance requirements that will provide long-term continued performance and sustainability of the measures.

Reconstruction or Replacement of Failed Facilities

In addition to inspecting and performing maintenance on the stormwater quality control measure(s), the property owner will be required by the maintenance agreement or permit to reconstruct or replace the measure when it ceases to function properly. For informational purposes, the table on the next page summarizes projected life span information for the various stormwater quality control measures, based on available literature.

Example Maintenance Agreements

Each agency will likely use a different format for the maintenance verification. For example purposes, two standard maintenance covenants/agreements are provided at the end of this appendix, for the County of Sacramento and City of Sacramento, respectively. The contents of each form are basically the same.

Resources for Additional Guidance

Maintaining Your Stormwater Management Facility: Homeowner Handbook, City of Portland, OR. http://www.portlandonline.com/shared/cfm/image.cfm?id=65926

Expected Life for Selected Stormwater Quality Control Measures *(Based on Published Literature)*

Control Measure	Average Life Expectancy[1]	Source/Reference
Runoff Reduction (Chapter 5)		
Porous Pavement[2]	20 years	*Maintaining Your Stormwater Management Facility: Homeowner Handbook*, City of Portland, OR. http://www.portlandonline.com/shared/cfm/image.cfm?id=65926
	30 years	http://www.seattle.gov/dpd/static/GF_RainGardens_1_37427_DPDP_019875.pdf
Green Roof	10–40 years	http://www.ecoroofsystems.com/cost_files/c_cost.html
Treatment Control (Chapter 6)		
Constructed Wetland Detention Basin	20 years	http://www.epa.gov/superfund/programs/aml/tech/cuwetlands.pdf
Water Quality Detention Basin	25 years and more	http://www.abe.msstate.edu/csd/p-dm/all-chapters/chapter4/chapter4/det-basin.pdf
Infiltration Basin	NA	Information to be provided in a future update
Infiltration Trench	30 years	http://www.portlandonline.com/shared/cfm/image.cfm?id=65926
	5–15 years	http://www.epa.gov/owmitnet/mtb/infltrenc.pdf
Sand Filter	5 - 20 years	http://www.fhwa.dot.gov/environment/ultraurb/3fs7.htm
Stormwater Planter	NA	Information to be provided in a future update
Vegetated Filter Strip	50 years	http://www.portlandonline.com/shared/cfm/image.cfm?id=65926
Vegetated Swale	20 years	http://www.highwaybmp.dfwinfo.com/FHWA_PDF/Grassed%20Swale.pdf
	no known limit	http://www.epa.gov/nrmrl/pubs/600r04121/600r04121asect6.pdf

NA: Not available

[1] Information is based on cited references/sources and assuming proper design, installation & long term maintenance. Life expectancy may vary depending on the design. The studies cited in this table may not have used the same design criteria as specified in this design manual.

[2] Expected life estimated to increase with increased pavement depth.

Example Maintenance Covenant
(Sacramento County)

The following information is presented for *<u>example purposes only</u>*
and may not be the current version. The other
permitting agencies in the region may use different forms.
Contact the permitting agency for your project to obtain their current form.

RECORDING REQUESTED BY and for the BENEFIT OF:

NAME Sacramento County
Department of Water Resources

MAILING ADDRESS 827 7th Street, Rm. 301
CITY, STATE ZIP CODE Sacramento, CA 95814

INTEROFFICE MAIL: Mail Code 01-301

NO FEE DOCUMENT
Gov. Code § 6103

SPACE ABOVE THIS LINE RESERVED FOR RECORDER'S USE

DECLARATION OF COVENANTS
(Provisional Device Monitoring, Maintenance and Access)

THIS DECLARATION OF COVENANTS ("Declaration") is executed as of ______________, 200___, by _________________________ a _____________________, (hereinafter the "Declarant") with reference to the following facts:

A. Declarant is the owner of that certain real property, located within the County of Sacramento, California (hereinafter, "Sacramento County"), commonly referred to as Assessor's Parcel Number ("APN") _________________, and more particularly described in Exhibit "A" and the plat thereof on Exhibit "B," attached hereto and incorporated by reference herein (hereinafter, the "Subject Property").

B. At the time of Sacramento County's initial approval of the development project known as ____________________ wherein the Subject Property is located, Sacramento County required installation of on-site control measures to minimize pollutants in urban runoff.

C. Declarant has chosen to install a _____________________________, hereinafter referred to as the "Device," as the on-site control measure to minimize pollutants in urban runoff.

D. The Device is provisionally accepted by Sacramento County for installation on the Subject Property in satisfaction of the Declarant's obligation to minimize pollutant run-off from the Subject Property provided the Device is monitored as herein provided in accordance with the monitoring requirements stated in Exhibit "D" attached here to and incorporated herein.

E. The Device has been installed in accordance with plans and specifications accepted by Sacramento County.

F. The Device, being installed on private property and draining only private property, is a private facility, and all maintenance or replacement of the Device is the sole responsibility of the Declarant in accordance with the terms of this Declaration.

G. The Declarant 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 the

Device in accordance with the maintenance procedures prepared for the Device which maintenance procedures are attached hereto as Exhibit "C" and incorporated herein.

H. Maintenance of the Device 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, in consideration of the foregoing benefits, as well as the benefits obtained by the Declarant and other valuable consideration, the receipt and adequacy of which is hereby acknowledged, Declarant hereby declares as follows:

1. **Covenant Running with Land**. The Declarant does hereby covenant that the burdens and benefits herein made and undertaken shall constitute covenants running with the Subject Property and constitute an encumbrance on said Subject Property which shall bind successors.

2. **Declarant Responsibility to Maintain:** Declarant, its successors or assigns, shall at all times maintain the Device in accordance with the requirements stated in Exhibit "C" and Declarant shall use its best efforts to maintain the Device in a manner assuring its peak performance at all times. All reasonable precautions shall be exercised by Declarant and Declarant's representatives in the removal and extraction of material(s) from the Device. Disposal of the material(s) shall be performed in a manner consistent with all relevant laws and regulations in effect at the time of removal. For a time period of the most recent three (3) years, Declarant shall maintain written documentation verifying all material(s) removed from the Device, including identifying the material(s) removed, quantity, and manner and place of disposal thereof. Such documentation is subject to review by Sacramento County from time to time upon request.

3. **Failure to Maintain:** In the event Declarant, or its successors or assigns, fails to maintain the Device as required by this Declaration, after thirty (30) days written notice thereof, Sacramento County may and is hereby authorized to cause, at the Declarant's expense, any and all maintenance to the Device necessary under the requirements specified in Exhibit "C." In addition to the actual costs of such maintenance, the Declarant shall reimburse Sacramento County for an additional fifteen percent (15%) thereof to cover costs of administration. All such actual and administrative costs shall accrue interest from the date incurred by Sacramento County at the maximum rate authorized by law until paid in full. The notice provided herein shall be effective on the date sent by U.S. Mail, first class postage prepaid to the record owner of the Subject Property as shown on the most recent tax roll.

4. **Declarant's Responsibility to** Monitor: Declarant, its successor and assign, shall at all times, monitor the Device as specified in Exhibit "D".

5. **Failure to Monitor**: In the event Declarant, or its successors or assigns, fails monitor the Device as required, after thirty (30) days written notice thereof by Sacramento County, Sacramento County shall be authorized to cause, at Declarant's expense, any and all monitoring of the Device necessary under the requirements specified in Exhibit "D". In addition to the actual costs of such monitoring, the Declarant shall reimburse Sacramento County for an additional fifteen percent (15%) thereof to cover costs of administration. Such costs shall accrue interest from the date incurred by the County at the maximum rate authorized by the law until paid in full. The notice provided herein shall be effective on the date sent by U.S. Mail, first class postage prepaid to the record owner of the Subject Property as shown on the most recent tax roll.

6. **Security:** If the Declarant fails to maintain the Device as required to the standards specified in Exhibit "C", or fails to monitor the Device as required by Exhibit "D", then Sacramento County may require the Declarant, at the Declarant's sole cost, to post security in a form, for a time period, and in an amount satisfactory to Sacramento County, to guarantee the Declarant's performance of the obligations set forth herein. Should the Declarant fail to perform the obligations under this Declaration, then Sacramento County may realize against said security, and in the case of a cash bond, act for the Declarant using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of this Declaration. Said security shall be available to Sacramento County to satisfy the Declarant's reimbursement obligation under paragraphs 3 and 5, hereof.

7. **Access by County:** Declarant grants Sacramento County or the County's designee the unrestricted right of access to the Device, including its immediate vicinity, and including ingress and egress to and from said Device, at any time, upon twenty-four (24) hour advance notice in writing, of any duration for the purpose of inspection, sampling and testing of the Device. Sacramento County shall make reasonable efforts at all times to minimize or avoid interference with Declarant's use of the Subject Property.

8. **Successors and Assigns Bound**: Declarant hereby agrees and acknowledges that maintenance and monitoring of the Device as herein above set forth and the costs of maintenance and monitoring, Sacramento County's access to the Device, and Sacramento County's rights of ingress and egress to the Device and recovery of costs if Declarant fails to maintain and monitoring the Device as herein set forth, are a burden and restriction on the use of the Subject Property. The provisions of this Declaration shall be enforceable as an equitable servitude and as conditions, restrictions and covenants running with the land, and shall be binding upon the Declarant and upon each an all of its respective heirs, devisees, successors, and assigns, officers, directors, employees, agents, representatives, executors, trustees, successor trustees, beneficiaries and administrators, and upon any future owners of the Subject Property and each of them.

9. **Enforcement**: It is the express intent of the Declarant that the terms and provisions of this Declaration shall be enforceable as an equitable servitude by Declarant. To the extent necessary to do so, Declarant and its successors and assigns, hereby confer and assign rights to enforce the terms and conditions of this Declaration to Sacramento County.

10. **Recording of Agreement:** This Declaration shall be recorded in the Office of the Recorder of Sacramento County, California and shall constitute notice to all successors and assigns of the title to the Subject Property of the rights and obligations herein set forth.

11. **Amendment**: This Declaration may be amended by Declarant, but only if in writing, and only after written approval of Sacramento County.

IN WITNESS WHEREOF, Declarant has executed this Declaration as of the day and year written above.

DECLARANT:

By: ______________________________

Its: ______________________________

[*attach*]

DECLARANT’S ACKNOWLEGEMENT

Exhibit “A” Legal Description of Subject Property
Exhibit “B” Plat of Subject Property
Exhibit “C” Device Maintenance Requirements
Exhibit “D” Device Monitoring Requirements

Example Maintenance Agreement
(City of Sacramento)

The following information is presented for example purposes only and may not be the current version. The other permitting agencies in the region may use different forms. Contact the permitting agency for your project to obtain their current form.

Recorded at the request of:
CITY OF SACRAMENTO
DEPARTMENT OF UTILITIES
No Fee per Government Code 6130

____

After recording, return to:
Office of the City Clerk
Historic City Hall
915 "I" Street, 1st Floor
Sacramento CA 95814

STORMWATER TREATMENT DEVICE
ACCESS AND MAINTENANCE AGREEMENT

OWNER: ____

PROPERTY ADDRESS: ____

APN: ____________________

THIS AGREEMENT is made and entered into in Sacramento, California, this _______ day of ________________ 20___, by and between ________________________________("Owner"), and the CITY OF SACRAMENTO, a municipal corporation ("City").

WHEREAS, the Owner owns real property (the "Property") in the City of Sacramento, County of Sacramento, 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; and

WHEREAS, at the time of initial approval of the development project on the Property known as _________________________________, the City's conditions of approval included a requirement for the Project to employ on-site control measures to minimize pollutants in urban runoff; and

WHEREAS, the Owner has chosen to install a __________________________________ (the "Device"), as the on-site control measure to minimize pollutants in urban runoff; and

WHEREAS, the Device has been installed in accordance with plans and specifications accepted by the City; and

WHEREAS, the Device, with installation on private property and draining only private property, is a private facility and all maintenance or replacement of the Device is the sole responsibility of the Owner in accordance with the terms of this Agreement; and

WHEREAS, the Owner is aware and agrees that periodic and continuous maintenance, including, but not necessarily limited to, filter material replacement and sediment removal, is required to assure peak performance of the 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 foregoing recitals are incorporated herein by this reference.

2. Owner hereby provides the City or City's designee complete access to the Device and its immediate vicinity at any time and for any duration, upon twenty-four (24) hour advance notice in writing, for the purpose of inspection, sampling and testing of the Device. 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. If 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 (but shall not have any obligation) to cause any maintenance necessary to be done and charge the entire cost to the Owner or Owner's successors or assigns, including administrative costs and interest thereon at the maximum rate authorized by the Civil Code from the date of notice of the cost until paid in full.

5. The City may require the Owner to post security in a form and for a time period satisfactory to the City, to guarantee performance of the obligations stated herein. Should the Owner fail to perform its obligations as required under this Agreement, the City may, in the case of a cash deposit or letter of credit, use the proceeds to pay costs incurred by the City to take any action(s) authorized by this Agreement, or in the case of a surety bond, the City may require the sureties to perform the Owner's obligations under the Agreement.

6. This Agreement shall be recorded in the Office of the Recorder of Sacramento County, California, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to the Property of the obligations herein set forth, and also a lien in such amount as will fully reimburse the City for costs incurred pursuant to Section 4, above, including interest as hereinabove set forth, subject to foreclosure in event of default in payment.

7. In the event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner, on behalf of itself 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 further agrees that the same shall become a part of the lien against the Property.

8. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with the Property and constitute a lien against the Property.

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 any part of the Property of 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. If an Owner shall convey all of its interest in the Property, the Owner shall be released from any obligations arising under this Agreement in connection with the maintenance of or failure to maintain the Device occurring after the date of such conveyance.

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.

12. If Owner consists of more than one party, each person, entity or other party described as the "Owner" in the first paragraph of this Agreement and/or executing this Agreement for Owner shall be jointly and severally liable for each and every obligation and requirement imposed on Owner herein.

IF TO CITY:

Director of Utilities – Stormwater Program
City of Sacramento, Department of Utilities
1395 35th Avenue
Sacramento, CA 95822

IF TO OWNER:

____
____
____
____

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

APPROVED AS TO FORM:

____
City Attorney

CITY OF SACRAMENTO:

____
Gary Reents,
Director, Department of Utilities

ATTEST:

____
City Clerk Date

OWNER:

____
Signature of Authorized Person

Print Name: ____________________
Title: __________________________

OWNER (if Necessary):

____
Signature of Authorized Person

Print Name: ____________________
Title: __________________________

NOTARIES ON FOLLOWING PAGE

EXHIBIT A
[Legal Description]

EXHIBIT B
[Map/Illustration]

Appendix C

Connecting to the Sanitary Sewer System: General Information

Unincorporated Sacramento County and the Cities of Citrus Heights, Elk Grove, Folsom and Rancho Cordova

Sanitary sewer collection service is provided by County Sanitation District 1 (CSD-1); all wastewater is treated by the Sacramento Regional County Sanitation District (SRCSD) at the Sacramento Regional Wastewater Treatment Plant (SRWTP) in Elk Grove.[1]

To install or replace sewer pipelines for new business or residence, both a building permit and a sewer impact (connection) permit will be required. If public right of way or publicly owned property will be used, an encroachment permit will be required. Building and encroachment permits are issued by the County for the unincorporated area or by the applicable city. The sewer connection permit is issued by CSD-1. The purposes of these permits are to ensure that plumbing is installed safely and legally and that everyone pays their fair share of the cost to construct the wastewater collection and treatment system (pipelines and treatment plant). Permits are not required for "spot repairs" (such as line replacement under 10 feet in length, or cleanout installation).

Sewer impact (connection) fees must be calculated by the CSD-1/SRCSD Permit Services Unit. Refer to CSD-1's web site (www.csd-1.com) or SRCSD's website at *www.srcsd.com* and call 876-6100 for a fee quote.

A $45 inspection fee will be collected at the time of permit issuance for all pipes within the County of Sacramento.

City of Sacramento

Sanitary sewer collection service is either provided by the City of Sacramento or CSD-1, depending on the service area. Within the City's service area, the City operates a combined sewer system (CSS) that collects both sewage and drainage for the area. Wastewater treatment for these areas is provided by the SRCSD.

All development projects within the City will be charged sewer impact fees:

- For projects served by the City-owned collection system, the project will be charged a City sewer/CSS development fee and must pay the SRCSD sewer impact fee (connection fee). The City's development fee will be charged through the City's building permit process.
- For projects served by CSD-1, the project must pay the CSD-1 and SRCSD sewer impact (connection) fees.

[1] CSD-1 covers sewer service from a residence or business (via what CSD calls the "little pipes") to SRCSD's "Interceptor System" (the "big pipes") that connect to the Sacramento Regional Wastewater Treatment Plant.

City of Folsom

The City of Folsom owns and operates its own sanitary sewer collection system which eventually ties into to SRCSD’s interceptor system and is treated by the SRCSD at their plant in Elk Grove.

Development projects in Folsom will be charged a City connection/impact fee and the SRCSD treatment fee.

City of Galt

Sanitary sewer collection service and wastewater treatment is provided by the City of Galt. Proposed sanitary sewer connections must be identified during the project application stage and will be reviewed on a case by case basis by the City's Public Works Department. Contact the City of Galt Public Works Department at (209) 366-7280.

City of Roseville

Sanitary sewer collection service and wastewater treatment is provided by the City of Roseville. Proposed sanitary sewer connections must be identified during the project application stage and will be reviewed on a case by case basis by the City's Environmental Utilities Department. Contact the Environmental Utilities Department Engineering Division at (916) 774-5751.

Appendix D

Runoff Reduction Credits Calculations Worksheets

Appendix D-1: Residential Sites: Runoff Reduction Credits and Treatment BMP Sizing Calculations

Name of Drainage Shed: ____________________

Project Located in ____________________

Fill in Highlighted Boxes

Step 1 - Calculate Area Requiring Treatment

Drainage Shed Area			acres	A
Open Space and Parks Acreage*				A_{OS}
Treatment Area	$A - A_{OS} =$	0.0		A_T
Number of Units in A_T				
Number of units per acre in A_T	$DU/A_T =$	0		
Assumed Initial Impervious Fraction (determine using Table D-1a)		#N/A		I

See Area Example Below

*. Includes all areas maintained in a natural state and planned for landscaped park areas

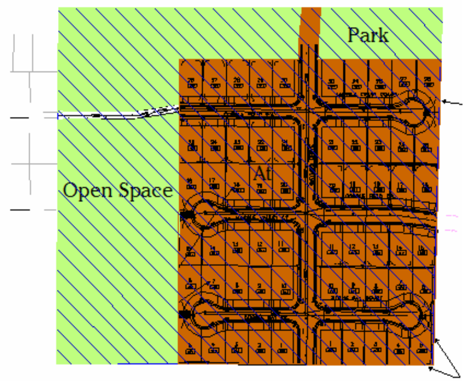
Table D-1a

Dwelling units per acre	Imperviousness
1	0.17
2	0.25
3,4	0.35
5,6	0.40
7	0.50
8,9	0.55
10-14	0.60
15-20	0.70

A - Drainage Shed Area

A_{OS} - Parks and Open Space

A_T - Area with Runoff Reduction Potential



Step 2 - Calculate Impervious Area Treatments

Runoff Reduction Measures			Effective Area Managed (A_C)	
Disconnected Roof Drains (see Fact Sheet)	use Form D-1a for credits	→	0.00	acres
Disconnected Pavement (see Fact Sheet)	use Form D-1b for credits	→	0.00	acres
Interceptor Trees (see Fact Sheet)	use Form D-1c for credits	→	0.00	acres
Alternative Driveway Design (see Fact Sheet)	use Form D-1d for credits	→	0.00	acres
Total Effective Area Managed (Credit Area)		A_C	0.00	acres

Adjusted Area for Flow-Based Treatment	$A_T - A_C =$	0.00	acres	A_{AT}
Adjusted Impervious Fraction for A	$(A_T(I) - A_C) / A =$	0.00		I_A

Form D-1a: Disconnected Roof Drains Worksheet

See Fact Sheet for more information regarding Disconnected Roof Drain credit guidelines

Effective Area Managed (A_C)

1. Determine efficiency Multiplier

Runoff is directed to a dispersal trench or dry well (Type A and B soils only) — 1.00

Runoff is directed across landscaping, determine setback

25 ft +	Use multiplier of	1.00
$\geq$ 20 and < 25 ft	Use multiplier of	0.90
$\geq$ 15 and < 20 ft	Use multiplier of	0.70
$\geq$ 10 and < 15 ft	Use multiplier of	0.45
$\geq$ 5 and < 10 ft	Use multiplier of	0.25

Efficiency Multiplier → [ ] Box J1

2. Determine percentage of roof drains disconnected → [ ] Box J2

3. Select project density in dwelling units per acre:

1	Use reduction factor of	0.08
2	Use reduction factor of	0.13
3,4	Use reduction factor of	0.19
5,6	Use reduction factor of	0.23
7	Use reduction factor of	0.29
8,9	Use reduction factor of	0.33
10-14	Use reduction factor of	0.37
15-20	Use reduction factor of	0.44

Reduction Factor → 0.00 Box J3

4. Determine Area Managed

Multiply Box J3 by A_T, and enter the result in Box J4 — 0.0 acres Box J4

5. Multiply Boxes J1, J2 and J4, and enter the Result in Box J — 0.0 acres Box J

This is the amount of area credit to enter into the "Disconnected Roof Drains" Box of Form D-1

Form D-1b: Disconnected Pavement Worksheet

See Fact Sheet for more information regarding NDC Pavement credit guidelines

Effective Area Managed (A_C)

Divided Sidewalks

1. Determine percentage of units with divided Sidewalks — [ ] Box K1

Multiply Box K1, A_T, and 0.04 and enter the result in Box K — 0.00 acres Box K

This is the amount of area credit to enter into the "Disconnected Pavement" Box of Form D-1

Form D-1c: Interceptor Tree Worksheet

See Fact Sheet for more information regarding Interceptor Tree credit guidelines

Effective Area Managed (A_C)

New Evergreen Trees

1. Enter number of new evergreen trees that qualify as Interceptor Trees in Box L1. — [ ] trees Box L1
2. Multiply Box L1 by 200 and enter result in Box L2 — 0 sq. ft. Box L2

New Deciduous Trees

3. Enter number of new deciduous trees that qualify as Interceptor Trees in Box L3. — [ ] trees Box L3
4. Multiply Box L3 by 100 and enter result in Box L4 — 0 sq. ft. Box L4

Existing Tree Canopy

5. Enter square footage of existing tree canopy that qualifies as Existing Tree canopy in Box L5. — [ ] sq. ft. Box L5
6. Multiply Box L5 by 0.5 and enter the result in Box L6 — 0 sq. ft. Box L6

Total Interceptor Tree Credits

Add Boxes L2, L4, and L6 and enter it into Box L7 — 0 sq. ft. Box L7

Divide Box L7 by 43,560 to get the number of acres effectively managed and enter the result in Box L8 — 0.00 acres Box L8

This is the amount of area credit to enter into the "Interceptor Trees" Box of Form D-1

Form D-1d: Alternative Driveway Design

See Fact Sheet for more information regarding Alternative Driveway Design credit guidelines

1. Select type of driveway

Pervious Driveway:	Multiplier:
Cobblestone Block Porous Pavement	0.40
Pervious Concrete/Asphalt Pavement	0.60
Modular Block Porous Pavement Porous Gravel Pavement & Hollywood Driveway	0.75
Not Directly-connected Driveway	1.00

[ ] Box M1

2. Determine percentage of units with Alternative Driveways: [ ] Box M2

4. Multiply Boxes M1, M2, A_T and 0.04, and enter the result in Box M
This is the amount of area credit to enter into the "Alternative Driveway Design" Box of Form D-1

0.00 acres Box M

Step 3 - Calculate Flow or Volume Requiring Treatment

Form D-1e Treatment - Flow-Based (Rational Method)

Calculate treatment flow (cfs): Flow = Runoff Coefficient x Rainfall Intensity x Adjusted Treatment Area

Determine C Factor using Table D-1b [ ] C

Determine i using Table D-1c (Rainfall Intensity) select location in part 1 i

A_{AT} from Step 2 0.00 A_{AT}

Flow = C * i * A_{AT} 0.00 cfs

TABLE D-1b

Runoff Coefficient (Rational), C	
Single-family areas	0.50
Multi-units, detached	0.60
Apartment dwelling areas	0.70
Multi-units, attached	0.75
User Specified	0.00

Table D-1c

Rainfall Intensity			
Roseville	i =	0.20	in/hr
Sacramento	i =	0.18	in/hr
Folsom	i =	0.20	in/hr

Form D-1f Treatment - Volume-Based (CASQA)

Skip this, use Form D-1g for volume calculations

Calculate treatment volume (Acre-Feet): Treatment Volume = Area x (Storage Volume ÷ Conversion Factor)

Determine Adjusted C_A using Table D-2d (for CASQA Method) and the Adjusted Impervious Fraction (I_A) from Step 2 0.04 C_A [ ] hrs Specified Draw Down time

Determine Unit Basin Storage Volume (Fig. D-2A) using C_A 0.03 SV

A from Step 1 0.00 A

Treatment volume = A_T x (SV / 12) 0.00 Acre-Feet

Form D-1g Treatment - Volume-Based (ASCE-WEF)

Calculate water quality volume (Acre-Feet): WQV = Area x Maximized Detention Volume (P_0)

A from Step 1 0.00 A [ ] hrs Specified Draw Down time

Obtain P_0: Maximized Detention Volume from figures E-1 to E-4 in Appendix E of this manual using I_A from Step 2. #N/A P_0

Treatment volume = A x (P_0 / 12) 0.00 Acre-Feet

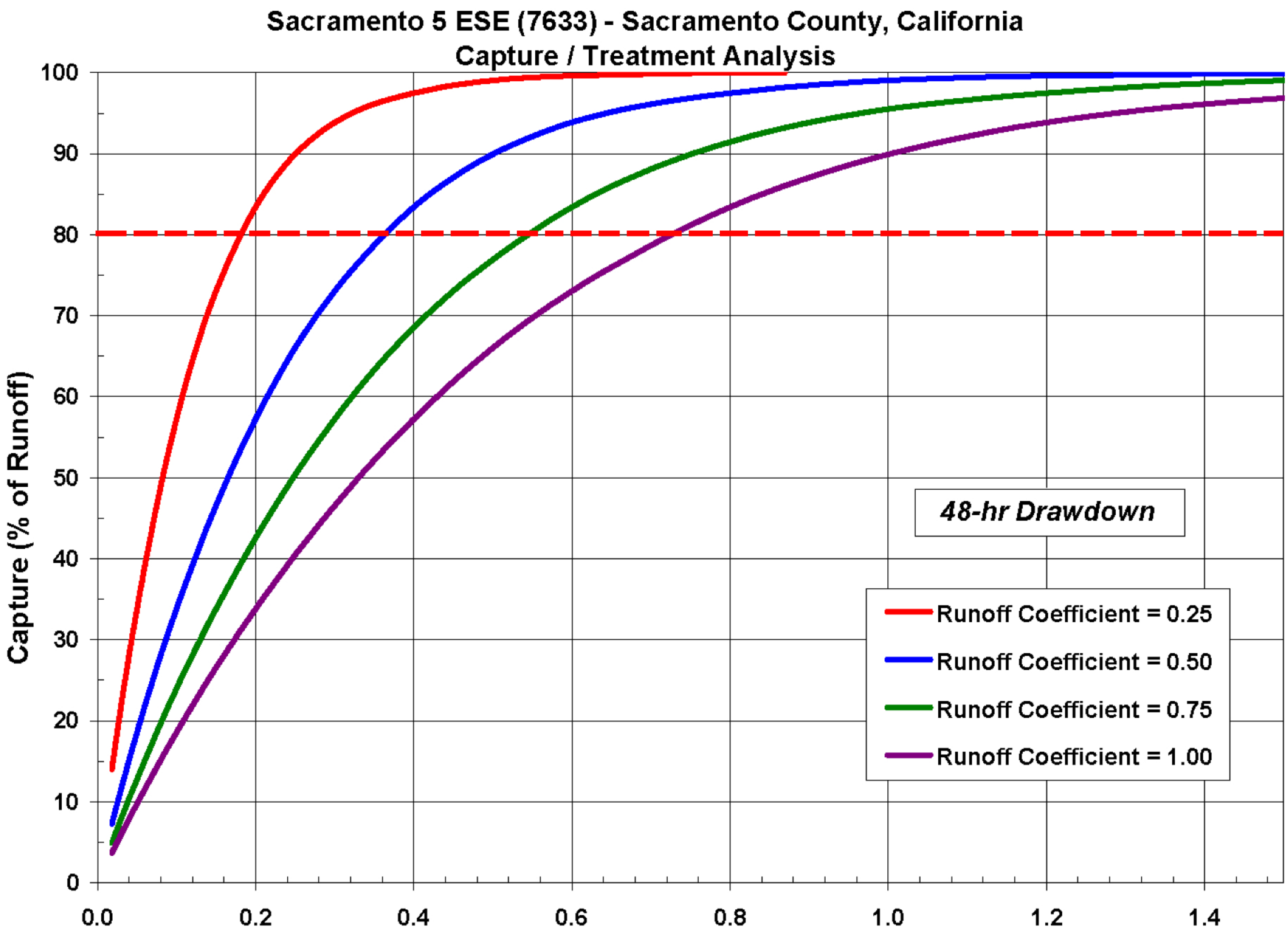


Figure D-1A. Unit Basin Storage Volume (inches)

Appendix D-2: Commercial and Multi-Family Sites*: Runoff Reduction Credits and Treatment BMP Sizing Calculations

Name of Drainage Shed: ______

Location of project: ______

Fill in Higlighted boxes

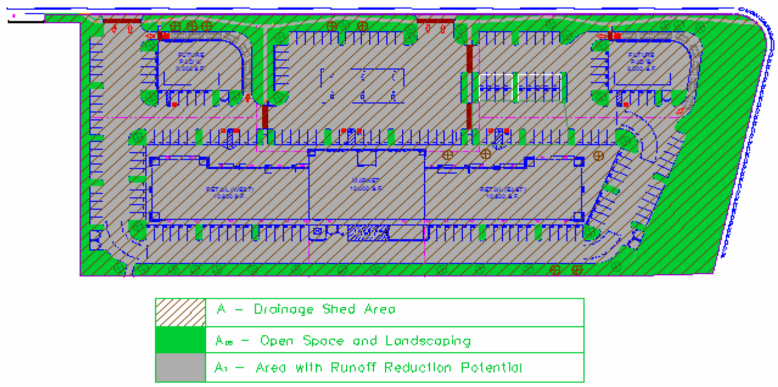
Step 1 - Calculate Area Requiring Treatment

Drainage Shed Area			acres	A
Open Space Acreage and Landscaped Areas**			acres	A_{OS}
Area with Runoff Reduction Potential	$A - A_{OS}$ =	0.00	acres	A_T
Assumed Initial Impervious Fraction	A_T / A =	0.00		I

see area example below

*. Includes apartments, condominiums, and townhouses

**. Includes all areas maintained in a natural state and planned for landscaping



Step 2 - Calculate Impervious Area Treatments

Runoff Reduction Treatments	Impervious Area Managed			Efficiency Factor		Effective Area Managed (A_C)	
Porous Pavement:							
Option 1: Porous Pavement (see Fact Sheet, excludes porous pavement used in Option 2)		acres	x		=	0.000	acres
Option 2: Disconnected Pavement use Form D-2a for credits → (see Fact Sheet, excludes porous pavement used in Option 1)						0.00	acres
Landscaping used to Disconnect Pavement (see Fact Sheet)		acres			=	0.00	acres
Disconnected Roof Drains (see Fact Sheet and/or Table D-2b for summary of requirements)		acres			=	0.00	acres
Ecoroof (see Fact Sheet)		acres			=	0.00	acres
Interceptor Trees use Form D-2b for credits → (see Fact Sheet)						0.00	acres
Total Effective Area Managed				A_C		0.00	acres
Adjusted Area for Flow-Based Treatment	$A_T - A_C$ = 0.00			A_{AT}			
Adjusted Impervious Fraction	A_{AT} / A = 0.00			I_A			

Table D-2a

Porous Pavement Type	Efficiency Multiplier
Cobblestone Block Pavement	0.40
Pervious Concrete/Asphalt Pavement	0.60
Modular Block Pavement & Porous Gravel Pavement	0.75
Reinforced Grass Pavement	1.00

Table D-2b

Maximum roof size	Minimum travel distance
≤ 3,500 sq ft	21 ft
≤ 5,000 sq ft	24 ft
≤ 7,500 sq ft	28 ft
≤ 10,000 sq ft	32 ft

Form D-2a: Disconnected Pavement Worksheet

See Fact Sheet for more information regarding Disconnected Pavement credit guidelines

Effective Area Managed (A_C)

Pavement Draining to Porous Pavement

2. Enter area draining onto Porous Pavement [ ] acres Box K1

3. Enter area of Receiving Porous Pavement [ ] acres Box K2
(excludes area entered in Step 2 under Porous Pavement)

4. Ratio of Areas (Box K1 / Box K2) 0.00 Box K3

5. Select multiplier using ratio from Box K3 and enter into Box K4

Ratio (Box D)	Multiplier
Ratio is ≤ 0.5	1.00
Ratio is > 0.5 and < 1.0	0.83
Ratio is > 1.0 and < 1.5	0.71
Ratio is > 1.5 and < 2.0	0.55

1 Box K4

6. Enter Efficiency of Porous Pavement (see table below) [ ] Box K5

Porous Pavement Type	Efficiency Multiplier
Cobblestone Block Pavement	0.40
Pervious Concrete Asphalt Pavement	0.60
Modular Block Pavement Porous Gravel Pavement	0.75
Reinforced Grass Pavement	1.00

7. Multiply Box K2 by Box K5 and enter into Box K6 0.00 acres Box K6

8. Multiply Boxes K1,K4, and K5 and enter the result in Box K7 0.00 acres Box K7

9. Add Box K6 to Box K7 and enter the Result in Box K8 0.00 acres Box K8
This is the amount of area credit to enter into the "Disconnected Pavement" Box of Form D-2

Form D-2b: Interceptor Tree Worksheet

See Fact Sheet for more information regarding Interceptor Tree credit guidelines

New Evergreen Trees

1. Enter number of new evergreen trees that qualify as Interceptor Trees in Box L1. [ ] trees Box L1

2. Multiply Box L1 by 200 and enter result in Box L2 0 sq. ft. Box L2

New Deciduous Trees

3. Enter number of new deciduous trees that qualify as Interceptor Trees in Box L3. [ ] trees Box L3

4. Multiply Box L3 by 100 and enter result in Box L4 0 sq. ft. Box L4

Existing Tree Canopy

5. Enter square footage of existing tree canopy that qualifies as Existing Tree canopy in Box L5. [ ] sq. ft. Box L5

6. Multiply Box L5 by 0.5 and enter the result in Box L6 0 sq. ft. Box L6

Total Interceptor Tree EAM Credits

Add Boxes L2, L4, and L6 and enter it into Box L7 0 sq. ft. Box L7

Divide Box L7 by 43,560 to get the number of acres effectively managed and enter the result in Box L8 0.00 acres Box L8

This is the amount of area credit to enter into the "Interceptor Trees" Box of Form D-2

Step 3 - Calculate Flow or Volume Requiring Treatment

Form D-2c Treatment - Flow-Based (Raional Method)

Calculate treatment flow (cfs): Flow = Runoff Coefficient x Rainfall Intensity x Area

Look up value for i in Table D-2c (Rainfall Intensity)	select a location on page 1	i
Obtain A_{AT} from Step 2	0.00	A_{AT}
Use C = 0.95	0.95	C
Flow = 0.95 * i * A_{AT}	#VALUE!	cfs

Table D-2c

Rainfall Intensity			
Roseville	i =	0.20	in/hr
Sacramento	i =	0.18	in/hr
Folsom	i =	0.20	in/hr

Form D-2d Treatment - Volume-Based (CASQA)

do not use form D-2d contiue to form D2-e

Calculate treatment volume (Acre-Feet): Treatment Volume = Area x (Storage Volume ÷ Conversion Factor)

Determine Adjusted C_A using Table D-2d (for CASQA Method) and the Adjusted Impervious Fraction (I_A) from Step 2	0.04	C_A
Determine Unit Basin Storage Volume (Figure D-2a) using C_A	0.03	SV
A from Step 1	0.00	A
Treatment volume = A x (SV / 12)	0.00	Acre-Feet

Form D-2e Treatment - Volume-Based (ASCE-WEF)

Calculate water quality volume (Acre-Feet): WQV = Area x Maximized Detention Volume (P_0)

Obtain A from Step 1	0.00	A	hrs	Specified Draw Down time
Obtain P_0: Maximized Detention Volume from figures E-1 to E-4 in Appendix E of this manual using I_A from Step 2.	#N/A	P_0		

Calculate treatment volume (acre-ft):

Treatment volume = A x (P_0 / 12)	#N/A	Acre-Feet

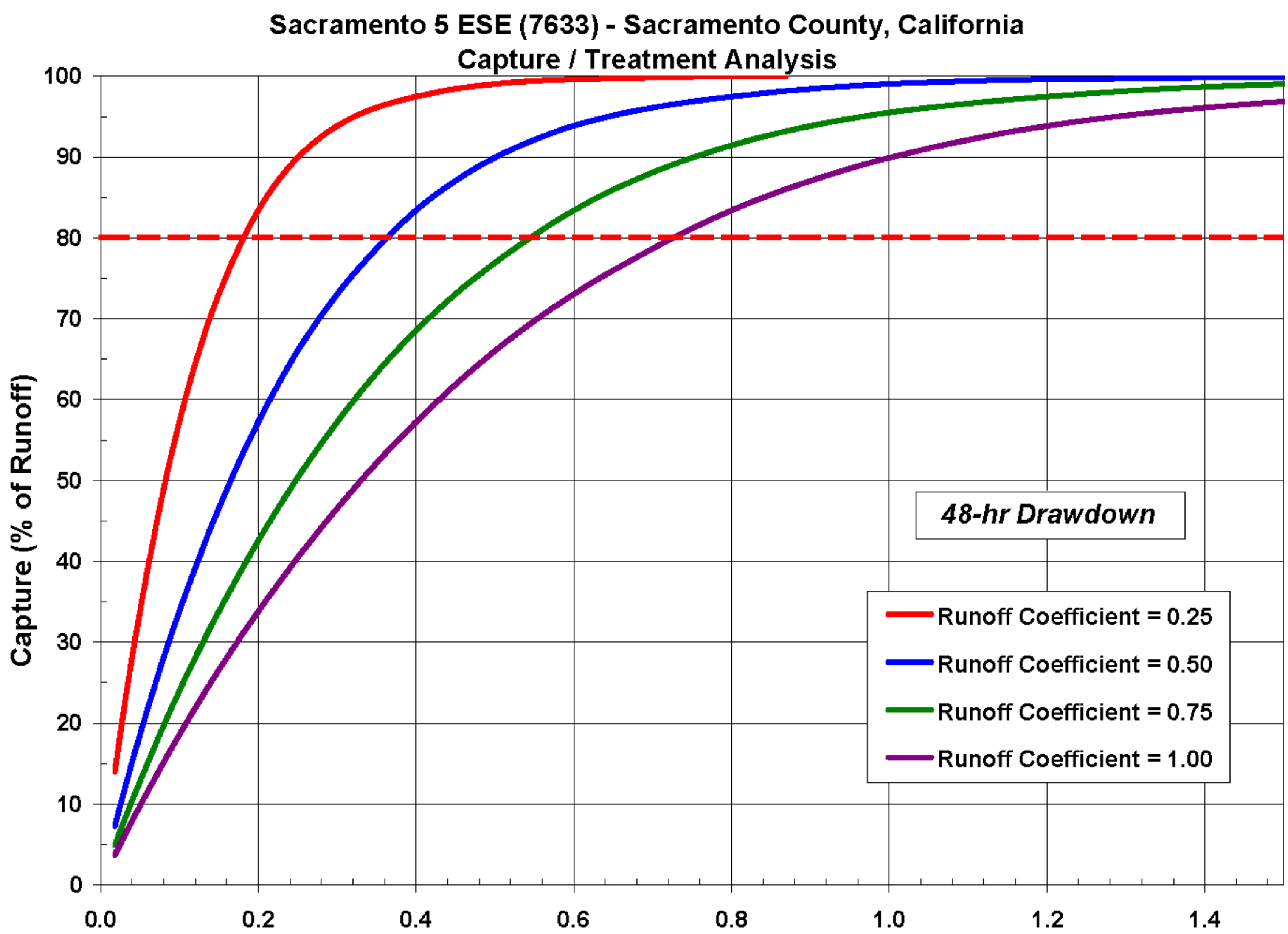


Figure D-2A. Unit Basin Storage Volume (inches)

Appendix D-3

Runoff Reduction Credit Criteria

The following series of tables presents information related to calculating runoff reduction credits for the control measures presented in Chapter 5 of the Design Manual.

Runoff Reduction Credits for Porous Pavement

This table refers to runoff reduction credit worksheets/forms which can be found in Appendix D-1 and D-2 of this Design Manual. Efficiency multipliers were taken from Denver manual.

Pavement Type	Applications and Runoff Reduction Credits
Pervious Concrete or Asphalt	Residential - Runoff Reduction Credits can be obtained for use of these materials in driveways (see Alternative Driveways Fact Sheet). The credit calculation is simplified in Appendix D-1.
	Commercial - Runoff Reduction Credits can be obtained for the use on any appropriate commercial surface. Credits are calculated using an efficiency multiplier of 60%. The credit calculation is simplified in Appendix D-2.
Modular Block Pavement	Residential - Runoff Reduction Credits can be obtained for use of modular block in driveways (see Alternative Driveways Fact Sheet). The credit calculation is simplified in Appendix D-1. Credits can be obtained for use of modular block in other areas of residential development where surfaces which would otherwise be impervious are substituted with MBP. Use an efficiency multiplier of 75%
	Commercial - Runoff Reduction Credits can be obtained for the use of modular block on any appropriate commercial surface. Credits are calculated using an efficiency multiplier of 75%. The credit calculation is simplified in Appendix D-2.
Reinforced Grass Pavement	Residential - Runoff Reduction Credits can be obtained for use of reinforced grass pavement in residential development where surfaces which would otherwise be impervious are substituted with reinforced grass pavement. Use an efficiency multiplier of 100%.
	Commercial - Runoff Reduction Credits can be obtained for the use of reinforced grass pavement on any appropriate commercial surface. Credits are calculated using an efficiency multiplier of 100%. This calculation is simplified in Appendix D-2.
Cobblestone Block Pavement	Residential - Runoff Reduction Credits can be obtained for use of cobblestone block pavement in driveways (see Alternative Driveways Fact Sheet). The credit calculation is simplified in Appendix D-1. Credits can be obtained for use of cobblestone block pavement in other areas of residential development where surfaces which would otherwise be impervious are substituted with cobblestone block pavement. Use an efficiency multiplier of 40%.
	Commercial - Runoff Reduction Credits can be obtained for the use of cobblestone block pavement on any appropriate commercial surface. Credits are calculated using an efficiency multiplier of 40%. This calculation is simplified in Appendix D-2.
Porous Gravel Pavement	Residential - Runoff Reduction Credits can be obtained for use of porous gravel pavement in residential development where surfaces which would otherwise be impervious are substituted with porous gravel pavement. Use an efficiency multiplier of 75%.
	Commercial - Runoff Reduction Credits can be obtained for the use of porous gravel pavement on any appropriate commercial surface. Credits are calculated using an efficiency multiplier of 75%. This calculation is simplified in Appendix D-2.

Runoff Reduction Credits for Disconnected Pavement

Efficiency multipliers were taken from Denver manual.

Variation/ Application	Runoff Reduction Credits
Pavement Draining to Landscaping	
Residential	Runoff Reduction Credits can be obtained for disconnection of sidewalks (simplified in Appendix D-1, Form D-1b) and driveways (see Alternative Driveways Fact Sheet, simplified in Form D-1d).
Commercial	Runoff Reduction Credits can be obtained for use of landscaping to disconnect impervious surfaces. Credit can apply to 100% of up to 1000 square feet of pavement draining to each properly designed vegetated area. (Source: Contra Costa Clean Water Program)
Pavement Draining to Porous Pavement (Source: Denver)	
Commercial	Runoff Reduction Credits can be obtained for disconnected impervious surfaces with the amount of credit dependent on the ratio of impervious surfaces to pervious surfaces. More credit is given for lower ratios. If the impervious surface area equals no more than half the area of the porous surface, then credit is given for the entire impervious surface. As the ratio increases above 0.5, the treatment provided is decreased resulting in a lower infiltration factor. Credit is not given for ratios above 2.0. Credit allowed for specific impervious/pervious ratios are listed below:

Impervious Area / Porous Area Ratio	Efficiency Multiplier
≤0.5	1.00
0.5 - 1.0	0.83
1.0 - 1.5	0.71
1.5 - 2.0	0.55

The efficiency of the porous pavement in infiltrating sheet flow is dependent on the type of pavement used. The following are the efficiency factors for different pavement types:

Porous Pavement Type	Efficiency Multiplier
Modular Block Pavement	0.75
Cobblestone Block Pavement	0.40
Reinforced Grass Pavement	1.00
Poured Porous Concrete Pavement	0.60
Porous Gravel Pavement	0.75

These tables refer to runoff reduction credit worksheets/forms which can be found in Appendix D-1 and D-2 of this Design Manual.

Runoff Reduction Credits for Alternative Driveways

Variation	Applications and Runoff Reduction Credits
Pervious Driveway	Residential — credits can be applied for the entire driveway surface when approved materials and specifications are used in accordance with the Design Requirements. Use Appendix D-1.
Hollywood Driveway	Residential — an efficiency multiplier of 75% of the driveway area when approved materials and specifications are used in accordance with the Design Requirements. Use Appendix D-1.
Disconnected Driveway	Residential — credits can be for the entire driveway surface when designed according to this fact sheet. Use Appendix D-1.
Shared Driveway	Residential — credits vary according to design. Consult municipal engineer

Runoff Reduction Credits for Disconnected Roof Drains

Variation	Applications and Runoff Reduction Credits
Splash Block/Pop-up Drainage Emitter	
Residential	Credit may be given for each disconnected roof drain with the amount of credit dependent upon building set back. This calculation is simplified in Appendix D-1.
Commercial	Credit may be given for each disconnected roof drain meeting the design requirements. The credit calculation is simplified in Appendix D-2.
Dispersal Trench and Dry Well	
Residential	Credit may be given for each disconnected roof drain meeting the design requirements. The credit calculation is simplified in Appendix D-1.
Commercial	Credit may be given for each disconnected roof drain meeting the design requirements. The credit calculation is simplified in Appendix D-2.

Runoff Reduction Credits for Interceptor Trees

Variation	Applications and Runoff Reduction Credits
All Planted Trees	Residential - Credit may be given for each new tree planted in the municipal right-of-way. Consult municipality about the possibility of credits for trees outside of the municipal right-of-way. This calculation is simplified in Appendix D-1.
	Commercial - Credit may be given for each new tree planted within 25 feet of ground level impervious surfaces. 25% of trees already required by zoning can be used for Interceptor Tree credits. This calculation is simplified in Appendix D-2.
New Evergreen Trees	200 square feet of credit
New Deciduous Trees	100 square feet of credit
Existing Trees	The Runoff Reduction Credit, as applied to existing trees, is calculated by identifying the square-footage equal to one-half of the existing tree canopy, measured within the drip line. The resulting square footage divided by the total site square footage is equal to the IRP. This calculation is simplified in Appendix D-1 and D-2.

*Trees required by the municipality as mitigation for other trees lost on the project will not count toward Runoff Reduction Credit

Trees Qualifying for Interceptor Tree Runoff Reduction Credits*

			Mature Tree		
Common Name	**Botanical Name**	**Type****	**Shape (max.)**	**Canopy (dia.)**	**Height**
American Chestnut	*Castanea dentata*		Oval to rounded or wide spreading	40-60'	80-120'
American Hornbeam	*Carpinus caroliniana*		Vase-shaped	20-30'	25-30'
American Linden	*Tilia americana*		Oval and informal	30-60'	60-80' (100')
American Sweet Gum	*Liquidambar styraciflua*		Conical	20-40'	45-65'
Amur Maackia	*Maackia amurensis*		Vase-shaped	15-20'	20-30'
Amur Maple	*Acer tataricum ginnala*		Rounded	15-20'	20'
Arizona Cypress	*Cupressus arizonica*	**E**	Conical to vase	25-30'	40-50'
Atlas (Blue) Cedar	*Cedrus atlantica*	**E**	Flat-topped, loose, open and spreading	30-40'	40-60' (120')
Autum Blaze Maple	*Acer fremanii 'Autumn Blaze'*		Oval	50'	50'
Bald Cypress	*Taxodium distichum*		Oval at maturity, uniform	20-30'	50-70' (100')
Bechtel Crabapple	*Malus ioensis 'Plena'*		Broad-rounded	20'	25'
Bigleaf Maple	*Acer macrophyllum*	**N**	Broad-rounded	30-75'	45-75' (100')
Blue Oak	*Quercus douglasii*	**N P**	Rounded umbrella	50-80'	50-60'
Burr Oak	*Quercus macrocarpa*		Broad-rounded	75-85'	70-80'
California Bay	*Umbellularia californica*	**EN**	Round	30'	25'
California Black Oak[a]	*Quercus kelloggii*	**N**	Vase	30-60'	30-80'
Callery Pear	*Pyrus calleryana*		Oval	25'	40'
Canary Island Date Palm	*Phoenix canariensis*	**E**	Round head	25-30'	60'
Canary Island Pine	*Pinus canariensis*	**E**	Pyramidal	25-35'	60-80'
Canyon Live Oak	*Quercus chrysolepis*	**E N**	Broad-rounded	50-70'	50-75'
Carob	*Ceratonia siliqua*	**E**	Broad to wide-rounded	30-45'	30-40'
Carolina Laurel Cherry	*Prunus caroliniana*	**E**	Irregular rounded	15-25'	20-30' (40')
Chaste Tree	*Vitex agnus-castus*		Rounded	15-20'	20-25'
Chestnut-Leafed Oak	*Quercus castaneafolia*		Broad and rounded	50-60'	70-90'
Chinese Evergreen Elm	*Ulmus parvifolia*		Rounded	40-50'	40-50' (70')
Chinese Fringe Tree	*Chionanthus retusus*		Rounded	20-25'	20-25'
Chinese Hackberry	*Celtis sinensis*		Rounded	50-60'	40-80'
Chinese Pistache	*Pistacia chinensis*		Broad-rounded	25-35'	30-35' (50')
Chinese Wingnut	*Pterocarya stenoptera*		Broad-rounded	30-40'	40-90'
Coast Live Oak	*Quercus agrifolia*	**EN**	Rounded	60'	40'
Coast Redwood	*Sequoia sempervirens*	**E**	Narrow pyramidal to wide conical	50-60'	350'
Colorado Spruce	*Picea pungens*	**E**	Narrow pyramidal to broad conical	10-20'	30-60' (135')
Common Horsechestnut	*Aesculus hippocastanum*		Pyramidal to oval	40-70'	50-75' (100'+)
Coolibah	*Eucalyptus microtheca*		Round head	30'	25-50'
Cork Oak	*Quercus suber*	**E**	Rounded	35-45'	70-100'
Crabapple 'Prariefire"	*Malus ioensis 'Prariefire'*		Broad-rounded	15-20'	25'
Crape Myrtle (Tree Form, some are large shrubs)	*Lagerstroemia hybrids*		Broad-rounded	15-20'	6-30'
Crimson Sentry Maple	*Acer platanoides 'Crimson Sentry'*		Oval	40'	40'
Dawn Redwood	*Metasequoia glyptostroboides*		Conical to narrow pyramidal and formal	25-35'	80-90' (120')
Deodar Cedar	*Cedrus deodara*	**E**	Wide and slightly flat-topped	30-60'	40-70' (200')

Common Name	Botanical Name	Type**	Mature Tree Shape (max.)	Canopy (dia.)	Height
Douglas Fir	*Pseudotsuga menziesii*	**E N**	Broadly cylindrical	30-40'	40-80' (200')
Eastern Dogwood	*Cornus florida*		Broad-rounded	15-20'	20-25'
Eastern Redbud	*Cercis canadensis*		Rounded	25-35'	20-30'
English Hawthorn 'Paul's Scarlet'	*Crataegus laevigata 'Paul's Scarlet'*		Vase-shape	20-25'	18-25'
English Oak	*Quercus robur*			50'	50'
European Beech	*Fagus sylvatica*		Oval to rounded	35-45'	50-60' (100')
European Hackberry	*Celtis australis*		Rounded	50-60'	40-80'
European Hornbeam	*Carpinus betulus 'Fastigiata'*		Broad oval-vase shaped	20-30'	40'
Evergreen Ash	*Fraxinus uhdei*	**E**	Round head	70'	40'
Flannel Bush	*Fremontodendron californicum*	**E**	Flat-topped Vase	20-25'	20-25'
Forest Green Oak	*Quercus frainetto 'Forest Green'*		Rounded	30'	50'
Formosan Flame	*Koelreuteria elegans*		Broad rounded	35'	35'
Fragrant Snowbell	*Styrax obassia*		Rounded	15-20'	20-30'
Frontier Elm	*Ulmus 'Frontier'*			30'	40'
Ginkgo Biloba (Male Only)	*Ginkgo biloba*		Wide rounded-pyramidal	30-40'+	35-80' (100')
Golden Flame Tree	*Koelreuteria bipinnata*		Rounded	15-25'	20-40'
Goldenchain Tree	*Laburnum anagyroides*		Oval to round-headed	15-20'	20-30'
Goldenrain Tree	*Koelreuteria paniculata*		Rounded	30-40'+	30-40'
Grecian Laurel	*Laurus nobilis*	**E**	Irregular rounded	20-25'	15-40'
Green Ash	*Fraxinus pennsylvanica 'Patmore', 'Leprichaun', 'Centerpoint'*		Oval, irregular	30'	40'
Hedge Maple	*Acer campestre*		Rounded	30-35'	30-70'
Holly Oak	*Quercus ilex*	**E**	Rounded	40-50'	40-70'
Honey Locust (thornless)	*Gleditsia triacanthos*		Rounded to wide-rounded	30-70'	35-70'
Incense Cedar	*Calocedrus decurrens*	**E N**	Conical	25-30'	30-50' (150')
Interior Live Oak	*Quercus wislizenii*	**E N P**	Irregular	30-60'	30-75'
Italian Stone Pine	*Pinus pinea*		Broad, flat topped	30-40'	40-80'
Japanese Maple	*Acer palmatum*		Broad-rounded	25'+	20'
Japanese Pagoda Tree	*Sophora japonica*		Rounded to broad-spreading	50-75'	50-75'
Japanese Red Pine	*Pinus densiflora*	**E**	Broad-pyramidal and irregular	40-60'	40-60' (100')
Japanese Snowdrop	*Styrax japonicus*		Rounded	15-20'	25-30'
Japanese White Birch	*Betula platyphylla japonica*		Oval	20-25'	40-50'
Jelecote Pine	*Pinu patula*	**E**		25'	30'
Kentucky Coffee Tree	*Gymnocladus dioica*		Oval with coarse branching	40-50'	60-75' (90')
Kobus Magnolia	*Magnolia kobus*		Rounded	15-25'	30'
Little-Leaf Linden	*Tilia cordata*		Rounded pyramidal	30-50'	60-70' (90')
Mexican Fan Palm	*Washingtonia robusta*	**E**	Round head	10-15'	100'
Norwegian Sunset Maple	*Acer truncatum 'Norwegian Sunset'*			25'	30'
Pin Oak	*Quercus palustris*		Uniformly pyramidal with a straight central leader	25-40'	50-80'
Ponderosa Pine	*Pinus ponderosa*	**E N**	Conical	30-50'	60-100' (230')
Prospector Elm	*Ulmus 'Prospector'*			30'	40'
Purple Leaf Plum	*Prunus cerasifera* 'Krauter Vesuvius'		Rounded	15-25'	15-30'
Red Maple	*Acer rubrum*		Oval to rounded	to 60'	40-60' (120')
Red Oak	*Quercus rubra*		Rounded	60-75'	60-75' (100')

Common Name	Botanical Name	Type**	Mature Tree Shape (max.)	Canopy (dia.)	Height
Saucer Magnolia	*Magnolia* x *soulangeana*		Rounded	20-30'	25'
Scarlet Oak	*Quercus coccinea*		Oval to rounded with an open habit	40-50'	70-75' (100')
She-oak	*Casuarina stricta*	**E**	Oval/vase	15-25’	20-35’
Shumard Red Oak	*Quercus shumardii*		Oval	50'	70'
‘Seville” sour orange	*Citrus* ‘Seville’	**E**	Rounded	15-20’	20-30’
Southern Live Oak	*Quercus virginiana*	**E**	Broad rounded, irregular	65'	60'
Southern Magnolia	*Magnolia grandiflora*	**E**	Broad pyramidal, rounded pyramidal and rounded	30-50'	60-80'
Southern Magnolia 'St. Mary'	*Magnolia grandiflora* 'St. Mary'	**E**	Rounded	15-20'	20'
Strawberry Tree	*Arbutus unedo*	**E**	Oval to rounded	8-35'	8-35'
Sugar Maple	*Acer saccharum*		Oval to rounded	40-60'	60-75' (120')
Sycamore	*Platanus* species	**S**	Oval to rounded	30-50'	40-100'
Texas Red Oak	*Quercus buckleyi*			25'	30'
Trident Maple	*Acer buergerianum*		Oval	20-25'	20-25'
Tulip Tree	*Liriodendron tulipifera*		Oval-rounded with a strong central leader	35-50'	70-90' (150')
Tupelo / Sour Gum	*Nyssa sylvatica*		Rounded pyramidal	20-30'	30-50'
Valley Oak	*Quercus lobata*	**N P**	Broad-rounded	50-80'	70'+
Vine Maple	*Acer circinatum*	**N**	Rounded	25-35'	5-35'
Washington Hawthorn	*Crataegus phaenopyrum*		Rounded, vase-shaped	15-20'	25'
Western Red Cedar	*Thuja plicata*	**E**	Conical to wide conical	50-80'	50-70' (200')
Western Redbud	*Cercis occidentalis*		Rounded	10-18'	10-18'
White Alder	*Alnus rhombifolia*	**N**	Pyramidal to rounded	15-25'	30-45'
White Ash	*Fraxinus americana 'Autum Purple', 'Chicago Regal'*		Oval	60'	40'
Willow Oak	*Quercus phellos*		Rounded	30-40'	40-60' (100')
Zelkova	*Zelkova serrata*		Vase-shaped and rounded	30-60'	50-80' (120')

*proposed tree's/landscaping plans are subject to the approval of the local permitting agency
[a] only allowed in foothills of Folsom
**E=Evergreen; N=Native; P=Protected Species; S=Some Can Be Native

Appendix D4

LID Credits Background Report

I. INTRODUCTION

Multiple environmental agencies, including the Central Valley Regional Water Quality Control Board, have recently adopted a strategy to encourage municipalities and developers to incorporate Low Impact Development (LID) into site planning and design. Low Impact Development includes a set of measures that reduce site imperviousness, thereby reducing storm water runoff, and/or provide filtration through vegetation or infiltration. In theory, use of LID controls within a given site results in a reduction of the amount of storm water requiring treatment, termed Runoff Reduction. The purpose of this report is to summarize an effort undertaken by local agencies to develop an LID, or Runoff Reduction, credit system. This system is being developed for use in the Stormwater Quality Design Manual for the Sacramento and South Placer Regions (Manual).

The NPDES Phase I and Phase II Municipal Stormwater Permits for the County of Sacramento (and co-permittees) and the City of Roseville, respectively, require that treatment of storm water occur for development projects of various types: residential and commercial being the most common. Thresholds (by size of development) for treatment vary by permit, but all participating municipalities have an interest in achieving regional consistency in the application of storm water design standards.

This document and the resulting worksheets are an attempt to 1) quantify the benefit obtained through the incorporation of specific Runoff Reduction measures, and 2) provide a mechanism by which developers can calculate the benefit for using Runoff Reduction and the resulting reduction in size of treatment controls. This is achieved by assigning “credits” to the use of Runoff Reduction measures.

This document focuses on the two most common types of development, residential and commercial, but the concepts presented could be easily adapted to other types of development projects.

Assumptions

The Runoff Reduction credit system has been developed based on the following assumptions.

- Pavement/asphalt and roof tops are 100% impervious.
- Landscaped areas, lawns, and natural areas are pervious and any runoff generated from these areas is assumed to be clean with no further treatment needed.
- Runoff from porous pavements is partially infiltrated/reduced depending on how pervious the material is and on the permeability of native soils.
- Runoff from impervious surfaces that flows across pervious surfaces is partially reduced with the amount of reduction dependent on the type of receiving surface.

II. RESIDENTIAL CREDITS CALCULATION

Background Data

Research was conducted in 2005 by the City of Roseville and the County of Sacramento using studies of available maps of residential developments of various sizes and types within Sacramento and Placer County. These maps were used to calculate the aggregate area of features of interest: streets, rooftops, sidewalks, and driveways, as well as the total area of each development. A value was calculated for rooftops, sidewalks, driveways, streets, and total impervious surface as a percentage of the total area. This information was compiled to obtain local, accurate, empirical values for the average impervious fraction of different types of residential developments with differing densities (dwelling units per acre), as well as information about how the different features contribute to total site imperviousness. Data collected in the research effort for 29 sites is summarized in Attachment A.

The Sacramento/Roseville data was used to compute an average impervious fraction for each of eight categories of residential development classified by density, which ranged from one dwelling unit per acre to 20 dwelling units per acre. Average total impervious fraction and percent imperviousness by surface type has been identified in Table 1.

Table 1 – Average Impervious Fraction by Surface Type for Eight Categories of Residential Development

DENSITY IN DWELLING UNITS PER ACRE (DU/A)	1	2	3-4	5-6	7	8-9	10-14	15-20
TOTAL IMPERVIOUS FRACTION	0.17	0.25	0.35	0.40	0.50	0.55	0.60	0.70
ROOFTOP	0.08	0.13	0.19	0.23	0.29	0.33	0.37	0.44
SIDEWALK	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
DRIVEWAY	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
STREET	0.01	0.04	0.08	0.09	0.13	0.14	0.15	0.18

Appendix D-1 in Manual

The Residential Runoff Reduction Worksheet, Form D-1, allows a designer to calculate a reduced treatment requirement based on the incorporation of various Runoff Reduction measures into their project. To use Appendix D-1, the designer must obtain an accurate estimate of the project area, then estimate how much of that area will be ‘open space and parks’ as defined in the Manual. Open space and parks does not include landscaping within individual residential lots. The open space/parks acreage is subtracted from the total acreage to find the size of the area that will require treatment, A_t. These calculations are completed in Step 1 of the form.

The designer then proceeds through Step 2 to determine how much credit is earned for Runoff Reduction techniques incorporated into the project. Using predetermined impervious fraction factors and Forms D-1a-d, the designer calculates the size of each area that will be affected by various Runoff Reduction techniques, and these areas become “effectively managed” under the system. The total Effective Area Managed (A_c) equals the amount of credit allowed for the incorporation of Runoff Reduction measures.

For every technique, an *efficiency multiplier* is provided which reflects the fraction of runoff that is being reduced or treated from the area being considered. For example, a porous pavement driveway reduces runoff from the driveway by 60% while a Hollywood driveway reduces runoff by 75%, based on each driveway's ability to infiltrate stormwater. After an efficiency multiplier is determined, a *use multiplier* representing the percentage of units in the development that are using the technique is determined. So, if 50% of the units in the development use the Runoff Reduction measure, then 50% of possible reduction is achieved. Finally, a *reduction factor* is selected, which represents the fraction of land that the surface of interest represents. For example, in calculating the amount of credits allowed for an alternative driveway, the reduction factor reflects the area of driveway surface as a fraction of the total area requiring treatment (A_t); in all residential developments, driveways comprise 4% of the total area. These fractions are all multiplied together to get a fraction of total site area effectively managed. This is multiplied by the total acreage of A_T to find the area of impervious surface that is effectively managed (A_c) by using the Runoff Reduction technique.

So the *effective area managed* is equal to:

efficiency multiplier * use multiplier * reduction factor * total acreage

Runoff Reduction measures for which credit can be obtained within residential development projects include *disconnected roof drains, disconnected pavement, interceptor trees, and alternative driveways*. All Runoff Reduction measures must be designed and installed in accordance with specifications and details provided in *Fact Sheets* included in the Manual. The basis for the credit allowed for each of the Runoff Reduction measures has been detailed below.

Disconnected Roof Drains (DRDs)

Disconnected roof drains (DRDs) can achieve the functional equivalent of reducing a large amount of imperviousness by directing rooftop runoff to a pervious surface, dispersal trench, or dry well, as allowed by the local permitting agency. Use of DRDs as a Runoff Reduction measure has been recommended in guidance manuals such as *Start at the Source* (1999) and *The Practice of Low Impact Development* (2003.) If the roof drainage is connected to a dispersal trench or a dry well that have been designed according to specifications provided in the fact sheet, then 100% of the impervious surface attributed to rooftop is considered treated for that unit, thus the *efficiency multiplier* is 1.00. Design standards for the dispersal trench and dry well are adapted from *High Point Community Site Drainage Technical Standards* (2004) and *Virginia Stormwater Management Program Handbook* (1999).

If the runoff, via the roof drain, is directed across the surface of the landscaping, then the amount of runoff that will be treated is dependent on the amount of vegetation the water will flow through before entering the storm drain system. The design specifications for Sacramento County require a 20-foot setback between the house and the sidewalk. Most new developments obtain variances to reduce their setback distances to 15 feet or 12.5 feet. The *efficiency multiplier* for disconnected roof drains draining to landscaping is then found using manning's equation to solve for hydraulic residence time. The manning's equation used is the equation described in *Filter Strip Worksheet 2005 Surface Water Design Manual Sizing Method* published in the King County Surface Water Design Manual published by King County Water and Land Resources Division.

$$L = t\,\frac{Q}{W}\left(\frac{1.49\,W\,\sqrt{s}}{Q\,n}\right)^{0.6}$$

Where,

L = filter strip length (feet)
t = hydraulic residence time (seconds)
Q = design flow (cfs)
W = filter strip width (feet)
n = Manning's roughness coefficient
s = longitudinal slope along path

$$WQF = C\ i\ A$$

Where,

WQF = design flow (cfs)
C = Rational Runoff coefficient
i = rainfall intensity (in/hr)
A = Area (acres)

The equation is solved for hydraulic residence time, using various setback lengths and the following assumptions.

Residential Disconnected Roof Drain Assumptions:

W = 5 feet (recommended by local hydrologist as typical average)
s = 0.01
n = 0.35 (residential is likely to have short grasses)
C = 0.9 (rational C) (corresponds to rooftop's 100% imperviousness)
Rooftop area = 2,500 sq feet (average roof area for 5-7 DU/A)

The hydraulic residence time is then computed as a percentage of the value for full treatment, identified as being 7 minutes by many stormwater manuals. The results are summarized in Table 2, and multipliers are rounded to the nearest 0.05 in the form.

Table 2 – DRD Efficiency Multipliers Based on Length of Front Yard Setback

Length of Setback	Residence Time	Percent of 7 minutes	Efficiency multiplier
25 feet	8.6 min	123%	1
20 feet	6.9 min	98%	0.98
15 feet	5.2 min	74%	0.74
10 feet	3.4 min	48%	0.48
5 feet	1.7 min	24%	0.24

The designer must determine how many of the roof downspouts are to be disconnected, as a percentage of total roof downspouts. This determines the *use multiplier* for disconnected rooftops.

The form is used to determine the area of impervious surface accounted for by rooftops, dependent on site density (1-20 DU/A). This area is the maximum amount of impervious surface that can be effectively managed with DRDs and comprises the *reduction factor*. Reduction factors for DRDs range from 0.08 to 0.44 and are summarized in Table 1.

Example:
If a 20-acre residential site, 5 DU/A (23% rooftop impervious surface), includes the disconnection of all roof drains on 40% of houses with a setback of 12 feet (48% treatment) the Runoff Reduction measure would result in:

(0.48)(0.40)(0.23)(20 acres) = 0.044(20 acres) = 0.88 acres of effectively managed area (A_c).

Divided Sidewalks (DS)

Divided Sidewalks (DS) function to drain water runoff from sidewalks onto a strip of grass located between the sidewalk and the street. Divided Sidewalks are essentially a variation on Disconnected Pavement (DP) and the credits application method for DP was adapted from the *Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices* for Denver (2005). The landscaping strips are usually as wide as the sidewalks themselves, so the sidewalks are considered entirely treated. Sidewalks account for approximately 6% of the total area of most residential developments, so if all units use divided sidewalks the development will treat 6% of total site runoff. If a development chooses to use divided sidewalks on some areas, connector streets for example, the amount of credits applied will be scaled by the percentage of units using the design. A designer chooses the percentage of units using the design, and the number is multiplied by 0.04 to get the total credits obtained.

If a designer uses divided sidewalks on 30% of units in a 200 acre development, the credit allowed: use multiplier * reduction factor * total acreage

(0.30)(0.04)(200 acres) = 0.012(200 acres) =2.4 acres of effectively managed area (A_c).

Interceptor Trees (IT)

Interceptor trees can prevent and/or delay water from landing on an impervious surface. Much of the intercepted water runs down along the tree's leaves and branches and evaporates, or runs down into the root system. Properly located trees can reduce the effective impervious fraction by diverting rain that would otherwise fall on streets and sidewalks. The *City of Portland Stormwater Management Manual* (2004) and City of San Jose policy apply 100 sq. ft of credit for a deciduous tree and 200 sq. feet for an evergreen tree. Research results published by Q. Xiao (1998, 2000(2), 2003) provides evidence that this credit system is appropriate for the central valley climate. The number of trees is multiplied by the credit to obtain an area reduced by interceptor trees. Credits may be applied for existing trees as defined in Interceptor Trees Fact Sheet. To calculate the credits allowed for existing interceptor trees, the designer must identify the square footage equal to one half of the existing tree canopy. The resulting area is considered the area effectively managed by the existing interceptor trees.

Alternative Driveway Design (ADD)

Alternative driveways can be designed to incorporate a pervious or semi-pervious surface or to direct runoff into vegetation. Use of ADD as a Runoff Reduction measure has been recommended in guidance manuals such as *Start at the Source* (1999) and *The Practice of Low Impact Development* (2003.) The amount of runoff infiltrated on driveways depends on the type of porous pavement used (acceptable types of porous pavements are listed under the Porous Pavement Section), therefore *efficiency factors* vary from 0.40 to 1.00 (see below **Porous Pavement**). For Hollywood driveways, which reduce pavement area but do not necessarily utilize alternative pavement types, the reduction of paved surface and the redirection of stormwater into the unpaved section results in an *efficiency factor* of 0.75.

The designer must determine how many of the driveways are to be designed using the alternative method, as a percentage of total driveways. This determines the *use multiplier* for ADD. Reduction factor for ADD measures for all development densities are 0.04.as summarized in Table 1.

Example:
If 50% of the homes in a 100 acre residential site, 5 DU/A (4% driveway impervious surface), use Hollywood driveways, the Runoff Reduction measure would result in:

(0.50)(0.04)(0.75)(100 acres) = 0.015(100 acres) = 1.5 acres of effectively managed area (A_c).

Using the Effective Area Managed (A_c) in Calculating Treatment Requirement

After each Runoff Reduction measure has been addressed on the subforms, Forms D-1a through D-1d, the A_c is totaled. This managed area is subtracted from the Area Requiring Treatment (A_T) found in Step 1. The Adjusted Area Requiring Treatment (A_{AT}) is also used to find an Adjusted Impervious Fraction (I_A).

After the A_{AT} is calculated, the water quality flow and/or volume must be calculated for sizing treatment controls. Whether the designer needs to calculate flow-based treatment or volume-based treatment depends on the type of treatment planned.

Treatment flow(WQF) is found using the standard flow equation,

$$\mathbf{WQF = C\ i\ A}$$

where C is the rational runoff coefficient based on the DU/A (Table D-1b in Form D-1), *i* is the rainfall intensity (varies by region, see Table D-1c in Form D-1), and A is the adjusted area requiring treatment (A_{AT}). This value is to be used when determining sizing criteria for structural treatment controls.

Treatment Volume is found using either the CASQA method (Roseville):

$$\mathbf{V = A \times SV / 12}$$

where A = the total area of the drainage shed,
SV = SV = the Unit Basin Storage Volume; use C_A adjusted for credits earned (see Adjusted Runoff Coefficient, below).

Or the ASCE-WEF method (Sacramento):

$$\mathbf{WQV\ (ac\text{-}ft) = P_0 * A / 12}$$

where A = the total area of the drainage shed,
P_0 = maximized detention volume using the ASCE-WEF method.

Please refer to chapter 6 and Appendix E for the selection of the treatment measures and design requirements. Then use form D-1f, Treatment – Volume Based (CASQA) for volume-based treatment controls within the City of Roseville, or form D-1g, Treatment – Volume Based, for treatment controls in areas outside of the City of Roseville.

Adjusted Runoff Coefficient

The *Adjusted Impervious Fraction* is converted to an *Adjusted Runoff Coefficient*, C_A, using the empirical regression equation presented in the *California Stormwater BMP Handbook* (CASQA, 2003).

$$\mathbf{C = 0.858\ I^3 - 0.78\ I^2 + 0.774\ I + 0.04}$$

where,
C = runoff coefficient
I = impervious fraction

The results of this equation for values of "I" between 0 and 1 are listed in Table D-1d, Form D-1.

III. COMMERCIAL AND MULTI-FAMILY CREDITS CALCULATION

Appendix D-2 in Manual

The Commercial and Multifamily Runoff Reduction Worksheet, Appendix D-2, allows a designer to calculate a reduced treatment requirement based on the incorporation of various Runoff Reduction measures into their project. To use Appendix D-2, the designer must obtain an accurate estimate of the area, then estimate how much of that area will be 'open space and parks' as defined in the Manual. This includes all landscaping areas and areas left in a natural state. The open space acreage is subtracted from the total acreage to find the size of the area that will require treatment, A_T. This area (A_T) generally includes parking lots, rooftops, and driveways, which are assumed to be impervious. The designer then calculates the size of each area that will be affected by various Runoff Reduction techniques, and these areas become "effectively managed" under the system. The total Effective Area Managed (A_c) equals the amount of credit allowed for the incorporation of Runoff Reduction measures.

Runoff Reduction measures for which credit can be obtained within commercial and multi-family development projects include *porous pavement, disconnected roof drains, green roofs, disconnected pavement, and interceptor trees*. All Runoff Reduction measures must be designed and installed in accordance with specifications and details provided in *Fact Sheets* included in the Manual. The basis for the credit allowed for each of the Runoff Reduction measures has been detailed below.

Porous Pavement (PP)

The amount of credit applied for the use of porous pavement varies depending on the pavement type. The effective impervious fraction of these different types of porous pavement has been studied and reported in *Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices* for Denver (2005). This source was used to determine the impervious fraction of the following porous pavement types. Modular Block Pavement is concrete blocks with open voids occupying at least 20% of total surface area. The voids are filled with gravel and then filled in with sand. These surfaces have an effective impervious fraction of 25%, thus the *efficiency multiplier* is 0.75. Cobblestone Block Pavement consists of concrete blocks that look like cobblestone and create open voids between the blocks. These create an effective impervious fraction of 60%, and have an *efficiency multiplier* of 0.40. Reinforced Grass Pavement is a stabilized grass surface that infiltrates rainwater well. Because of this, it is given an *efficiency multiplier* of 1.00. Pervious Pavement is a concrete/asphalt that does not contain the normal fine sand and has 15-20% of its volume as void space. These are found to have an impervious fraction of 40%, and thus an *efficiency multiplier* of 0.60. Porous Gravel Pavement is a loose gravel paving and has an effective impervious fraction of 25%, and an *efficiency multiplier* of 0.75. The *efficiency multipliers* are listed in Table D-2a of Appendix D-2. For all pavement types, the *efficiency multiplier* is multiplied by the area of land utilizing the porous pavement type to determine total credits applied.

If Modular Block Pavement, which has an *efficiency multiplier* of 0.75, was used on 5,000 sq. ft of parking lot, the A_c would be:

5,000*0.75 = 3,750 square feet.

Disconnected Pavement (DP)

Disconnected Pavement is pavement designed to allow stormwater to sheet flow over vegetated areas or porous pavement prior to entry into a storm drain system. The efficiency of this method depends on both the impervious fraction of the receiving porous surface, as well as the ratio of contributing area to receiving area. These two factors taken together allow for the calculation of an effective impervious fraction for the not directly connected surface. These values are derived from Figure PP-1 of the *Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices* for Denver (2005). The designer begins by selecting the type of surface (landscaping or one of the porous pavements) that the disconnected pavement will run onto. If the pavement will be draining onto landscaping the entire pavement area is effectively treated, providing that the area draining onto the landscaping is not more than twice the area of landscaping.

If the pavement will be draining onto a porous pavement, first the ratio of contributing pavement to receiving pavement is calculated, then based on the resulting ratio, a multiplier is determined, as listed in Table 3. Porous pavement for which credit is obtained under Appendix D-2, Step 2, Porous Pavement Option, cannot be included in Disconnected Pavement calculations.

Table 3 – Multipliers Based on Ratio of Contributing Pavement to Receiving Pavement

Ratio of Contributing Pavement to Receiving Pavement	Multiplier
< 0.5	1.00
$\geq$0.5 and <1.0	0.83
$\geq$1.0 and <1.5	0.71
$\geq$1.5 and <2.0	0.55

The *efficiency multiplier* for the selected porous pavement is selected from Table D-2a in Appendix D-2. The formula for calculating the A_c is as follows:
(area of receiving pavement)(efficiency multiplier)
+ (area of contributing pavement)(ratio multiplier)(efficiency multiplier) = A_c

Disconnected Roof Drains (DRD)

Disconnected roof drains (DRDs) can achieve the functional equivalent of reducing a large amount of imperviousness by directing rooftop runoff to a pervious surface, dispersal trench, or dry well. Use of DRDs as a Runoff Reduction measure has been recommended in guidance manuals such as *Start at the Source* (1999) and *The Practice of Low Impact Development* (2003.) If the roof drainage is connected to a dispersal trench or a dry well that have been designed according to specifications provided in the fact sheet, then 100% of the impervious surface attributed to rooftop is considered treated for that unit, thus the *efficiency multiplier* is 1.00. Design standards for the dispersal trench and dry well are adapted from *High Point Community Site Drainage Technical Standards* (2004) and *Virginia Stormwater Management Program Handbook* (1999).

If the runoff, via the roof drain, is directed across the surface of the landscaping, then the amount of runoff that will be treated is dependent on the amount of vegetation the water will flow through before entering the storm drain system. In order to receive credits for DRDs on a commercial site, the runoff must be conveyed across a minimum length of landscaping or conveyance furrow. This minimum value is different for different rooftop sizes. The minimum values are calculated using a filter strip calculation which is a variation of manning’s equation to solve for hydraulic residence time. The manning’s equation used is the equation described in *Filter Strip Worksheet 2005 Surface Water Design Manual Sizing Method* published in the King County Surface Water Design Manual published by King County Water and Land Resources Division.

$$L = t\,\frac{Q}{W}\left(\frac{1.49\,W\,\sqrt{s}}{Q\,n}\right)^{0.6}$$

Where,

L = filter strip length (feet)
t = hydraulic residence time (seconds)
Q = design flow (cfs)
W = filter strip width (feet)
n = Manning’s roughness coefficient
s = longitudinal slope along path

$$Q = C\ i\ A$$

Where,

Q = design flow (cfs)
C = Rational Runoff coefficient
i = rainfall intensity (in/hr)
A = Area (acres)
The equation is solved for hydraulic residence time, using various setback lengths and the following assumptions. The setback lengths are that which will provide a 7 minute hydraulic residence time.

Commercial Disconnected Roof Drain Assumptions:
W = 8 feet (recommended by local hydrologist as typical average)
s = 0.01
n = 0.3 (commercial planter strip, will contain some bushes and larger plants)
Rooftop C = 0.9 (rational C) (corresponds to 100% imperviousness)
T = 7 minutes (standard residence time for treatment)
This results in the following setback/travel distance values for commercial sites.

Table 4- Minimum Travel Distance for Disconnected Roof Drains in Commercial/Multi-family Development Projects

Area (maximum roof size)	Length (min travel distance)	Depth of flow
3,500 sq ft	21 feet	0.4 in
5,000 sq ft	24 feet	0.5 in
7,500 sq ft	28 feet	0.6 in
10,000 sq ft	32 feet	0.7 in

Interceptor Trees (IT)

Interceptor trees can prevent and/or delay water from landing on an impervious surface. Much of the intercepted water runs down along the tree's leaves and branches and evaporates, or runs down into the root system. Properly located trees can reduce the effective impervious fraction by diverting rain that would otherwise fall on streets and sidewalks. The *City of Portland Stormwater Management Manual* (2004) and City of San Jose policy apply 100 sq. ft of credit for a deciduous tree and 200 sq. feet for an evergreen tree. Research results published by Q. Xiao (1998, 2000(2), 2003) provides evidence that this credit system is appropriate. The number of trees is multiplied by the credit to obtain an area reduced by interceptor trees. Credits may be applied for existing trees as defined in Interceptor Trees Fact Sheet. To calculate the credits allowed for existing interceptor trees, the designer must identify the square footage equal to one half of the tree canopy. The resulting area is considered the area effectively managed by the existing interceptor trees.

Using the Effective Area Managed in Calculating Treatment Requirement

After each Runoff Reduction measure has been addressed on the subforms, forms D-2a and D-2b, the A_c is totaled. This managed area is subtracted from the Area Requiring Treatment ($A_{T)}$ found in Step 1. The Adjusted Area Requiring Treatment (A_{AT}) is also used to find an Adjusted Impervious Fraction (I_A).

After the A_T, A_{AT}, and I_A have been calculated, the water quality flow and/or volume must be calculated for sizing treatment controls. Whether the designer needs to calculate flow-based treatment or volume-based treatment depends on the type of treatment planned.

Treatment flow (WQF) is found using the standard flow equation,

$$\mathbf{WQF = C\ i\ A}$$

where C is the rational runoff coefficient for A_{AT} (assumed to be 0.95), *i* is the rainfall intensity, and A is the adjusted area requiring treatment (A_{AT}). This value is to be used when determining sizing criteria for structural treatment controls.

Treatment Volume (WQV) is found using either the CASQA method (Roseville):

$$\mathbf{V = A \times SV / 12}$$

where A = the total area of the drainage shed,
SV = SV = the Unit Basin Storage Volume; use C_A adjusted for credits earned (see Adjusted Runoff Coefficient, below).

Or the ASCE-WEF method (Sacramento):

$$\mathbf{WQV\ (ac\text{-}ft) = P_0 * A / 12}$$

where A = the total area of the drainage shed,
P_0 = maximized detention volume using the ASCE-WEF method.

Please refer to chapter 6 and Appendix E for the selection of the treatment measures and design requirements. Then use form D-1f, Treatment – Volume Based (CASQA) for volume-based treatment controls within the City of Roseville, or form D-1g, Treatment – Volume Based, for treatment controls in areas outside of the City of Roseville.

Adjusted Runoff Coefficient

The *Adjusted Impervious Fraction* is converted to an *Adjusted Runoff Coefficient*, C_A, using the empirical regression equation presented in the *California Stormwater BMP Handbook* (CASQA, 2003).

$$C = 0.858\ I^3 - 0.78\ I^2 + 0.774\ I + 0.04$$

where,
C = runoff coefficient
I = impervious fraction

The results of this equation for values of "I" between 0 and 1 are listed in Table D-2d of Appendix D-2.

IV. REFERENCES

Adams, M.C. 2003. *Porous Asphalt pavement with recharge beds: 20 years & still working.* Stormwater. May/June 2003.

California Stormwater Best Management Handbook: New Development and Redevelopment. California Stormwater Quality Association, 2003.

Cappiella, K. 2004. *Urban Watershed Forestry Manual* (draft). Prepared for USDA Northeastern Area State and Private Forestry. Center for Watershed Protection, Ellicott City, MD.

Christensen, Summer. November 30, 2005. *Memorandum on Results of Residential Impervious Study.* County of Sacramento Department of Water Resources, Sacramento, CA.

City of Davis Community Forest Management Plan , September 11, 2002. http://www.cityofdavis.org/pcs/trees/cfmp.cfm

City of Pasadena. California Code of Regulations. Hollywood Driveway. http://www.ci.pasadena.ca.us/zoning/P-8.html accessed March 6, 2006.

City of Portland Stormwater Management Manual. Revision 3, September 1, 2004.

High Point Community Site Drainage Technical Standards. Seattle, WA, June 2004.

King County Department of Natural Resources and Parks. January 2005. *Stormwater Pollution Prevention Manual: Best Management Practices for Business and Residential Properties.* King County Washington.

National Menu of Best Management Practices for Storm Water Phase II. United State Environmental Protection Agency. 2002. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

New York State Stormwater Management Design Manual. Center for Watershed Protection, New York State Department of Environmental Conservation, Albany, NY, October 2001.

Nonpoint Education for Municipal Officials. University of Connecticut. accessed May 26, 2006. http://nemo.uconn.edu

Paris N. and M. Chusid. 2006. *Coloring Pervious Pavement…because protecting the environment should be beautiful*. www.ConcreteDecor.net Dec/Jan 2006.

Post-Construction Urban Runoff Management. City Council Policy. City of San Jose, California. February 3, 1998.

Shueler T., Swann C., Wright T, and S. Sprinkle. 2004. *Urban Subwatershed Restoration Manual No 8: Pollution Source Control Practices*. Version 1.0. Center for Watershed Protection. Ellicot City, MD. July 2004.

SMRC, The Stormwater Manager's Resource Center. Fact Sheets. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm accessed June 14, 2006.

SMRC, The Stormwater Manager's Resource Center. Manual Builder. http://www.stormwatercenter.net/Manual_Builder/Credits/SITE/reforestation.htm

SMRC, The Stormwater Manager's Resource Center. Manual Builder. http://www.stormwatercenter.net/Manual_Builder/Credits/SITE/rooftop.htm

Start at the Source - Design Guidance Manual for Stormwater Quality Protection, Bay Area Stormwater Management Agencies Association, 1999.

Stormwater C.3 Guidebook: Stormwater Quality Requirements for Development Applications. Contra Costa Clean Water Program. Contra Costa, CA, March 2005.

Stormwater Pollution Prevention Manual: Best Management Practices for Business and Residential Properties. King County Department of Natural Resources and Parks, Water and Land Resources Division, Stormwater Services Section. January 2005.

Sustainable Infrastructure Alternative Paving Materials Subcommittee Report. City of Portland. October 3, 2003.

The Practice of Low Impact Development. U.S. Department of Housing and Urban Development. Washington, D.C. July 2003.

Truckee Meadows Regional Storm Water Quality Management Program: Draft Low Impact Development Handbook. August 2005.

Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices. Urban Drainage and Flood Control District. Denver, CO. September, 1999 (Rev. October, 2005).

Virginia Stormwater Management Program Handbook. Virginia Department of Conservation and Recreation. 1999.

Xiao Q., and E.G. McPherson. 2003. *Rainfall interception by Santa Monica's municipal urban forest.* Urban Ecosystems

Xiao, Q., E.G. McPherson, S.L. Ustin and M.E. Grismer. 2000. *A new approach to modeling tree rainfall interception*. Journal of Geophysical Research 105(D23) :29,173-29,188.

Xiao, Q. 1998. *Rainfall interception by urban forests.* Davis, CA: University of California. Ph.D. Dissertation.

Xiao, Q., E.G. McPherson, S.L. Ustin, M.E. Grismer, and J.R. Simpson. 2000. *Winter rainfall interception by two mature open grown trees in Davis, CA.* Hydrological Processes. 14(4) :763-784.

Appendix E

Design Requirements for Stormwater Quality Treatment Control Measures (Volume and Flow-Based Measures)

The Sacramento Areawide and City of Roseville NPDES Municipal Stormwater Permits contain provisions that require the local municipal agencies to establish and enforce stormwater quality treatment standards for many new and redevelopment projects. This appendix presents the minimum standards for sizing the treatment control measures.

General Methodology

Follow these steps:

- Refer to Table 3-2 in this Design Manual to determine if your project requires treatment control measures.
- Once you have made that determination, use the fact sheets in Chapter 6 to identify the type of control measures most appropriate for your project site and whether or not those measures are volume or flow-based.
- (Optional) Use Chapter 5 and the runoff reduction worksheets in Appendix D to select runoff reduction measures for your project which will reduce the runoff discharged; this may result in reduced treatment needs (and associated costs) for your project.
- Use the rest of the information in this appendix to size the treatment control facilities for your project.

The local Sacramento agencies have developed a presumptive approach, whereby, if project applicants follow the methodology presented herein, it is presumed that the project is reducing stormwater pollution in runoff to the “maximum extent practicable” NPDES municipal permit standard. A key principle here is that treatment control measures are most efficient and economical when they target small, frequent storm events that over time produce more total runoff than the larger, infrequent storms conventionally targeted for design of flood control facilities. Further, studies in other areas of the country have shown that much of the pollutant load is contained in the “first flush” of rainfall during a storm event, typically the first 0.5-inches. Targeting design storms larger than this may result in some improvements in pollutant removal effectiveness, but at considerable cost.

It is important to note that arbitrarily targeting large, infrequent storm events can actually reduce the pollutant removal capabilities of some treatment control measures. This occurs when outlet structures, detention times, and drain down times are designed to accommodate unusually large volumes and high flows. When over-designed in this way, the more frequent, small storms that produce the most annual runoff and a large part of the pollutant load pass quickly through the over-sized facility and therefore receive inadequate treatment. (CASQA, 2003).

<u>Sizing Flow-Based Treatment Control Measures</u>

Use this method for sizing flow-based control measures (e.g., vegetated swales) in both Sacramento County and the City of Roseville.

Flow-based control measure design standards apply to control measures whose primary mode of pollutant removal depends on the rate of flow of runoff through the facility or device. Examples of control measures in this category include swales, sand filters, diversion structures for off-line control measures, and many proprietary products. Typically, flow-based design criteria calls for the capture and infiltration or treatment of the flow runoff produced by rain events of a specified magnitude. For the local area, the intensity of such a storm event is 0.20 inches/hour for the Cities of Folsom and Roseville and 0.18 inches/hour for other cities in Sacramento County and unincorporated Sacramento County.

This method satisfies the provisions of the Sacramento Areawide and City of Roseville NPDES Municipal Stormwater Permits, which requires that flow-based measures be designed for at least the maximum (peak) flow rate of runoff produced by the 85th percentile hourly precipitation intensity multiplied by a factor of two, referred to here as the flow-based 85th percentile method. (CDM, 2003). This criterion is the same as the one prescribed by the 2003 California BMP Handbook. From Appendix D of that handbook, the 85th percentile hourly precipitation intensity for the Sacramento gage is approximately 0.09 inches/hour. Multiplying by two, the required intensity is at least 0.18 inches/hour. The factor of two specified for this method by the municipal stormwater permits appears to be provided as a factor of safety: therefore, caution should be exercised when applying additional factors of safety during the design process so that over design can be avoided. (CASQA, 2003).

The flow-based BMP design criteria should be used in conjunction with the Rational Formula, a simplified, easy to apply formula that predicts flow rates based on rainfall intensity and drainage area characteristics. The Rational Formula is as follows:

$$\mathbf{WQF\ (cfs) = C\ i\ A}$$

where

WQF = flow in ft^3/s
i = rain intensity in inches/hr
A = drainage area in acres
C = rational runoff coefficient

The Rational Formula is widely used for hydrologic calculations, but it does have a number of limitations. For stormwater treatment control measure design, a key limitation is the ability of the Rational Formula to predict runoff from undeveloped areas where runoff coefficients are highly variable with storm intensity and antecedent moisture conditions. This limitation is accentuated when predicting runoff from frequent, small storms used in stormwater quality treatment design because many of the runoff coefficients in common use were developed for predicting runoff for drainage design where larger, infrequent storms are of interest. Table 5-3 in the California BMP Handbook (May 2003) provides some general guidelines on use of the Rational Equation. In summary, the Rational Formula, when used with commonly tabulated runoff coefficients in undeveloped drainage areas, will likely result in predictions higher than will be experienced under actual field conditions. However, given the simplicity of the equation, its use remains practical and it is therefore the preferred method recommended by the local permitting agencies.

The following steps describe the approach for application of the flow-based design criteria. For simplicity, the worksheets presented in Appendix D (see Step 3 of Appendix D-1 and D-2) already incorporate these steps.

1. Identify and delineate the drainage shed that drains to the proposed control measure. This includes all areas that will contribute runoff to the proposed control measure, including pervious areas, impervious areas, and off-site areas, whether or not they are directly or indirectly connected to the control measure.

2. Select design rainfall intensity for the project area:
   0.20 inches/hour – projects in the Cities of Folsom and Roseville
   0.18 inches/hour – projects located in other cities in Sacramento County and unincorporated Sacramento County

3. Calculate the composite runoff coefficient "C" for the drainage shed identified inStep 1 using table E-1. For contributing areas with multiple coefficients, use the weighted coefficient for the contributing area.

Table E-1: Runoff coefficients for the Rational Formula:

Type of Drainage Area	**Runoff Coefficient, C**
Business:	
Downtown areas	0.95
Neighborhood areas	0.70
Residential:	
Single-family areas	0.50
Multi-units, detached	0.60
Multi-units, attached	0.75
Apartment dwelling areas	0.70
Industrial:	
Light areas	0.80
Heavy areas	0.90
Parks, cemeteries	0.25
Playgrounds	0.40
Railroad yard areas	0.40
Unimproved area	0.30
Lawns:	
Sandy soil, flat, 2%	0.10
Sandy soil, average, 2 – 7%	0.15
Sandy soil, steep, 7%	0.20
Heavy soil, flat, 2%	0.17
Heavy soil, average 2 – 7%	0.22
Heavy soil, steep, 7%	0.35
Streets:	
Asphaltic	0.95
Concrete	0.95
Brick	0.85
Drives and Walks	0.85
Roofs	0.95

4. Apply the Rational Formula to calculate the water quality design flow (WQF):

   WQF = C i A

Sizing Volume-Based Treatment Control Measures

Volume-based design standards apply to control measures whose primary mode of pollutant removal depends on the volumetric capacity of the facility. Examples of control measures in this category include water quality detention basins, constructed wetlands, stormwater planters, and infiltration basins/trenches. Volume-based design criteria calls for the capture and infiltration or treatment of a certain percentage of the runoff from the project site, usually in the range of the 75th to 85th percentile average annual runoff volume.

The agencies in Sacramento County require use of the Urban Runoff Quality Management method (also for sizing volume-based control measures, while the City of Roseville requires use of the CASQA method, as described below. These methods are two of the three alternative design approaches allowed by the NPDES municipal stormwater permits.

Sacramento County Volume-Based Design Method

For projects in Sacramento County, volume-based control measures shall be designed to capture and treat the maximized stormwater quality capture volume for the area, based on historical rainfall records, determined using the formula and volume capture coefficients set forth in Urban Runoff Quality Management (WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998), pages 175-178). The Urban Runoff Quality Management approach (also known as WEF/ASCE approach) is based on the translation of rainfall to runoff using two regression equations. The first regression equation relates rainfall to runoff. The rainfall to runoff regression equation was developed using 2 years of data from more than 60 urban watersheds nationwide. The second regression equation relates mean annual runoff-producing rainfall depths to the "Maximized Water Quality Capture Volume" which corresponds to the "knee of the cumulative probability curve". This second regression was based on analysis of long-term rainfall data from seven rain gages representing climatic zones across the country. The Maximized Water Quality Capture Volume corresponds to approximately the 85th percentile runoff event, and ranges from 82 to 88%.

The two regression equations that form the Urban Runoff Quality Management approach are as follows:

$$\mathbf{C = 0.858\ I^3 - 0.78\ I^2 + 0.774\ I + 0.04}$$

$$P_0 = (a \bullet C) \bullet P_6$$

Where
C = runoff coefficient;
I = watershed imperviousness ratio which is equal to the percent total imperviousness divided by 100;
P_0 = Maximized Detention Volume, in watershed inches;
a = regression constant, a= 1.312 for 12 hrs, a=1.582 for 24 hrs, and a=1.963 for 48-hour draw down time.

P_6 = mean annual runoff-producing rainfall depths, in watershed inches.

The following steps describe the use of the approach. For simplicity, the worksheets presented in Appendix D (see Step 3 of Appendix D-1 and D-2) already incorporate these steps.

1. Identify the drainage shed (A in acres) that drains to the proposed control measure. This includes all areas that will contribute runoff to the proposed facility, including pervious areas, impervious areas (such as roofs, roads, parking lots, etc), and off-site areas, whether or not they are directly or indirectly connected to the control measure.

2. Determine the "Maximized Detention Volume" (P_0) in inches for the drainage shed. Please refer to the attached figures (figure E-1 though figure E-4).

3. Calculate the required water quality volume of the control measure by multiplying the drainage shed area from Step 1 by the "Maximized Detention Volume" from Step 2.

$$\mathbf{WQV\ (ac\text{-}ft) = P_0 \bullet A / 12}$$

<u>City of Roseville Volume-Based Design Method</u>

For projects in the City of Roseville, volume-based control measures shall be designed to capture and treat stormwater runoff equal to eighty (80) percent of the volume of annual runoff, determined in accordance with the methodology set forth in the California BMP Handbook, using local rainfall data. Also referred to as the "CASQA approach", the approach is simple to apply, and relies largely on commonly available information about a project.

The following steps describe the use of the sizing curves contained in the California BMP Handbook. For simplicity, the worksheets presented in Appendix D (see Step 3 of Appendix D-1 and D-2) already incorporate these steps.

1. Identify the drainage shed that drains to the proposed control measure. This includes all areas that will contribute runoff to the proposed facility, including pervious areas, impervious areas, and off-site areas, whether or not they are directly or indirectly connected to the control measure.

2. Calculate the composite runoff coefficient "C" for the area identified in Step 1.

3. Select a capture curve representative of the site and the desired drain down time using Appendix D of the California BMP Handbook (*not to be confused with Appendix D in this Sacramento/Placer Design Manual*). Curves are presented for 24-hour and 48-hour draw down times. The 48-hour curve should be used in most areas of California. Use of the 24-hour curve should be limited to drainage areas with coarse soils that readily settle and to watersheds where warming may be detrimental to downstream fisheries. Draw down times in excess of 48 hours should be used with caution, as vector breeding can be a problem after water has stood in excess of 72 hours.

4. Determine the applicable requirement for capture of runoff (Capture, % of Runoff).

5. Enter the capture curve selected in Step 3 on the vertical axis at the "Capture, % Runoff" value identified in Step 4. Move horizontally to the right across capture curve until the curve corresponding to the drainage area's composite runoff coefficient "C" determined in Step 2 is intercepted. Interpolation between curves may be necessary. Move vertically down from this point until the horizontal axis is intercepted. Read the "Unit Basin Storage Volume" along the horizontal axis. If a local requirement for capture of runoff is not specified, enter the vertical axis at the "knee of the curve" for the curve representing composite runoff coefficient "C." The "knee of the curve" is typically in the range of 75 to 85% capture.

6. Calculate the required capture volume of the control measure by multiplying the drainage shed from Step 1 by the "Unit Basin Storage Volume" from Step 5 to give the design volume. Due to the mixed units that result (e.g., ac-in., ac-ft) it is recommended that the resulting volume be converted to cubic feet for use during design.

References

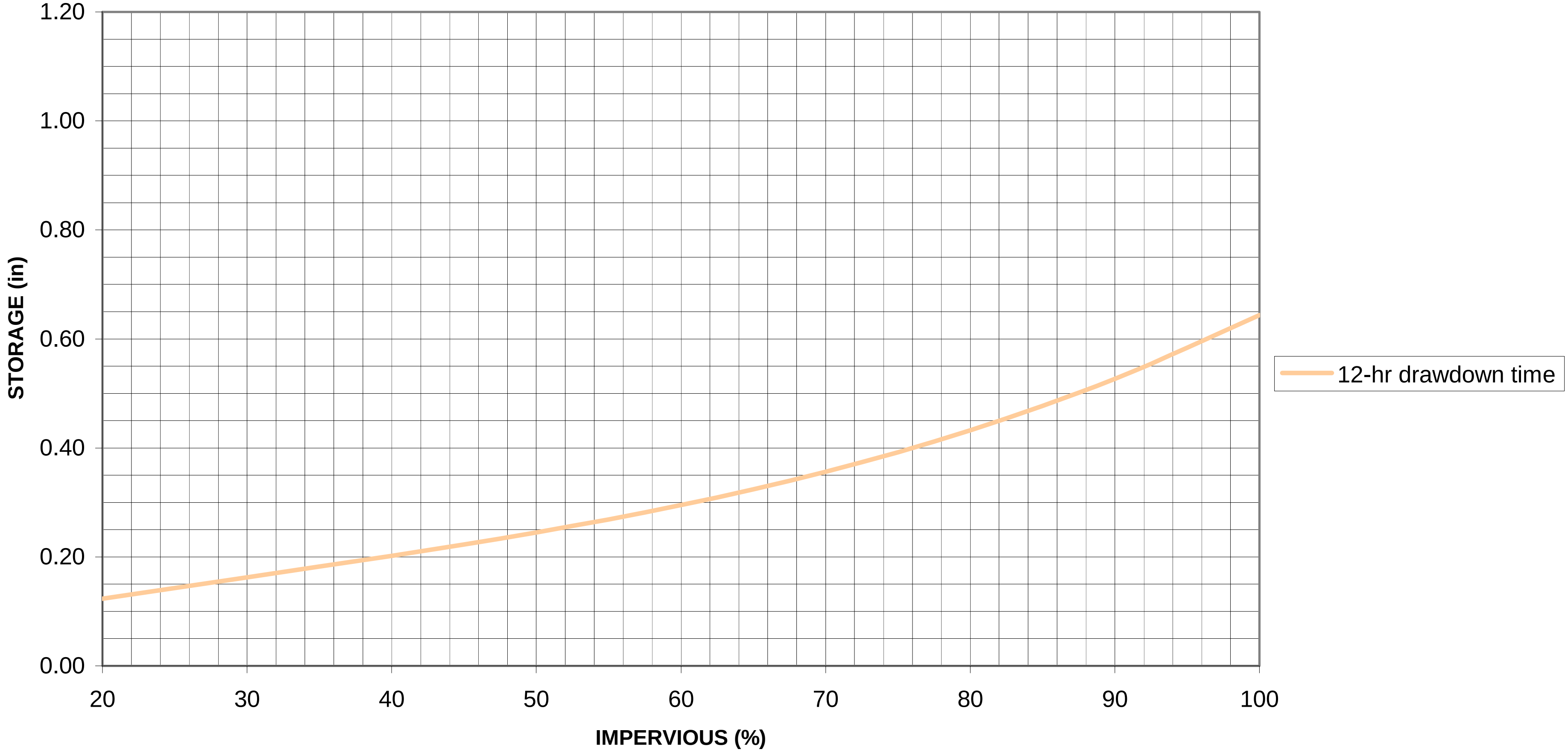
California Stormwater Quality Association (CASQA), 2003. *California Stormwater BMP Handbook for New Development and Redevelopment*, www.cabmphandbooks.com.

Development Standards Plan, Dec. 2003. *Appendix F: Technical Memorandum- Review of Design Criteria for Stormwater Quality Treatment Facilities for the Sacramento Stormwater Management Program.*

Placer Regional Stormwater Coordination Group (PRSCG). May 2005. *Guidance Document for Volume and Flow-Based Sizing of Permanent Post-Construction Best Management Practices for Stormwater Quality Protection.*

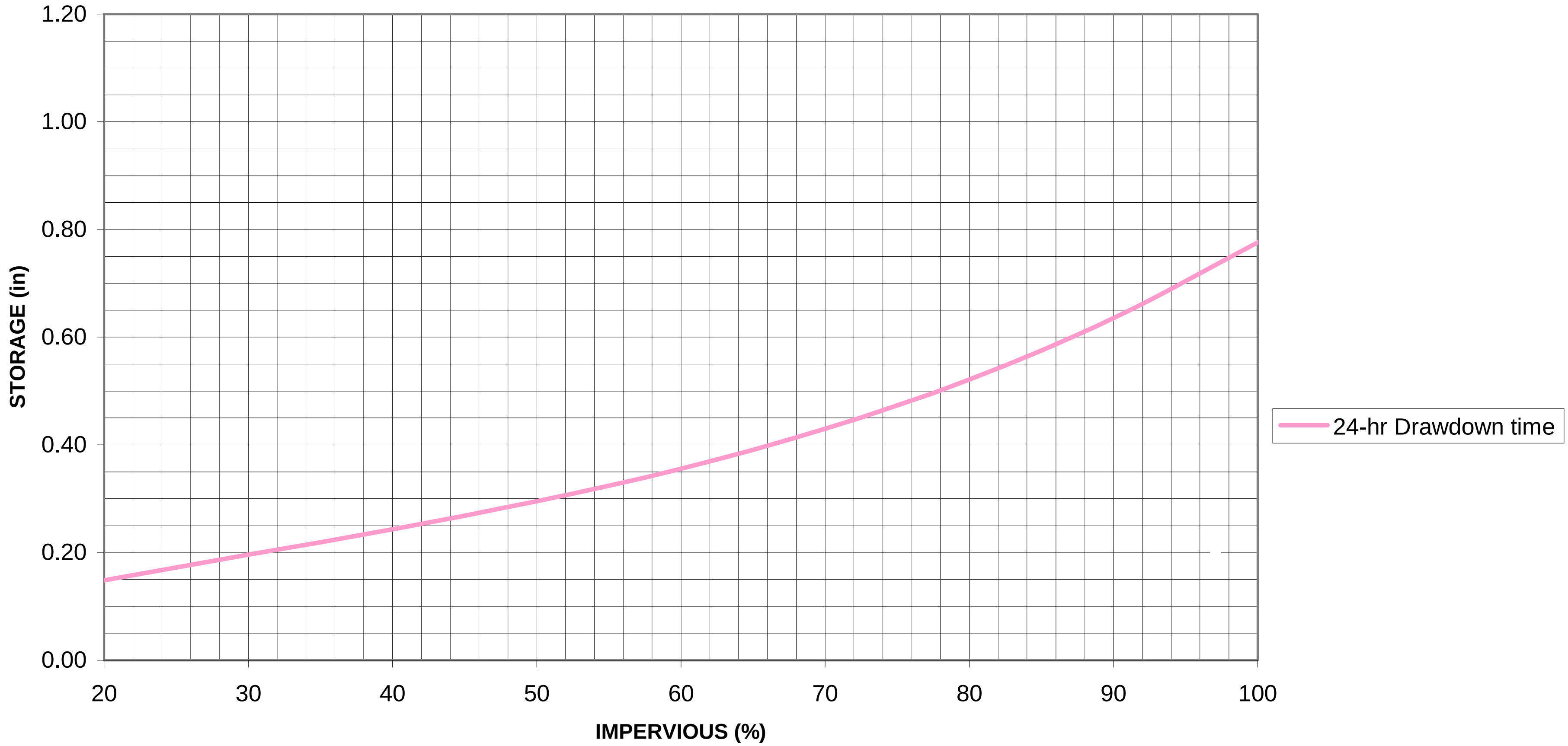
US Department of Transportation, Federal Highway Administration. November 1996. *Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22*, FHWA-SA-96-078.

Water Environment Federation and American Society of Civil Engineers (WEF and ASCE). 1998. *Urban Runoff Quality Management*. WEF Manual of Practice No. 23 and ASCE Manual and Report on Engineering Practice No. 87.



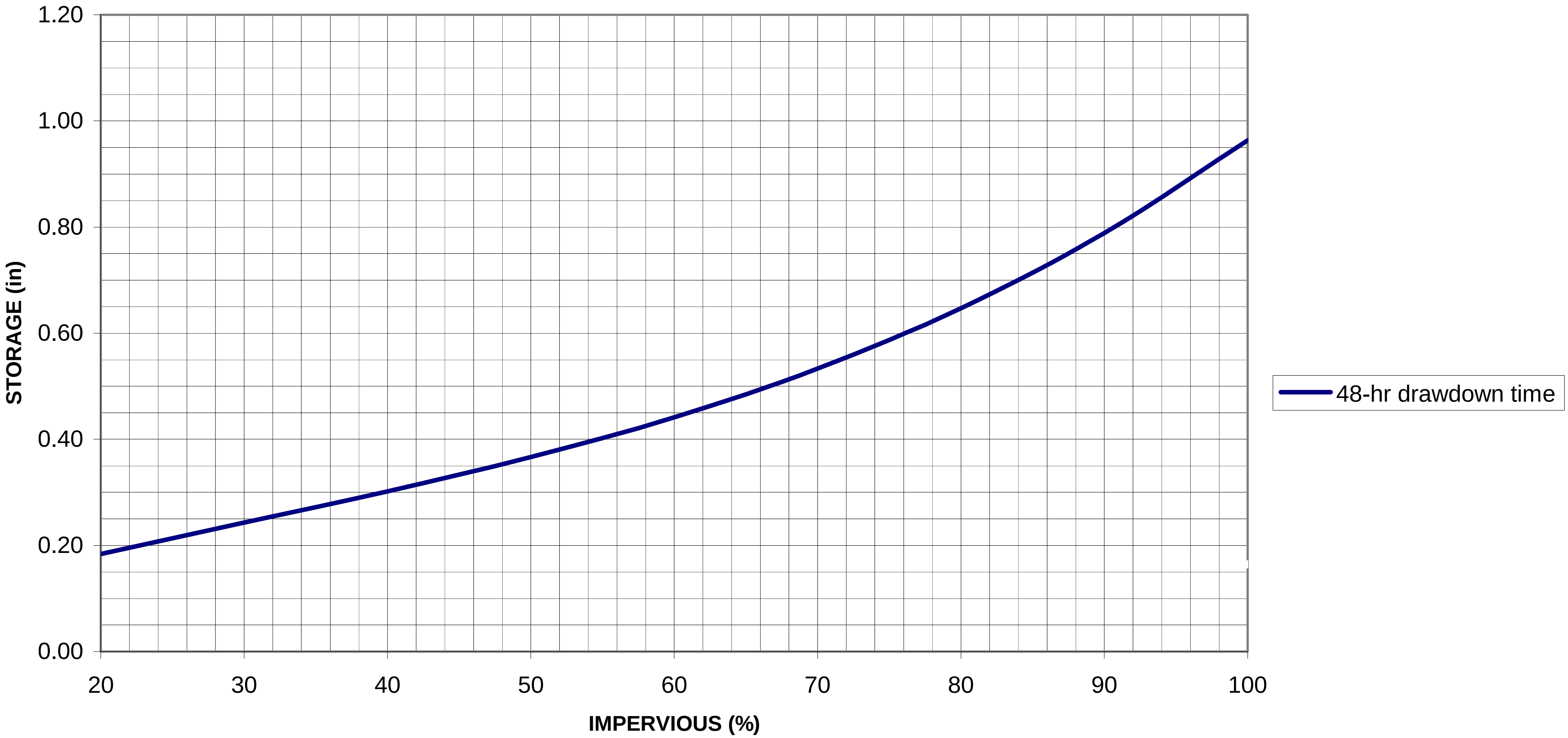
Souce: URBAN RUNOFF QUALITY MANAGEMENT: WEF Manual of Practice No. 23 and Report on Engineering Practice No. 87.

Curve for Maximized Detention Volume P_0	Date: August 2006
	Figure: E-1



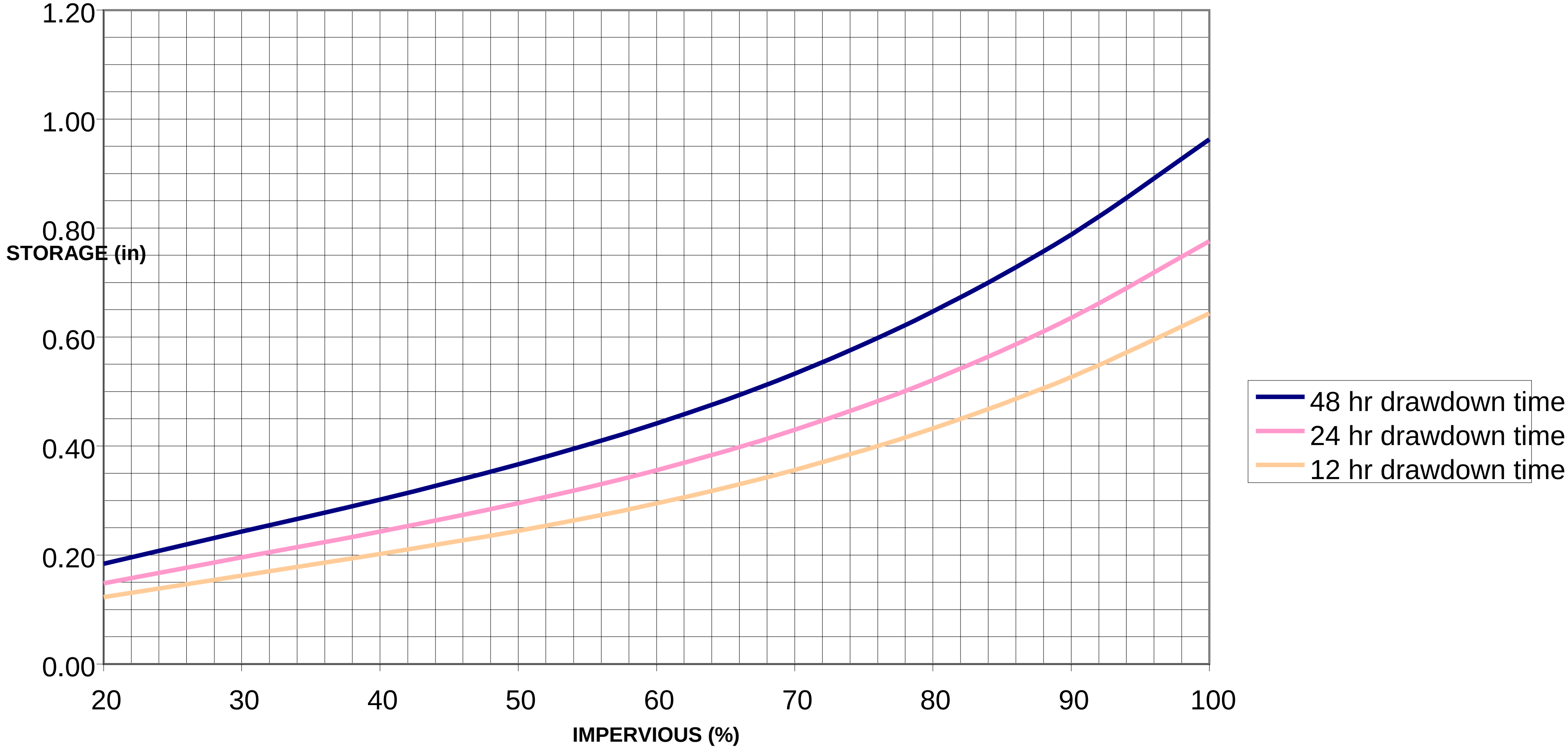
Source: URBAN RUNOFF QUALITY MANAGEMENT: WEF Manual of Practice No. 23 and Report on Engineering Practice No. 87.

Curve for Maximized Detention Volume P_0	Date: August 2006
	Figure: E-2



Source: URBAN RUNOFF QUALITY MANAGEMENT: WEF Manual of Practice No. 23 and Report on Engineering Practice No. 87.

Curve for Maximized Detention Volume P_0	Date: August 2006
	Figure: E-3



Souce: URBAN RUNOFF QUALITY MANAGEMENT: WEF Manual of Practice No. 23 and Report on Engineering Practice No. 87.

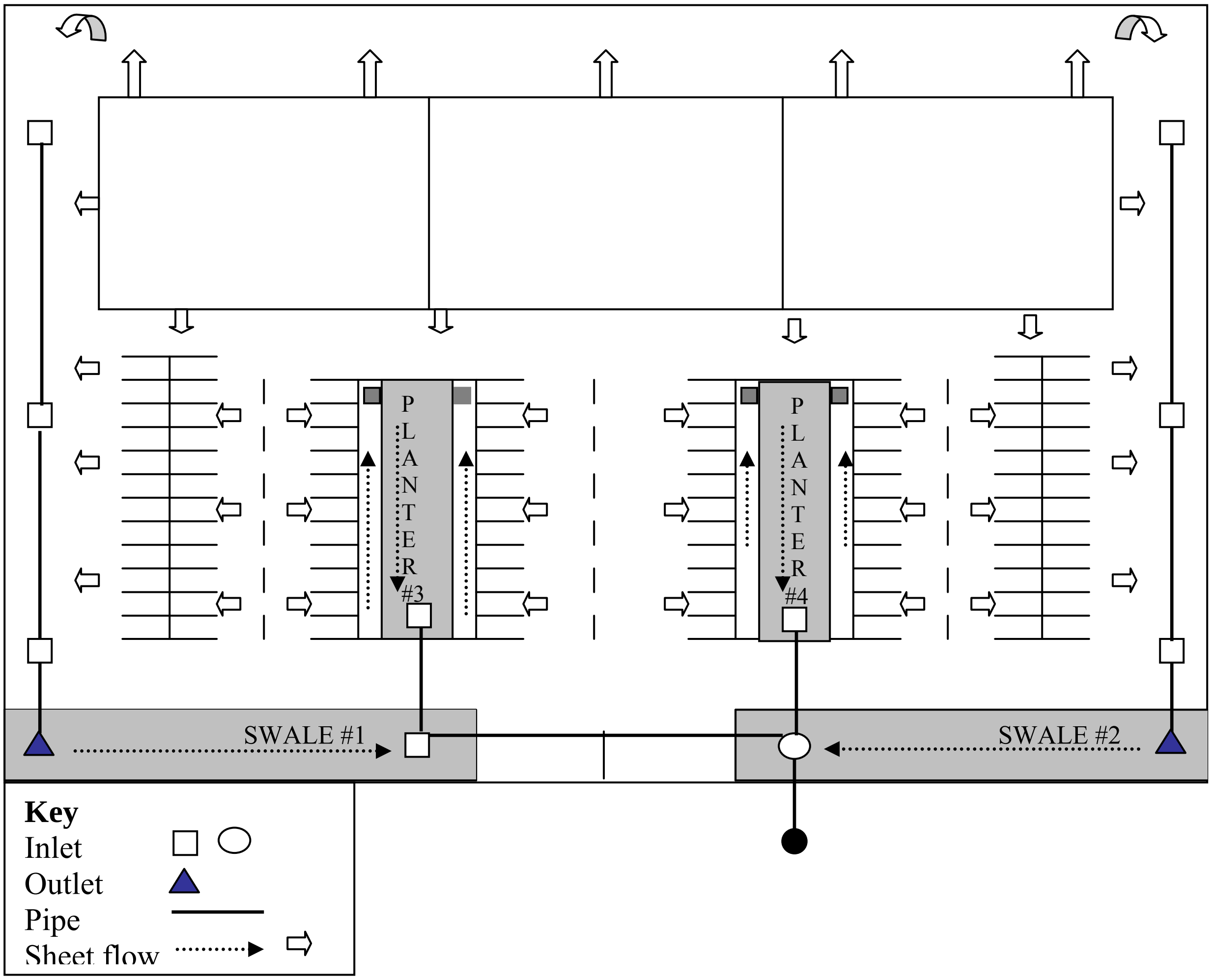
Curve for Maximized Detention Volume P_0	Date: August 2006
	Figure: E-4

Appendix F

Example Design Calculations

Vegetated Swale
Water Quality Detention Basin
Stormwater Planter

Subject: VEGETATED SWALE EXAMPLE



Site: 8 Acre Professional/Commercial Development

PART I:

(Used Table VS- 3 - The Design data Summary Sheet for Vegetated Swale for necessary calculations for ***Swale #1***)

1. **Design Flow: WQF = CiA** WQF = 0.486 cfs
   a. i = Rainfall Intensity = 0.18 in/hr i = 0.18 in/hr
   b. C = Runoff Coefficient C = 0.9
   c. A = Tributary area for ***Swale #1*** A = 3 acres

2. **Swale Geometry**
   a. Swale Bottom Width (b) b = 5 ft
   b. Side Slope (Z) Z = 3

3. **Depth of flow (d) at WQF (3" – 5" with Manning's n = 0.20)** d = 'y_1' ft.
(Description on how to calculate d is explained below)

$A = by + Zy^2$ (eqn 1)
$R = A/P = [(by + Zy^2) / (b + 2y\sqrt{(1 + Z^2)})]$ (eqn 2)
$Q = (1.49/n) (by + Zy^2) [(by + Zy^2) / (b + 2y\sqrt{(1 + Z^2)})]^{2/3} (s)^{1/2}$ (eqn 3)

Using Eqn. 3:

$\mathbf{0.486} = (1.49/.2) (5y + 3y^2) [(5y + 3y^2) / (5 + 2y\sqrt{10})]^{2/3} (.01)^{1/2}$

Trial & Error

Y

~~.35~~ => 7.45(2.1175)(.44169)(.1) = .696
~~.29~~ => 7.45(1.7023)(.3959)(.1) = .502
~~.28~~ => 7.45(1.6352)(.3878)(.1) = .472
~~.282~~ => 7.45(1.64857)(.38945)(.1) = .478

.285 ft. => 7.45(1.668675)(.39186)(.1) = .487 cfs

$\boxed{\mathbf{y_1 = Depth\ of\ WQF = 0.285\ ft.}}$

4. **Design Slope**
   a. s = 1% minimum without underdrains; 4% maximum without grade controls s = 1%

5. **Design Flow Velocity (Manning's n = 0.20)** V = 0.29 ft/sec

Velocity = Q/A = (using eqn. 3&1) = 0.486cfs / 1.67ft. = 0.29 ft/sec.

6. **Contact time** (t_c = 7 minutes minimum) t_c = 7 minutes

7. **Design Length**
   L = (t_c) x (flow velocity) x 60

   L = 7min x (.291ft/sec) x 60 = 122.22 ft L = 122.32 ft

PART II:

Routing Excess Runoff through a Vegetative Swale
(Use peak hydraulic flows on the site.)

Q = Peak hydraulic flow rate

(For Sacramento area projects, use Figure 2-5 Design Runoff Nolte Method from Section 9 of County of Sacramento Municipal Services Agency Improvement Standards October 1, 2006 to find Q.)

$Q = 1.5$ cfs (***Swale #1*** treating a 3 acre site)

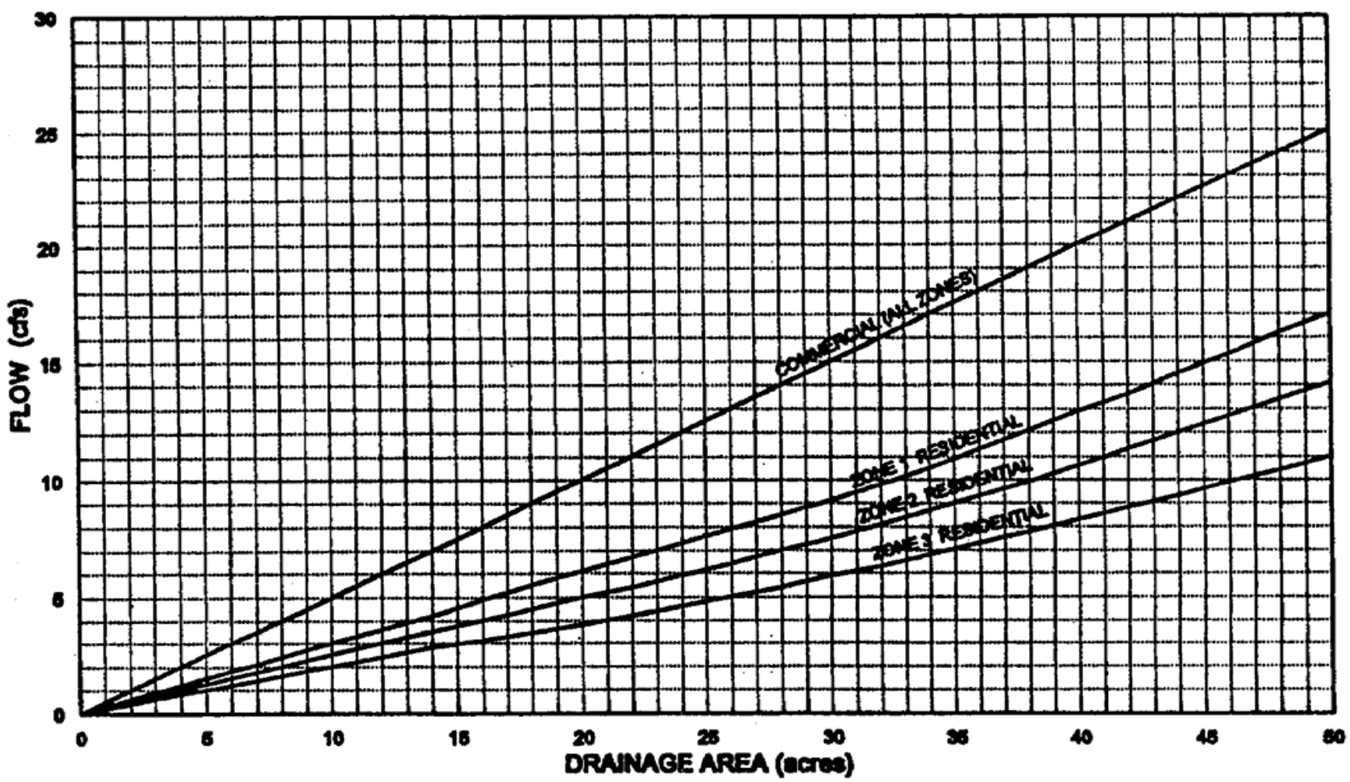
To determine the capacity of the swale to convey peak hydraulic flows, use a roughness coefficient *(n) of 0.10* with Manning's Equation.

$$Q = (1.49/n)\,(by + Zy^2)\,[\,(by + Zy^2) / (b + 2y\sqrt{(1 + Z^2)})]^{2/3}\,(s)^{1/2} \qquad \text{(eqn 3)}$$

$$\mathbf{1.5} = (1.49/.1)\,(5y + 3y^2)\,[(5y + 3y^2) / (5 + 2y\sqrt{10})]^{2/3}\,(.01)^{1/2}$$

(Using the solver function**: <u>y_2 = .365 ft.</u>**)

$\boxed{\mathbf{y_2 = \text{Depth of peak drainage flow} = 0.365\ ft.}}$



NOTE: Design runoff for multiple family development shall be based on the following formula:

$Qm = Qr + (Qc - Qr)(I-50)/40$

Where:

RD-7	I = 60
RD-10	I = 70
RD-20	I = 80
RD-30	I = 90

Source: County of Sacramento Master Drainage Plan, Part 1, County-wide Hydrology, Nolte and Assoc.

Design Runoff
Nolte Method
Drainage Areas, <50 Acres

Date December 1996

Figure 2-5

Design Example – Sizing of Water Quality Combination Basin in Sacramento County

Watershed and Basin Data

Watershed Area = 210 acres

Watershed Imperviousness = 39%

Basin Type = Combination Water Quality Basin also used for Flood Control

1. Calculate the Water Quality Storage Volume (WQV)

For a Water Quality Detention Basin, the WQV is calculated from the methodology in Appendix E using a 48-hour drawdown time.

- From Figure E-3 the unit storage is determined to be 0.29 inches
- WQV = 0.29 (in) x 210 (acre) ÷ 12 = 5.1 acre-feet
- Permanent Pool Volume = 0.625 x WQV = 3.2 acre-feet
- Wet Weather Pool Volume = 0.500 x WQV = 2.5 acre-feet

2. Size the Sediment Forebay

The sediment forebay size should be 5 to 10 percent of the maximum total design volume.

- Minimum Sediment Forebay Volume = (3.2 + 2.5) x 0.05 = 0.29 acre-feet minimum

3. Design the Basin

Detention basin layouts will vary significantly based on site specific conditions. For this example, it is assumed that the permanent pool will have an average depth of 4 feet and a length to width ratio of 3 to 1. Based on these requirements, the bottom dimensions of the basin will be 300' x 100' (L x W) and the side slopes will be 3 to 1. The hypothetical basin will have the following elevation storage relationship.

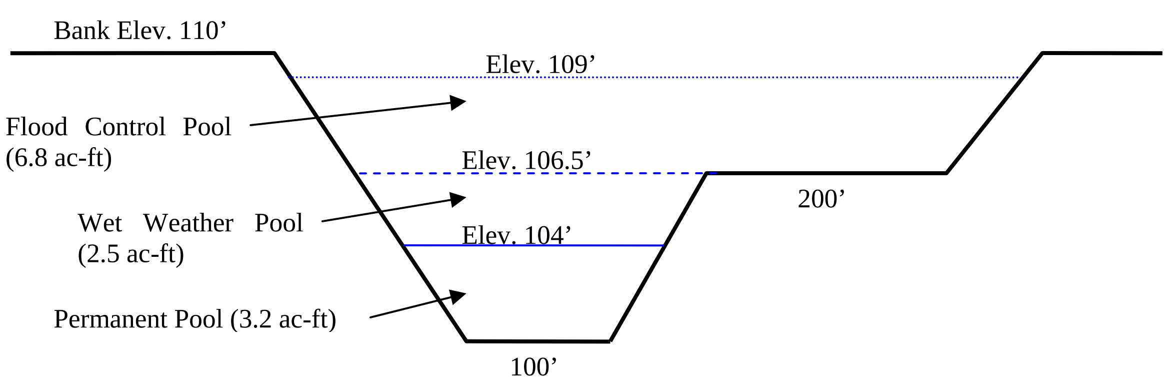
Elev. (ft)	Depth (ft)	Area (ac)	Storage (ac-ft)	Notes
100.0	0.0	0.7	0.0	
101.0	1.0	0.7	0.7	
102.0	2.0	0.8	1.5	
103.0	3.0	0.9	2.3	
104.0	4.0	0.9	3.2	Permanent Pool Elevation
105.0	5.0	1.0	4.2	
106.0	6.0	1.0	5.2	
106.5	6.5	1.1	5.7	Wet Weather Pool Elevation
107.0	7.0	2.7	6.7	

4. **Design the Outlet**

The outlet should be sized to release the 75 percent of the wet weather pool volume in a minimum of 24 hours and release the remaining volume over an additional 16 to 24 hours. For this example the outlet is assumed to be a stand pipe with the top of the pipe at the wet weather pool elevation and a single orifice placed just above the permanent pool elevation. The orifice can be sized using the orifice equation and a simple spreadsheet calculation such as the one shown on Exhibit 1. As shown on Exhibit 1, an orifice with an area of 23.8 square inches will produce the desired drain time. The size of the stand pipe is based on the capacity required to pass the appropriate design storms.

5. **Flood Control Design**

Water quality basins can often be used to provide flood control benefits. The storage volume above the water quality pool can act to reduce peak flood flows downstream of the basin. The required storage volume and storm outlet size are typically determined by routing flood hydrographs through the detention basin using a computer program such as SacCalc, HEC-1, HEC-RAS, or other equivalent program. For this example, it is assumed that flood routing was performed and 6.8 acre-feet of storage is required to attenuate flood flows to the desired downstream level. To meet this storage requirement, the basin is widened to create a flood control bench just above the maximum water quality pool as shown in the following cross section.



The resulting storage elevation-storage relationship including the flood control pool is shown below.

Elev (ft)	Depth	Area (ac)	Total Storage Volume (ac-ft)	Notes
100.0	0.0	0.7	0.0	
101.0	1.0	0.7	0.7	
102.0	2.0	0.8	1.5	
103.0	3.0	0.9	2.3	
104.0	4.0	0.9	3.2	Permanent Pool Elevation
105.0	5.0	1.0	4.2	
106.0	6.0	1.0	5.2	
106.5	6.5	1.1	5.7	Wet Weather Pool Elevation
106.6	6.6	2.65	5.9	
107.0	7.0	2.69	7.0	
108.0	8.0	2.78	9.7	
109.0	9.0	2.88	12.5	Flood Control Pool Elevation
110.0	10.0	2.98	15.5	

Exhibit 1

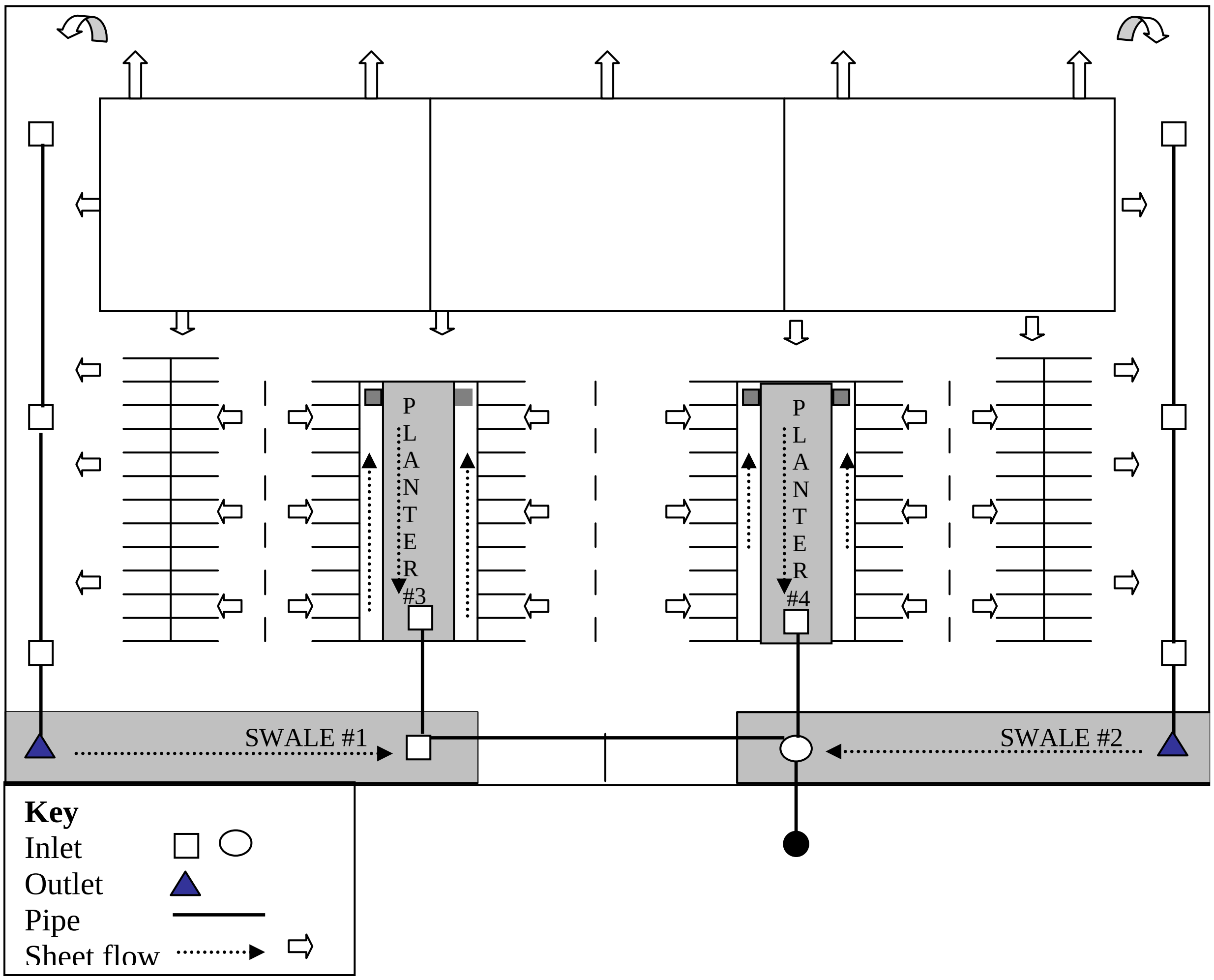
Water Quality Orifice Outlet Sizing

<u>Orifice Data</u>

Orifice Size = 23.8 square inches
Orifice Coefficient = 0.61
Orifice Elevation = 104.0

Time (hr)	Volume	Elev.	Outflow (cfs)
0.00	5.72	106.4	1.26
1.00	5.62	106.4	1.24
2.00	5.51	106.3	1.22
3.00	5.41	106.2	1.20
4.00	5.31	106.1	1.18
5.00	5.22	106.0	1.15
6.00	5.12	106.0	1.13
7.00	5.03	105.9	1.11
8.00	4.94	105.8	1.08
9.00	4.85	105.7	1.06
10.00	4.76	105.6	1.04
11.00	4.67	105.6	1.01
12.00	4.59	105.5	0.99
13.00	4.51	105.4	0.96
14.00	4.43	105.3	0.94
15.00	4.35	105.3	0.91
16.00	4.28	105.2	0.88
17.00	4.20	105.1	0.86
18.00	4.13	105.1	0.83
19.00	4.06	105.0	0.80
20.00	4.00	104.9	0.77
21.00	3.93	104.9	0.75
22.00	3.87	104.8	0.72
23.00	3.81	104.7	0.69
24.00	3.75	104.7	0.66
25.00	3.70	104.6	0.63
26.00	3.65	104.6	0.60
27.00	3.60	104.5	0.57
28.00	3.55	104.5	0.54
29.00	3.51	104.4	0.51
30.00	3.46	104.4	0.48
31.00	3.42	104.3	0.45
32.00	3.39	104.3	0.42
33.00	3.35	104.2	0.39
34.00	3.32	104.2	0.36
35.00	3.29	104.2	0.33
36.00	3.26	104.1	0.29
37.00	3.24	104.1	0.26
38.00	3.22	104.1	0.23
39.00	3.20	104.1	0.20
40.00	3.18	104.0	0.16
41.00	3.17	104.0	0.13
42.00	3.16	104.0	0.09
43.00	3.15	104.0	0.05
44.00	3.15	104.0	0.00

Subject: STORMWATER PLANTER EXAMPLE



Site: 8 Acre Professional/Commercial Development

PART I:

(Used Table SP-3 - The Stormwater Planter Design Criteria for the necessary calculations for ***Planter #3***)

1. **Design Volume: WQV = P_0*A/12** — WQV = 0.04 ac-ft
   a. I = imperviousness (%) — I = 82%
   b. P_0 = Detention Volume (inches) using 12 hr drawdown curve Figure E-1 — P_0 = .45 in
   c. A = Tributary area for ***Planter #3*** — A = 1 acre

2. **Design Average Surcharge Depth (d_s)**
   a. Surcharge Depth (d_s) (0.5-1 foot) — d_s = 1 ft

3. **Calculate Planter Surface Area A_s=WQV/ d_s** A_s=0.04 acres
   A_s=1634 ft^2
4. **Design Base Course**
   a. Bottom Gravel Layer: minimum 9 inches
   b. Sand/Peat layer: minimum 18 inches
   c. Topsoil Layer: minimum 6 inches
5. **Planter Type**
   a. Select type
      i. Infiltration without under drain
      ii. Infiltration with under drain
      iii. Flow through with impermeable liner
6. **Select Vegetation**
7. **Design Overflow Device**
   a. Select type
      i. Drop inlet
      ii. Standpipe
      iii. Other

APPENDIX G
DESIGNING AND MAINTAINING STORMWATER QUALITY CONTROL MEASURES TO AVOID VECTOR PROBLEMS

Public health and safety is a major component of all stormwater programs. Accordingly, minimizing mosquitoes in structural stormwater treatment systems is essential to prevent disease transmission and maintain quality of life. Basic mosquito management guidelines have been developed that are relevant to the location, design, and operation of proprietary and nonproprietary treatment systems; unfortunately, the rapid growth and evolution of stormwater programs and treatment system design combined with the tremendous number of local factors that may influence mosquito production at any given site preclude any “cure-all” recommendations or solutions.

General Design and Maintenance Recommendations

Managing mosquitoes successfully in stormwater treatment systems requires carefully thought out preventative design and maintenance plans. The following list of actions represent general design and maintenance recommendations to minimize suitable mosquito breeding habitat and mosquito production from runoff treatment control measures covered in this stormwater quality design manual. For more information please refer to Managing Mosquitoes in Stormwater Treatment Devices (http://anrcatalog.ucdavis.edu/pdf/8125.pdf).

Vegetated Swales, Infiltration Trenches, Infiltration Basins

- Trenches, basins and swales should be designed and maintained so that runoff is capable of completely passing through the structure within three days after introduction, especially during the peak mosquito breeding months of April through October.
- The bottom of the trenches, basins and swales must be free of depressions i.e. tire ruts in order to limit standing water within the structure.
- Vegetation management should be performed annually to remove excessive vegetation within the structure.
- Grass clippings and other debris should be removed from trenches, basins and swales on a regular basis.

Detention Basins

- Basins should be adequately sloped to allow positive drainage from inlet to outlet if the basin is required to be drained.
- Shallow water should never be interfaced with emergent vegetation.
- Water depths should be > 4 feet to discourage emergent vegetation.
- Side slopes of 3:1 are recommended for any permanent or semi-permanent ponds.
- All aquatic and periphery vegetation should be completely or significantly reduced on a yearly basis.
- Levees and other water structures should be constructed and maintained to prevent seepage or flooding into adjacent lowland areas.
- Allow access for continual larval and adult mosquito surveillance.
- Outlets should be regularly cleaned of debris.
- Avoid the combination of low dissolved oxygen levels and high organic content. Immature mosquito species thrive in low oxygen and high organic content.

Constructed Wetland Basins

- Each wetland cell should have an independent inlet and outlet water structure allowing for the wetland to be rapidly drained during situations of severe mosquito production.
- Wetland cells should not be constructed greater then 40 feet in width.
- Shallow areas of < 1 foot should be kept to a minimum; pond depths of > 4 feet are encouraged.
- Embankments with slopes 4:1 or steeper are recommended.
- Levees, drain ditches and other water structures should be constructed and maintained to prevent seepage or flooding into adjacent lowland areas.

- Bottom slopes of 0.01 to 0.05% are recommended so wetland can be de-watered for vegetation or mosquito management.
- Shallow water areas (< 1 foot), interfaced with emergent vegetation should not hold water for more then 3 days during the summer months.
- Limit dense stands of aquatic vegetation along shore margins and shallow areas.
- The wetland in its entirety should consist of at least 50% open water.
- Avoid stocking game fish that will reduce the population density of mosquitofish.
- Provide road access around entire wetland for mosquito control and surveillance.
- Avoid water quality associated with high organic content and low oxygen levels.

Stormwater Drainage Channels

- Water conveyance systems should be constructed and graded sufficiently to allow for a continuous flow of water.
- Drains should be cleaned yearly of emergent vegetation and other debris to prevent water blockage and mosquito breeding habitat.
- Drains should be designed with sufficiently sloped sides to allow adequate drainage without standing water.
- Drains should be maintained to prevent flooding to adjacent lowland areas.

Below-Ground Systems

- Stormwater systems that incorporate permanent water sumps, vaults, or basins should be made to deny mosquito access (e.g., tight-fitting covers). Any gaps or holes should not be greater then 1/16th of an inch.
- Design devices for easy access for inspection and without the need for confined-space-entry.

Involving Vector Control District in Planning and Design

It is strongly encouraged that municipalities refer projects with stormwater devices designed to hold water for longer than 72 hours (April-October) or longer than 14 days (November through March) to the appropriate Vector Control District for review. Early involvement by the District should alleviate potential regulatory issues in the future.

Maintenance Responsibility

Property owners, either public or private, retain the responsibility of ensuring that stormwater devices do not breed mosquitoes regardless if design, construction or maintenance of stormwater devices follow guidelines from any agency. Sacramento-Yolo Mosquito & Vector Control District, through the California Health and Safety Code, has the authority to impose civil penalties of up to $1,000 per day on public health nuisances in the form of mosquito breeding sites.

Resources should be available to readily address maintenance issues relating to mosquito breeding activity within specific stormwater devices. It is essential that specific maintenance responsibilities are delineated early in the device planning process.

Resources

Metzger, Marco E., California Dept. of Health Services, *Managing Mosquitoes in Stormwater Treatment Devices.* University of California, Division of Agriculture and Natural Resources. ANR Publication 8125. January 2004. 11 pp. (http://anrcatalog.ucdavis.edu/pdf/8125.pdf).

Placer Mosquito Abatement District and California Dept. of Health Services, *Guidelines and Standards for Vector Prevention in Proposed Developments*, Draft, June 13, 2006. Obtain a copy from: charlied@placermosquito.org.

Contra Costa Clean Water Program, *Vector Control Plan*, June 1, 2004. 18 pp. (http://www.cccleanwater.org/construction/Publications/CCCWP%20Vector%20Control%20Plan%20Final.pdf).

Contact for More Information

Projects in Sacramento and Yolo Counties
Sacramento-Yolo Mosquito & Vector Control District Contact information:
Bob Rooker
8631 Bond Road
Elk Grove, CA 95624-1477
916-405-2085
Brooker@sac-yolomvcd.com

Projects in Placer County
Placer Mosquito Abatement District
P.O. Box 216
150 Waverly Drive
Lincoln, CA 95648
916-435-2140
charlied@placermosquito.org
www.placermosquito.org

Appendix H

Drainage Design and Stormwater Management Information Not Included in the Design Manual

Drainage/Flood Control Design Reference Documents

The design manual does not contain general drainage design standards and details. For that information refer to:

City and County of Sacramento Drainage Manual -Volume II Hydrology Standards – Hard copy/CD can be purchased from Sacramento County. Contact the Sacramento County Dept. of Water Resources at (916) 874-6851 for ordering information.

City of Sacramento Department of Utilities Procedures Manual and Utility Standards – Electronic copies can be downloaded at www.sacstormwater.org. Hard copies can be purchased at the City Department of Utilities or one of the two City Permit Centers; call (916) 808-1400 for more information.

City of Folsom Design and Procedures Manual – Electronic copy can be downloaded at: www.folsom.ca.us/depts/community_development/ engineering/design.asp. Or contact the City Department of Public Works for more information at (916) 355-7272.

Placer County Flood Control District – Stormwater Management Manual, available at the following web address: www.placer.ca.gov/Home/Works/Resources/Swmm.aspx.

Construction Erosion and Sediment Control Documents

Sacramento County Improvement Standards (Section 11 – October 2006). (Theses standard details area also used by cities in Sacramento; check with your local permitting agency for verification.) Electronic copies can be downloaded at *http://www.msa.saccounty.net/waterresources/* under "Reports and Publications". Hard copies can be purchased at: 827 7th Street, Sacramento, CA 95814, the cashier's office in first floor.

City of Roseville Improvement and Construction Standards.

Electronic copies can be downloaded at *www.roseville.ca.us*. Hard copies can be purchased at the City Permit Center, call (916) 746 -1300 for more information.

Industrial/Commercial Facility Operational BMP Guidance Documents

Sacramento County and Cities in Sacramento County: Guidance materials are published by the Sacramento County Environmental Management Department, which is responsible for conducting stormwater compliance inspections of many industrial/commercial facilities in the county. Visit http://www.emd.saccounty.net/WP/EMDstormwater.htm for more information.

City of Roseville: The City of Roseville will be developing a guidance manual for industrial and commercial facilities. Visit the City's stormwater web site for information as it becomes available: www.roseville.ca.us/eu/stormwater_management.

Statewide Guidance: *California Stormwater Best Management Practice Handbook (Industrial and Commercial Edition)*, CASQA, 2003. www.cabmphandbooks.com/