DRAFT

# The City Of Salinas

# Storm water Development Standards

# For

# New Development and Significant Redevelopment Projects

**May 2008**

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## Abbreviations

| | |
|---|---|
| BMP | Best Management Practice |
| CASQA | California Stormwater Quality Association |
| CEQA | California Environmental Quality Act |
| CFR | Code of Federal Regulations |
| COA | Conditions of Approval |
| DRC | Development Review Committee |
| LID | Low Impact Development |
| MEP | Maximum Extent Practicable |
| MS4 | Municipal Separate Storm Sewer System |
| NOI | Notice of Intent |
| RWQCB | Regional Water Quality Control Board |
| SMC | Salinas Municipal Code |
| SWCP | Stormwater Control Plan |
| SWPPP | Stormwater Pollution Prevention Plan |
| SWRCB | State Water Resources Control Board |

# Glossary

**“Accelerated Erosion”** – erosion caused by development activities that exceeds the natural processes by which the surface of the land is worn away by the action of water, wind, or chemical action.

**“Applicant”** – a property owner or agent of a property owner who has filed an application for a stormwater management permit.

**“Best Management Practices (BMP)”** – any procedure, activity, facility or device that helps to achieve stormwater management objectives at a designated site.

“**Building”** – any structure, either temporary or permanent, having walls and a roof, designed for the shelter of any person, animal, or property, and occupying more than 100 square feet of area.

**“Channel”** – a natural or artificial watercourse with a definite bed and banks that conducts continuously or periodically flowing water.

**“Construction BMP”** – temporary source control (e.g. cover soil stockpiles) and/or treatment control (e.g. silt fence, temporary detention basin) BMPs intended to minimize pollutants from stormwater during project construction.

**“Dedication”** – the deliberate appropriation of property by its owner for general public use.

**“Detention”** – the temporary storage of storm runoff in a stormwater management practice with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

**“Detention Facility”** – a basin or alternative structure designed for the purpose of temporary storage of stream flow or surface runoff and gradual release of stored water at controlled rates.

**“Developer”** – a person who undertakes land disturbance activities.

**“Discharge”** – when used as a verb, means to allow pollutants to directly or indirectly enter stormwater, or to allow stormwater or non-stormwater to directly or indirectly enter the storm drain system from an activity or operation. When used as a noun, "discharge" means the pollutants, stormwater and/or non-stormwater that are discharged.

**“Drainage Area”** – an area, as defined by the highest topography of a site, where all precipitation falling within the area will flow to a single common point.

**“Drainage Easement”** – a legal right granted by a landowner to a grantee allowing the use of private land for stormwater management purposes.

**"Drainage Sub-area"** – a smaller portion of the drainage area.

# Glossary

**"Effective Impervious Area (EIA)"** – that portion of the impervious area that drains directly to a receiving surface waterbody via a hardened storm drain conveyance without first draining to a pervious area. Impervious surfaces that drain first to pervious areas (e.g. landscaping or porous pavements) are not considered Effective Impervious Areas.

**"Erosion and Sediment Control Plan"** – a plan that is designed to minimize the accelerated erosion and sediment runoff at a site during construction activities.

**"Fee in Lieu"** – a payment of money in place of meeting all or part of the stormwater performance standards required by this ordinance.

**"Flow-based Treatment Control BMPs"** – structural treatment controls designed to convey, treat or infiltrate the maximum flow rate produced by a rain event equal to two times the 85th percentile hourly rainfall intensity based on local rainfall records. Examples of flow-based treatment control BMPs include vegetated swales and buffer strips.

**"Hotspot"** – an area where land use or activities generate highly contaminated runoff, with concentrations of pollutants in excess of those typically found in stormwater.

**"Hydrologic Soil Group (HSG)"** – a Natural Resource Conservation Service classification system in which soils are categorized into four runoff potential groups. The groups range from HSG-A soils, with high permeability and little runoff production, to HSG-D soils, which have low permeability rates and produce much more runoff.

**"Impervious Cover"** – those surfaces that cannot effectively infiltrate rainfall (e.g., building rooftops, pavement, sidewalks, driveways, etc).

**"Impervious Surface"** – constructed or modified surface that cannot effectively infiltrate rainfall. Impervious surface includes but is not limited to building rooftops, pavement, sidewalks, and driveways where such surfaces are not constructed with pervious materials. "Impervious surface area" means the ground area covered or sheltered by an impervious surface, measured as if from directly above.

**"Industrial Stormwater Permit"** – an NPDES permit issued to a commercial industry or group of industries which regulates the pollutant levels associated with industrial stormwater discharges or specifies on-site pollution control strategies.

**"Infiltration"** – the process of percolating stormwater downward into the subsurface soil. Infiltration can occur through existing site soils that are not covered by impervious surfaces, or it can occur through infiltration devices designed to collect and treat urban runoff.

**"Infiltration Device"** – any structure designed to infiltrate stormwater into the subsurface. Infiltration devices may be above grade or below grade. Infiltration devices that do not meet the design criteria in these standards must be reviewed and approved by the Monterey County Environmental Health Department before City building permits are approved

**"Infiltration Rate" -** is the time it takes stormwater to percolate into the soil surface. Infiltration rates are generally reported in units such as inches of water infiltrated per hour (in/hr) or the number of minutes required to drain one inch of stormwater (min/in).

"**Integrated Management Practices (IMPs)" -** are small on-lot treatment control BMPs that are integrated into the site layout, landscaping and drainage design of urban development. They typically treat runoff from relatively small drainage areas (less than 5 acres) and include LID practices such as vegetated swales and filter strips, bioretention systems, and porous paving systems.

**"Jurisdictional Wetland"** – an area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation.

**"Land Disturbance Activity"** – any activity which changes the volume or peak flow discharge rate of rainfall runoff from the land surface. This may include the grading, digging, cutting, scraping, or excavating of soil, placement of fill materials, paving, construction, substantial removal of vegetation, or any activity which bares soil or rock or involves the diversion or piping of any natural or man-made watercourse.

**"Landowner"** – the legal or beneficial owner of land, including those holding the right to purchase or lease the land, or any other person holding proprietary rights in the land.

**"Low Impact Development (LID)"** – the principles and techniques used in designing sites (starting from site layout, and grading and compaction phases of construction) that disturb only the smallest area necessary, minimize soil compaction and imperviousness, preserve natural drainages, vegetation, and buffer zones, and utilize on-site, lot sized stormwater treatment techniques. LID sites reduce and compensate for development's impact(s) on hydrology and water quality.

**"LID Practice"** – are design techniques and facilities that effectively reduce the rate, volume and pollutant loading of urban runoff to pre-development conditions, LID practices include Integrated Management Practices (IMPs – see definition above) designed to capture, treat and infiltrate urban runoff (where existing site soils permit) through engineered soil mixtures.

**"Maintenance Agreement"** – a legally recorded document that acts as a property deed restriction, and which provides for long-term maintenance of stormwater management practices.

**"Maximum Extent Practicable (MEP)"** – generally a result of emphasizing pollution prevention and source control best management practices (BMPs) as the first lines of defense in combination with structural treatment control BMPs where appropriate serving as additional lines of defense. The MEP approach is an ever evolving, flexible, and advancing concept, which considers technical and economic feasibility. MEP is defined by what is required in the NPDES Permit, EPA guidance, and current applied and available methods and financially feasible technology. The Regional Board has determined that the MEP criteria are to be met in the City of Salinas with the use of LID practices and IMPs that reduce the rate, volume and pollutant loading of urban runoff.

**"Municipal Separate Storm Sewer System (MS4)"** – the system of stormwater conveyances (including streets, curbs, gutters, ditches, man-made channels, catch basins and underground storm drain pipes) owned and operated by a public body (such as a City or County) having jurisdiction over of the discharge of stormwater to waters of the United States (e.g. local streams, wetlands and other surface waters).

**"Nonpoint Source Pollution"** – pollution from any source other than from a discernible, confined, and discrete conveyance, including but not be limited to stormwater pollutants from developed urban areas, construction sites, agriculture and mining.

**"Non-stormwater Discharges"** – non-stormwater discharges are those flows that do not consist entirely of stormwater. Non-stormwater discharges without pollutants can include uncontaminated groundwater and natural springs. Non-stormwater discharges that may contain low levels of pollutants can include car washing, air conditioner condensate, and hydrant flushing water.

**"Numeric Sizing Criteria"** – hydraulic sizing design criteria to for treatment BMPs for stormwater runoff. The criterion is different for volume or flow hydraulic design basis, depending on the primary mode of action for the treatment BMP.

**"Offset Fee"** – a monetary compensation paid to a local government for failure to meet pollutant load reduction targets.

**"Off-Site Facility"** – a stormwater management measure located outside the subject property boundary described in the permit application for land development activity.

**"On-Site Facility"** – a stormwater management measure located within the subject property boundary described in the permit application for land development activity.

**"Post-Construction BMP"** – permanent source control and/or treatment control BMPs, including LID practices, intended to be in place to treat stormwater and minimize pollutants discharged to the City's storm drain collection system **after** the project is constructed. If a

Stormwater Control Plan (SWCP) is required for a site, then information as to the design, operation, and maintenance of the Post-Construction BMPs must be included in the SWCP.

**"Recharge"** – the replenishment of underground water reserves.

**"Redevelopment"** – land-disturbing activity that result in the creation, addition, or replacement of impervious surface area on an already developed site. Redevelopment includes, but is not limited to the expansion of a building footprint; addition or replacement of a structure; replacement of impervious surface area that is not part of a routine maintenance activity; and land-disturbing activities related to structural or impervious surfaces.

**"Significant Redevelopment" –** the creation or addition of at least 5,000 square feet of impervious surfaces on an already developed site. It also includes, but is not limited to expansion of a building footprint, or replacement of a structure; replacement of impervious surface that is not part of a routine maintenance activity; and land-disturbing activities related to structural or impervious surfaces.

**"Source Control BMP"** – any schedule 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"** – surface runoff and drainage associated with storm events.

**"Stormwater Control Plan** (**SWCP**)**"** – a plan identifying the measures that will be used for stormwater and non-stormwater management after construction is complete for any new development or significant redevelopment project subject to the requirements of City of Salinas Stormwater Ordinance. The SWCP should include treatment and source control Best Management Practices (BMPs) and site design measures that will treat and control stormwater coming from the site to the maximum extent practicable (MEP). It must also reflect the information presented in project plan sheets as approved by Plan Check in the Salinas Building Division. SWCPs may be required for projects that add or replace 5,000 square feet or more of impervious area. The SWCP shall also include a copy of the construction Stormwater Pollution Prevention Plan (SWPPP) developed for the project.

**"Stormwater Management"** – the use of structural or non-structural practices that are designed to reduce stormwater runoff pollutant loads, discharge volumes, peak flow discharge rates and detrimental changes in stream temperature that affect water quality and habitat.

**"Stormwater Pollution Prevention Plan (SWPPP)"** – a plan identifying the measures that will be used to manage stormwater and non-stormwater during the construction phase of a project. A SWPPP is required for those facilities that disturb one or more acres of land and must file a Notice of Intent (NOI) with the Regional Water Quality Control Board. A SWPPP may also be required for projects in the City that are issued a grading permit.

**“Stormwater Retrofit”** – a stormwater management practice designed for an existing development site that previously had either no stormwater management practice in place or a practice inadequate to meet the stormwater management requirements of the site.

"**Stormwater Runoff**" – flow on the surface of the ground, resulting from precipitation.

**“Stormwater Treatment Practices”** – measures, either structural or nonstructural, that are determined to be the most effective, practical means of preventing or reducing point source or non-point source pollution inputs to stormwater runoff and water bodies.

**“Treatment”** – the use of designed and/or engineered systems, which 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 ultraviolet (UV) radiation.

**“Treatment Control BMP”** – any engineered system designed to remove pollutants by simple gravity settling of particulate pollutants, filtration, biological uptake, media adsorption or any other physical, biological, or chemical process.

**“Volume-based Treatment Control BMPs”** – structural treatment controls designed to capture, treat or infiltrate the volume produced by the local 24-hour, 85th percentile storm event or 80% of the volume of annual runoff. Examples of volume-based treatment control BMPs include extended detention basins, infiltration basins, and bioretention systems. Numerically, the volume will vary as a function of drainage area size, percentage of impervious area, geographic location and long-term rainfall statistical data.

**“Watercourse”** – a permanent or intermittent stream or other body of water, either natural or man-made, which gathers or carries surface water.

# Executive Summary

The purpose of this document is to assist project applicants with the stormwater management requirements set forth by the Central Coast Regional Water Quality Control Board (Regional Board), and the associated City of Salinas (City) storm drainage and flood control requirements. These requirements are complex and technical; relatively large projects will require the assistance of an interdisciplinary team of professionals, including a registered civil engineer, a geotechnical engineer, an architect, and a landscape architect. Because every project is different, applicants should begin by scheduling a pre-application meeting with City planning staff during the conceptual design of development projects. As shown in Figure ES-1 (next page), when integrated early in the planning of development and community design, Low Impact Development (LID) has the greatest relative effectiveness in reducing of the rate, volume and pollutant loading of urban runoff to pre-development levels, which is required by the Regional Board. Although an important part an overall strategy to reduce pollutants in stormwater discharges, other methods such as Source Control best management practices (BMPs) and many Structural Treatment Control BMPs do not effectively reduce the rate and volume of post-development runoff.

### Plan To Avoid the Three Most Common Mistakes

The most common (and costly) errors made by applicants for development approvals with respect to compliance with the new stormwater management requirements are:

1. Not planning for compliance and incorporation of LID designs and practices into a project early enough. Applicants should think about a strategy for implementing LID before completing a conceptual site design or sketching a layout of subdivision lots. They should schedule a pre-application meeting with City staff and conceptualize the project while incorporating accepted LID practices and City zoning requirements.

2. Assuming manufactured (proprietary) stormwater treatment devices will be adequate for compliance. Most manufactured structural treatment control devices do not adequately reduce the pollutants of concern in stormwater discharges and they typically do not reduce the rate and volume of runoff.

3. Not planning for periodic inspections and maintenance of stormwater treatment and flow-control facilities. Applicants should consider who will own and who will inspect and maintain these facilities in perpetuity and how they will obtain access. Applicants should also identify which arrangements are acceptable to the City.

### How to Use This Document

To use this document, start by reviewing Section 1.1 to become familiar with the federal NPDES stormwater program and the Salinas NPDES permit issued by the Regional Board. Refer to Sections 1.2 and 1.3 for and Appendices A and B information about the City's new Stormwater and Grading ordinances, respectively. Refer to Section 1.4 for information related to the City's new stormwater management requirements; Section 1.5 Stormwater Management Performance Criteria; Section 1.6 for an overview of the required Stormwater Control Plan (SWCP), Section 1.7 for information related to the Stormwater Pollution Prevention Plan (SWPPP) required during construction, and Section 1.8 for information regarding the required Maintenance and

Repair of Stormwater Facilities. Then proceed to Section 1.9 for flow charts that explain the City's new Development Review Process for new and redevelopment projects. For additional assistance developing a SWCP for your site, go to Appendix D.

To better understand the concept of Low Impact Develop (LID) and commonly used stormwater management terms and acronyms, refer to Section 2:. For the actual design of LID practices, particularly Integrated Management Practices (IMPs), which are small on-lot treatment control BMPs that are integrated into the site layout, landscaping and drainage design of urban development, proceed to Section 3:. For general assistance selecting IMPs and Treatment Controls for your site, go to the Design Matrices in Section 3.4.1. For detailed design criteria, such infiltration testing and bioretention system design requirements, and numeric sizing criteria for flow- and volume-based IMPs, go to Section 4:.

Finally, since LID practices are designed to capture and treat runoff from the relatively frequently occurring small storm events (< the 2-year storm event), designers must also plan for the use of conventional storm drain system infrastructure (e.g., catch basins, open channels, underground pipes and detention basins) for conveyance and flood control to safely manage runoff during the relatively large storm events (e.g., 5-, 20- and 100-year storm events). Design standards for conventional storm drain system infrastructure are presented in Section 5.

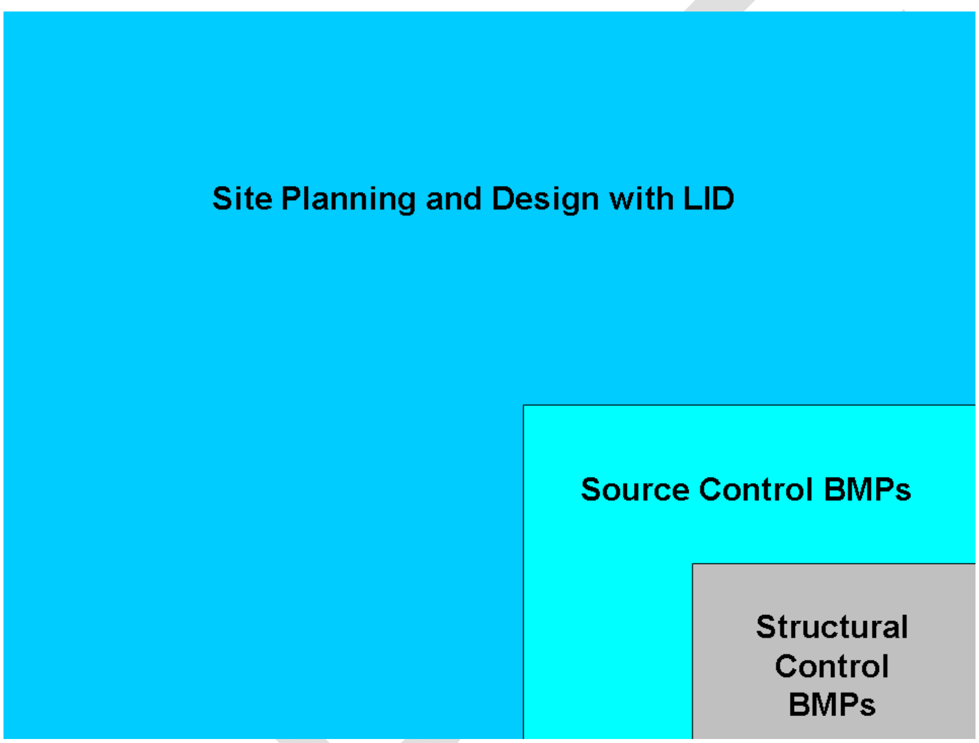



Figure ES-1: Relative Effectiveness of LID Planning Techniques

The graphic above illustrates the relative effectiveness of LID planning techniques relative to other methods to reduce the rate, volume and pollutant loading of urban runoff.

# Section 1: City of Salinas Requirements

This City of Salinas Stormwater Development Standards for new development and significant redevelopment projects, is being provided by the City to guide project applicants and City staff in the planning, preparation, review, and approval of said projects according to the current requirements of the City's National Pollutant Discharge Elimination System (NPDES) Stormwater Discharge Permit (NPDES permit) and flood protection needs. This NPDES permit was issued by the Regional Board and is included in Appendix C of this document.

These standards integrate required stormwater management, flood control and channel/stream bank erosion considerations into one set of design criteria for stormwater handling in development design. They are intended to ensure that management of stormwater quantity and quality are integrated into the early planning of development and community design.

The integration of development stormwater management and flood control design standards into this document is also concurrent with the deletion of storm drain design standards contained within the City's *Standard Specifications, Design Standards and Standard Plans* (2008) document.

These Stormwater Development Standards shall be used in conjunction with the most current version of the California Stormwater Quality Association *Stormwater Best Management Practice Handbook for New Development and Redevelopment* (CASQA Handbook - http://www.cabmphandbooks.com/). The primary use of the CASQA Handbook for the site development engineer is that of a technical guidance manual. It provides additional design guidance for the LID practices and the Integrated Management Practices (IMPs) presented in this Stormwater Development Standards document, as well as design guidance for Source Control BMPs and Treatment Control BMPs (both public domain and manufactured or proprietary designs). Unless otherwise stated, methods used in the CASQA Handbook are approved for use in development design in the City of Salinas. However, when used alone, a number of the Treatment Control BMPs presented in the CASQA Handbook do not meet the Regional Board's definition of maximum extent practicable (MEP). Therefore, the City may allow their use to supplement LID designs and IMPs as part of a treatment train, or to provide pretreatment for an IMP (e.g. for up-gradient sediment removal). In the event of any conflict between the two, the City requirements contained in this Stormwater Development Standards document supersede any recommendations of the CASQA Handbook.

This Stormwater Development Standards document is organized in follows:

4. Section 1 specifies the requirements of the City of Salinas Stormwater Development Standards and outlines the City of Salinas development review process.

5. Section 2 provides a general discussion on Low Impact Development (LID) planning techniques that are required in the preliminary design phase of new development projects. This section also provides descriptions of commonly used stormwater management and LID terms and acronyms.

6. Section 3 presents information on LID designs and practices such as Integrated Management Practices (IMPs). LID design examples are provided for parking lots, roadways, driveways, sidewalks and bike paths. Detailed information is also provided on the siting, design, inspection and maintenance requirements for IMPs such as vegetated swales, bioretention systems, permeable pavements and other techniques.

7. Section 4 provides a list of common stormwater pollutants and sources and the anticipated and potential pollutants generated by the "**Priority Project Categories**" listed in Section 1.4.1. Also included are stormwater infiltration setback considerations, site screening and infiltration testing requirements for projects 20 acres or greater, and the NPDES Permit required numeric-sizing criteria that must be applied to flow and volume-based IMPs and structural treatment control BMPs. Guidance on diversion structures needed to capture and/or isolate the water quality flow rate ($WQ_F$) or the water quality volume ($WQ_V$) for treatment, and bypass the excess runoff from relatively large storm events, is also provided in this section.

8. Section 5 presents information regarding requirements for flood control protection and site stormwater peak discharge design criteria. These requirements are necessary to safely manage stormwater runoff during relatively large storm events (e.g., 5-, 20- and 100-year storm events) because LID designs and IMPs are typically only effective at reducing the rate and volume of runoff for the relatively small storm events (< the 2-year storm event).

## 1.1 Salinas's NPDES Stormwater Discharge Permit

As of November 1990, the Federal Clean Water Act requires that all operators of municipal separate storm sewer systems (MS4) obtain NPDES permits for stormwater discharge and develop Stormwater Management Plans. The purpose of these requirements is to reduce harmful pollutants being washed by stormwater runoff into the City's storm drain system (e.g., the MS4) and then being discharged into local streams, creeks, and other water bodies.

In 1999, the Regional Board issued to the City of Salinas a NPDES MS4 permit with requirements in compliance with the NPDES program.

In February 2005, the Regional Board issued a revised NPDES MS4 permit to the City with new, expanded requirements. These expanded requirements related to new development and significant redevelopment include:

9. Requirements for site design and pollutant source control measures

10. Numeric design standards for sizing stormwater treatment controls

11. Requirements for the operation and maintenance of stormwater control and treatment BMPs

The 2005 NPDES MS4 permit requires the City of Salinas to issue Stormwater Development Standards consistent with this permit. The full text of the development standards requirements is contained within Attachment 4 of the 2005 NPDES MS4 permit (Appendix C).

In December 2005, the Regional Board declared that LID met the criteria for Maximum Extent Practicable (MEP) in Salinas; and as such, LID was a required element in all future developments and significant redevelopments.

Additional information about the City of Salinas Stormwater and Watershed Management program can be found at: http://www.ci.salinas.ca.us/MtcSvc/StormWater-NPDES/index.html

## 1.2 City of Salinas Stormwater Ordinance

In compliance with the 2005 NPDES permit, the City revised its Stormwater Ordinance in 2007. The Ordinance requires all new developments and significant redevelopments to meet the requirements of this City of Salinas Stormwater Development Standards.

The full text of the City of Salinas 2007 Stormwater Ordinance can be found in Appendix A.

## 1.3 City of Salinas Standards to Control Excavation, Cuts, Fills, Clearing, Grading, Sediment and Erosion

In compliance with its 2005 NPDES permit, the City of Salinas revised its Standards to Control Excavation, Cuts, Fills, Clearing, Grading, Sediment and Erosion in 2007. The full text of the City of Salinas 2007 Standards to Control Excavation, Cuts, Fills, Clearing, Grading, Sediment and Erosion ("Grading Standards") can be found in Appendix B.

All projects requiring a grading permit (see detailed requirements in Appendix B) shall submit to the City a Stormwater Pollution Prevention Plan (SWPPP) for control of erosion and stormwater runoff quality during construction. For construction sites of one acre or greater, a Waste Discharge Identification number (WDID number) issued by the State Water Resource Control Board shall be submitted to the City as proof of application of coverage pursuant to the state General Construction Stormwater Permit. See Section 1.7 for additional information.

## 1.4 City of Salinas Stormwater Requirements

### 1.4.1 Priority Project Categories

Per the Salinas NPDES Permit (see Appendix C, Attachment 4, Section 3.c.i.), all new projects falling under the "**Priority Project Categories**" listed below are required to comply with the design, construction and maintenance process requirements of these Stormwater Development Standards:

1. Home subdivisions with ten housing units or more. This category includes single-family homes, multi-family homes, condominiums, and apartments.

2. Commercial developments. This category is defined as any development on private land that is not for heavy industrial or residential uses where the impervious land area for development is 100,000 square-feet or more. The category includes, but is not limited to hospitals, laboratories, and other medical facilities, educational institutions, recreational facilities, commercial nurseries, car wash facilities, mini-malls and other business

complexes, shopping malls, hotels, office buildings, public warehouses, and other light industrial facilities.

3. Automotive repair shops. This category is defined as a facility that is described by one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, 7536-7539, where the total impervious area for development is 5,000 feet or more.

4. Restaurants. This category is defined as 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) and has 5,000 or more feet of impervious area.

5. Hillside developments 5,000 square feet or more of impervious area. This category is defined as any development that creates 5,000 square feet of impervious surface in area with known erosive soil located in an area with natural slopes having a twenty-five percent or greater grade.

6. Parking lots exposed to rainfall that are 5,000 square feet or more, or with 25 or more parking spaces. This category is defined as uncovered impervious area for the temporary parking or storage of motor vehicles used personally, for business, or for commerce.

7. Street, roads, highways, and freeways. The category includes any paved surface five acres or greater used by automobiles, trucks, motorcycles, and other vehicles.

8. Retail Gasoline Outlets. “Retail Gasoline Outlet” is defined as any facility engaged in selling gasoline with 5,000 square feet or more of impervious surface.

All significant redevelopment projects are also required to comply with the design, construction and maintenance process requirements of these Stormwater Development Standards. “Significant Redevelopment” is defined as the creation or addition of at least 5,000 square feet of impervious surfaces on an already developed site. Where significant redevelopment results in an increase of less than 50% of the impervious surfaces of a previously existing development, and the existing development was not subject to the Stormwater Development Standards, the Development standards only apply to the addition, not to the entire development.

For projects for which these Stormwater Development Standards are not applicable, the applicant will follow the usual City process for permitting and shall be required to:

- *Minimize impervious surfaces, directly connected impervious surfaces and treat stormwater by incorporating IMPs that collect, detain, and infiltrate runoff.*

- *Design efficient landscaping to reduce runoff irrigation, promote surface infiltration, and minimize the use of fertilizers and pesticides that can contribute to water pollution.*

### 1.4.2 Permit Required

No land owner or land operator shall receive any building, grading or other land development permits required for land disturbance activities without first meeting the requirements of these

City of Salinas Stormwater Development Standards prior to commencing the proposed activity. As discussed in Section 1.6, a conceptual SWCP, developed in consultation with City staff, shall be submitted to and approved by the City prior to the City accepting applications for planning level permits. No building, grading, or land development permits shall be issued until a satisfactory final SWCP, or a waiver thereof, has been approved by the City Engineer.

### 1.4.3 Application Requirements

Unless specifically excluded by these requirements, any land owner or operator desiring a permit for a land disturbance activity shall submit to the City of Salinas a permit application on a form provided for that purpose.

Unless otherwise excluded by these requirements, a permit application must be accompanied by the following documents in order for the permit application to be considered: a SWCP and a non-refundable permit review fee.

The SWCP shall show how the applicant intends to comply with the City's LID stormwater planning requirements (see Section 0 and Appendix D)

### 1.4.4 Building Permit Requirements

A project site specific SWCP shall be prepared to meet the requirements of Section 1.6 of these requirements.

Prior to final approval for occupancy, a maintenance agreement for the stormwater management system shall be submitted and approved to meet the requirements of Section 1.8.

### 1.4.5 Application Procedure

The application procedure shall comply with Section 1.9 Development Review Process.

### 1.4.6 Waivers for Providing Stormwater Management

If, after assessment by the City Engineer, conditions of the applicant's project are such that compliance is infeasible, the applicant may apply for a waiver of these provisions. Such a waiver will only be considered after all appropriate means for compliance have been considered and rejected as infeasible. The City Engineer shall use the Maximum Extent Practicable (MEP) criteria, discussed in Section 2.5.3, for the evaluation of the waiver request. The waiver shall be granted only for aspects of these standards that are deemed infeasible - all other requirements are still applicable.

If granted a waiver, the applicant shall pay into a City Stormwater Mitigation Fund at the rate of 135% of the estimated construction savings. Funds may be used for projects to improve urban runoff quality within the watershed of the waived project.

The City is currently in the process of developing a Waiver Program for approval by the Regional Board. At a minimum, the approved waiver program will identify the following:

- The entity or entities that will manage and assume full responsibility for the stormwater mitigation fund;
- The range and types of acceptable projects for which mitigation funds may be expended;
- The entity or entities that will assume full responsibility for each mitigation project, including its successful completion; and
- How the dollar amount of fund contributions will be determined and managed.

Once approved, the City will notify the Regional Board within one month of each waiver issued and shall include the name of the person granting each waiver.

## 1.5 Stormwater Management

Overall, stormwater management practices for development shall rely on a "tiered" approach. The first tier shall be planning and site design measures to avoid and preserve natural drainage features, minimize topography changes, maintain the same overall size of drainage areas that discharge to receiving waters, and to mimic natural pre-development hydrology. The second tier shall be site source control measures that minimize or eliminate stormwater contamination. The third tier shall be stormwater treatment controls using LID techniques; and if necessary due to site constraints, use of additional structural treatment control BMPs.

### 1.5.1 General Performance Criteria for Stormwater Management

The following shall be addressed for stormwater management:

All site designs shall establish stormwater management practices to (in order of priority):

1. Minimize the rate, volume and pollutant loading of stormwater runoff using the LID Site Design Planning techniques presented in Section 2.4 and the Integrated Management Practices (IMPs) presented in Section 3.4 of these standards. All IMPs presented in Section 3.4 and any other structural treatment controls approved by the City Engineer shall be sized per the Numeric Sizing Criteria presented in Section 4.4. All site designs shall minimize the amount of impervious surfaces and limit disturbance of natural terrain.
2. Effective Impervious Area[1] for New Development Priority Project Categories (see Section 1.4.1 above) shall be minimized to the maximum extent practicable (MEP). Plans for Effective Impervious Area in excess of 5% of the total project area will only be approved if the applicant demonstrates, to the satisfaction of the City Engineer, that achievement of such is impracticable.

[1] Per the Regional Board, "Effective Impervious Area is that portion of the impervious area that drains directly to a receiving surface waterbody via a hardened storm drain conveyance without first draining to a pervious area." Impervious surfaces that drain first to pervious areas (e.g., landscaping or porous pavements) are not considered Effective Impervious Areas.

3. Minimize contaminants in stormwater using source control techniques. Minimize directly connected impervious surfaces in areas of new development and redevelopment and use on-site infiltration of runoff in areas with appropriate soils where the infiltration of stormwater would not pose a potential threat to groundwater quality, infrastructure, or off-site property.

4. Reduce pollutants in the runoff to the MEP. These practices should seek to utilize pervious areas for stormwater treatment and to infiltrate (where possible) stormwater runoff from driveways, sidewalks, rooftops, parking lots, and landscaped areas to provide treatment for both water quality and quantity. The Regional Board has determined that the MEP criteria are to be met with the use of LID practices.

5. Control the peak flow rates of stormwater discharge for the relatively large storm events (e.g., the 5-, 20- and 100-year storm events) as specified in Section 5: of these standards.

### 1.5.2 Site Design Planning

The first priority regarding approval of site design for stormwater management shall be proper site planning. Consideration in the planning process shall be given to the following:

1. Reducing the extent of clearing and grading to only what is needed for structures

2. Minimizing the amount of impervious surfaces and soil compaction during construction

3. Minimizing directly connected impervious areas

4. Planning for use of LID techniques for stormwater management

5. Planning for source control of potential stormwater pollutants

Physical conditions of the site that shall be considered include the following:

1. Topography

2. Maximum Drainage Area

3. Depth to Groundwater Table

4. Soils - for all development sites greater than 20 acres in total size, soil percolation tests and soil borings to determine the depth of the clay layer shall be required. The scope of the percolation tests shall be representative of the entire site, overseen by a licensed professional, and shall be conducted in a manner satisfactory to the City Engineer.

5. Location in relation to environmentally sensitive features/areas - if determined by the City during the planning (or subsequent) phase that the project stormwater runoff, either in terms of volume or released pollutants, impacts downstream environmentally sensitive features/areas, the applicant must mitigate such in the design, construction and future maintenance of the project.

Applicants shall consult these Development Standards for guidance on the factors that determine site design when selecting stormwater management practices.

### 1.5.3 Conveyance Issues

Stormwater management practices shall be designed to first minimize runoff and mimic natural hydrology through site planning, then minimize the transport of stormwater and pollutants offsite. Site stormwater conveyance design shall facilitate the reduction in flow velocities and maximum removal of pollutants. This shall include, but not be limited to:

1. Maximizing of flow paths from inflow points to outflow points
2. Protection of all storm drain inlet and outfall structures
3. Elimination of on-site and off-site erosive flow rates, velocities and volumes
4. Providing underdrain systems in site infiltration devices, where applicable.
5. Providing overflow features for the relatively large storm events (e.g., the 5-, 20- and 100-year storm events).

### 1.5.4 Stormwater Runoff Flow and Volume Calculation

Stormwater runoff flow and volume for the LID practices and IMPs presented in these Design Standards, and for any other structural treatment control approved by the City Engineer, shall be calculated using the Numeric Sizing Criteria presented in Section 4.4. Stormwater runoff flow and volume for conventional storm drainage infrastructure (e.g., catch basins, storm drain pipes and flood control detention basins) shall be calculated using the Rational Method for drainage areas of 25 acres or less, but will require an approved computer simulation method for larger areas and evaluation of detention basin facilities (see Section 5: for additional details). Applicants shall submit for approval by the City Engineer alternate methods for calculation of runoff flow and volume, and those for use with a development 25 acres or greater in size. Alternative methods shall comply with Section 5: of these standards.

### 1.5.5 BMP Selection

The BMPs selected for implementation for new development and significant redevelopment projects shall:

1. Have pollutant prevention and minimize the exposure of potential pollutants to rainwater (source control BMPs) the first consideration in stormwater design.
2. Be selected on the basis of the type of developed site use, identified criteria pollutants, and other pollutants expected to be on site in concentrations that would pose potential water quality concerns (see BMP Design and Selection Matrices in Section 3.4.1).
3. Manage stormwater treatment and volume to the MEP. All site stormwater runoff shall be treated using the IMPs presented in Section 3.4 of these standards. Stormwater

treatment shall be located on each individual drainage area within a project site using LID techniques, unless otherwise shown to be impracticable and alternatives are approved by the City Engineer. The Regional Board has determined that use of LID meets the MEP criteria for stormwater management.

4. For flow-based BMPs, be minimally sized to mitigate (infiltrate or treat), the maximum flow of runoff produced by the $85^{th}$ percentile hourly rainfall intensity, as determined from the local rainfall records, multiplied by two. Based on an analysis of historical rainfall records, the $85^{th}$ percentile hourly rainfall intensity for Salinas is 0.11 inches/hour and the resultant flow-based BMP size shall be minimally sized based on a rainfall intensity of 0.22 inches/hour. Additional information about sizing flow-based BMPs is presented in Section 4.4.3 of these standards.

5. For volume-based BMPs, be minimally sized to mitigate (capture, detain and infiltrate or treat) the volume of runoff produced from a 24 hour $85^{th}$ percentile storm event, as determined from the local rainfall records. Based on an analysis of historical rainfall records, the 24-hour $85^{th}$ percentile rainfall quantity is 0.6 inches. Additional information about sizing volume-based BMPs is presented in Section 4.4.2 of these standards.

6. Be designed and maintained with an engineered soil mix with minimum infiltration rate of 5.0 inches per hour and be engineered to accommodate overflow during larger storm events (e.g., storm events exceeding the design criteria for flow and volume-based BMPs discussed above).

### 1.5.6 Restrictions

Stormwater devices or systems shall not be installed or operated in a manner which can lead to potential impacts on groundwater quality or civil infrastructure damage if direct or indirect stormwater infiltration facilities are to be proposed. Restrictions on these structural treatment control BMPs include the following:

1. Stormwater infiltration practices must not be used in drainage areas that include industrial or commercial sites with outdoor storage of materials and/or chemicals.

2. Unless it can be demonstrated that existing site soils have infiltration rates that are 0.5 inches/hour or greater, underdrain systems or equivalent will be required to adequately drain flow and volume-based BMPs.

3. There must be a designed separation of 3 feet between the bottom of a proposed stormwater infiltration practice and the seasonally high groundwater level.

4. Stormwater infiltration practices must be located at least 100 feet from drinking water supply wells.

5. Stormwater infiltration practices must be located at least 500 feet from underground storage tanks (UST's) and areas of known groundwater contamination, such as the Leaking Underground Fuel Tank (LUFT) sites.

Additional design criteria and potential setback requirements for stormwater infiltration practices are presented in Section 4.3.2.

Stormwater devices or systems shall not be installed or operated in a manner which can lead to potential impacts to vector, potable water, or general sanitation conditions. Capture of stormwater for greater than 72 hours shall be considered storage. Stormwater devices or systems with possible storage of stormwater shall be equipped with means to be drained, and operated in a manner consistent with proper vector and sanitary controls. Distribution of stored stormwater shall not be connected or indirectly connected to a potable water supply system unless expressly approved by the Monterey County Health Department.

### 1.5.7 Minimum Flood Control Requirements

Mitigation for the retention/detention difference between the one hundred year post development volume and the ten-year pre-development volume with a ten-year pre-development maximum discharge rate will be required for flood control, unless otherwise approved by the City Engineer. Explanation of the retention requirement is given in Section 5.8.

Besides conventional detention/retention basins, LID design techniques can be used to mitigate much of this requirement. However, the applicant must provide additional stormwater storage for flood control beyond what is required for water quality improvement as described in Section 4.4.2. For example, this could be accomplished by oversizing the gravel storage layer beneath a section of porous pavement to provide detention for the difference between the 100-year post development volume and the 10-year pre-development volume.

In addition, if site or off-site conditions warrant greater control than that provided by the minimum control requirements, the City of Salinas reserves the right to impose any and all additional requirements deemed necessary to control the volume, timing, rate and pollutant loading of runoff from applicable new and redevelopment projects.

## 1.6 Stormwater Control Plan Requirements

No application for development of applicable projects in Section 1.4.1 will be approved unless it includes a project site specific SWCP detailing in concept how runoff and associated water quality impacts resulting from the development will be controlled or managed.

### 1.6.1 Preparing Your SWCP

A conceptual SWCP shall be developed during the pre-application and design phase and prior to applying for planning level permits. As discussed in Section 1.9, the first step in the development process is to schedule a pre-application meeting with City staff to review a strategy for implementing LID planning practices into the conceptual site design. As the project planning process progresses, the SWCP should be revised as necessary to reflect design changes.

A SWCP shall be submitted to the City with the project Grading and Building Permit applications. The final SWCP, as approved by the City, must be stamped and signed by a California licensed professional civil engineer, who will verify that the design of all stormwater management practices meet the submittal requirements outlined herein. No building, grading, or sediment control permit shall be issued until a satisfactory final SWCP, or a waiver thereof, shall have undergone a review and been approved by the City Engineer, after determining that the plan is consistent with the requirements of these Stormwater Development Standards.

### 1.6.2 Minimum SWCP Elements

After review of the conceptual SWCP, and modifications to that plan are completed as deemed necessary by the City of Salinas, a final SWCP must be submitted for approval. The final SWCP, in addition to the information from the concept plan, shall include all of the following required information (**Additional Step by Step guidance for preparing a SWCP is presented in Appendix D**):

1. Contact Information

   The name, address, and telephone number of all persons having a legal interest in the property and the parcel number(s) of the property or properties affected.

2. Topographic Base Map

   A 1" = 200' topographic base map of the site which extends a minimum of 100 feet beyond the limits of the proposed development and indicates existing surface water drainage including streams, ponds, culverts, ditches, and wetlands; current land use including all existing structures; locations of utilities, roads, and easements; and significant natural and manmade features not otherwise shown.

   The site map shall show all drainage areas and associated locations of BMPs.

3. Calculations

   Hydrologic design calculations for the development conditions for the project design specified in these requirements shall include:

   a) For each drainage area in the project, flow and/or volume calculations for each drainage area and associated BMPs capacities.

   b) Calculated peak flow and volume runoff rates from each drainage area and total project.

   c) Existing site soil infiltration rates, where applicable.

   d) Site conveyance piping size/capacities.

4. Soils Information

   If a stormwater treatment control measure depends on the hydrologic properties of existing site soils (e.g., stormwater infiltration basins and existing site soil infiltration rates), then a soils report shall be submitted. The soils report shall be based on on-site boring logs or soil pit profiles and percolation testing results. The number and location of required soil borings or test pits shall be determined based on what is needed to determine the suitability and distribution of soil types present at the location of the proposed stormwater infiltration structural treatment control BMPs.

5. Landscaping Plan

   The applicant must present a detailed plan for management of vegetation at the site after construction is finished, including who will be responsible for the maintenance of vegetation at the site and what practices will be employed to ensure that adequate vegetative cover is preserved. The plan shall also address the long-term maintenance of vegetated LID practices (a.k.a. IMPs), such as vegetated swales and bioretention systems (see Section 3.4 of these standards).

6. Construction Stormwater Pollution Prevention Plan (SWPPP)

   The applicant must prepare a detailed plan that outlines the erosion, sediment and waste control measures that will be implemented during the construction phase of development projects that will disturb less than one (1) acre of land. Construction projects that will disturb of one (1) acre of land or greater must follow State Water Resources Control Board regulatory process (see Section 1.7 below).

7. Other Environmental Permits

   The applicant shall assure that all other applicable environmental permits have been acquired for the site prior to approval of the final stormwater design plan.

## 1.7 Construction Stormwater Pollution Prevention Plan (SWPPP)

As part of the building permit process, a SWPPP must be prepared, which includes specific BMPs that are to be installed for only the duration of the construction project to protect existing storm drains near to the construction activities, control soil erosion, and prevent discharge of materials to stormwater collection systems that can impact aquatic life in receiving water bodies. The SWPPP must be treated as a living document and remain on or near the construction site and be updated as necessary to document activities such as, but not limited to, different phases of site construction, schedule or design changes, when BMPs are installed, maintained and replaced, when discharges occur, when samples are collected, and when site inspections occur.

All development projects requiring a grading permit (see detailed requirements in Appendix B) shall submit to the City a copy of the SWPPP for control of erosion and stormwater runoff quality during construction activities. Projects that create one acre or more of soil disturbance must submit a Notice of Intent (NOI) to the State Water Resources Control Board (SWRCB) to be covered under the SWRCB General Stormwater Construction Permit. Other information about the SWRCB Construction NOI program can be found at http://www.swrcb.ca.gov/stormwtr/construction.html. Part of the NOI is the preparation of a SWPPP that defines the BMPs that will be in place during construction. The Waste Discharge Identification number (WDID number) issued by the State Water Resource Control Board shall be submitted to the City as proof of application of coverage pursuant to the state General Construction Stormwater Permit.

### 1.7.1 Preparing Your SWPPP

The SWPPP shall contain a site map, which shows the construction site perimeter, existing and proposed buildings, lots, roadways, stormwater collection and discharge points, general topography both before and after construction, and drainage patterns across the project. The SWPPP must list BMPs the discharger will use to protect stormwater runoff and the location of those BMPs.

Additionally, the SWPPP must contain a visual monitoring program; a chemical monitoring program for "non-visible" pollutants to be implemented if there is a failure of BMPs; and a sediment monitoring plan if the site discharges directly to a water body listed on the Federal Clean Water Act Section 303(d) list for sediment. Section A of the Construction General Permit describes the elements that must be contained in a SWPPP. It should be emphasized that the Regional Board administers the NOI and SWPPP program and this information is provided for the applicant's benefit. In accordance with Regional Board Order No. R3-2004-0135, the applicant shall be prepared to demonstrate to City staff, upon request, compliance with the NOI and SWPPP program.

Guidance for preparation of a SWPPP, as well as additional information and details for construction BMPs is contained in the CASQA Stormwater BMP Handbook for Construction. (http://www.cabmphandbooks.com/)

### 1.7.2 City Construction Inspections

The applicant must notify the City of Salinas in advance before the commencement of construction. Inspections of construction sites by the City's Construction Inspection Group will occur periodically through the construction phases. This includes review of the SWPPP, the temporary erosion and sediment control BMPs in place during the construction phase of the project, and the post-construction BMPs that are being built according to the approved plans for stormwater management when the facility is completed (such as the Stormwater Control Plan). Enforcement actions will be taken, including referral to the Regional Board and/or notices will be issued if the project does not comply with the SWPPP.

Once the project is constructed, the City's Construction Inspection Group will conduct a final site inspection of the post-construction stormwater BMPs included in the project plan sheets as well as for the other structures that are a part of the project before a Building Permit is finalized or Certificate of Occupancy is issued for new buildings.

If there have been any changes to the design plans for the stormwater treatment BMPs from those originally submitted and approved in the Stormwater Control Plan, then the revised "as-built" information needs to be included in an amendment the SWCP for the facility before the Building Permit is finalized or Certificate of Occupancy is granted. All applicants are required to submit actual "as built" plans for any stormwater management practices located on-site after final construction is completed. The plan must show the final design specifications for all stormwater management facilities and must be certified by a California licensed professional civil engineer employed by the project engineer of record.

## 1.8 Maintenance and Repair of Stormwater Facilities

Once a project is completed, the post-construction BMPs (e.g., LID practices or IMPs and other structural treatment controls) must be maintained and inspected as described in the project's SWCP, so that they can provide the water quality protection required for the site. Installation, operation, maintenance, inspection and recordkeeping of the post-construction BMPs are the responsibility of the applicant and/or the property owner identified in the SWCP. Records supporting post-construction BMP operation and maintenance activities need to be kept by the property owner of record. A stormwater facilities maintenance agreement, recorded on the deed of the property, for post-construction BMPs, shall be required prior to project finalization or issuance of the Final Building Certificate of Occupancy.

Additional resources for Post-Construction BMP maintenance can be found in the CASQA Municipal Handbook Sections 3 and 4 for Maintenance of Municipal Facilities, in the CASQA Industrial and Commercial Handbook Sections 3 and 4 for Maintenance of Industrial and Commercial Facilities and in the CASQA New and Redevelopment Handbook, Section 5, for maintenance of residential facilities. (http://www.cabmphandbooks.com/).

### 1.8.1 Maintenance Agreements

All stormwater treatment practices shall have an enforceable operation and maintenance agreement to ensure the system functions as designed. This agreement will include any and all access rights for inspection by the City of the stormwater treatment practices. The agreement shall require the owner or tenant to perform routine maintenance as necessary to ensure proper functioning of the stormwater treatment practice. In addition, a legally binding covenant specifying the parties responsible for the proper maintenance of all stormwater treatment practices shall be secured prior to issuance of any permit for occupancy.

All applicable developments shall provide verification of maintenance provisions for post-construction structural treatment control BMPs. Verification shall include the developer's signed statement accepting responsibility for maintenance until the maintenance responsibility is legally transferred to another party and one or more of the following as applicable:

1. Written conditions in the sales or lease agreement that require the recipient to assume responsibility for maintenance; or

2. 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

3. Any other legally enforceable agreement that assigns responsibility for maintenance of structural or treatment control BMPs.

A sample maintenance agreement is given in Appendix F.

### 1.8.2 Inspection of Stormwater Facilities

All stormwater management facilities must undergo, at the minimum, two inspections per year to document maintenance and repair needs and ensure compliance with the requirements of these requirements and accomplishment of its purposes. These needs may include; removal of silt, litter and other debris from all catch basins, inlets and drainage pipes, grass cutting and vegetation removal, and necessary replacement of landscape vegetation. Any maintenance needs found must be addressed in a timely manner, as determined by the City of Salinas, and the inspection and maintenance requirement may be increased as deemed necessary to ensure proper functioning of the stormwater management facility.

Inspection programs may be established on any reasonable basis, including but not limited to: routine inspections; random inspections; inspections based upon complaints or other notice of possible violations; inspection of drainage basins or areas identified as higher than typical sources of sediment or other contaminants or pollutants; inspections of businesses or industries of a type associated with higher than usual discharges of contaminants or pollutants or with discharges of a type which are more likely than the typical discharge to cause violations of state or federal water or sediment quality standards or the NPDES stormwater permit; and joint inspections with other agencies inspecting under environmental or safety laws. Inspections may include, but are not limited to: reviewing maintenance and repair records; sampling discharges, surface water, groundwater, and material or water in drainage control facilities; and evaluating the condition of drainage control facilities and other stormwater treatment practices.

#### 1.8.2.1 Right-of-Entry for Inspection

When any new drainage control facility is installed on private property, or when any new connection is made between private property and a public drainage control system, sanitary sewer or combined sewer, the property owner shall grant to the City of Salinas the right to enter the property at reasonable times and in a reasonable manner for the purpose of inspection. This includes the right to enter a property when it has a reasonable basis to believe that a violation of these requirements is occurring or has occurred, and to enter when necessary for abatement of a public nuisance or correction of a violation of these requirements.

#### 1.8.2.2 Records of Installation and Maintenance Activities

Parties responsible for the operation and maintenance of a stormwater management facility shall make records of the installation and of all maintenance and repairs, and shall retain the records for at least three (3) years. These records shall be made available to the City of Salinas during inspection of the facility and at other reasonable times upon request.

## 1.9 Development Review Process

The City of Salinas stormwater development review process for applicable new and significant redevelopment projects is done in conjunction with the City's Permit Center building permit process.

The review and approval process for projects that require a SWCP is slightly different from the City's usual project review process. Projects that require a SWCP are identified in the **"Priority**

**Project Categories**" list presented in Section 1.4.1. As shown in **Figure 1-1** there are four major steps in the project review process; Project Conceptualization and Development, Planning Permit Process, Building Permit Process, and Construction. The figure shows the start of the project from its conception (prior to formal application(s) with the City) at the top through project plan design/review, and construction phases, to the completion of the project and implementation of post-construction maintenance requirements at the bottom. Sections 1.9.1 through 1.9.4 provide additional details about each major project review process.

The left side of Figure 1-2 represents the steps that the applicant must take to prepare and submit appropriate documentation that describes the LID site design and BMP approaches that will be used in a project specific SWCP. The center portion of the figure shows the City's review process and actions needed to reach the project milestones listed within each step. This graphic is included to show a project applicant where their project is in the approval process.

As shown on Figure 1-1, applicants should first schedule a pre-application meeting with City staff to review a strategy for implementing LID planning practices into a conceptual site design. City staff will assist applicants with the development of a conceptual SWCP, which shall revised and updated as necessary throughout the project planning process. A draft and final SWCP shall be submitted to the City with the project Grading and Building Permit applications. Section 1.6.2 presents the required contents of the final SWCP.

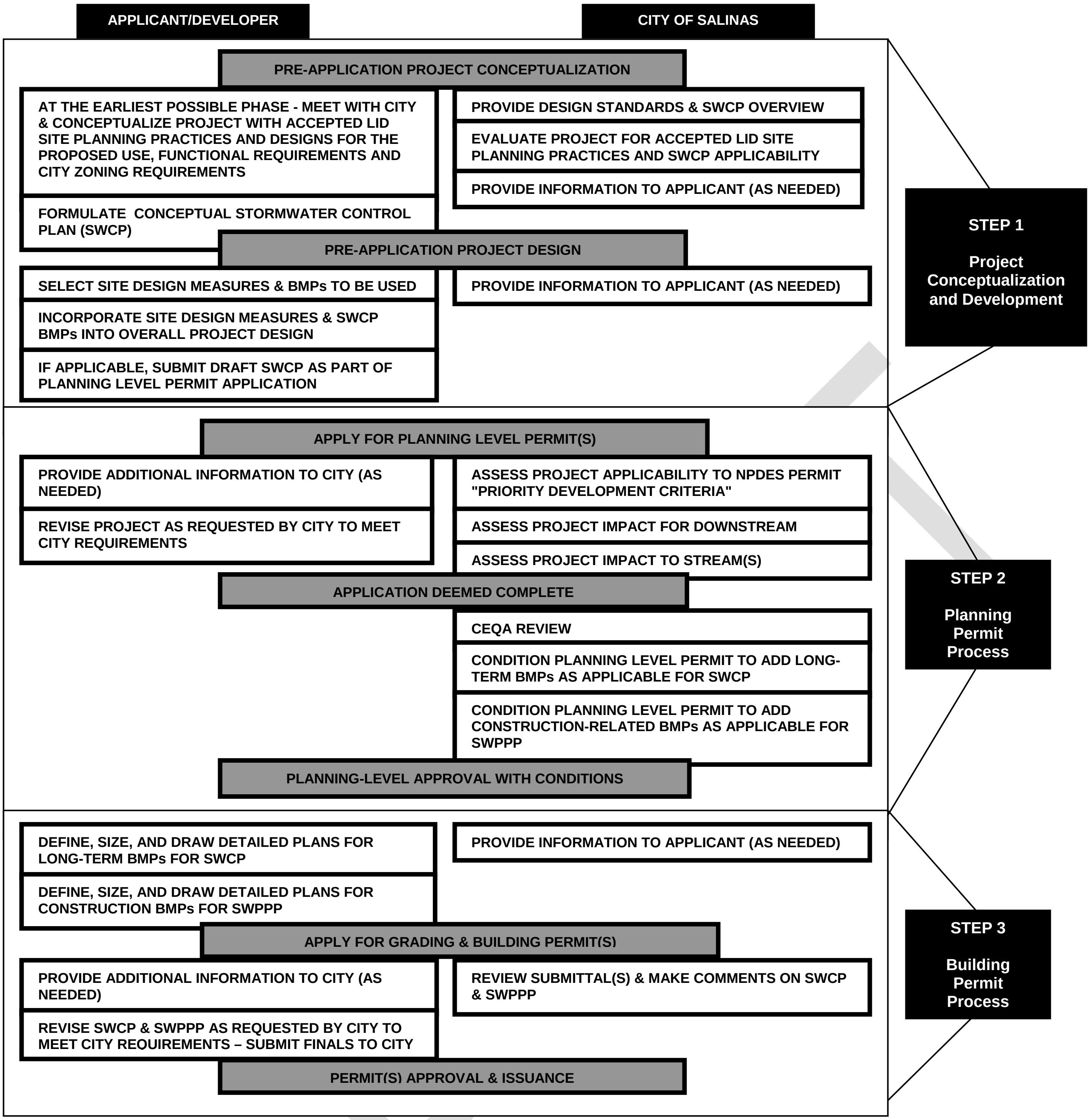



Figure 1-1: Steps in the Development Review Process for New and Redevelopment Projects in Salinas

LIST OF ABBREVIATIONS

BMP: Best Management Practice
SWCP: Stormwater Control Plan
SWPPP: Stormwater Pollution Prevention Plan
CEQA: California Environmental Quality Act

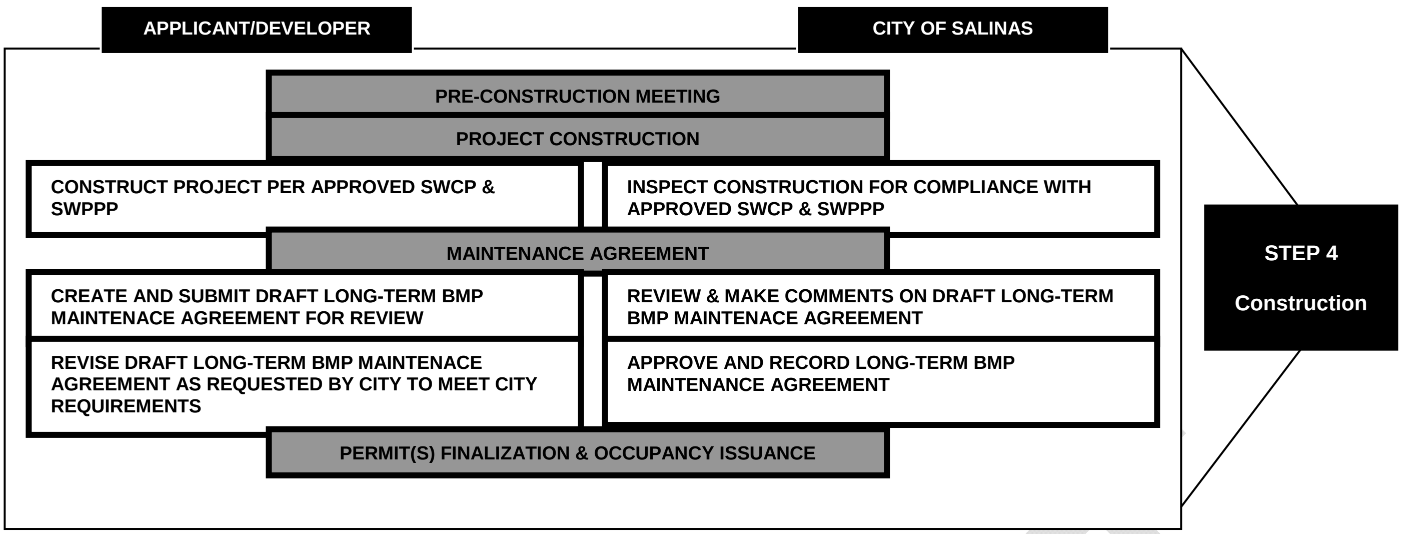



Figure 1-1 (continued)

### 1.9.1 Project Conceptualization and Development

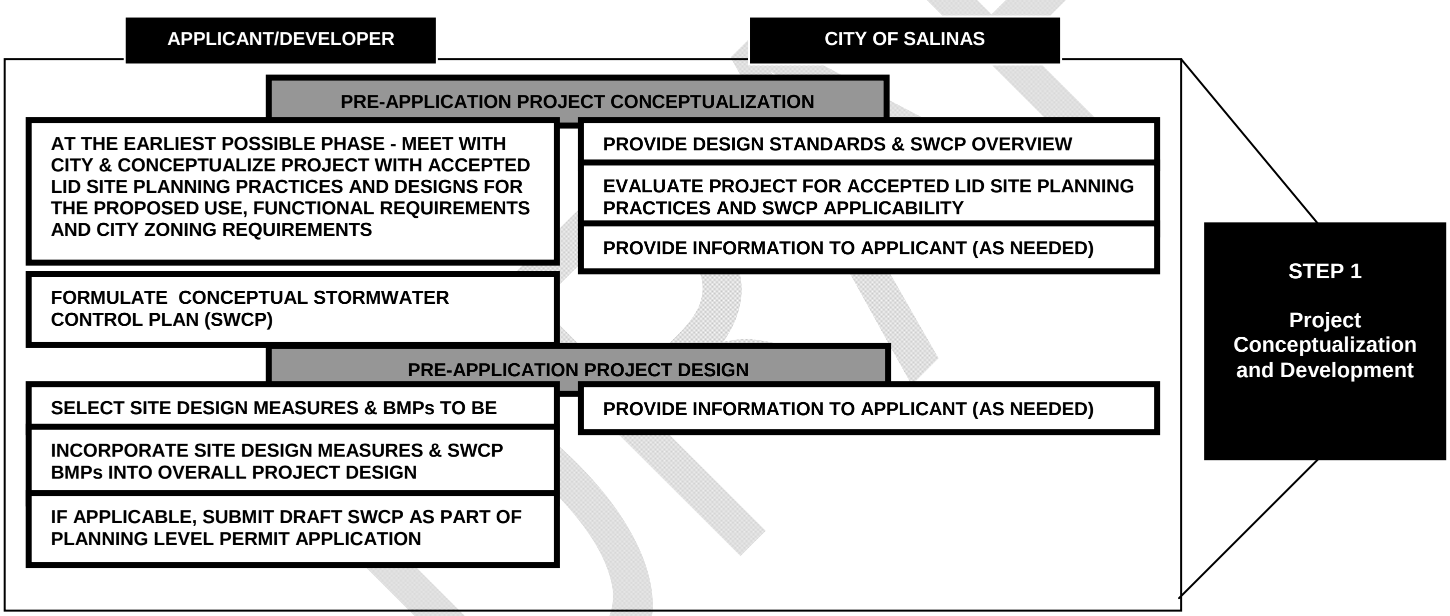



Figure 1-2: Step 1 Project Conceptualization

The project concept proposed by the applicant/developer shall incorporate elements to:

- Minimize disturbance of the existing land
- Avoid natural drainage features
- Minimize topography changes
- Mimic the natural hydrology of the land to the extent practicable
- Provide for water quality treatment of the urban runoff.

LID practices shall be planned and designed integrally with the site planning and landscape for development projects. The best approach is to start with general project requirements and preliminary site design concepts; then prepare the detailed site design, landscape design, and Stormwater Control Plan simultaneously.

If a site design has already been prepared but does not incorporate needed planning concepts, the site design will be required to be redone.

When an applicant is first developing a concept for a project and prior to applying for a zoning amendment or permit, it is highly recommended that the applicant meet with City Permit Center staff for guidance and to evaluate whether the Stormwater Development Standards apply to their project as shown and described in Figure 1-2.

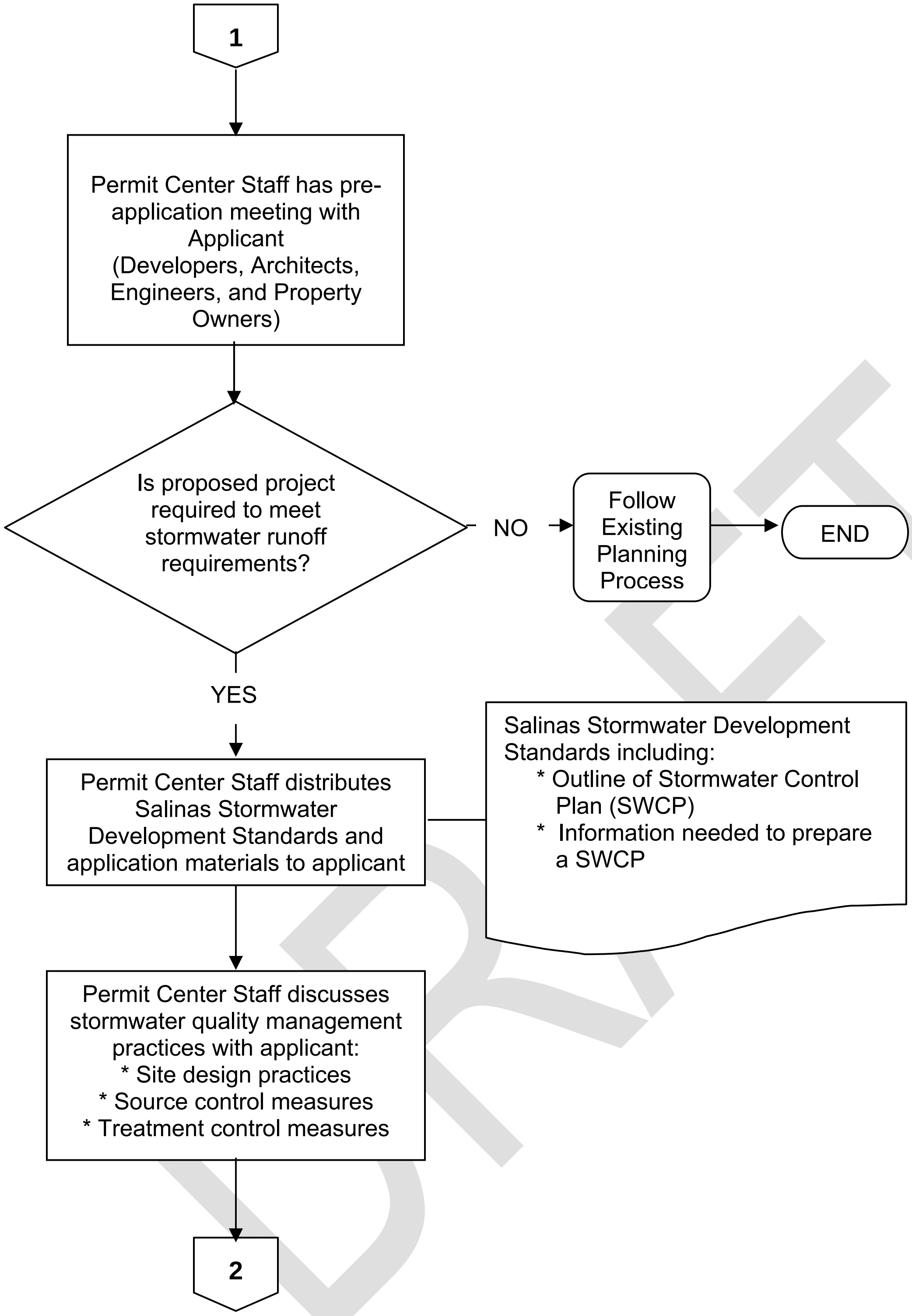



Figure 1-3: Project Applicability & Applicant Education

### 1.9.1.1 When Stormwater Development Standards Are Applicable

In compliance with its NPDES Permit, the City of Salinas requires that stormwater BMPs be implemented to minimize the short and long-term impacts on receiving water quality for new developments and significant redevelopment. As indicated in Section 1.4, new development projects as specified and significant redevelopment projects are subject to these stormwater standards.

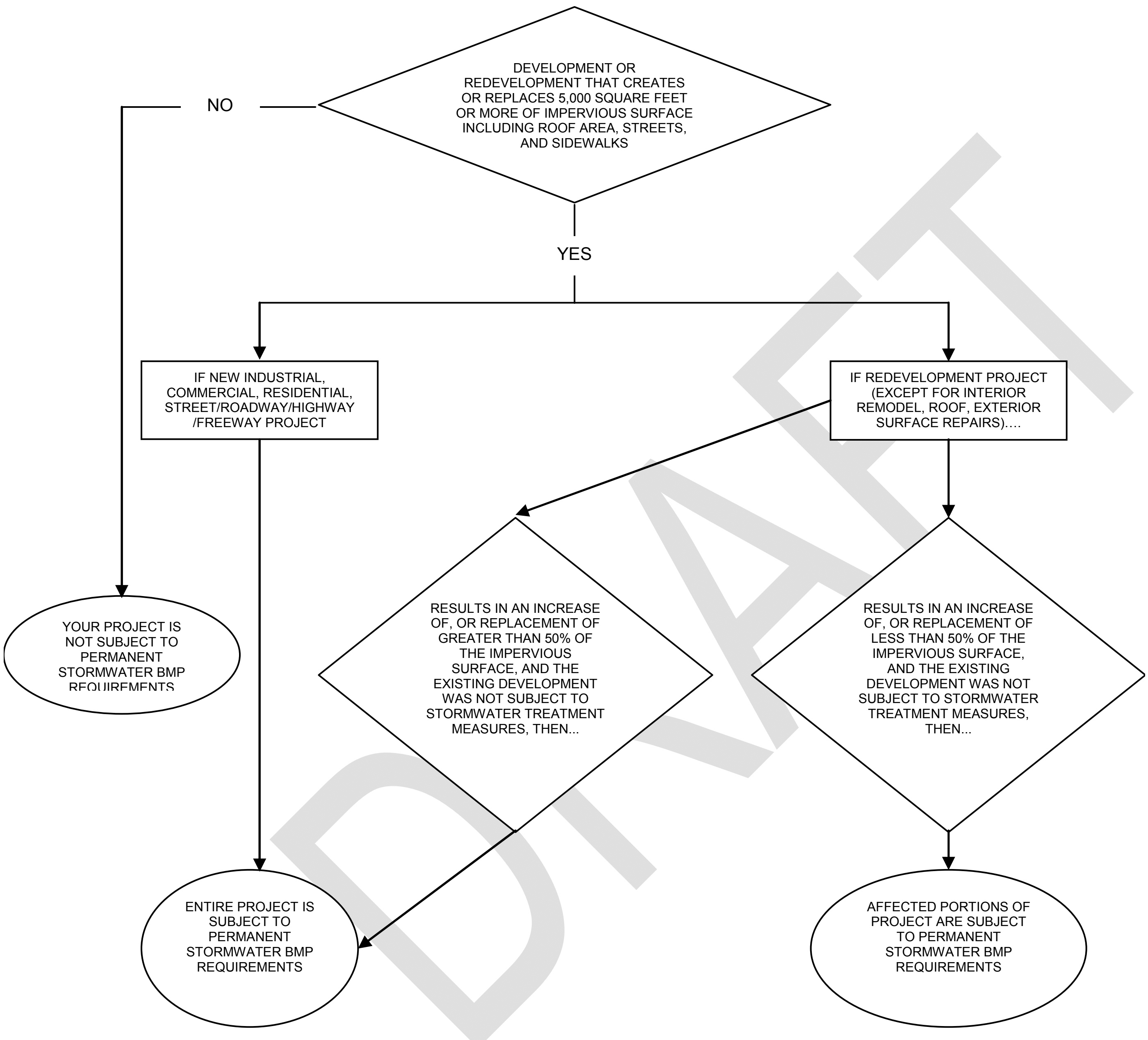



Figure 1-4: Significant Redevelopment Determination

## 1.9.2 Planning Permit Process

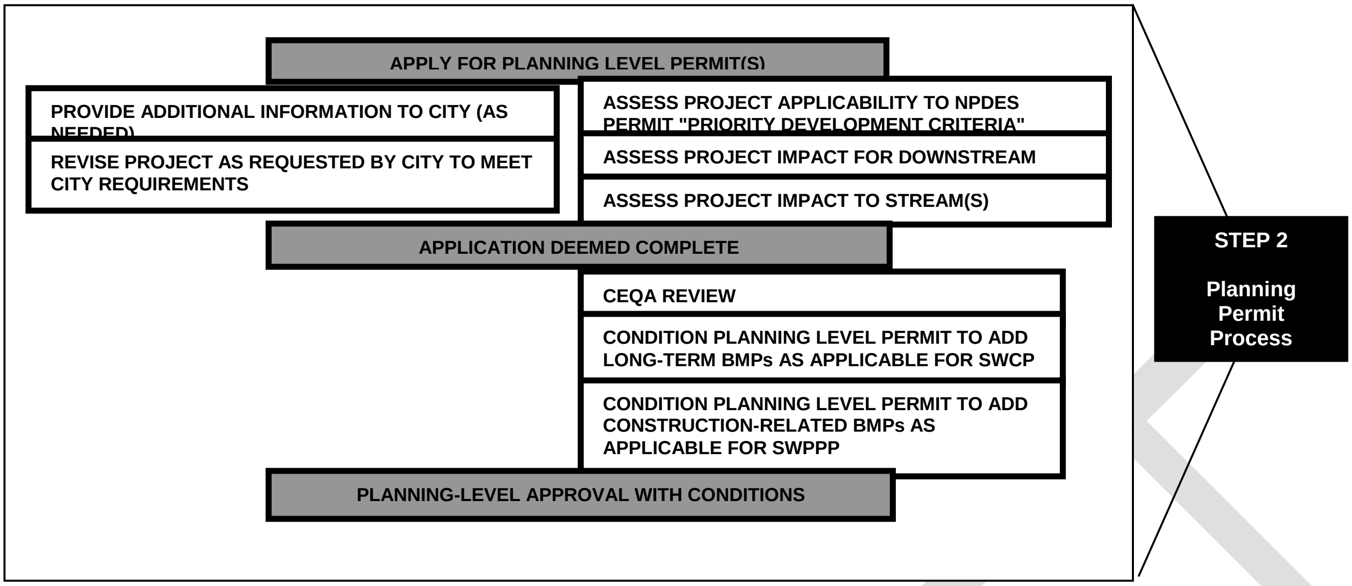



Figure 1-5: Planning Permit Process

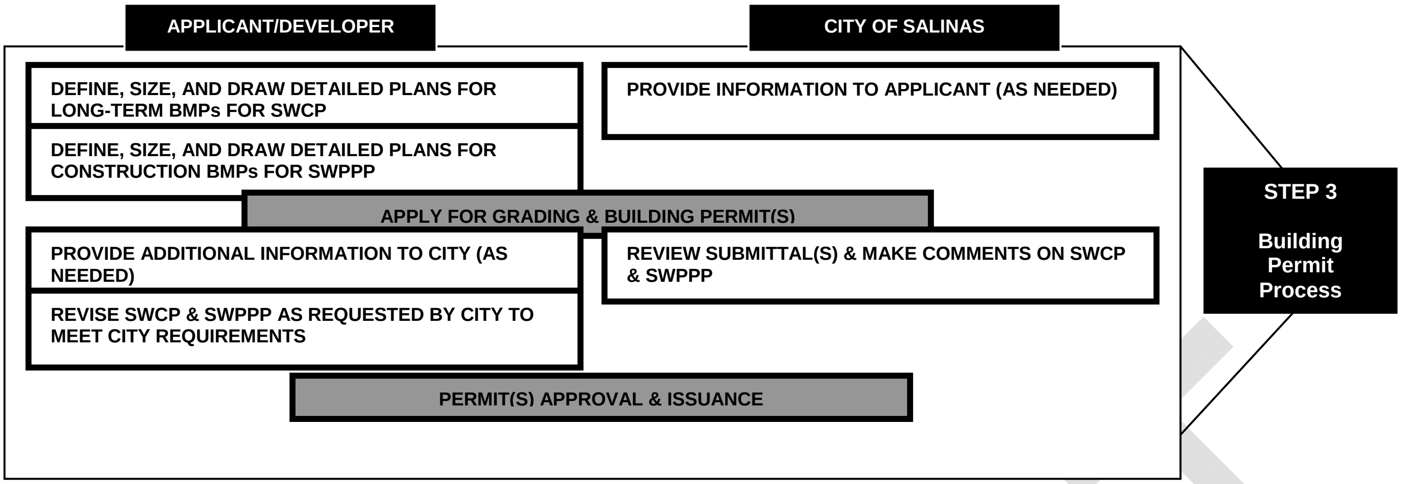
Once a conceptual SWCP has been prepared at the earliest planning level application for the project, the flow chart in Figure 1-7 describes the City's planning-level review and approval process for the SWCP.

All development proposals within the City of Salinas may be subject to one (1) or more development application processing procedures contained in Article 6 of the City of Salinas Zoning Code. The exact application processing procedure applicable to a specific project will be determined by the Community Planning group based on the provisions of the General Plan, the Zoning Code, and an understanding of the project specifics.

Applications shall be prepared on forms provided by the Community Planning Group for all land use actions. The accuracy of all information, maps, conceptual SWCP sheets, and lists submitted shall be the responsibility of the applicant. The Planning Manager may reject as incomplete an application that does not supply the required information or that includes inaccurate or incomplete information.

All projects required to conform to NPDES stormwater permit requirements shall submit a conceptual SWCP at the time of the initial planning-level application, This "Concept" plan shall be formally reviewed and approved by the Permit Center Engineering section prior to over-all planning-level approval with condition(s). This is normally achieved by way of the Development Review Committee (DRC). The DRC is the internal forum by which both discretionary and non-discretionary planning-level permit application packages are distributed to the various discipline groups within the City.

## 1.9.3 Building Permit Process




Once a project has been approved through the “planning permit process”, the applicant then works with the City’s Permit Center staff to obtain a building permit, which includes compliance with the Conditions of Approval for stormwater management approved by the City’s Community Planning group (see **Figure 1-8**).

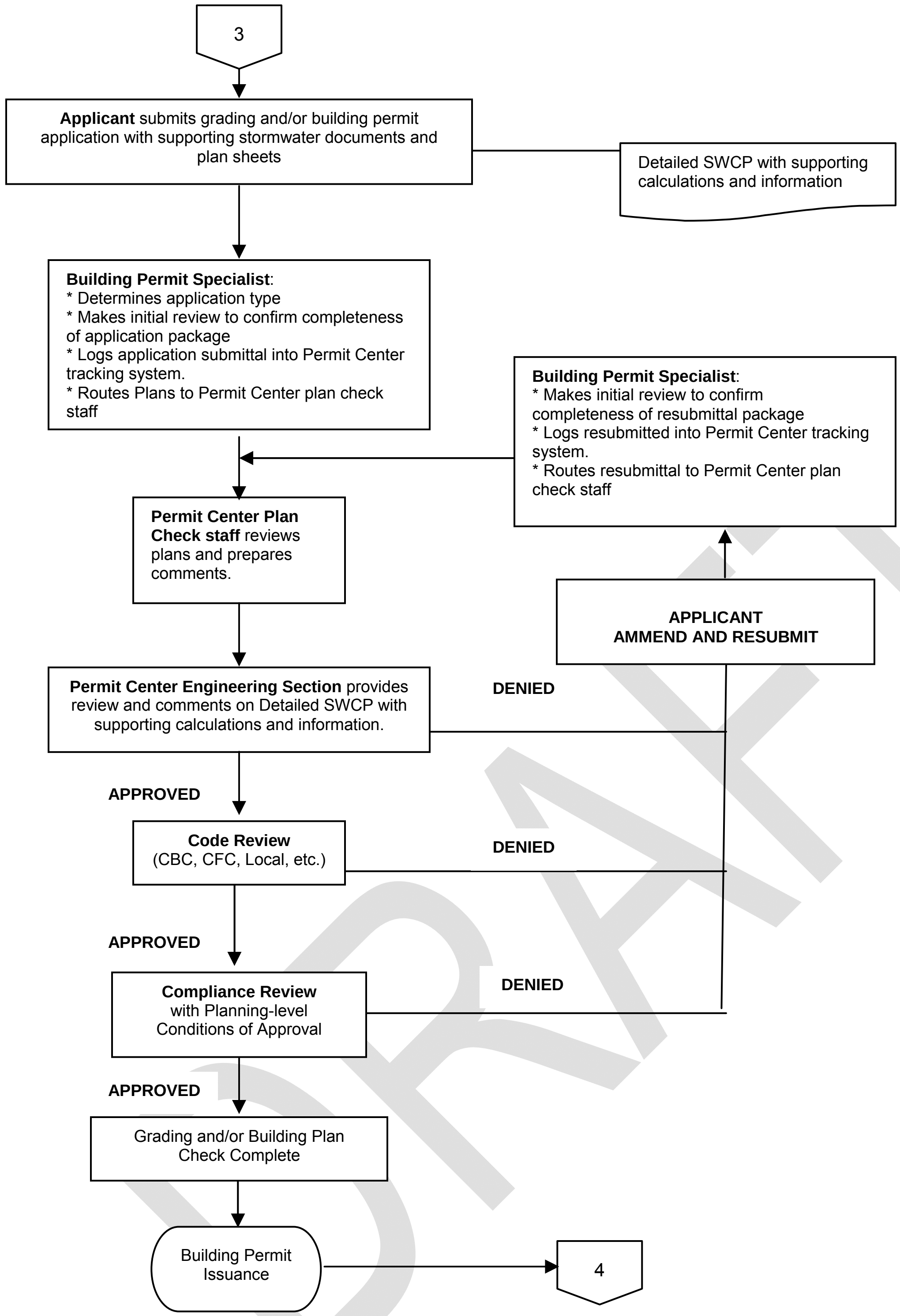
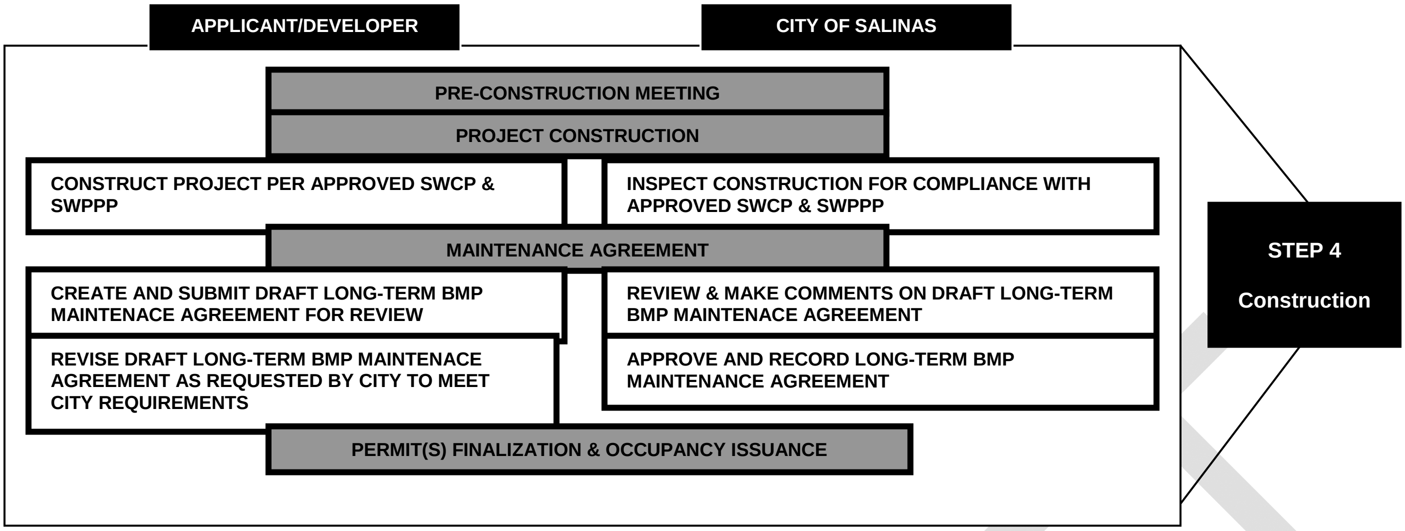



Figure 1-6: Plan Check and Building Permits

## 1.9.4 Construction




Implementation of Section 1.7.2 City Construction Inspection occurs during this phase. Concurrent with other building inspections occurring at the project site, inspections for compliance with the SWCP and the SWPPP will be conducted regularly by City staff.

Prior to, or during construction, draft maintenance agreements are submitted to the City for approval. City approval and filing with the County recorder is required prior to final occupancy.

# Section 2: Low Impact Development (LID) and Stormwater Management Planning

The City of Salinas NPDES permit requires stormwater management to the Maximum Extent Practicable. Per the Salinas NPDES permit, MEP is defined as "the emphasis of pollution prevention and source control BMPs as the first lines of defense in combination with structural and treatment methods where appropriate serving as additional lines of defense. The MEP approach is an ever evolving, flexible, and advancing concept, which considers technical and economic feasibility."

The MEP standard places an emphasis on pollution prevention and source control through site planning. Also, the Regional Board has indicated that Low Impact Development (LID) meets the MEP standard. This section will review LID and stormwater site planning concepts.

## 2.1 What is LID?

LID represents the storm drainage component of sustainable development. It is an innovative stormwater management approach with the basic principle that is modeled after nature: manage runoff from rainfall and urban use of water at the source using uniformly distributed decentralized small scale controls, also known as integrated management practices (IMPs). IMPs are small on-lot treatment control BMPs that are integrated into the site layout, landscaping and drainage design of urban development. The primary goal of LID is to mimic a site's pre-development hydrology by using design practices and techniques that effectively capture, filter, detain, infiltrate, and evaporate runoff close to its source. LID practices or IMPs that mimic a site's predevelopment hydrology can be accomplished by implementing the following:

- Site designs that protect natural drainage ways, areas of native vegetation and high value open space, and direct runoff to soils that support infiltration;
- Site designs that maintain the size of pre-development drainage areas and mimic pre-development flow rates and volumes in natural drainages and runoff to streams and other surface waters.
- Site fingerprinting techniques (e.g. minimal disturbance of site except what is needed for structures) to reduce the amount of compacted soil during construction;
- Site design that reduce the amount and direct connection of constructed impervious surfaces;
- Grading features that direct runoff from impervious surfaces to below grade vegetated areas with permeable engineered soils; and,
- Education of landowners on the function of LID designs and IMPs and the need to maintain the viability of these practices so that they continue to function as designed.

This order mirrors the order of events that a developer/designer would undergo to apply LID to promote the successful long term performance of LID designs and IMPs.

As noted above, LID designs protect natural drainage features and incorporate them into the site design. Since natural drainage features such as dry channels often have developed soil structures that formed over long periods of time, they can be utilized in the design of LID practices or IMPs such as vegetated swales and often function much more efficiently than vegetated swales installed on imported fill materials. Conventional development techniques often remove native vegetation, reduce open space and fill natural drainage features; therefore LID designs preserve natural drainage features and particularly high value open space areas such as wetlands, natural riparian corridors and soils with good groundwater recharge potential.

Figure 2-1 presents a comparison between the way urban runoff is typically managed in a conventional residential development and an LID landscaping approach. In the conventional development model, impervious surfaces (roofs, driveways, sidewalks, and compacted soils), and elevated (convex) landscaped areas that drain to impervious surfaces, increase runoff and pollutant discharges to the storm drain system. This approach typically results in an inefficient use of water resources and a system that drains water and other resources (e.g. topsoil and fertilizers) away and into local waterways. In the LID approach, runoff from impervious surfaces drains to depressed (concave) landscaped areas with amended soils and only runoff from relatively large storm events discharges to the storm drain system. With the LID landscaping approach, the rate, volume and pollutant loading of urban runoff can generally be reduced to pre-development levels and the biological and physical integrity of local waterways can be preserved and maintained.

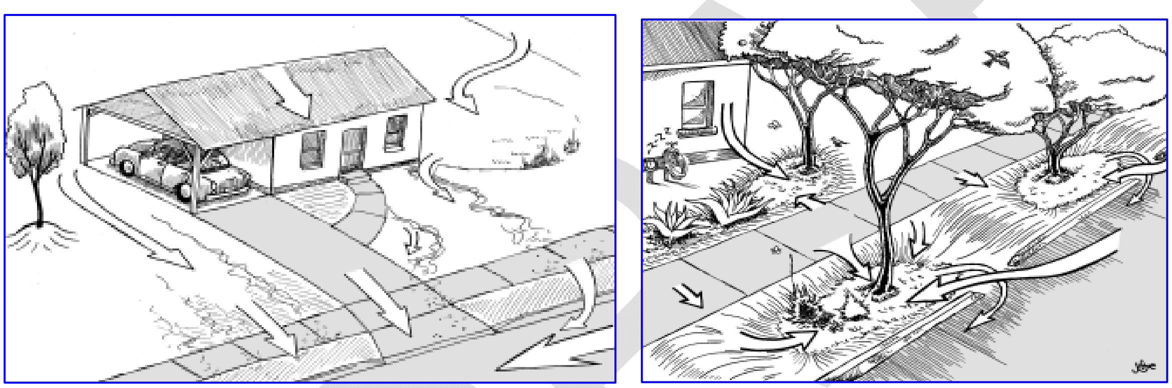


Figure 2-1: Comparison of Urban Runoff from a Conventional Development and an LID Approach that Uses Landscaping to Capture and Treat Runoff (Graphics courtesy of: Brad Lancaster www.harvestingrainwater.com)

Conventional development and storm drainage system designs typically increase the rate, volume and pollutant loading of urban runoff, which can result in environmental impacts to local surface water resources. This occurs because man made impervious surfaces such as roofs, driveways, sidewalks, and compacted soils are often directly connected to each other. Runoff from directly connected impervious surfaces often drains to impervious curb and gutter systems, which then drain to storm drain inlets and a network of impervious underground pipes that discharge directly local waterways untreated. Conventional storm drain systems are designed as stormwater disposal systems, which efficiently drain urbanized areas and rapidly transport stormwater to receiving waters. However, they also increase peak flow rates and volumes, more rapidly transport pollutants, and can cause downstream erosion and resultant stream habitat degradation.

Conventional detention methods located downstream of underground storm pipe networks, such as open basins with outflow control structures (e.g. detention basins), are often used to reduce peak discharge rates and provide flood control. The City of Salinas generally requires detention to release post-development 100-year runoff at no greater than the pre-development 10-year peak runoff rate. Although conventional detention basins are typically effective at reducing post development discharge rates to receiving water bodies, they typically do not reduce the overall increased volume of runoff created by the addition of developed impervious surfaces (unless the basins are located on relatively permeable non compacted soils).

Figure 2-2 provides a graphic example of the hydrologic response to development and conventional storm drain system design with and without detention. Figure 2-2 is a series of three hydrographs, which compare flow rates as a function of time. As can be seen on the post development with detention hydrograph, the peak flow rate has been reduced to predevelopment levels. However, the overall increased volume of runoff, which is represented by the area under the curve, is not reduced, but released gradually over time through an outflow control structure. This can result in longer duration peak stream flows which can increase erosion, change stream channel morphology, and result in a loss of habitat.

Conventional development also typically covers soils that previously infiltrated a portion of the annual rainfall and recharged groundwater. This can result in reduced groundwater flow to urban area streams and a decline in stream base flows during extended periods of dry weather. It should also be noted that conventional detention basins typically do not provide sufficient detention time to allow for settling of fine sediment and particulates, which is often associated with the pollutants of concern. In addition, the pollutants that do accumulate in conventional detention basins are often susceptible to resuspension and release during relatively large events.

Almost all components of the urban environment have the potential to serve as LID practices and IMPs. This includes the rooftops, streetscapes, parking lots, driveways, sidewalks, medians and the open spaces of residential, commercial, industrial, civic, and municipal land uses. Anywhere landscaping can be applied also presents an opportunity for implementation of vegetated LID practices and IMPs. LID is a versatile approach that can be applied equally well to new development, urban retrofits, redevelopment, and revitalization projects. However, site challenges in urban retrofits, redevelopment, and revitalization projects can be significant because of the available space is often limited because of existing infrastructure and buildings. Local hydrologic and geotechnical conditions (especially infiltration and soil characteristics), land uses and regulatory requirements must be considered in the design of LID designs and IMPs.

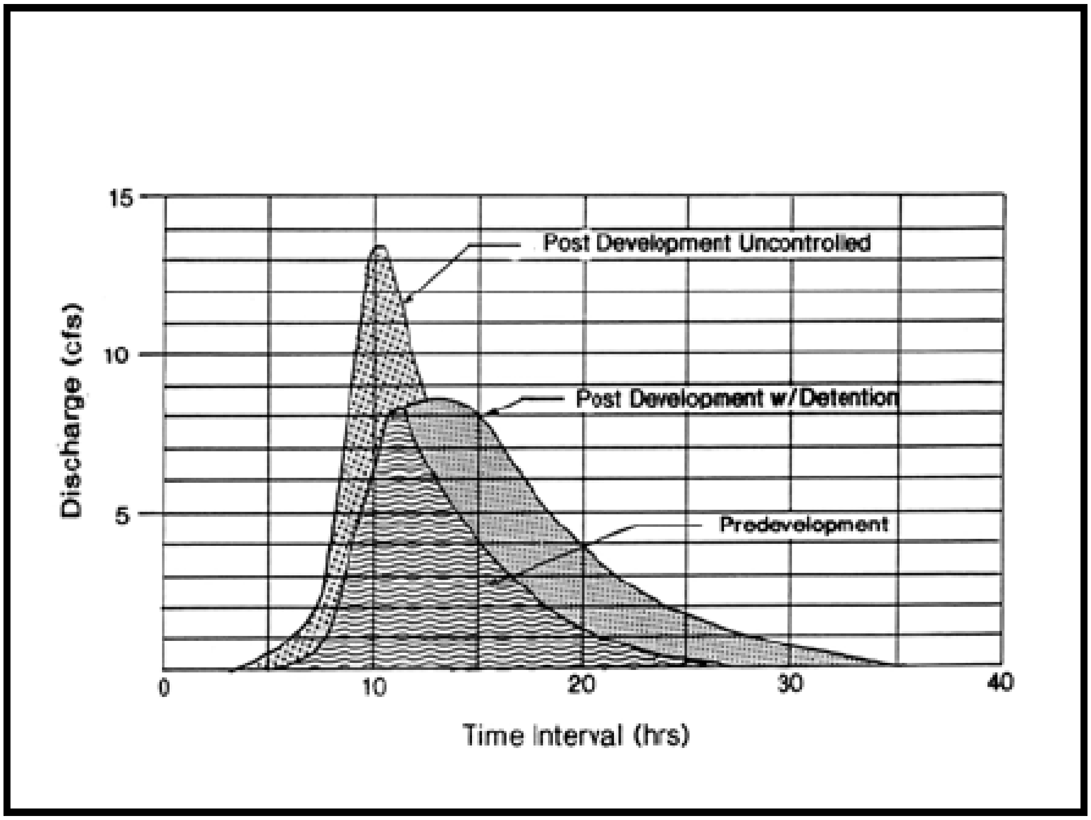



Figure 2-2: Comparison of Stormwater Discharge Rates and Volumes from an Undeveloped Drainage Area (e.g., pre-development), a Developed Drainage Area without Peak Flow Rate Controls (e.g., Post-Development Uncontrolled), and a Developed Drainage Area with Conventional Detention/Flood Control Measures.

As noted above, LID addresses the drainage component of new development and redevelopment projects by implementing practices that mitigate the increased volume, rate, and pollutant loading of urban runoff. LID designs and IMPs mimic natural hydrologic functions by filtering urban runoff through vegetation, soils and organic matter, allowing evapotranspiration by vegetation, biodegradation of pollutants by soil bacteria, infiltration and groundwater recharge. LID practices and IMPs that mimic natural hydrologic functions include green roofs, vegetated swales, bioretention basins and permeable pavements. With the exception of green roofs, these LID practices or IMPs can indirectly infiltrate urban runoff into underlying soils and eventually reach groundwater. Soil infiltration rates and the potential presence of low permeability layers must be identified to successfully use infiltration techniques without underdrains. In addition, protection of groundwater quality is of utmost importance when designing stormwater infiltration systems. However, the potential to contaminate groundwater by infiltrating urban runoff in properly designed and constructed treatment control BMPs with proper pretreatment is low[2]. In addition, surface soils are typically very effective at urban runoff pollutant removal and retention because a multitude of natural processes occur, including physical filtering, ion exchange, adsorption, biological processing, conversion, and uptake. In addition to providing water quality benefits and increasing groundwater recharge, LID designs and IMPs can also reduce flooding potential and assist with water conservation. The Regional board supports the use of LID practices because they meet the "maximum extent practicable" (MEP) definition for management of stormwater and have been proven to be effective, feasible and economically practicable in other communities.

### 2.1.1 LID and Smart Growth

LID is one of several new urban planning techniques. LID is compatible with other techniques such as "Smart Growth" and "Sustainable Development," LID is a component of these new urban planning techniques and is primarily focused on alternative storm drainage techniques. Smart Growth is a term that describes the efforts of communities across the country to manage and direct growth in a way that minimizes damage to the environment and builds livable and economically sustainable towns and cities. Livability suggests, among other things, that the quality of our built environment and how well we preserve the adjacent natural environment directly affects our quality of life. Smart Growth calls for the investment of time, attention, and resources in central cities and older suburbs to restore community and vitality. It advocates patterns for newly developing areas that promote both a balanced mix of land uses and a transportation system that accommodates pedestrians, bicycles, transit and automobiles.

### 2.1.2 LID and LEED

LID is also a component of the Leadership in Energy and Environmental Design (LEED) Green Building Rating System. LEED green building credits for LID designs include credits for erosion control and site selection, and site designs that protect or restore habitat, maximize open space, control the quantity and quality of storm water, and utilize roofs that reduce the heat island effect (e.g. green roofs). The LEED system also provides credits for water efficient landscaping and water use reduction. Because vegetated LID practices and IMPs such as bioretention systems and vegetated swales harvest rainwater and can be designed with native low water use plants, they may also apply for LEED green building credits. In addition to sustainable site design and water efficiency, the LEED Green Building Rating System also applies credits for projects that improve energy efficiency and air quality, utilize recycled and locally manufactured materials, reuse materials and reduce construction waste. Additional information about LEED standards can be obtained from the U.S. Green Building Council (www.usgbc.org)

## 2.2 What Is Not LID?

Conventional urban development and storm drainage system design (see Figure 2-1, left image) is not LID because it typically increases the rate, volume and pollutant loading of urban runoff. Conventional storm drainage systems typically consist of impervious streets, parking lots, sidewalks, driveways, and roofs that are directly interconnected to drain to impervious curb and

[2] Pitt et al., 1994. Potential Groundwater Contamination from Intentional and Non-intentional Stormwater Infiltration, U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory, May 1994. EPA/600/SR-94/051.

gutter systems and discharge to storm drain inlets and a network of impervious underground pipes. Conventional flood control detention basins are also not LID because they are typically designed to only reduce the peak flow rates of runoff from the relatively large storm events (e.g., the 5-, 20- and 100-year storm event). They typically do not reduce pollutants in urban runoff that are most common in first flush storm events, and unless sited on permeable soils that have not been compacted, conventional flood control detention basins typically do not allow significant infiltration and groundwater recharge (therefore they typically do not significantly reduce the volume of runoff from developed areas).

In addition, conventional landscaping that consists of mounded areas that drain onto impervious surfaces is not LID. To be considered LID, landscaping must be depressed and below the grade of adjacent impervious surfaces and have the impervious surfaces graded to drain into the landscaped areas. LID landscaping must also be designed with amended or engineered soils that provide sufficient infiltration and pollutant removal characteristics. Provision of engineered features to accommodate overflow from LID landscaping into conventional storm drain systems during large storm events can extend the range of the conditions over which a LID landscape can function. While removal efficiencies can decrease at higher flows, pollutant loads at these flows are also expected to be lower.

Some public domain, and most manufactured (proprietary), structural treatment control BMPs (such as those presented in the CASQA Handbook) are also typically not considered LID practices or IMPs because most do not meet the Regional Board's MEP definition.  When these devices are constructed of concrete enclosures, such that they do not allow infiltration through soils and/or water uptake by plants, they typically do not reduce the volume of excess runoff produced by man made impervious surfaces. In addition, devices such as underground treatment vaults and hydrodynamic or vortex separators are typically only effective at removing relatively coarse sediment, trash, debris and some oil and grease from urban runoff. They typically do not remove fine sediment, suspended sediment or dissolved pollutants, which are the primary pollutants of concern in the Salinas area and in many other areas of the nation. A number of manufactured structural treatment control BMPs also require relatively frequent maintenance and/or specialized equipment. Because they are typically underground, they can easily become "out of sight and out of mind" and are easily forgotten (i.e. not maintained). Some hold standing water permanently and can be susceptible to mosquito breeding. Therefore, they do not meet the MEP standard when used alone. However, the City may allow the use of some public domain and/or manufactured structural treatment control BMPs for pretreatment and removal of coarse sediment, trash and debris prior to further treatment by a downstream IMP, such as a bioretention basin.

Managing and treating urban runoff with a conventional storm drainage system and costly end-of-pipe structural treatment control BMPs located at the bottom of a relatively large drainage area in also not LID. As noted previously, LID addresses urban runoff through small, cost-effective landscape features located at the lot- or neighborhood-level. However, the science and technology of storm water treatment control BMPs is new and evolving. Innovative public domain and manufactured structural treatment control BMPs are constantly being developed to meet NPDES permit requirements. Therefore the City of Salinas will periodically review and consider approval of new structural treatment control BMPs.

## 2.3 LID Site Planning Principles

As shown on Figure ES-1, in the Executive Summary of these standards, LID stormwater management techniques, when implemented in the planning phase of new and redevelopment projects, can have the greatest relative impact on reducing the rate, volume and pollutant loading of urban runoff. This is particularly true in relatively large development projects.

## 2.4 LID Planning Techniques

As discussed in detail in the previous section, conventional development and storm drain system designs typically increase runoff, contribute pollutants to surface waters, and reduce groundwater recharge. Therefore LID designs and practices must be implemented to offset these negative impacts. All successful designs and practices require proper planning and engineering. Therefore LID designs and practices must be carefully planned and adhere to a set of basic planning principles. LID planning principles require different site and facility design considerations than conventional development and storm drain system design. To be successful, LID planning principles for the protection of local water resources consist of the following strategies:

- Minimizing post-project runoff though site design
- Using LID techniques to control sources of pollutants
- Treating polluted stormwater runoff before discharging it to the storm drain system or to receiving waters.

Planning elements 1 and 2 emphasize reducing or eliminating pollutants in stormwater runoff at their source by capturing and reducing the volume and rate of runoff and the exposure of pollutants to rainfall and runoff from other sources. This can be accomplished by implementing LID site designs and source control BMPs. Planning element 3 considers the implementation of IMPs and other structural treatment control BMPs, which are engineered systems typically consisting of piping, filter media, and concrete structures that primarily use physical methods to reduce pollutants in stormwater. IMPs are discussed in detail in Section 3.4. If LID planning principles 1 and 2 are incorporated into the design of many new development and redevelopment projects, particularly land uses such as residential developments, LID designs and source control BMPs alone can effectively reduce runoff and control sources of pollutants. However, some sites may require a combination of LID designs, source controls, IMPs and potentially other structural treatment control BMPs to meet local water quality standards and the MEP definition discussed in Section 2.5.3.

Every potential development site possesses a unique combination of topographic, physical, hydrologic, soil, and vegetative features. Some sites are more suitable than others for certain types of BMPs. However the integration and incorporation of LID landscaping techniques can be widely applied. Landscaping strategies that drain and filter stormwater are the one of the most effective methods of minimizing surface and groundwater impacts from stormwater runoff. Green roofs and routing roof runoff through LID landscaping techniques provide additional stormwater management benefits.

Reducing the amount of dry-weather flows through the use of efficient irrigation systems and discouraging outdoor washing activities also helps to reduce runoff and the transport of pollutants to receiving waters. LID landscaping techniques, roof runoff controls and efficient irrigation techniques have the additional benefit of assisting with water conservation efforts while minimizing public health vector nuisances.

Finally, the labeling of storm drain inlets with messages such as "No Dumping – Flows to Creek" provides a highly visible public education message. It helps to educate the general public that the stormwater runoff from streets and parking lots is conveyed through the storm drain system and does not receive treatment prior to discharge to local streams, rivers and lakes.

The following sections discuss the LID planning principles of protecting Preserving Existing Vegetation, Filtering Waterways, Creating and Preserving Open Space, and Tree Planting and Parkway Designs. Additional information about planning principles and site design techniques that replicate pre-existing hydrologic site conditions can be obtained at the Low Impact Development Center http://www.lowimpactdevelopment.org/

### 2.4.1 Preserving Existing Vegetation

Measures to preserve existing vegetation, both native and established landscaping, shall be implemented wherever possible to protect and preserve existing high value plants and trees in areas that will be exposed to land-disturbing activities. This LID planning principle shall be used on all construction sites and is particularly applicable where projects areas are located in floodplains, near streams, wetlands, and steep slopes.

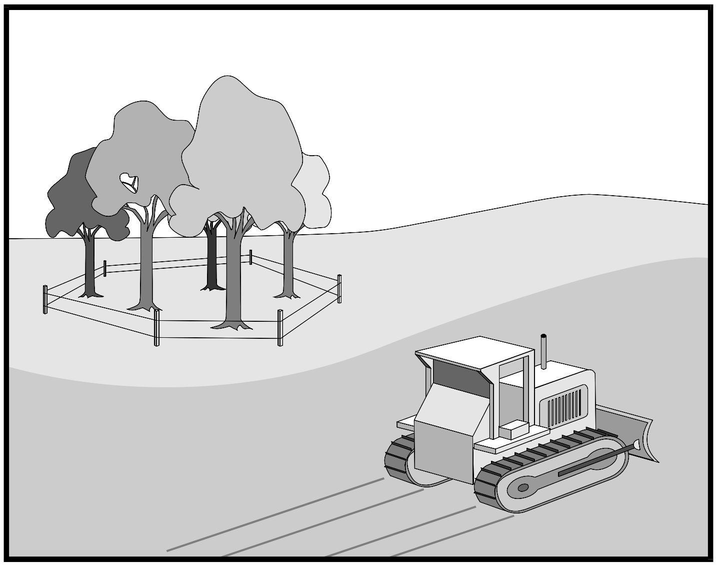
**Design Planning Considerations**

- Assess proposed development areas to determine areas of existing vegetation to be preserved. Appropriate assessment professionals include botanists, biologists, arborists and landscape architects
- Design sites to fit into existing contours and preserve existing vegetation to the extent feasible or required by local ordinances
- Consider plant and tree health, age, species, space needed, aesthetic values, and habitat benefits
- Design new landscaping to provide consistency with existing vegetation to be preserved on site or in the surrounding area
- Follow existing contours and avoiding stands of trees and other high value vegetation when locating temporary roadways.

**Construction Planning Considerations**

- Clearly mark areas to be preserved on maps and plans with Preserve Existing Vegetation (PEV) lines

- Install temporary fencing to protect existing vegetation before beginning clearing or other soil-disturbing activities
- When protecting trees, extend the limits of fencing to at least the tree drip-line (the horizontal extent of the tree branches)
- Do not place equipment, construction materials, topsoil, or fill dirt within the limit of tree drip-lines or other preserved areas
- Do not cut tree roots within the tree drip line and curving trenches around trees to avoid large root concentrations
- Repair or replace damaged vegetation immediately. If tree roots are cut, the ends shall be smoothly cut. Cover exposed tree roots with soil or wet burlap as soon as possible
- Conduct excavation activities within tree drip lines by hand, and preserve all roots 1/2" in diameter and larger
- Any pruning of the branches or roots shall be completed by, or under the supervision of, an arborist
- Maintaining existing irrigation systems and supply additional supplemental irrigation when necessary to protect the health of existing plants and trees
- Fertilizing broadleaf trees that have been stressed or damaged to aid the recovery and consulting an arborist to determine if and what kind of fertilizer is needed



**MAP SYMBOL**

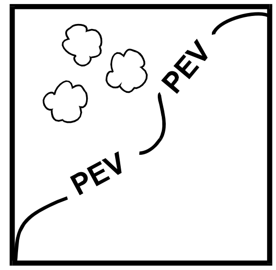



Figure 2-3: Example BMPs for Preserving Existing Vegetation at Construction Sites (Graphics used with permission of Caltrans)

### 2.4.2 Filtering Waterways

Waterways include wetlands, estuaries, streams, rivers, ponds, lakes and other surface waters. Areas adjacent to streams and rivers that support a wide variety of plant and animal species are known as “riparian areas”. Riparian areas are dependent on the hydrology of streams and rivers and typically have shallow groundwater. The City has developed codes and ordinances to protect waterways and prevent or significantly limit development within specified limits or setbacks. For example, the City of Salinas General Plan protects riparian corridors and wetlands through minimum 100-ft setbacks. Developments must retain creeks and wetlands in their natural channels. It discourages the use of culverts or underground pipes and requires a riparian/wetland habitat mitigation and management plan if impacts are incurred to such waterways during development.

### 2.4.3 Creating and Preserving Open Space

The City of Salinas Zoning Code, Municipal Code, and General Plan contain language that supports the creation and preservation of open space in development areas. Protecting natural drainage ways (e.g. dry channels that convey water during storm events), areas of native vegetation, and high value open space is one of the primary principles of LID. Open space filters and greenbelt areas shall be established to help define boundaries between development areas and neighborhoods, to prevent urban sprawl, and to protect sensitive habitats.

Cluster and open space development are LID site design strategies that concentrate development to specific areas of a site, leaving portions of the development in open space. These designs include strategies such as smaller lot sizes, alternative street layouts to reduce road networks and area of impervious pavements, alternative driveway designs, and alternative sidewalk designs (discussed in the following sections). When choosing the development envelope for a site, features such as riparian areas, woodland conservation areas, steep slopes, and highly erosive or permeable soils must be protected.

**Conventional Site Plan** **LID Site Plan Utilizing Open Space and Cluster Development**

Figure 2-4: Comparison of a LID Site Plan to a Conventional Site Plan on the Same Site (Images courtesy of Puget Sound Action Team)

### 2.4.4 Tree Planting and Parkway Designs

Trees can be used in urban settings as part of a stormwater management plan to reduce runoff and pollutant loads from development projects. Urban areas with large numbers of trees exhibit hydrology more similar to pre-development conditions than urban areas with little to no tree canopy. This occurs because trees intercept rainfall and can retain a significant volume of the captured water on 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[3]. Evergreen trees have the greatest potential to provide stormwater management benefits because they retain their leaves throughout the rainy season. Generally, the larger the tree and the smaller the leaves, the more rain is intercepted. In addition, tree roots help to support infiltration into urban soils by providing pathways through relatively tight soils (clayey and silty soils).

The shade provided by trees also keeps the ground and impervious surfaces under trees cooler. This reduces the amount of heat gained in runoff that flows over the ground and impervious surfaces located under the trees. This attenuation of heat in stormwater helps control increases in stream temperatures. On slopes, tree roots also hold soil in place and minimize erosion.



[3] Cappiella, K. 2004. *Urban Watershed Forestry Manual* (draft). Prepared for USDA Northeastern Area State and Private Forestry. Center for Watershed Protection, Ellicott City, MD

**Planning Considerations**

- Check with the City about requirements for trees located in public utility easements.
- Locate trees appropriate distances from infrastructure and structures that could be damaged by roots and branches. 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.
- Select tree species based on the soils found on the site, available water, and aesthetics.
- Consult a landscape architect or arborist regarding suitability of species for site conditions and design intent

## 2.5 Stormwater and LID Concepts

Planners, designers, engineers and landscape architects working on stormwater management and LID designs have created an array of terms and acronyms to describe key concepts. Some are based on federal and state regulations; others have evolved based on design practices. The following terms are important to understand when communicating with project designers, reviewers and regulatory agency staff.

The Salinas National Pollutant Discharge Elimination System (NPDES) stormwater discharge permit requires the City to implement Best Management Practices (BMPs) and reduce the discharge of pollutant loads to and from the municipal separate storm sewer system (MS4) to the "maximum extent practicable" (MEP). The following section provides a description of each of these stormwater management terms and other terms related to the design LID practices.

### 2.5.1 NPDES and MS4

The **Salinas NPDES stormwater discharge permit** is discussed in Section 1.1 of these standards. Appendix C presents a copy of Attachment 4 of the 2005 Salinas NPDES stormwater discharge permit, which requires the implementation of LID planning and design practices in new development and significant redevelopment projects within the City. Additional information about the federal NPDES stormwater program can be found at http://cfpub1.epa.gov/npdes/home.cfm?program_id=6

The **Municipal Separate Storm Sewer System (MS4)** is the system of stormwater conveyances (including streets, curbs, gutters, ditches, man-made channels, catch basins and underground storm drain pipes) owned and operated by a public body (such as a City or County) having jurisdiction over of the discharge of stormwater to waters of the United States (e.g., local streams, wetlands and other surface waters).

### 2.5.2 BMPs and IMPs

**A Best Management Practice (BMP)** refers to any kind of procedure or device designed to minimize the quantity of pollutants that enter the municipal storm drain system (e.g., the MS4). Since the beginning of the NPDES stormwater program in 1990, a rough taxonomy of BMPs has emerged. BMPs can be classified in three general ways; temporary construction BMPs, source control BMPs and structural treatment control BMPs. Source control BMPs can be further subdivided into operational BMPs and integrated management practices, or IMPs.

**Source Control BMPs** (also known as source control measures or non-structural BMPs) aim to stop pollutants from entering stormwater at their source. All **Operational BMPs** (described below) are for source control, but source control BMPs can also be site design features that prevent rainwater from contacting a potential pollutant source (e.g., a roof over a storage area). Since the objective of LID is to control and treat urban runoff as close to the source as possible, many LID design practices can be considered source control BMPs.

**Structural Treatment Control BMPs** are built devices or facilities that remove pollutants that have already become suspended or dissolved in stormwater. When designed by an engineer based on public design guidance manuals, they are considered **Public Domain Structural Treatment Control BMPs**. When pre-manufactured devices are purchased from a supplier they are considered **Manufactured (Proprietary) Structural Treatment Control BMPs**. A sedimentation basin designed to treat and infiltrate runoff from an urban drainage area that includes a number of impervious surfaces is considered a public domain structural treatment control BMP. LID practices integrated into the landscape design and distributed throughout the site are known as **Integrated Management Practices (IMPs)** and can be considered as another form of treatment control. IMPs and some public domain structural treatment control BMPs effectively reduce the rate, volume and pollutant loading of urban runoff. Therefore they meet the MEP standard of the Salinas NPDES permit. They can also be designed as part of the flood control system that must be incorporated into urban development to safely convey runoff from the infrequent large storm events.

Some public domain, and most manufactured (proprietary), structural treatment control BMPs do not meet the MEP definition. These devices, such as hydrodynamic or vortex separators, are typically only effective at removing relatively coarse sediment, trash, debris and some oil and grease from urban runoff. They typically do not remove fine sediment, suspended sediment or dissolved pollutants, which are the primary pollutants of concern in the Salinas area. Also, most manufactured structural treatment control BMPs do not reduce the volume, rate and duration of urban runoff. However, these systems can be used for pretreatment and removal of coarse sediment, trash and debris prior to further treatment by a downstream LID practice, such as a bioretention basin.

**Operational BMPs** are practices or procedures that prevent pollutants from entering stormwater. Activities such as dumping wash water in an indoor sink rather than the gutter, sweeping outside work areas daily, and conducting routine maintenance activities to ensure structural treatment controls function as designed are considered operational BMPs.

### 2.5.3 Maximum Extent Practicable (MEP)

As discussed at beginning of Section 2:, the Salinas NPDES permit (see Finding No. 16 in Regional Board ORDER NO. R3-2004-0135, Appendix C) defines the **Maximum Extent Practicable (MEP)** standard as “the emphasis of pollution prevention and source control BMPs as the first lines of defense in combination with structural and treatment methods where appropriate serving as additional lines of defense. The MEP approach is an ever evolving, flexible, and advancing concept, which considers technical and economic feasibility." . In addition, the Regional Board has determined that the MEP criteria are to be met with the use of LID practices that effectively reduce the rate, volume and pollutant loading of urban runoff to pre-development conditions. The LID planning and design techniques that can be implemented to meet the MEP criteria are presented in Section 2.4 and Sections 3.2, 3.3, and 3.4 . The City of Salinas requires LID planning and design techniques to reduce the rate, volume and pollutant loading of urban runoff to the MEP, including management practices, control techniques, system design, and engineering methods.

The MEP standard involves applying best management practices (BMPs) that are effective in reducing the discharge of pollutants in stormwater runoff. MEP requires permittees to choose effective BMPs, and to reject applicable BMPs only where other effective BMPs will serve the same purpose, the BMPs would not be technically feasible, or the cost would be prohibitive. MEP is the result of the cumulative effect of implementing, continuously evaluating, and making corresponding changes to a variety of technically and economically feasible BMPs that ensure the most appropriate controls are implemented in the most effective manner. This process of implementing, evaluating, revising, or adding new BMPs is commonly referred to as the iterative approach.

### 2.5.4 Impervious Surfaces and the Rational Method for Stormwater Runoff Calculations

Imperviousness is the characteristic of a material, which allow or prevent the effective passage of water through it (e.g., no effective infiltration). **Impervious surfaces** are hard surfaces that prevent or retard the entry of water into the soil mantle and cause water to runoff the surface in greater quantities or at a greater rate of flow than under natural pre-developed conditions. Impervious surfaces include, but are not limited to, building rooftops, roads, streets, driveways, parking lots, rooftops, patios, sidewalks and compacted soils. Gravel pavement over sandy soils is highly permeable and is not considered an impervious surface. However gravel pavement over clay soils is considered an impervious surface. Open, uncovered retention or detention facilities are not considered impervious surfaces.

Peak runoff flow and total runoff volume from urban drainage areas (less than 20 acres) can be calculated as a function of the ratio of impervious area to total area using the empirically derived Rational Method. **The Rational Method** correlates peak flow to the runoff coefficient "C", where the maximum value is 1.0 and the minimum value is 0.01. Relatively high C values are assigned to impervious surfaces such as roadway pavement (e.g., C = 1.0), whereas relatively pervious surfaces such as sandy soils are typically assigned relatively low values (e.g., C = 0.05). The appropriate C values to be used with sizing the BMPs presented in these Design Standards shall be those presented on Table 4-4.

### 2.5.5 Infiltration and Percolation

As a stormwater management/LID method, the term infiltration refers to practices that retain or detain urban runoff within permeable soils. Depending on: a) the amount of runoff, b) the design of the stormwater infiltration practice and, c) the soil permeability in existing site soils, a portion of the runoff that enters the device can percolate through unsaturated subsurface soils and recharge groundwater. *Infiltration is the primary mechanism in LID practices and IMPs for* *reducing the rate, volume, and pollutant loading of urban runoff*. Soil amendments are typically required to increase the permeability and pollutant removal effectiveness of existing site soils, particularly in areas with clayey soils. The following presents several important concepts with respect to the infiltration of stormwater and LID.

**Infiltration Rate** means the rate at which water percolates into the subsoil measured in inches per hour or minutes per inch.

**Direct Stormwater Infiltration** means any structure that is designed to infiltrate stormwater into the subsurface and by design, bypasses the natural groundwater protection afforded by surface or near-surface soils. Direct infiltration systems include infiltration trenches, infiltration basins, and dry wells. These devices are typically constructed of gravel and can impact groundwater quality if improperly sited (e.g., in a drainage area susceptible to spills).

**Indirect Stormwater Infiltration** means infiltration into subsurface soils via surface facilities that include amended or engineered soils. Indirect infiltration practices include vegetated swales, bioretention systems, and porous pavements. These LID practices or IMPs are expressly designed to convey or detain runoff and allow it to filter through amended or engineered soils with vegetation prior to infiltration into existing subsurface soils, generally less than 5 ft below ground surface. Treated stormwater may reach groundwater indirectly, or it may be under drained through subsurface pipes to the conventional storm drain system. These devices are highly effective at removing pollutants from stormwater and typically present little threat to groundwater quality.

**Soil Percolation** describes the transport of soil water based on the most restrictive shallow soil layer (e.g., a clayey soil layer). Infiltration or percolation testing of existing site soils is often required by municipalities when stormwater infiltration BMPs are proposed to be installed because infiltration or percolation rates are necessary to properly design stormwater infiltration BMPs. Infiltration testing is typically conducted using a double ring infiltrometer and infiltration rates are typically reported in units of inches/hour. Whereas percolation testing methods typically utilize single ring infiltrometers and procedures established for the permitting of septic system leach fields. Percolation rates are typically reported in units in minutes/inch. As can be seen on Figure 2-5, infiltration and percolation rates are dimensionally opposite from each other; as infiltration rates reported in inches/hour decrease, corresponding percolation rates reported in minutes/inch increase (e.g., 1.0 in/hr = 60 min/in and 0.5 in/hr = 120 min/in). This concept is important to understand when interpreting infiltration or percolation testing data for the design of stormwater infiltration systems. Specifications for soil infiltration/permeability testing are presented in the Treatment Control BMP fact sheets of the CASQA Handbook.

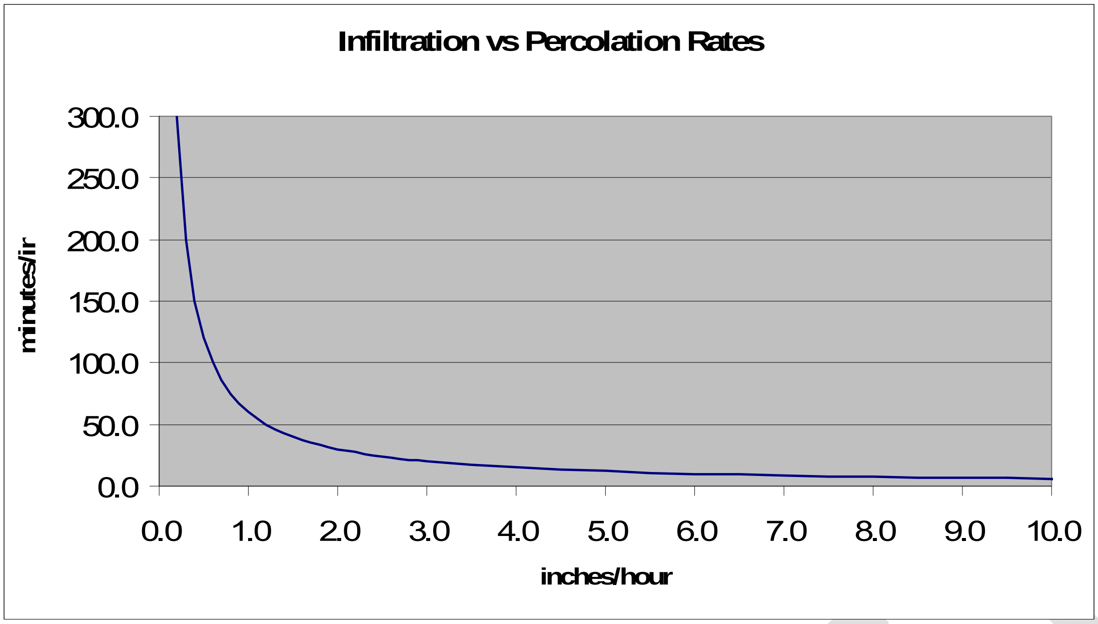



Figure 2-5: Relationship Between Infiltration Rates and Percolation Rates

Additional information about infiltration of stormwater in urban areas and the measures that must be taken to protect groundwater quality and building foundations, as well as a number of other parameters, is discussed in detail in Section 4.3.2.

### 2.5.6 Amended and Engineered Soils

Soil amendments are materials added to improve the physical properties of soils. They are typically mixed into soils to provide a better environment for plant roots. Engineered soils for LID practices and IMPs are specific mixes of soil materials and amendments developed for the purpose of infiltrating and treating urban runoff while producing a favorable environment for plants.

When properly selected and applied, organic soil amendments increase soil organic matter content and improve soil aeration, water infiltration, and both water and nutrient holding capacity. Many organic amendments contain plant nutrients and act as organic fertilizers. Organic matter is also an important energy source for bacteria, fungi and earthworms that live in the soil. Soil bacteria and fungi degrade a number of the pollutants commonly found in urban runoff. Therefore establishment of soil bacteria and fungi are critical components of engineered soils for LID practices and IMPs such as bioretention systems.

Soil amendments can be organic and inorganic. Organic amendments are derived from plant matter and animal waste. Inorganic amendments are either mined or man-made. Organic amendments include sphagnum peat moss, grass clippings, straw, compost, manure, biosolids, wood chips, sawdust and wood ash. Inorganic amendments include vermiculite, perlite, pea gravel and sand. Mulches are not considered soil amendments because they are placed on the soil surface to reduce erosion and improve soil moisture (e.g., they are not mixed into the soil).

Not all of the amendments noted above are recommended for use in vegetated LID practices and IMPs. They are merely provided as examples. For example, wood products such as wood chips and sawdust are not desirable because they can tie up nitrogen in the soil and cause nitrogen deficiency in plants. Wood ash is typically high in both pH and salts and can magnify common soil problems. Therefore wood ash shall not be used as a soil amendment in vegetated LID practices and IMPs. Sand shall also not be added to clay soils because it can create a soil structure similar to concrete.

Biosolids are byproducts of sewage treatment facilities. They may be found alone or composted with leaves and/or other organic materials. The primary concern about biosolids is that they may contain heavy metals, pathogens, and salts that can leach into groundwater or discharges to the storm drain system. Therefore biosolids shall not be used as a soil amendment in vegetated LID practices and IMPs. Manure can also contain elevated levels of ammonia and pathogens and shall not be used. Manure must be composted for at least two heating cycles at 130 to 140 degrees F to kill any pathogens. Most home composting systems do not sustain temperatures at this level. In addition, composted manure typically contains elevated levels of phosphorus, potassium and salts. Therefore composts containing manure shall also not be used in vegetated LID practices and IMPs.

Care should always be applied to the selection of the soil amendments in vegetated LID practices and IMPs such as bioretention systems. As noted above, if they are not properly designed, they can leach nutrients (nitrogen and phosphorous) and soluble salts out of the soil mix and into groundwater or to a storm drain system that discharges to a surface water body. Vegetated LID practices and IMPs such as bioretention systems differ from ordinary conventional landscaping (e.g., they are designed to have urban runoff flow into them from adjacent developed impervious surfaces). Therefore, by design, urban runoff concentrates in vegetated LID practices and IMPs, increasing the potential to leach nutrients and salts out of the soil mix included in the IMP. To reduce the potential of increasing nutrient concentrations in stormwater discharges from bioretention systems, the soil mix of bioretention systems must be carefully designed (e.g., an engineered soil mix). Certified compost made from purely plant sources and sphagnum peat moss have a low P-index, are low in salts and are good choices for amending soils in vegetated LID practices and IMPs. An analysis of the soil mix is always recommended prior to installation. Additional detailed design criteria for bioretention systems are presented in Section 4.3.5.

As noted above, engineered soils for LID practices and IMPs represent specific mixes of soil materials and amendments. They are developed exclusively for the purpose of infiltrating and treating urban runoff while producing a favorable environment for plant roots. As discussed in detail in Section 4.3.5, engineered soils for bioretention systems shall have a sandy loam or loamy sand texture and consist of 50-60% clean sand; 5-20% certified compost or peat moss; and 20-30% topsoil with a no more than 5% clay content and a low P-index.

## 2.6 Source Controls

As noted above in Section 2.5.2, Source Controls are BMPs designed to stop pollutants from entering stormwater at their source. They include Operational BMPs (also described in Section 2.5.2) and site design features that prevent rainwater from contacting a potential pollutant source (e.g., a roof over a storage area or a cover on a dumpster). Source Control BMPs, which minimize or eliminate pollutants from entering stormwater runoff, are the second tier in the City's stormwater implementation measures, following LID planning. Many of these BMP measures are operational in nature, and specific to the application. See the CASQA BMP Handbooks for additional information (www.cabmphandbooks.com).

## 2.7 References and Additional Resources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# Section 3: LID Designs and Practices

## 3.1 Designing and Documenting LID Designs

LID designs require thoughtful and detailed design of grading and drainage and careful integration with site and landscaping designs. It is important to document in the Stormwater Control Plan (SWCP) that site designs have effectively minimized the amount of impervious surfaces and have appropriately designed Integrated Management Practices (IMPs) per the required design criteria presented in these standards. As noted in Section 1.5.1, Effective Impervious Area (EIA) must be minimized to the MEP. EIA is that portion of the projects impervious area that drains directly to a receiving surface waterbody via a hardened storm drain conveyance without first draining to a pervious area. And as noted above, IMPs are LID practices and IMPs that are integrated into the landscape design and distributed throughout the site. They typically receive runoff from relatively small drainage areas (e.g. less than 5 acres). Detailed design information about the IMPs that are approved for use by the City of Salinas is presented in Section 3.4.

Proper design and documentation includes accounting for each separate IMP drainage area to show that each IMP is appropriately sized to receive runoff from that area. The proper procedure requires careful delineation of pervious areas and impervious areas (including roofs) throughout the site. As impervious drainage areas are delineated, the concentration of runoff and the need for conveyance out of the drainage area by distributing drainage from opposite sides of driveways and buildings, and from different sections of parking lots should be minimized.

The size (in square feet) and imperviousness (landscaped or paved/roofed) of each discrete drainage area should be delineated and how drainage from each drainage area should be documented. Drainage areas can be divided into the following four types:

1. Self-treating areas

2. Self-retaining areas (also called “zero-discharge” areas)

3. Impervious areas draining to self-retaining areas

4. Areas that drain to IMPs.

Detailed explanations of these drainage areas (also called drainage management areas) are presented in the document titled “Using Site Design Techniques to Meet Development Standards for Stormwater Quality, A Companion Document to Start at the Source” dated May 2003 and produced by the Bay Area Stormwater Management Agencies Association. This concise and helpful document can be downloaded at http://www.basmaa.org/documents/ and is also included as Appendix H.

For relatively dense new and redevelopment projects, such as commercial and mixed-use developments and small-lot residential subdivisions, most drainage areas will drain to IMPs.

Whereas self-retaining and self-treating drainage areas are more commonly used on sites with extensive landscaping, such as relatively large-lot residential subdivisions, civic facilities and parks.

## 3.2 Minimizing and Disconnecting Impervious Surfaces

### 3.2.1 LID Designs for Roofs

Runoff from the roofs of buildings and homes contributes to the volume of stormwater runoff as well as acting as a source of pollutants, particularly at industrial and commercial facilities. During a storm event, runoff from rooftops is generally collected in gutters and poured into downspouts, or, when downspouts are not present, it flows from eaves in concentrated sheet flows causing erosion if it falls onto unprotected surfaces such as bare ground. This water is also often directed straight from downspouts onto impervious surfaces and directly into the storm drain system. Controlling roof runoff by directing it to vegetated areas, filtering it through bioretention systems, vegetated swales or buffer strips, storing it for irrigation, or allowing for infiltration, reduces the peak flow rates and volume of stormwater runoff and associated pollutants loads. Green or vegetated roofs, discussed in Section 3.4.5, can also be installed to reduce runoff at its source.

Figure 3-1: A Rooftop Downspout Directed to a Landscaped Area

**Design Considerations**

- Direct downspouts towards landscaping, vegetated swales, filter strips, bioretention systems, sand filters, infiltration trenches, infiltration basins and other pervious areas

- Install splash blocks or gravel splash pads beneath the outlet of downspouts to dissipate runoff energy and minimize erosion
- Stormwater planters and rock-lined trenches located under roofline/drip lines help to control erosion from concentrated sheet flow off of the roof and promote infiltration
- Plants installed along a building's drip line shall be sturdy enough to handle heavy runoff sheet flows from rooftop runoff
- Roof runoff can also be stored for irrigation by directing downspouts to rainwater collection devices
- If used, rain barrels and cisterns must be securely covered to prevent vector breeding and must be child proof

**Limitations**

- Plantings under rooflines must be able to withstand heavy runoff sheet flows and soil saturation.
- Soil permeability may limit applicability of infiltration trenches.
- An uncovered rain barrel or cistern can provide mosquito habitat if it contains standing water. All stormwater storage devices must be designed, to the satisfaction of the City Engineer, to provide sanitary storage conditions, including vector control.

**Maintenance Considerations**

- Routine landscape maintenance required for plantings located under rooflines and around downspouts.
- Inspect and maintain rain barrels and cisterns at least twice a year to ensure they are secure, functioning properly, and not breeding mosquitoes.

**Additional Resources**

The following web links provide useful information related to educating homeowners about the benefits of disconnecting downspouts:

The City of Indianapolis Correct Connect Program:
http://www.indygov.org/eGov/City/DPW/Environment/CleanStream/Help/Residents/Connect/home.htm

Washington D.C. Gutter and Downspout Diversion Program
http://www.dcgreenworks.org/LID/diversion.html

City of Boston Downspout Disconnection Program
http://www.bwsc.org/Customer_Service/Programs/downspout.htm

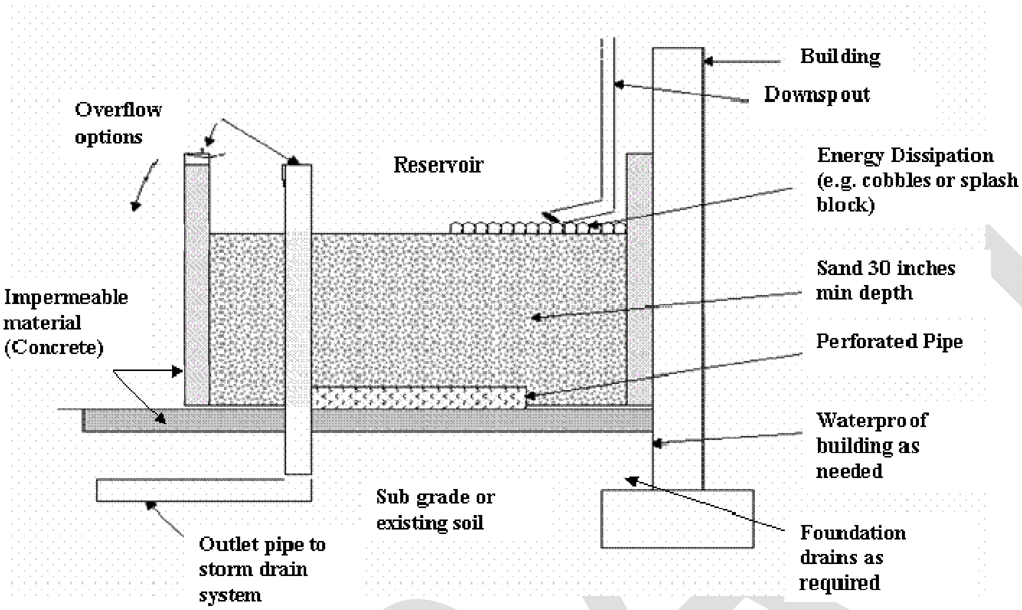


Figure 3-2: Example of a Sand Filter for Roof Runoff Control
(modified from Portland 2000)

## 3.3 LID Designs for Paved Surfaces

In conventional development, impervious pavement in parking lots, streets, roads, highways, freeways, driveways, sidewalks and bike paths are often directly connected to each other and convey runoff directly to the storm drain system (e.g. curb and gutter systems that flow directly to catch basins and underground storm drain pipes). Disconnecting pavement by designing runoff to sheet flow onto adjoining vegetated areas or porous pavement before it reaches the storm drain system reduces the rate, volume and pollutant loading of urban runoff. Urban runoff slows as it travels though vegetation or over a porous surface and water is infiltrated into the soil where the majority of pollutant removal occurs.

Paved surfaces, particularly those related to transportation, typically make up the majority of developed impervious surfaces that increase the rate, volume of pollutant loading of urban runoff in new development and redevelopment projects. Therefore this section provides alternative LID design and maitnenace considerations for the following common paved surfaces:

- Parking Lots
- Streets & Roads (including alternative cul-da-sac and turnaround designs)
- Driveways
- Sidewalks and Bike Paths

Severval Integrated Management Practices (IMPs), which can be used with these alternative LID designs are introduced in this section (e.g., swales, bioretention systems, porous pavements, etc,). As noted previously, IMPs are LID practices that are integrated into the landscape design and distributed throughout the site. Detailed design information for the IMPs that are approved for use by the City of Salinas is presented in Section 3.4.



### 3.3.1 LID Parking Lot Design

Parking lots contribute a sizeable area of impervious coverage to urban developments and are significant sources of stormwater runoff and the discharge of associated pollutants to the storm drain system and local surface waters. Several strategies can be implemented to mitigate this impact, including reducing impervious surfaces using permeable paving alternatives in overflow parking areas and landscaped detention (bioretention) basins installed in parking lot islands and perimeter landscaping.

**Managing Runoff**

Stormwater management in parking lots can mimic natural hydrologic functions by installing design features that capture, treat, and infiltrate stormwater runoff rather than conveying it directly into the storm drain system. Management options include:

- Landscaped detention and bioretention areas (Figure 3-3) can be installed within and/or at the perimeter of parking lots to capture and infiltrate runoff. These include permeable landscaped areas designed with grades below the impervious parking surface and can be delineated by flat concrete curbs, shrubs, trees or bollards.

Figure 3-3: Parking Lot Bioretention

Figure 3-4: Parking Lot Made of a Permeable Paving Surface

(photo sources: Kennedy/Jenks and ToolBase Services)

- Porous surfaces can be installed in down gradient parking stalls and in overflow parking areas (Figure 3-4). Permeable materials that can be utilized include permeable pavers, porous asphalt, and porous concrete (see Section 3.4.4). In some circumstances, gravel or wood chips can also be used.

- Stormwater runoff from the top floor of parking garages can be drained to planter boxes located at the perimeter of the parking lot or at street level.

**Design Considerations**

- Utilize minimum stall dimensions and compact parking spaces. In larger commercial lots, 30 percent of the parking spaces should be for compact cars.
- Use porous concrete, porous asphalt or permeable pavers in overflow parking areas or down gradient parking stalls (e.g., at areas located at low points in the parking lot).
- Utilize the most space-efficient design for parking stalls.
- Utilize vegetation and landscaping for capture and infiltration of rainfall and stormwater runoff, for impervious surface reduction, and for shading.
- Utilize flat curbs or curb cuts (Figure 3-5) to direct runoff into landscaped areas.

**Maintenance Considerations**

- Regular maintenance of landscaped areas is required
- Irrigation of landscaped areas may be required.


Figure 3-5: Curb Cuts Direct Water into This Parking Lot Bioretention System in the City of Salinas



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### 3.3.2 Elements of LID Street and Road Design

Streets and roads include a significant portion of impervious coverage in a community and are one of the largest contributors of stormwater flows and pollutant loads. LID street and road design is a strategy to curb this impact by reducing impervious coverage and maximizing stormwater infiltration and pollutant uptake.

Road layout – consider alternatives that reduce impervious coverage, reducing the length of the road network by exploring alternative street layouts. Clustering homes and narrowing lot frontages can reduce road length by reducing the overall development area. Another approach is to lengthen street blocks and reduce cross streets, providing pedestrian and bicycle paths mid-block to increase access.

Street width – determine based on a function of land use, density, road type, average daily traffic, traffic speeds, street layout, lot characteristics and parking, drainage and emergency access needs.

Cul-de-sac design – cul-de-sacs create large areas of impervious coverage in neighborhoods. Alternatives to the traditional cul-de-sac that can reduce impervious coverage include landscaped center islands with bioretention (shown in Figure 3-6), reduction of the radius to 30 feet, a T-shaped hammerhead design, or a loop road network. Alternative cul-de-sacs shall be designed to accommodate street sweepers, which can provide source control for pollutant that accumulate on paved surfaces.

Figure 3-6: Landscaped Cul-de-sac

Right-of-way – shall reflect the minimum required to accommodate the travel lane, parking, sidewalk, and vegetation, if present.

Permeable materials – use in alleys and on-street parking, particularly pull out areas.

Increased access – create paths to open space and other streets for pedestrians and bicyclists in subdivisions where alternative street layouts such as loop networks and cul-de-sacs are utilized.

Traffic calming features – traffic circles, chicanes, chokers, speed tables, center islands, and speed humps offer the opportunity for stormwater management through the use of bioretention areas or infiltration within these areas while providing pedestrian safety.

**Drainage Options**

Maximize drainage – preserve natural drainage patterns and avoid locating streets in low areas or highly permeable soils.

Uncurbed roads – where feasible, build uncurbed roads using vegetated swales as an alternative (Figure 3-7).

Urban curb/swale system – runoff runs along a curb and enters a surface swale via a curb cut, instead of entering a catch basin to the storm drain system.

Dual drainage system – a pair of catch basins with the first sized to capture the water quality volume into a swale while the second collects the overflow into a storm drain.

Concave medians – median is depressed below the adjacent pavement and designed to receive runoff by curb inlets or sheet flow. Can be designed as a landscaped swale or a biofilter.

Figure 3-7: An Uncurbed Road Utilizing a Vegetated Swale

**Benefits of LID Street Designs**

- Stormwater runoff is reduced
- Narrower streets slow traffic and increase pedestrian, bicycle and driver safety

- Less runoff generated from decreased impervious surfaces creates a reduction in stormwater runoff, which may result in a decrease in expenses in stormwater management structures and treatment

- Paving costs of street network are reduced.

**Design Considerations**

- Reduce the length of residential streets by reviewing minimum lot widths and exploring alternative street layouts.

- When siting streets, consider natural drainage patterns and soil permeability.

- Consider access for large vehicles, equipment, and emergency vehicles when designing alternative street layouts and widths.

- Consider access for street sweepers and American Disabilities Act requirements.

- Impervious cover created by each cul-de-sac turnaround option is presented below. (Schueler 1995)

| Turnaround Option | Impervious Area (square feet) |
|---|---|
| 40-foot radius | 5,024 |
| 40-foot radius with island | 4,397 |
| 30-foot radius | 2,826 |
| 30-foot radius with island | 2,512 |
| Hammerhead | 1,250 |

**Limitations**

- Local zoning standards may require wide streets, sidewalks on one or both sides of streets, and curbed roads.

- Arterial, collector and other street types with greater traffic volumes are not candidates for narrower streets.

- Street width and turnaround design need to accommodate fire trucks and other large vehicles and equipment.

**Maintenance Considerations**

- Narrower streets should require less maintenance than wider streets as they present less surface area to maintain and repair.

- Landscaped and bioretention cul-de-sacs and traffic calming areas will require routine maintenance associated with these areas.

**Examples**

In Seattle, WA, a pilot project, Street Edge Alternatives Project (SEA Streets), attempts to mimic pre-developmental hydrologic conditions by reducing impervious surfaces by 11 percent less than a traditional street, incorporating LID principles such as reducing on-street parking, narrowing street widths, reducing sidewalks, eliminating curbs and gutters by providing surface detention in swales, and adding 100 evergreen trees and 1,100 shrubs. One of the most prominent features of the project is the 14-foot wide curvilinear streets, which is wide enough for two standard size cars to pass each other slowly (Figure 3-10). The edge of the roadway has no curb and has a two-foot grass shoulder capable of bearing traffic loading to accommodate emergency vehicle passage. Parking stalls are grouped between swales and driveways with the number of spaces determined by homeowner needs. The sidewalk also follows a curvilinear design and is only located on one side of the street. Swales are located in the right of way adjacent to the street to capture runoff from the street, sidewalk and adjacent property. After two years of monitoring, the project has reduced the total volume of stormwater leaving the street by 98 percent for a two-year storm event. (Seattle Public Utilities District 2003).

Figure 3-8: Images of Seattle's Street Edge Alternatives (SEA) Project Streets (images courtesy of Seattle Public Utilities District)



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### 3.3.3 LID Driveway Design

Driveways add a significant amount of impervious coverage to a community and are an element of a site's design that can be altered to minimize total impervious coverage. Driveways often slope directly to the street and storm drain system and contribute significantly to stormwater pollution. There are several strategies that can be implemented to reduce this impact, including:

- Utilize shared driveways to provide access to several homes.
- Reduce driveway length by reducing front yard setbacks.
- Reduce driveway width by allowing tandem parking (one car in front of the other).
- Install a narrowed driveway with a flared entrance for multi-car garage access.
- Disconnect the driveway by directing surface flow from the driveway to a permeable landscaped area, such as a below grade bioretention basin.
- Consider ribbon driveways, which consist of two strips of pavement with grass or some other permeable surface in between the strips.
- Utilize porous surfaces such as porous concrete or asphalt, permeable pavers or crushed aggregate.
- Create a temporary parking area where parking or access is infrequent. These areas can be paved with permeable surfaces.

Figure 3-9: Driveway Designed with Multiple LID Strategies
(Photo courtesy of NEMO Nevada)

This driveway is designed with multiple LID strategies including permeable pavers and a slotted drain built in to catch sediment and runoff, which is funneled into a grassy swale.

**Design Considerations**

- Shared Driveways:
  - Shared driveways can provide access to several homes
  - Access may not need to be as wide as residential streets.
- Disconnected Driveways:
  - The driveway cross slope must be greater than the longitudinal slope in order for runoff to be directed into adjacent landscape.
  - Adjacent landscape must be sized to accommodate the water quality volume.
  - The edge of the driveway must be approximately 3 inches above the vegetated area so to not impede flow from the driveway.
  - A slotted channel drain installed at or slightly below the surface of the driveway and roughly perpendicular to the flow path, captures flow from driveway and directs it to an infiltration system or vegetated area. Slotted channel drains shall have removable grates to allow access for cleaning. (See Figure 3-10)

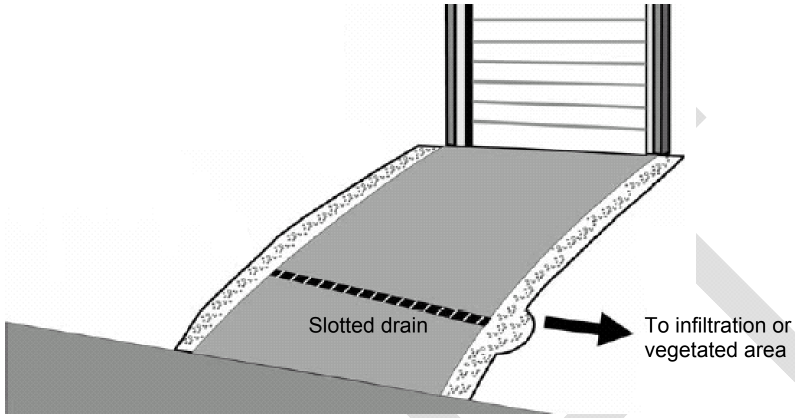



Figure 3-10: A Schematic of a Driveway with a Slotted Drain
(adapted from BMP Retrofit Partners, 2003)

- Ribbon or Hollywood Driveways (Figure 3-11):
  - Wheel tracks shall be wide enough to accommodate variability in driving and vehicle widths
  - For soils with low infiltration rates, a perforated drain line buried between the wheel tracks may be appropriate to collect and direct runoff
  - If vegetation is incorporated, it should be irrigated.

Figure 3-11: A Ribbon or Hollywood Driveway (Photo courtesy of NEMO Nevada)

- Flared Driveways:
  - Single lane width at street with flare at garage to serve multiple garage door openings
  - Provide adequate space in front of multi-car garage for vehicle parking and maneuvering.

- Crushed Aggregate Driveways:
  - Use open-graded crushed aggregate rather than rounded stones
  - Utilize a rigid edging material such as wood, concrete, metal, or brick to contain aggregate material.

**Limitations**

- Driveway length is generally determined by front yard setback requirements
- Driveway width is usually mandated by municipal codes.

**Maintenance Considerations**

- For driveways connected to landscaped areas, maintenance and edging of the adjacent lawn is important to allow unimpeded flow
- For ribbon driveways, the area between the wheel tracks requires edging and maintenance, including periodic weed control
- Crushed aggregate driveways may require periodic weed control and replenishment of the aggregate
- Slotted channel drains generally need to be cleaned twice a year, in the spring and fall
- When cleaning, slotted channel drains, sweep or vacuum out sediment and debris (do not remove sediment and debris with water and do not allow polluted stormwater to enter the storm drain system)
- Periodically check the outlets of slotted channel drains for clogging.

**References and Additional Sources of Information**

BASMAA. 1999. Start at the Source: Design Guidance Manual for Stormwater Quality Protection. Bay Area Stormwater Management Agencies Association. Prepared by Tom Richman & Associates. www.basmaa.org

BMP Retrofit Partners. 2003. How to Install Best Management Practices in the Lake Tahoe Basin: Manual for Building Landscaping Professionals. University of Nevada Cooperative Extension.

Gibbons, J. 1999. NEMO Technical Paper Number 6: Driveways. University of Connecticut Cooperative Extension. www.nemo.uconn.edu/publications/tech_papers/tech_paper_6.pdf

Puget Sound Action Team. 2005. Low Impact Development: Technical Guidance Manual for Puget Sound. Olympia, WA. http://www.psat.wa.gov/Publications/LID_tech_manual05/LID_manual2005.pdf

### 3.3.4 LID Sidewalks and Bike Paths

Sidewalks and bike paths are another source of impervious coverage that can adversely affect water quality by the runoff generated from their surface. Several management opportunities and strategies are available to reduce this impact, including:

- Reducing sidewalks to one side of the street
- Disconnect bike paths from streets. Bike paths separated from roadways by vegetated strips reduce runoff and traffic hazards
- Utilizing pervious materials to infiltrate or increase time of concentration of storm flows (Figure 3-12)
- Reducing sidewalk width when possible
- Directing sidewalk runoff to adjacent vegetation to capture, infiltrate, and treat runoff
- Installing a bioretention area (Section 3.4.3) or a vegetated swale (Section 3.4.2.1) between the street and sidewalk and grading runoff from the sidewalk to these areas.
- Planting trees between the sidewalk and streets to intercept rainfall.

Figure 3-12: The Sidewalk on the Left is Made of Porous Concrete; the Walkway on the Right is Made of Porous Asphalt
(Photos courtesy of Cahill Associates and Stormwater Journal)

**Design Considerations**

- Grade sidewalks and bike paths at a two percent slope to direct runoff to adjacent vegetated areas

- Use pervious materials such as permeable pavers, porous concrete or asphalt for sidewalk surfaces
- In some cases, sidewalks and bike paths can be placed between rows of homes to increase access and decrease overall effective imperviousness
- For design of pervious surfaces, such as porous concrete and asphalt and permeable pavers, see Section 3.4.4
- For design of swales, see Section 3.4.2.1
- For design of bioretention systems, see Section 3.4.3

**Limitations**

- Ordinances and ADA compliance may require sidewalks on both sides of the street.

**Maintenance Considerations**

- For maintenance of pervious surfaces, such as porous concrete and asphalt and permeable pavers, see Section 3.4.4
- For maintenance of bioretention systems, see Section 3.4.3
- For maintenance of swales, see Section 3.4.2.1.

The Seattle, WA Street Edge Alternatives (SEA) Streets project (see Figure 3-13), is a demonstration project that mimicked pre-developmental hydrologic conditions by reducing impervious surfaces 11 percent less than a traditional street, incorporating LID principles such as reducing on-street parking, narrowing street widths, reducing sidewalks, eliminating curbs and gutters, providing surface detention in swales, and adding 100 evergreen trees and 1,100 shrubs. After two years of monitoring, the project has reduced the total volume of stormwater leaving the street by 98 percent for a two-year storm event (Seattle Public Utilities District 2003).

Figure 3-13: Seattle's Street Edge Alternatives (SEA Streets) Project
(image courtesy of Seattle Public Utilities District)



**References and Additional Sources of Information**


California Stormwater Quality Association (CASQA).2003. Stormwater Best Management Practice Handbook – New Development and Redevelopment. http://www.cabmphandbooks.com/

Prince George's County, Maryland. 2002. Low Impact Development: Integrated Management Practices Handbook. Department of Environmental Resources Programs & Planning Division. http://www.epa.gov/watertrain/smartgrowth/resources/pdf/LID_National_Manual.pdf

Seattle Public Utilities District. 2003. Street Edge Alternatives (SEA Streets) Project. http://www.seattle.gov/util/About_SPU/Drainage_&_Sewer_System/Natural_Drainage_Systems/Street_Edge_Alternatives/index.asp


## 3.4 Integrated Management Practices

The City of Salinas has developed design criteria for the following approved Integrated Management Practices (IMPs):

- Vegetated Swales and Filter Strips
- Bioretention Systems (landscape detention, tree box filters, and stormwater planters)
- Porous Paving Systems
- Green Roofs
- Stormwater Ponds and Wetlands

- Infitlration Basins

With the exception of Green Roofs and Infiltration Basins, the IMPs noted above are considered indirect infiltration devices (e.g., they fitler urban runoff through engineered surface soils prior to infitlration into subsurface soils). Inftilration Trenches and Dry Wells are not approved for general use in the City of Salinas. Infiltration Basins differ from Infiltration Trenches in that they distribute runoff over a larger surface area and can be designed with a broad range of filter media and planted with vegetation (whereas Infiltration Trenches consist of rectangular trenches backfilled with drain rock). Sufficient permeability is required of exisiting site soils (> 0.5 in/hr) to be able to install Vegetated Swales and Filter Strips, Bioretention Systems, Porous Paving Systems, and Infitlration Basins without underdrains (e.g., a gravel underlayer and perforated pipe system).

### 3.4.1 Selecting IMPs and Treatment Controls For Your Site

The following design matrices are intended to assist planners and designers with the proper selection of the appropriate IMPs for their project based on their sites particular conditions and contraints. These include, but are not limited to the following:

- Land Use
- Site Physical Features
- Storm Water Management Capability
- Community and Environmental Factors
- Pollutant Removal Effectiveness.

Following the design matrices are the fact sheets that provide detailed design information for the IMPs that are approved for use by the City of Salinas.

| Treatment Control Group | Treatment Control Design | Design Matrix 1. Land Use<br>Rural | Residential | Roads and Highways | Commercial/ High Density | Hotspots/ Industrial | Ultra Urban |
|---|---|---|---|---|---|---|---|
| Vegetative Treatment Systems | Vegetated Swales | A (L-U) | A (L-U) | S (L-U) | S (L-U) | S (L-U) | S (L-U) |
| | Vegetated Filter Strips | A | A | S | S | S | S |
| Infiltration Systems | Infiltration Basins | S (i) | S (i) | S (i) | S (i) | X | X |
| Bioretention Systems | Landscape Detention, Tree Box Filters & Storm Water Planters | A (L-U) | A (L-U) | A (L-U) | A (L-U) | S (L-U) | S (L-U) |
| Extended Detention Basins | Sedimentation Basins | A | A | S | S | S | S |
| | Sand Filter Basins | A | A | S | S | S | S |
| Ponds and Constructed Wetlands | Storm Water Ponds | A | A | S | S | S | X |
| | Storm Water Wetlands | A | A | S | S | S | X |
| Porous Pavements | | A (L-U) | A (L-U) | A (L-U) | A (L-U) | S (L-U) | S (L-U) |

**Explanation:**

A = Applies under most conditions

S = Applies under some conditions

X = Generally not applicable

(L-U) = BMP may require an impermeable liner and an underdrain system - See Section 4.3

(i) = Feasibility of BMP depends on existing onsite soil infiltration rates - See Section 4.3.3

| | | Design Matrix 2. Site Physical Features | | | | |
|---|---|---|---|---|---|---|
| **Treatment Control Group** | **Treatment Control Design** | **Underlying Site Soils** | **Seasonal High Water Table** | **Contributing Drainage Area** | **Contributing Site Slopes** | **Required Head (ft)** |
| Vegetative Treatment Systems | Vegetated Swales[1] | Min infiltration rate 0.5 inch/hr | >5 feet | 10 acres max | Generally no more than 5% | 3 to 5 ft |
| | Vegetated Filter Strips | No restrictions | | 5 acres max | | NA |
| Infiltration Systems | Infiltration Basins | Min infiltration rate 1.0 inch/hr | >10 feet | 5 to 50 acres | Generally no more than 15% | 3 to 5 ft |
| Bioretention Systems | Landscape Detention[1], Tree Box Filters[1] & Storm Water Planters[1] | Min infiltration rate 0.5 inch/hr | >5 feet | 1 acre max | Generally no more than 20% | ~ 5 ft |
| Extended Detention Basins | Sedimentation Basins | No restrictions | >5 feet | 5 acres min | Generally no more than 20% | ~4 ft |
| | Sand Filter Basins | | | 10 acres max | | ~4 ft |
| Ponds and Constructed Wetlands | Storm Water Ponds | HSG A soils may require liner | NA | 25 acres min | Generally no more than 15% | 6 to 8 ft |
| | Storm Water Wetlands | | | | | 3 to 5 ft |
| Porous Pavements | | Min infiltration rate 0.5 inch/hr | >5 feet | *See Note 2* | Generally no more than 5% | *See Note 2* |

**Notes:**

1 - Underdrains required for these treatment controls when underlying site soils have infiltration rates less than 0.5 inch/hr (120 min/inch)
2 - Refer to manufactures recommendations for maximum amount of contributing area, depth of gravel sub-base layer, and required head

| Treatment Control Group | Treatment Control Design | Design Matrix 3. Stormwater Management Capability<br>Water Quality Improvement | Groundwater Recharge | Reduce Runoff Velocity | Reduce Runoff Volume |
|---|---|---|---|---|---|
| Vegetative Treatment Systems | Vegetated Swales | A | S | A | S |
| | Vegetated Filter Strips | A | S | A | S |
| Infiltration Systems | Infiltration Basins | A | A | A | A |
| Bioretention Systems | Landscape Detention, Tree Box Filters & Storm Water Planters | A | S | A | A |
| Extended Detention Basins | Sedimentation Basins | A | S | A | S |
| | Sand Filter Basins | A | S | A | S |
| Ponds and Constructed Wetlands | Storm Water Ponds | A | S | A | S |
| | Storm Water Wetlands | A | S | A | S |
| Porous Pavements | | A | S | A | A |

**Explanation:**

A = Practice generally meets storm water management goals

S = Practice can provide some benefit depending on site constraints

X = Practice can rarely be used to meet this goal

| Treatment Control Group | Treatment Control Design | Design Matrix 4. Community and Environmental Factors | | | |
|---|---|---|---|---|---|
| | | Ease of Maintenance | Community Acceptance | Safety | Habitat |
| Vegetative Treatment Systems | Vegetated Swales<br>Vegetated Filter Strips | M | M - H | M - H | M |
| Infiltration Systems | Infiltration Basins | M | M - H | M - H | L |
| Bioretention Systems | Landscape Detention, Tree Box Filters & Storm Water Planters | M | H | M - H | M |
| Extended Detention Basins | Sedimentation Basins<br>Sand Filter Basins | M | M | M | L |
| Ponds and Constructed Wetlands | Storm Water Ponds<br>Storm Water Wetlands | M | M | M | H |
| Porous Pavements | | M | M | M | L |

**Explanation:**
H = High benefit and/or low limitations
M = Medium benefit and/or limitations
L = Low benefit and/or high limitations

| Treatment Control Group | Treatment Control Design | Design Matrix 5. Pollutant Removal Effectiveness | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Sediment | Nutrients | Trash | Metals | Bacteria | Oil and Grease | Organics |
| Vegetative Treatment Systems | Vegetated Swales | M | L | M | M | L | M | M |
| | Vegetated Filter Strips | H | L | M | H | L | H | M |
| Infiltration Systems | Infiltration Basins | H | H | H | H | H | H | H |
| Bioretention Systems | Landscape Detention, Tree Box Filters & Storm Water Planters | H | M | H | H | H | H | H |
| Extended Detention Basins | Sedimentation Basins | M | L | H | M | L | L | L |
| | Sand Filter Basins | H | M | H | M | L | L | M |
| Ponds and Constructed Wetlands | Storm Water Ponds<br>Storm Water Wetlands | H | L-M | H | H | H | H | H |
| Porous Pavements | | H | M | L | M | M | M-H | M-H |

**Explanation:**

H = High pollutant removal effectiveness

M = Medium pollutant removal effectiveness

L = Low pollutant removal effectiveness

### 3.4.2 Swales and Filter Strips

Swales and filter strips can be effective stormwater treatment control systems if runoff depths are shallow and velocities are slow. These systems rely upon the vegetation and the subsoil matrix to filter pollutants from runoff and can also provide infiltration and groundwater recharge. They can provide desirable open space buffers between developed impervious surfaces, the storm drain system, and receiving water bodies. Wherever possible, swales should be incorporated into natural drainage paths. Vegetative treatment systems such as swales and filter strips reduce the velocity of urban runoff and can serve as part of the storm drain system. They can be accessed by curb cuts or they can replace curbs, gutters and subsurface storm drain pipe systems. Swales sited on existing clayey or silty soils with low infiltration rates (less than 0.5 in/hr or greater than 120 min/in) shall also include underdrain systems.

Swales and filter strips can be accessed by grade design, curb cuts, or they can replace curbs, gutters, and subsurface storm drain pipe systems. By designing the grade of impervious surfaces such as driveways and sidewalks to flow towards vegetated areas instead of towards streets, they can be accessed directly. To facilitate flow into these IMPs and accommodate vegetation growth and sediment deposition, the edges of driveways and sidewalks shall be designed to be 2 to 5 inches above the adjacent edge of swales and filter strips.

Swales are shallow open channels. Also known as vegetated swales, biofiltration swales or grassy swales, they are commonly vegetated with grasses (Figure 3-14). Rock lined low flow channels and underdrain systems can be added where existing site soils have poor infiltration characteristics (Figure 3-15) and grades that are less than 0.5 percent. Low flow channels and underdrain systems can reduce the potential of extended ponding and mosquito breeding. Xeriscape swales (Figure 3-16) are planted with native vegetation or low water use plants interspersed among rock and have little to no water requirements once established. Stormwater runoff is conveyed along the length of the low slope channel, which decreases the velocity, traps sediments, and reduces erosion. Stormwater runoff is treated by filtering sediments and associated pollutants through the engineered subsoil and vegetation and by infiltration into the underlying soils. Pollutant removal and treatment efficiency improves as contact time and the amount of infiltration increases.

Figure 3-14: Grassy Swale

Figure 3-15: Rock-Lined Swale

Grassy and xeriscape swales are simple to design and install. They can serve as part of the storm drain system or can be used in place of curbs and gutters. These practices can also be used with other structural treatment controls and IMPs as part of a treatment train. They can be used to convey and treat runoff from parking lots, buildings, and roadways and can be applied in residential, commercial, industrial, and municipal land uses. Xeriscape swales are recommended wherever possible to assist with water conservation strategies. Grassy swales are appropriate in parks or private landscaped areas that are irrigated.

Figure 3-16: Xeriscape Swale

Figure 3-17: Xeriscape Buffer Strip

Filter strips are also known as vegetated filter strips or buffer strips. They are gently sloping and uniformly graded vegetated strips that provide stormwater treatment to relatively small drainage areas. Filter strips slow the velocity of runoff to promote filtration of sediments and pollutants and infiltration into underlying soils. They require sheet flow to function properly and often require a flow spreader to evenly distribute runoff across the width of the filter strip. This may be a porous pavement strip or another type of structure. Grassed or vegetated filters consist of uniformly graded, densely vegetated turf surfaces that can be interspersed with shrubs and trees to improve aesthetics and provide shade. In the semi arid climate of the Central Coast, irrigation is typically required for grassy filter strips to maintain a healthy and dense vegetative cover capable of withstanding the erosive forces of runoff from adjacent impervious areas. Filter strips are typically located on the edge of landscaping areas and can provide pretreatment for other treatment controls.

Xeriscaped filter strips (Figure 3-17) use the same concept as vegetated filter strips except they incorporate low to no water use plants and rock, allowing for water conservation. Xeriscape filter strips are ideal at the edge of lawn areas to reduce runoff and conserve water. Lawn areas adjacent to sidewalks, driveways and streets are typically hotter and drier and require more water than areas not adjacent to these impervious surfaces. By planting a xeriscape filter strip between sidewalks, driveways, and streets and the lawn, water needs will be reduced. Less runoff will also occur as the xeriscape filter strip captures and infiltrates the water leaving the lawn area. This can be particularly useful where lawn areas are located directly downwind of prevailing winds. Studies have shown that up to 40 percent of the water that leaves sprinklers can be lost to overspray, runoff, and evaporation.

The recommended plant species for vegetated swales and filter strips shall meet the following criteria:

- Native or easily naturalized
- Low water requirements
- Low fertilizer requirements
- Low maintenance requirements
- Attractive in all seasons.

Plant species located in the low zone (bottom) of vegetated swales must be able to withstand periodic flooding. Turf or other soil erosion grasses can also be used in vegetated swales (e.g., grassy swales) and buffer strips. However, turf requires regular irrigation, fertilizer application, and maintenance which may result in reduced pollutant removal effectiveness. Fertilizer use shall be minimized in vegetated swales and buffer strips. Slow release fertilizers may be used provided it does not become a pollutant in stormwater (e.g., never apply fertilizers when rain is predicted). Herbicides and pesticides are also not recommended unless absolutely required. Maintaining mulch and hand-weeding are the recommended weed-control measures. If herbicides are necessary, use natural alternatives such as corn gluten and insecticidal and/or herbicidal soap or herbicides that degrade quickly such as glyphosphate (e.g., Roundup). If pesticide use is necessary, biological pest and disease controls are recommended. Sources of information for natural pesticide alternatives include the following:

*Suppliers of Beneficial Organisms in North America*, available from the California Department of Pesticide Regulation, Environmental Monitoring and Pest Management Branch, 830 K Street, Sacramento, CA, 95814, (916) 324-4100.

*Directory of Least-toxic Pest Control Products,* available from the Bio-Integral Resource Center, P.O. Box 7414, Berkeley, CA, 94707, (510) 524-2567.

#### 3.4.2.1 Vegetated Swales

Vegetated swales are also known as biofilters, biofiltration swales, landscaped swales, and grass swales. To be effective at stormwater management, vegetative swales should be designed as wide, shallow earthen open channels covered with a dense vegetative growth (commonly grasses) along the bottom and side slopes. Stormwater runoff is conveyed along the length of the low slope channel and vegetation traps sediments, decreases the velocity of overland flows, and reduces erosion. Stormwater runoff is treated by filtering sediments and associated pollutants through the vegetation and by infiltration into underlying soils. Pollutant removal and treatment efficiency improves as contact time and infiltration increases. For this reason, the length of vegetated swales should not be less than 100 feet.

Vegetated swales are considered an LID practice and are relatively simple to design and install. They can serve as part of the storm drain system or can be used in place of curbs and gutters and can be used with other structural treatment controls as part of a treatment train. Vegetative swales can provide some reduction in peak flows during storm events by slowing the velocity of runoff and depending upon the properties of the underlying soils, they can also facilitate infiltration. However they do not typically reduce post construction flow rates and volumes to the levels required by local ordinances or NPDES stormwater permit requirements. Therefore, additional detention, retention and/or infiltration facilities typically may need to be added to vegetated swales to address local, regional, and/or state requirements.

**Applications and Advantages**

Vegetated swales can be used to convey and treat runoff from parking lots, buildings, roadways, and residential properties. They are typically located in parks, parkways or private landscaped areas (in ROWs) and can also be used as pretreatment devices for other structural treatment controls. They can be designed as natural drainage features with temporary irrigation provided to establish the vegetation and annual maintenance, or they can be designed as landscaped areas with permanent irrigation systems.

## Performance Data

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 60 – 95% |
| Total Phosphorus | 5 – 45% |
| Total Nitrogen | 15 – 65% |
| Nitrate | -25 – 65% |
| Metals | 20 – 90% |

**Sources:**

UDFCD 1999, CASQA 2003.

The large range in pollutant removal efficiencies reflects differences in design, variable influent concentration levels and flow rates, and the permeability of underlying soils. Pollutant removal efficiencies for vegetated swales generally increase when underlying soils provide for infiltration. The literature reviewed does not discuss the removal efficiency for organics or petrochemicals. Additional BMPs may be needed for treatment of these pollutants.

## Limitations

- Vegetated or grassy swales typically require supplemental irrigation
- Effectiveness is decreased by compacted soils, short grass heights, steep slopes, large storm events, high discharge rates, high velocities, and a short runoff contact time
- Requires a sufficient amount of available land area
- May not be appropriate for industrial sites or locations where spills may occur
- Infiltration rates of local soils can limit the application of vegetated swales, unless under drains are installed
- Effectiveness may be limited in areas where gophers or other burrowing animals are abundant
- Possible formation of mosquito breeding habitat if water does not drain or infiltrate.

## Siting Criteria

- Maximum swale drainage area is 10 acres. Smaller drainage areas are preferred.
- Not to be applied in areas with adjacent slopes of 5 percent or greater or in areas with highly erodible soils.
- If possible, the preferred installation site is in a natural topographic low to preserve natural drainage and recharge patterns.

- To provide adequate contact time for pollutant removal, generally the minimum length of the swale should be 100 feet.

- Swales shall be established with a minimum longitudinal slope of 0.5 percent and a maximum longitudinal slope of 2.5 percent. Swales or swale sections with longitudinal slopes between 2.5 and 5.0 percent may be allowed if check dams are installed to reduce runoff velocity to 2.0 ft/sec or less.

- If designed to infiltrate stormwater into underlying soils, swales are considered indirect infiltration systems. Therefore apply site screening, infiltration testing (if the site is 20 acres in size or greater), separation, and setback standards for indirect infiltration systems presented in Section 4.3.3.

**Design and Construction Criteria**

- Registered professional civil engineers and landscape architects shall work together on the design vegetated swales.

- Design vegetated swales to convey the Water Quality Flow ($WQ_F$) rate based on the method presented in Section 4.4.3.

- If possible, flows in excess of the $WQ_F$ rate should be diverted around vegetated swales with upstream diversion structures (see Section 4.5).

- If a swale is be designed to both convey and treat the $WQ_F$ rate and to convey the flows produced by larger storm flows, the swale shall be designed to safely convey flows produced by the 5-, 20- and 100-year storm events.

- Trapezoidal or parabolic channels are recommended with a minimum bottom of 2 feet.

- Swale side slopes shall not be steeper than 4H:1V (see Figures 3-18 and 3-19).

- The maximum bottom width of swales shall not exceed 10 ft.

- To size the bottom width, use the Manning's equation at the $WQ_F$ with a roughness coefficient (*n*) value of 0.25 for grass and 0.40 for mixed vegetation and rocks.

  – *Note*: Manning's roughness coefficient (*n*) values used for open channels have historically ranged from approximately 0.02 to 0.10. However, these values were typically applied to channels designed to efficiently and quickly transport water for flood control. For vegetated swales designed to treat stormwater quality, the higher *n* values noted above should be applied (Minton 2006).

- Improved pollutant removal efficiency occurs with a minimum 10-minute hydraulic residence time at the $WQ_F$.

- To determine the capacity of the swale to convey peak hydraulic flows, use a roughness coefficient (*n*) of 0.10 with Manning's Equation.

- A design vegetation height of 4 - 6 inches is recommended.

- A diverse selection of low growing plants that thrive under site specific soils and proposed watering conditions shall be specified.

- Guidance on plant selection for vegetated swales is presented in Appendix G LID Planting Zones and Plant List.

- Sod shall not be used in the design of swales as it typically contains a high percentage of clay that inhibits infiltration.

- For areas without regular irrigation, use drought tolerant vegetation, however pollutant removal efficiencies will typically be reduced.

- Effectiveness can be improved by installing check dams at regular intervals.

- The swale must meet local ordinances and shall be included on site plans.

- The swale must not hold standing water for more than 72 hours to prevent vector problems.

- To provide proper drainage, a minimum 4-inch diameter perforated PVC under drain pipe shall be provided where underlying soils have infiltration rates less than 0.5 in/hr (120 min/in or greater).

- Soil amendments shall be specified based on soil testing results and vegetation requirements. Improper application of fertilizer can result in contamination of stormwater runoff.

**Inspection and Maintenance Requirements**

- With proper inspection and maintenance, vegetated swales can last indefinitely.

- Proper maintenance includes mowing, weed control, removal of trash and debris, watering during the dry season, and reseeding of non-vegetated areas.

- When mowing grass, never cut shorter than the design flow ($WQ_F$) depth, and remove grass cuttings.

- Inspect swales at least twice annually for damage to vegetation, erosion, sediment accumulation and ponding water standing longer than 72 hours.

- Periodic litter collection and removal will be necessary if the swale is located adjacent to a main road.

- Sediments shall be removed when depths exceed 3 inches.

- If a spill occurs and hazardous materials contaminate soils in vegetated swales, the affected areas shall be removed immediately and the appropriate soils and materials replaced as soon as possible.

### References

CASQA. 2003. California Stormwater Best Management Practice Handbook, New Development and Redevelopment. California Stormwater Quality Association.

City of Livermore. 2003. South Livermore Valley Specific Plan, Residential Street Parkway and Swale Area Planting Policies and Standards.

City of Livermore. 2005. Bioswale Design Guidance Standard Detail No. L-21.

City and County of Sacramento. 2000. Guidance Manual for Onsite Stormwater Quality Control Measures. Sacramento Stormwater Management Program.

Minton, G.R., 2006. Stormwater Treatment, Biological, Chemical and Engineering Principles.

Stormwater Quality Design Manual for the Sacramento and South Placer Regions, February 2007 Public Review Draft.

UDFCD. 1999. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices. Urban Drainage and Flood Control District .Denver, Colorado.

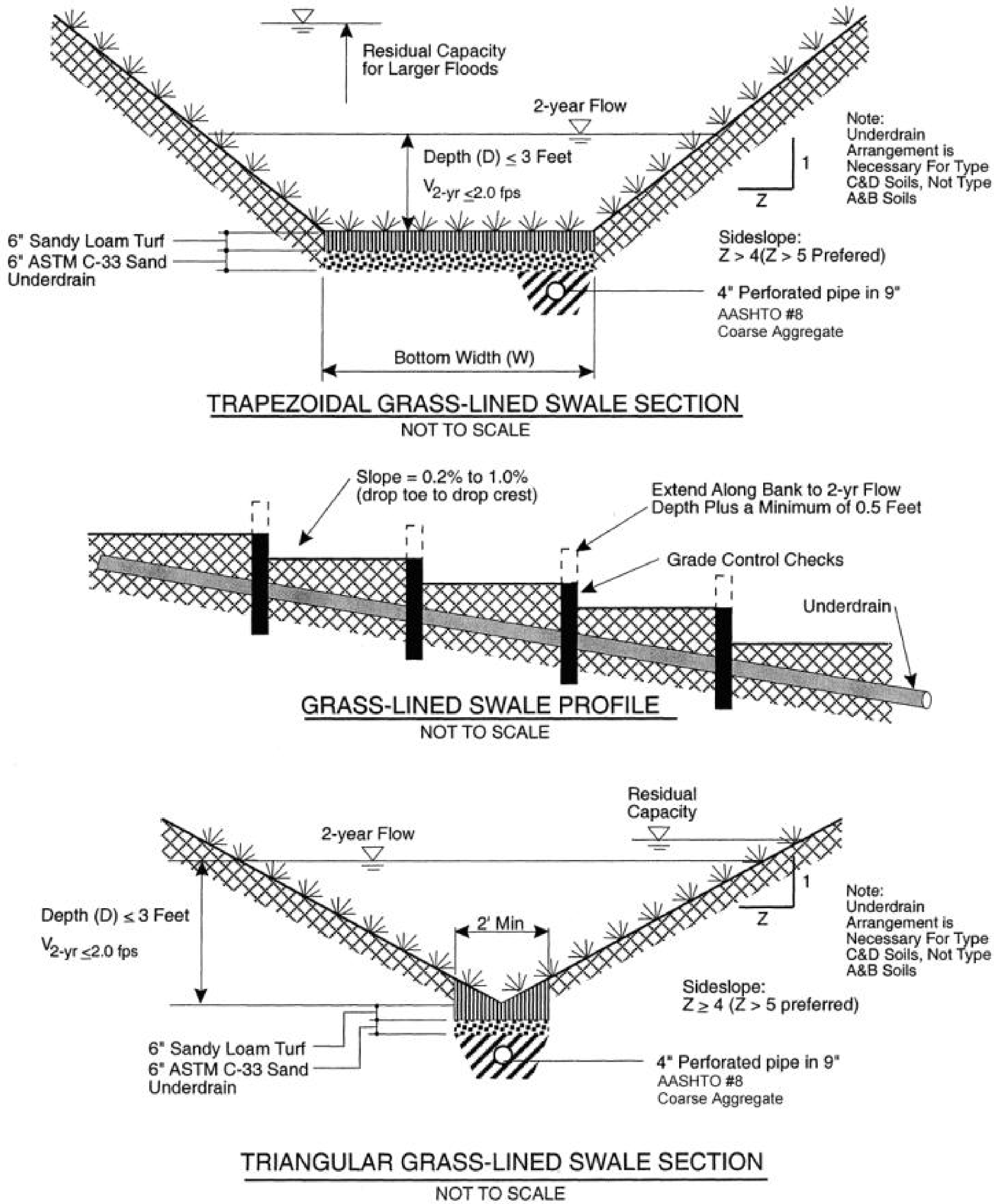
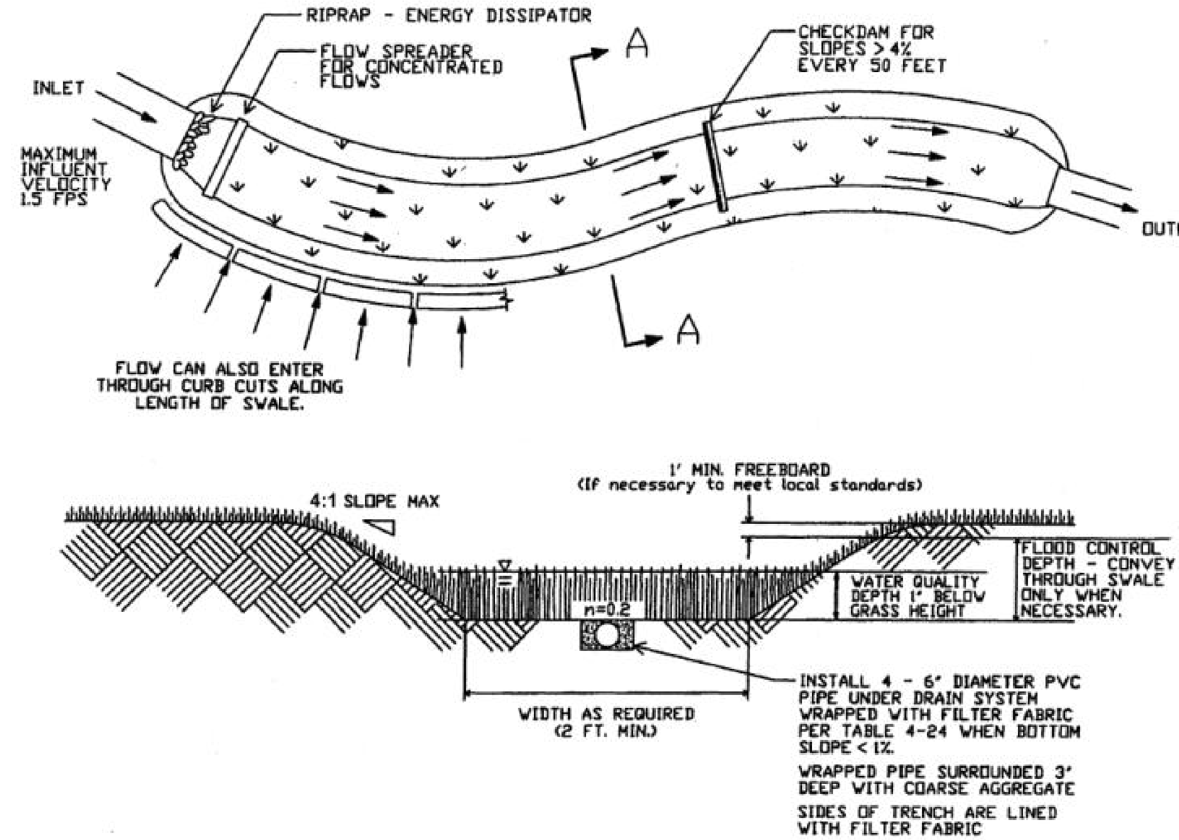



Figure 3-18: Typical Design and Structure of a Vegetated Swale
(modified from UDFCD 1999)




NOTES:

1. An energy dissipator and flow spreader should be installed at the entrance to the swale to reduce velocity and evenly distribute flows across the swale.
2. Maximum allowable side-slope 4H:1V
3. Grass height maintained in accordance with design specifications. Design grass height between 4 to 6 inches.
4. Flow height to be one-inch below design grass height for water quality design storm flow (2 year - 6 hour storm). Use a Mannings roughness coefficient of 0.2 to design for water quality flow through the swale vegetation.
5. n value above water quality height determined based on type of vegetation used. Typical value: 0.035
6. If the swale bottom slope exceeds 4% or soils very permeable, install check dams every 50 feet to slow the velocity to prohibit scouring and promote infiltration.
7. If the swale bottom slope is less than 1% install under drain system to prevent standing water.
8. Flows in excess of water quality flow should be diverted around the swale. If necessary for swale to convey flood waters, provisions shall be made to ensure conveyance in accordance with City or County Standards. Provide 1 ft. freeboard if necessary for flood control.

Figure 3-19: General Design Guidelines for a Typical Vegetated Swale
(modified from Sacramento 2000)

### 3.4.2.2 Vegetated Filter Strips

Also known as buffer strips, or grassed buffers, vegetated filter strips consist of dense turf surfaces that can be interspersed with shrubs and trees to improve aesthetics and provide shade. They are gently sloping and uniformly graded and provide stormwater treatment to relatively small drainage areas. Vegetated filter strips slow the velocity of runoff waters to promote infiltration and the filtration of sediments and pollutants. They require sheet flow to function properly and often require a flow spreader to evenly distribute runoff across the width of the filter strip. Vegetated filter strips can be used as pretreatment devices for other treatment controls and can also be combined with riparian zones for treating sheet flows and stabilizing channel banks adjacent to drainage ways and receiving water bodies. Irrigation is typically required to maintain a healthy and dense vegetative cover capable of withstanding the erosive forces of runoff from adjacent impervious areas.

**Applications and Advantages**

Vegetated filter strips are appropriate along the edge of residential and commercial developments where irrigated landscaping is planned. They are commonly applied along roadside shoulders in humid areas and have historically been used in agricultural practices.

**Performance Data**

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 10 - 74 |
| Total Phosphorus | 0 - 10 |
| Total Nitrogen | 0 - 15 |
| Total Recoverable Zinc | 0 - 10 |

**Source:**

UDFCD 1999, CASQA 2003.

Pollutant removal depends on factors such as soil permeability, land uses and slopes of adjacent drainage area, runoff volumes and velocities, the flow path across the filter strip and the type and density of the vegetation used. The general pollutant removal efficiency for both particulate and soluble pollutants is low to moderate.

**Limitations**

- Typically requires supplemental irrigation.
- A uniformly graded thick vegetative cover is required to function properly.
- May not be applicable adjacent to industrial sites or locations where spills may occur.
- Filter strips are not capable of treating stormwater from large drainage areas.
- It may be difficult to establish the level slopes necessary for filter strips.

- Sheet flow is required.
- Drainage area is limited due to the sizing requirements for a filter strip.
- Cannot be applied in areas with highly erodible soils.

**Siting Criteria**

- Avoid areas that are highly trafficked, both by automobiles and people.
- Limited to areas with gently sloping surfaces where vegetation is hearty and shallow flow occurs.
- Best suited for treating runoff from roads, roofs, small parking lots, and pervious surfaces.
- Impractical in highly urban areas with little pervious ground.
- Vegetated filter strips do not increase water temperatures and thus are useful for protecting cold-water streams.
- If designed to infiltrate stormwater into underlying soils, filter strips are considered indirect infiltration systems. Therefore apply site screening, infiltration testing (if the site is 20 acres in size or greater), separation, and setback standards for indirect infiltration systems presented in Section 4.3.3.

**Design and Construction Criteria**

- A conceptual design can be found on Figure 3-22.
- Registered professional civil engineers and landscape architects shall work together on the design vegetated filter strips.
- Slopes shall not be greater than 4 percent (2 to 4 percent is preferred)
- Maximum drainage area is 5 acres.
- Sheet flow must be maintained across filter strips.
- To create sheet flows install a level spreader at the top edge of the filter strip along a contour. A porous pavement strip may be used to create sheet-flow conditions.
- Channelized flow across filter strips shall not be permitted.
- The top of the vegetated filter strip shall be installed 2 – 5 inches lower than the impervious surface that is being drained.
- If supplemental irrigation is not available, use drought tolerant species in the filter strip to minimize irrigation in dry climates.

- Sod shall not be used in the design of filter strips as it typically contains a high percentage of clay that inhibits infiltration.

- If seeds are used to plant the vegetated filter strip, they shall be protected with mulch for a minimum of 75 days.

- The hydraulic load shall not exceed 0.05 cfs/linear foot of the vegetated filter strip during the 2-year storm ($WQ_F$) to maintain a sheet flow of 1 inch or less trough dense grass that is at least 2 inches high.

- The minimum length of a vegetated filter strip (normal to flow) shall be determined using the following equation:

$$L_G = WQ_F / 0.05$$

Where:

$L_G$ = minimum design length (ft)

$WQ_F$ = water quality flow (cfs)

- The minimum width of a vegetated filter strip (in the direction of flow) shall be determined based on the flow conditions upstream of the filter strip.

- For a sheet flow control level spreader, use the following equation:

$$WG = 0.2LL \text{ or } 8 \text{ feet (whichever is greater)}$$

Where:

$W_G$ = width of the filter strip

$L_L$ = the length of the flow path over the upstream impervious drainage area (ft)

- For a concentrated flow control level spreader, use the following equation:

$$WG = 0.15(A\ t / Lt) \text{ or } 8 \text{ feet (whichever is greater)}$$

Where:

$A_t$= the drainage area ($ft^2$)

$L_t$ = the length of the drainage area (normal to flow) adjacent to the filter strip (ft)

- Increasing the width ($W_G$) will increase runoff contact time, filtration of particulates and pollutants, and infiltration of runoff

- A vegetated swale can be used to collect outflow from a filter strip and can provide additional treatment prior to conveying flows to the storm drain system or receiving waters.

**Inspection and Maintenance Requirements**

- Required maintenance includes weed removal as well as mowing and irrigation of grasses

- Grasses or turf shall be maintained at a height of 4 - 6 inches.
- If turf is used, filter strips shall be irrigated during the dry season.
- Trash, litter, rocks, and branches shall be frequently collected from filter strips, especially those located along highways.
- Regularly inspect filter strips for pools of standing water that may be acting as mosquito breeding habitat.
- Filter strips shall be inspected at least two times a year, preferably before and after the winter/wet season.
- Sediments that accumulate along the upstream edge of filter strips and/or in level spreaders shall be collected and removed at least once a year.
- The owner/operator of the property must be responsible for maintaining vegetated filter strips.
- If a spill occurs and hazardous materials contaminate soils in vegetated filter strips, the affected areas shall be removed immediately and the appropriate soils and materials replaced as soon as possible.

**References**

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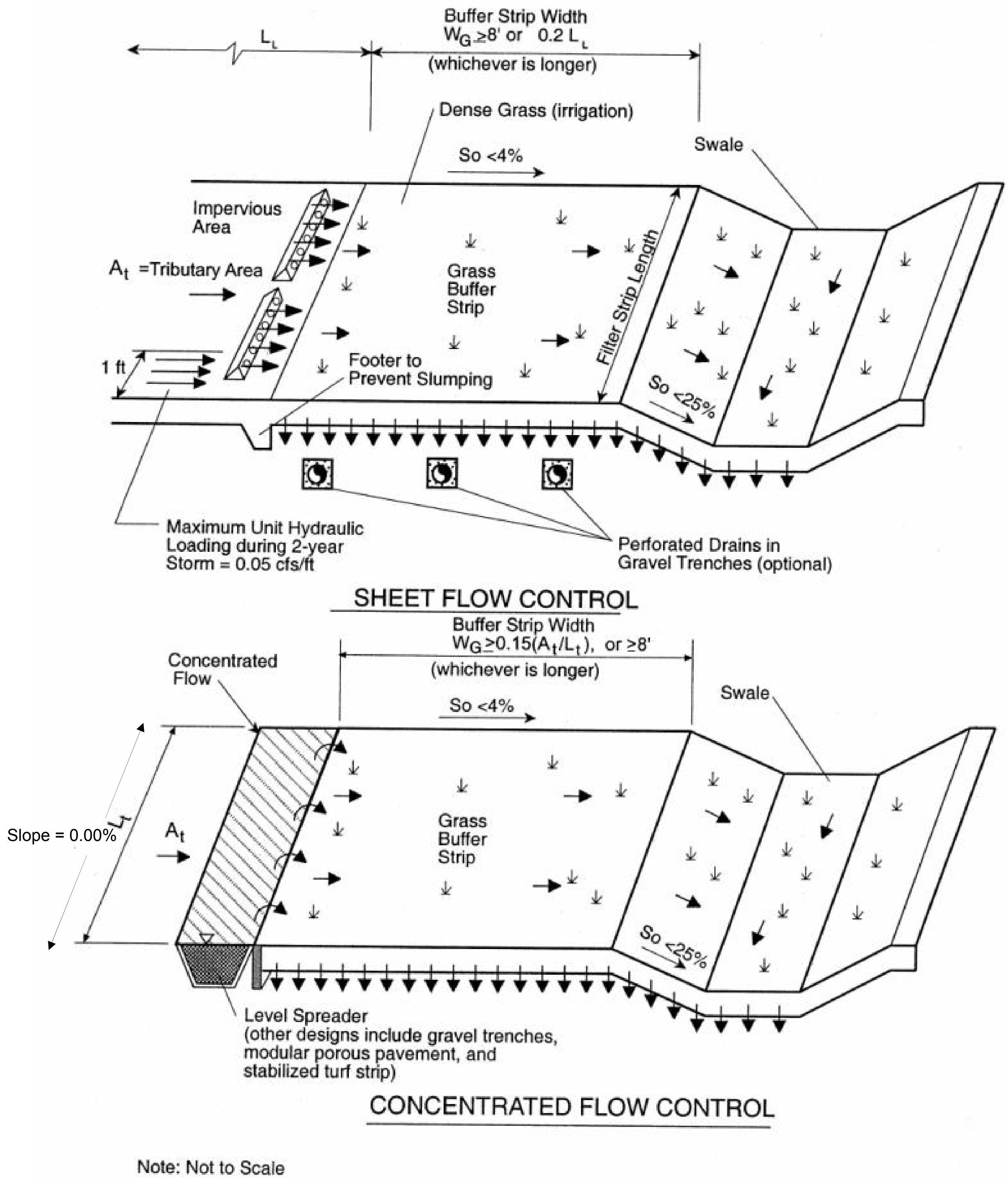


Figure 3-20: General Design Guidelines for a Typical Vegetated Filter Strip
(modified from UDFCD 1999)

### 3.4.3 Bioretention Systems

**General Description**

Bioretention systems consist of depressed vegetated areas with porous engineered soils and underdrain systems that capture and treat urban stormwater runoff. Bioretention systems are also known as landscape detention, rain gardens, tree box filters, and stormwater planters. This type utilizes a combination of porous engineered soils, plants, and their root systems. The volume of urban runoff is reduced by soil retention, plant uptake, evapotranspiration and infiltration. Pollutants are effectively removed by a number of processes including physical filtering, ion exchange, adsorption, biological processing, and conversion. Bioretention systems can be installed into existing site soils or within concrete enclosures. When existing soils are excavated and replaced with engineered soils to create a bioretention system, a layer of pea gravel (not filter fabric) should be used at the base of the excavated pit. Although generally not considered necessary, a geotextile filter fabric or an impermeable liner can be placed along the sides of the excavation to separate the engineered soils from the existing site soils.

A typical bioretention system design includes a depressed ponding area (at a grade below adjacent impervious surfaces), an engineered soil mix, and where existing soils have slow infiltration rates, an underdrain system. The ponding area is designed to capture, detain and infiltrate the water quality volume ($WQ_V$) into an engineered soil mix consisting of a well mixed combination of topsoil, clean sand, and certified compost and/or peat moss (see Section 4.3.5 for additional engineered soil mix details). Where underlying existing site soils have relatively slow infiltration rates (less than 0.5 inch/hr or greater than 120 min/inch), an underdrain system consisting of a perforated pipe in a gravel layer shall be included in the design to facilitate proper drainage. Discharge from the underdrain pipe can be routed to a down gradient storm drain pipe or channel. Urban runoff from relatively small storm events, as well as from up gradient washing and irrigation activities; passes through pipes, slotted curbs curb cuts or curb inlets and is distributed evenly at non erosive velocities along the length of the flat ponding area of bioretention systems. Runoff ponds to a depth of approximately 6 to 12 inches and then gradually filters through the engineered soils mix, where it is retained in the porous soils, utilized by plants, evapotranspired, and either infiltrated into the underlying soils, or drained into an underdrain system over a period of days.

Erosion control/energy dissipation features shall be provided where runoff enters bioretention systems (e.g., cobbles or riprap beneath a curb cut opening or a splash block beneath a roof drain downspout). In addition, vegetated swales or filter strips can be added to the design to provide pretreatment (e.g., for sediment reduction). Excess runoff from large storm events should be allowed to bypass bioretention systems and flow towards the conventional storm drain system or another downstream BMP. This can be accomplished by providing overflow outlets or inlet control structures such as weirs, inlet pipes and/or grade control features.

Photo: Center for Watershed Protection

Photo: Seattle SEA Streets Project

Figure 3-21: Bioretention Systems Located On-lot in a Multifamily Development (left) and in a Street Right of Way of a Residential Development (right)



### Performance Data

The literature reported range of removal for various pollutants is as follows:

| Pollutants | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 75 - 90 |
| Total Phosphorus | 70 - 80 |
| Total Nitrogen | 65 - 80 |
| Total Zinc | 75 - 80 |
| Total Lead | 75 - 80 |
| Organics | 75 - 90 |
| Bacteria | 75 - 90 |

**Sources:**

CASQA 2003; UDFCD 1999.

### Applications and Advantages

Bioretention systems can be incorporated into all aspects of urban development, including residential, commercial, municipal, and industrial areas. They are well suited for planters along buildings, within street median strips, parking lot islands, and roadside areas where landscaping is planned. In addition to providing significant water quality benefits, bioretention systems can provide shade and wind breaks, absorb noise, improve an area’s aesthetics, reduce irrigation needs, and reduce or eliminate the need for an underground storm drain system. Bioretention systems shall be integrated into a site’s overall landscaping to reduce the volume, rate and pollutant loading of urban runoff to pre-development levels.

Figures 3-22 through 3-26 provide examples of the various applications of bioretention systems. These versatile IMPs can be applied to:

- Parking lot islands

- Parking lot perimeters – curb less or curbed with curb cuts
- Tree wells and tree box filters – boxed bioretention cells placed at the curb typically just upstream of storm drain inlets
- Within right-of-ways along roads
- Street median strips
- Driveway perimeters
- Cul-de-sacs
- Landscaped areas in apartment complexes and multifamily housing
- Landscaped areas in commercial, industrial, and municipal developments
- Residential on-lot bioretention – landscape detention or rain gardens
- Planters at rooftop eaves
- Rooftop gardens, particularly on large commercial structures and parking garages.


*Photo: Kennedy/Jenks Consultants*

Figure 3-22: Parking Lot Island Bioretention System

*Photo: Kennedy/Jenks Consultants*

Figure 3-23: Roadway ROW Bioretention System

*Photo: Filterra ™*

Figure 3-24: Tree Box Filter Bioretention System

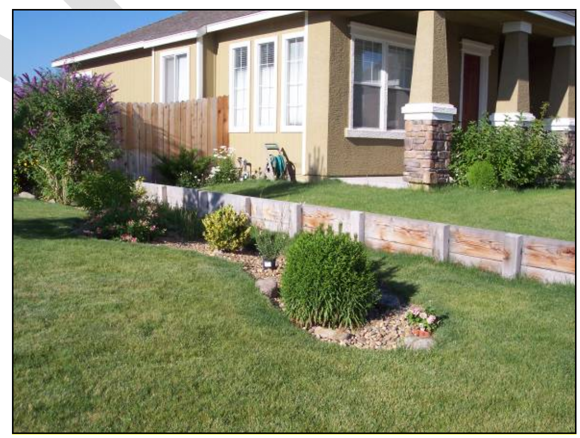

*Photo: Kennedy/Jenks Consultants*

Figure 3-25: Residential On-lot Bioretention System

**Limitations**

- Not be suitable for locations where the seasonally high groundwater table is within 5 feet of the bottom of the bioretention system (unless enclosed within an impermeable liner or a concrete box with an underdrain system). See Section 4.3.3 for additional setback, site screening requirements.

- Clogging may be a problem in areas with high sediment loads in the runoff. In this case up gradient pretreatment may be required with sediment traps and/or vegetated swales or filter strips.

- If located in the vicinity of active construction sites, sediment controls and fencing shall be installed to prevent clogging and compaction of engineered and existing site soils from heavy equipment.

- If the engineered soil mix is not properly designed, it may leach nutrients and salts into the groundwater or the treated effluent that discharges to an underdrain system. Leaching of nutrients and salts may only occur during the first year when the plants and soil system are becoming established.

**General Design Considerations**

- The temporary ponding area in bioretention systems shall be designed to retain the water quality volume ($WQ_V$) determined using the method outlined in Section 4.4.2.

- Bioretention systems shall include an engineered soil mix consisting of a well mixed combination of 50-60% clean sand, 20-30% topsoil, and 5-20% certified compost and/or peat installed to a minimum depth of 18 inches beneath the temporary ponding area (see Section 4.3.5 for additional details).

- Bioretention systems installed in existing site soils with infiltration rates of 0.5 in/hr or greater (120 min/inch or less) typically do not require an underdrain system. Discharge from underdrain pipes can be directed to nearby underground storm drain pipes, channels or other drainage features if sufficient head is available.

- If an underdrain system is required, it shall consist of a minimum 4 inch diameter perforated pipe inside the bioretention system, surrounded by an envelope of clean coarse aggregate and pea gravel.

- Bioretention systems shall include design features which will allow large flows from relatively large storm events to either bypass the system or overflow to a conventional storm drain structure such as a channel, a curb and gutter system, or a storm drain inlet. Bypass flows or overflows can also be routed to another downstream stormwater treatment system such as a vegetated swale or an extended detention basin. The design of diversion structures is discussed in Section 4.5.

- Additional detailed design guidance can be found at www.bioretention.org


Figure 3-26: Bioretention System Incorporated into a Traffic Calming Feature with Inflow and Overflow through Curb Openings

### 3.4.3.1 Landscape Detention

**Description**

Landscape detention is a type of bioretention system that is also known as a bioretention basin or porous landscape detention. It consists of a low-lying vegetated area underlain by an engineered soil mix. If underlying existing site soils allow for a significant amount of infiltration (0.5 inch/hr or more or 120 min/inch of less), an underdrain system may not be needed. Stormwater runoff from relatively small storm events and urban water use (e.g., washing and irrigation) typically passes through curb opening and onto a rock apron, which slows its velocity and distributes it evenly along the length of the ponding area. Water ponded to approximately 6 to 12 inches gradually infiltrates through the engineered soil mix an infiltrates into underlying soils and/or into an underdrain system (if included). The surrounding impervious area shall be graded to direct runoff into the landscape detention area. Curb openings, weirs or grade controls structures shall be included in the design to divert excess runoff from large events away from the landscape detention area towards the conventional storm drain system.

**Siting Criteria**

- Drainage area shall be less than 1 acre
- May be located on-line or off-line of the primary drainage system
- Not recommended for areas with slopes greater than 20 percent
- Layout shall be determined based on site constraints such as location of utilities, underlying soil conditions, existing vegetation, and drainage patterns
- Not to be used in areas where the infiltration rate of existing site soils is less than 0.5 inch/hr (120 min/inch) and there is no adjacent storm drain system or other

acceptable drainage feature nearby that can be used accept discharge from an underdrain system.

**Design and Construction Criteria**



- Registered professional civil engineers and landscape architects shall work together on the design landscape detention basins. Appropriate plant species can stabilize banks and increase the infiltration capacity and the pollutant treatment effectiveness of landscape detention basins. See Appendix G for recommended plant species and planting zones for LID practices.

- The size of a landscape detention basin is a function of the drainage area that will discharge to the system, the additional runoff generated from the impervious surfaces in the drainage area, and the ponding depth in the basin.

- Size the ponding area in a landscape detention basin to capture and treat the Water Quality Volume ($WQ_V$) using the method outlined in Section 4.4.2.

- If an underdrain system is required (e.g., existing site soils have an infiltration < 0.5 in/hr), it shall consist of a minimum 4 inch diameter perforated pipe surrounded by an envelope of clean coarse aggregate and pea gravel. The underdrain pipe system shall have a vertical solid section that extends above the surface of the ponding area in the basin to provide a monitoring well and clean out access port. The opening shall be normally sealed with a watertight screw on cap to prevent short circuiting (e.g., direct drainage into the underdrain pipe).

- Flows in excess of the $WQ_V$ should bypass the landscape detention basin or overflow and flow to the conventional storm drain system or another downstream BMP. Figures 3-29 and 30 show schematic cross sections of landscape detention basins that overflow through a curb opening and onto a pavement that slopes away from the basin and flows towards the conventional storm drain system. Figures 3-32 and 33 show landscape detention basins that overflow to storm drain inlets located into and next to the basins, respectively. Refer to Section 4.5 for additional information on diversion structures.

- Determine the ponding depth of the landscape detention basin ($D_{WQV}$) based on the available surface area (SA) using the following equation:

  $$D_{WQV} = (WQ_v / SA) \times 12$$

  Where:

  $D_{WQV}$ = ponding depth of the temporary ponded runoff (ft)

  $WQ_v$ = Water Quality Volume ($ft^3$) per the method outlined in Section 4.4.2

  SA = Surface area of ponding area based on the length and width at the toe of the side slopes and the ponding depth.

- Maximum recommended ponding depth is 12 inches and minimum ponding depth is 6 inches with water standing no longer than 4 to 6 hours. This minimizes potential problems with mosquito breeding and plants that can't tolerate standing water for extended periods.

- Landscape detention basins longer than 20 ft should be twice as long as they are wide.

- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure.

- Approximately 2-3 inches of shredded hardwood mulch can be applied to the surface of the landscape detention area to assist with soil moisture retention and plant health.

- A general rule of thumb is one tree or shrub should be included for each 50 $ft^2$ of landscape detention area.

- Plant selection and layout should consider aesthetics, maintenance, native versus non-native invasive species, and regional landscaping practices.

- Guidance on plant selection for landscape detention basins is presented in Appendix G LID Planting Zones and Plant List.

- Sod shall not be used in the design of landscape detention basins as it typically contains a high percentage of clay that inhibits infiltration.

- Trees can also be planted on the perimeter of landscape detention basins to provide shade and shelter.

- Whenever possible, avoid the use of heavy equipment during construction on areas where bioretention systems are to be installed. If soils are compacted, additional ripping may be necessary to re-establish soil permeability.

- After basin excavation, do not compact the native underlying soils.

- When installing the engineered soil mix, drop it from the bucket and *do not compact it*.

**Inspection and Maintenance Requirements**

- Upon installation and during the first year, landscape detention basins should be inspected monthly and after relatively large storm events for potential erosion and/or extended ponding.

- Key inspection/maintenance areas include inlet and overflow areas for potential erosion, the ponding area in basin for trash and debris, and the monitoring well/clean out port for potential early signs of stagnant water in the system if an underdrain system is included.

- Inspections can be reduced to a semi-annual schedule once the landscape detention basin has proven to work efficiently and properly and vegetation is established.

- A health evaluation of trees and shrubs shall be conducted biannually.

- Pruning, weeding and trash removal shall be conducted as necessary.

- Mulch replacement is generally required every two to three years.

- If ponding is observed to exceed 72 hours, particularly during the primary mosquito breeding season (June through October), the cause may be clogged filter fabric (if used, which is not recommend), compacted soils from construction activities, improper placement and compaction of the engineered soil mix, or surface clogging with fines from a heavy loading source in the drainage area (e.g., a dirt lot or a construction site without BMPs). The reason for the extended ponding shall de determined and mitigated (e.g., removal of filter fabric, cleaning of the underdrain system, replacement of engineered soils, and/or ripping of underlying native soils to re-establish permeability).

- If a spill occurs and hazardous materials contaminate soils in landscape detention areas, the affected materials shall be removed immediately and the appropriate soils and materials replaced as soon as possible.

*Photo: Center for Watershed Protection*


*Photo: Colorado AWARE*

Figure 3-27: Landscape Detention Basins Located at the Edge of a Parking Lot (left photo) and in a Parking Lot Island with Turf and Shrubs and Trees (right photo)

*Photo: Center for Watershed Protection*

*Photo: Center for Watershed Protection*

Figure 3-28: Curb Opening Design for a Landscape Detention System Located Upstream of a Conventional Storm Drain Inlet (left photo). A Bioretention System Retrofit into an Existing Parking Lot Island (right photo)

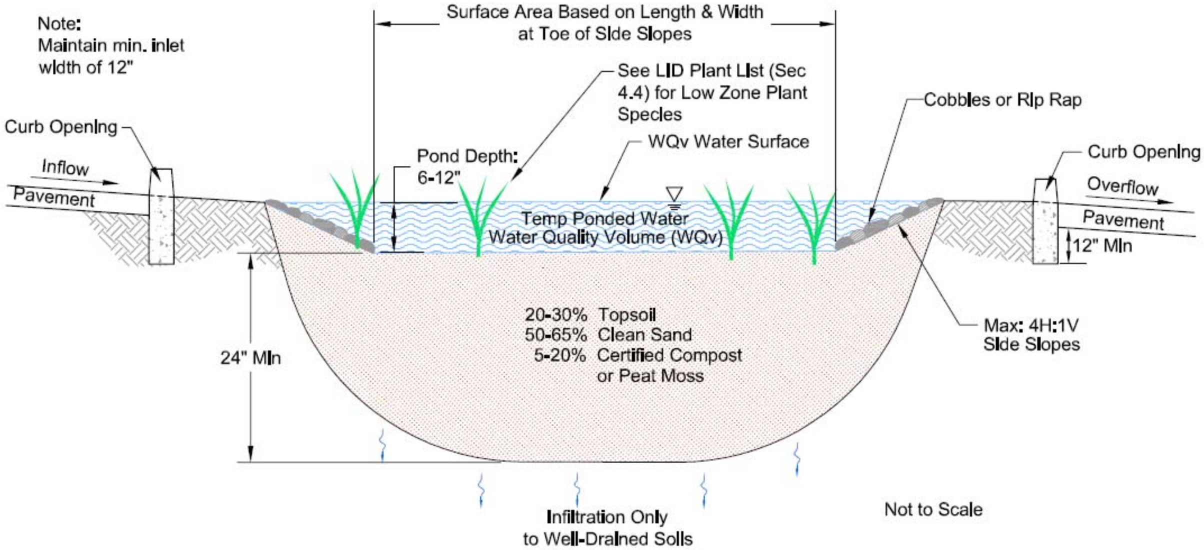


Figure 3-29: Schematic of a Landscape Detention Basin Located in Existing (Native) Site Soils with an Infiltration of 0.5 inch/hr or Greater (120 min/inch or less)

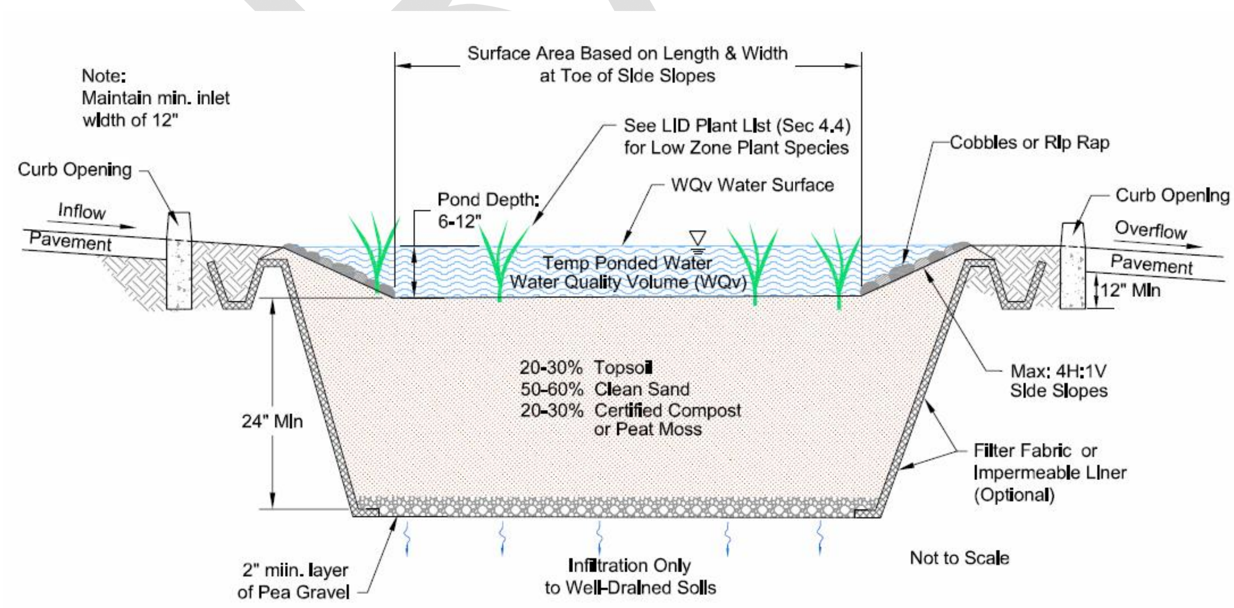


Figure 3-30: Schematic of a Landscape Detention Basin in Well-draining Soils with an Optional Filter Fabric Liner Installed Along the Basin Side Walls

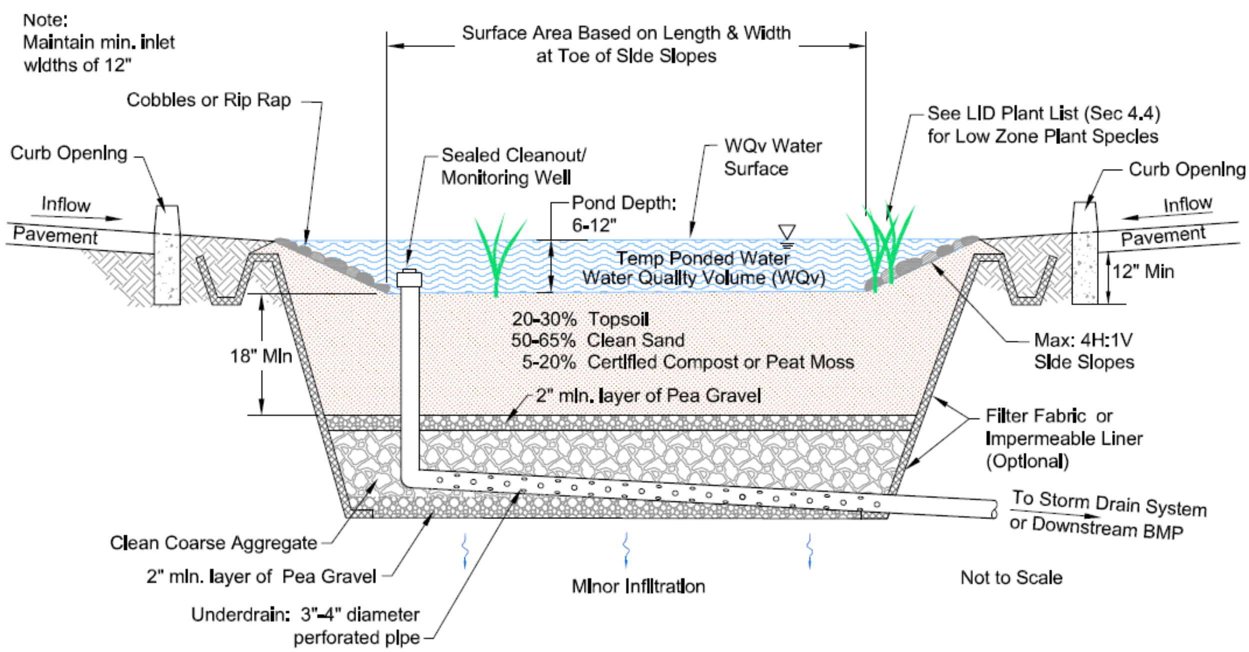


Figure 3-31: Schematic of a Landscape Detention Basin in Slow-draining Soils with an Underdrain System Piped to a Nearby Down gradient Storm Drain Pipe, Channel, or BMP. In This Example the Overflow Feature is Not Shown

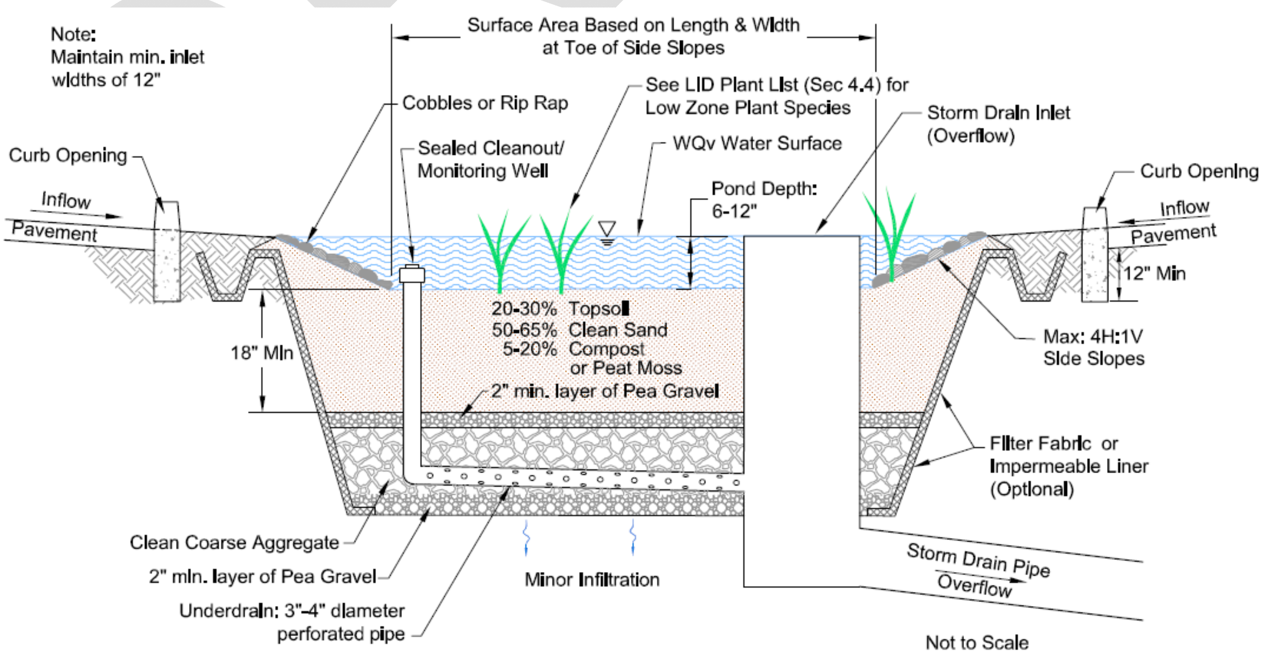


Figure 3-32: Schematic of a Landscape Detention Basin Located in Slow-draining Soils with an Underdrain System and a Storm Drain Inlet Located Inside the Basin to Capture Overflow from Relatively Large Storm Events

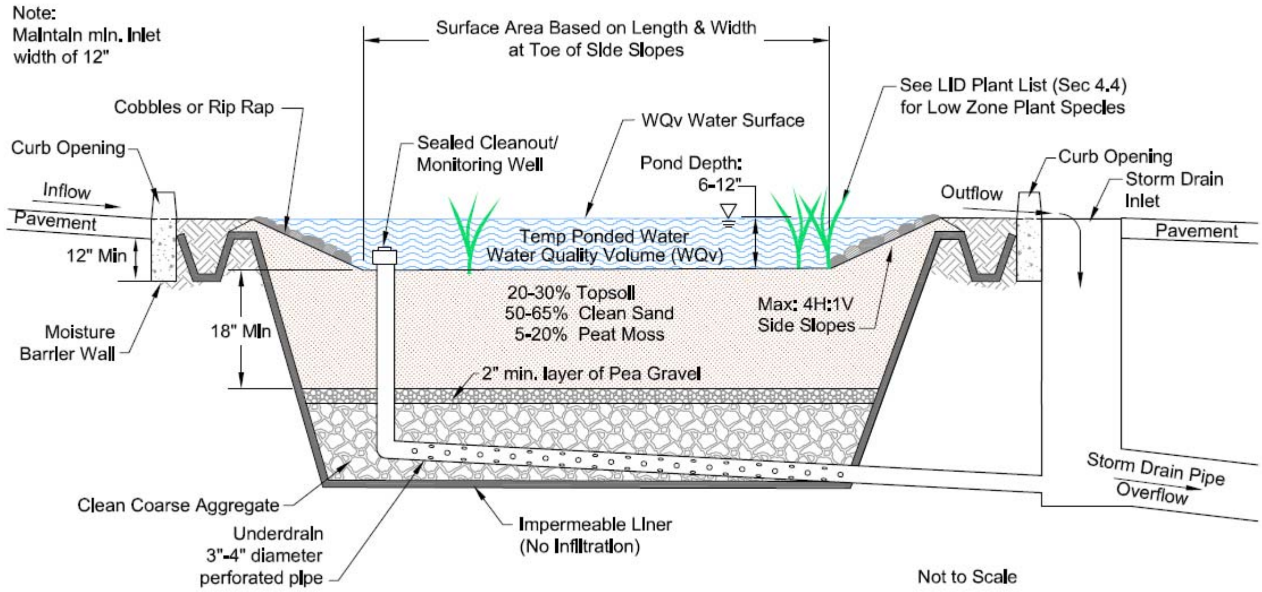


Figure 3-33: Schematic of a Landscape Detention Basin Located in Expansive Clays or Where There is Outdoor Storage or Use of Chemicals or Materials within the BMP Drainage Area that could Threaten Groundwater Quality if a Spill Were to Occur

### 3.4.3.2 Tree Box Filters

Tree box filters are bioretention systems enclosed in concrete boxes that drain runoff from paved areas via a standard storm drain inlet structure. They are typically located upstream of a conventional storm drain inlet and shall not be located in sump areas (e.g., topographic low points). Where existing site soils are sufficiently permeable (infiltration rates > 0.5 in/hr), tree box filters can be designed to drain directly to underlying soils via drain holes installed in the base of the concrete box. Where slow draining native soils exist, they shall be designed with an underdrain pipe which is typically connected to the conventional storm drain system pipe in the street. Most of the general design standards noted above for landscape detention basins also apply to tree box filters. In addition tree box filters should generally be designed per the bioretention system design criteria and engineered soils testing requirements discussed in Section 4.3.5, and the Water Quality Volume ($WQ_V$) method outlined in Section 4.4.2. However many of the setback standards for indirect infiltration systems may not apply if a tree box filter is contained with a concrete box and only drains to an underdrain system that discharges to the conventional storm drain system.

Filterra™ manufactures a proprietary tree box filter system (See Figure 3-34). Therefore designers shall contact Filterra™ to avoid potential patent right infringement claims if a tree box filter design is similar to the Filterra™ system noted in Figure 3-34 below.



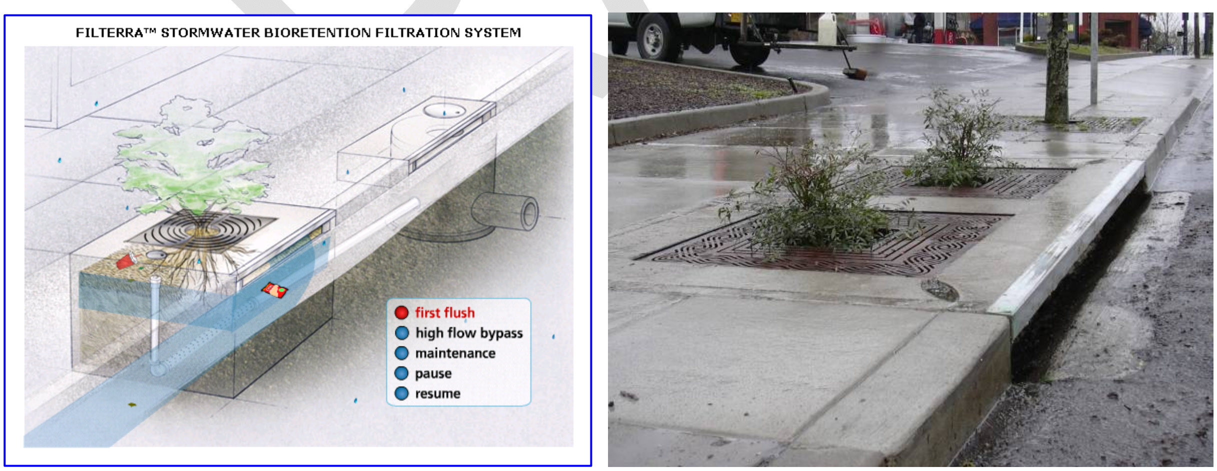


Figure 3-34: Schematic and Photo of a Tree Box Filter, Which is a Manufactured (Proprietary) Bioretention System
(figure and photo provided by Filterra™)

**Providing parking lot treatment by impaired waters.**

**Typical Filterra placement at a fast food chain.**

**Even the largest Filterra unit blends in with landscaping.**

**Filterra used with a flumed bypass in a commercial parking lot.**

**Ideal for stormwater treatment where space is tight.**

**Filterra featuring a beautiful Crape Myrtle in bloom.**

Figure 3-35: Various Filterra™ Tree Box Filter Configurations (photographs provided by Filterra™)

### 3.4.3.3 Stormwater Planters

Stormwater planters, also known as infiltration planters or flow through planters, are also bioretention systems in enclosed in concrete structures. They can be designed to drain runoff from paved areas via curb inlet structures or pipes (Figure 3-36), or they can be located under roof drain downspouts (Figure 3-37) for treatment of roof runoff. Where existing site soils are sufficiently permeable (infiltration rates > 0.5 in/hr), stormwater planters can be designed as flow through systems with concrete walls on 4 sides and no floor (Figure 3-38). This type of system drains directly to underlying soils and shall consider the setback standards for indirect infiltration systems presented in Section 4.3.3. When located next to buildings and other structures, or when slow draining native soils exist, they shall be designed with an underdrain pipe. Waterproofing shall be incorporated into the designs of stormwater planters sited near buildings and other structures per a licensed Geotechnical Engineer recommendation. When designed with under drains and waterproofing, stormwater planters typically do not need to apply the setback standards noted in Section 4.3.3.

Most of the general design standards noted above for landscape detention basins also apply to stormwater planters. For example, the ponding area in stormwater planters shall be designed to detain the Water Quality Volume ($WQ_V$) per the method outlined in Section 4.4.2. In addition, stormwater planters shall be designed with engineered soils per the standards presented in Section 4.3.5. Plants can also be selected from the LID plant list presented in Appendix G.



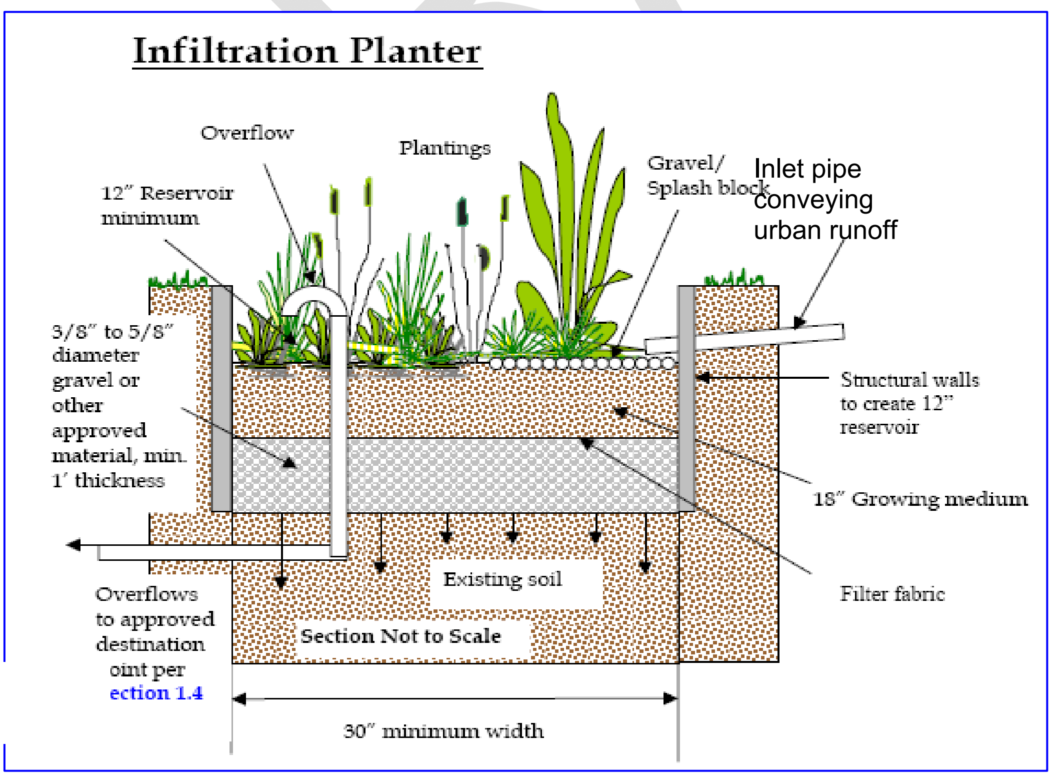


Figure 3-36: Schematic of a Stormwater Planter that Receives Urban Runoff from a Pipe, Drains Directly to Underlying Soils, and Overflows to the Conventional Storm Drain System via an Overflow Pipe (adapted from Portland BES)

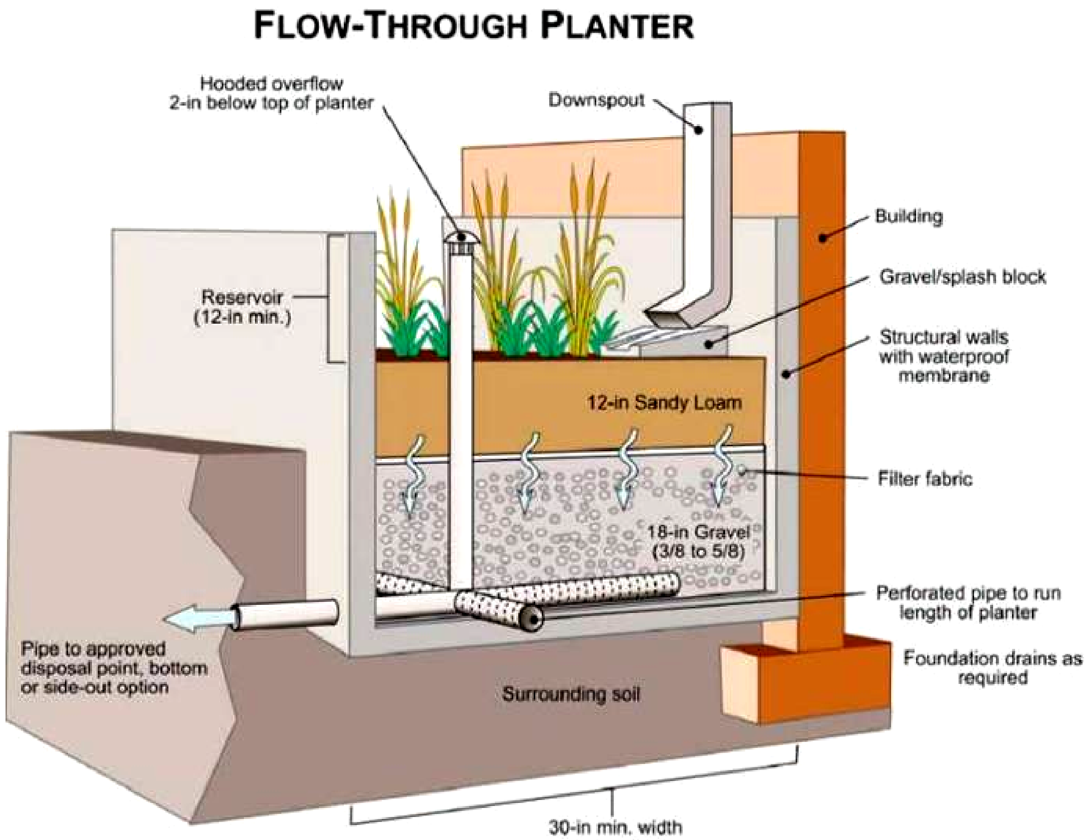


Figure 3-37: Schematic of a Stormwater Planter that Detains and Treats Roof Runoff, and Drains and Overflows to the Conventional Storm Drain System via an Underdrain and Overflow Pipe System (Source: Portland BES)


Figure 3-38: Stormwater Planters Installed next to Office Buildings (Source: Portland BES)

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## 3.4.4 Porous Paving Systems

Porous paving systems allow infiltration of stormwater while providing a stable load-bearing surface for walking and driving. These systems contain void spaces to provide infiltration of runoff into their underlying engineered porous materials and then into existing site soils. Generally, underlying engineered materials consist of clean sands or gravels separated from existing site soils by a synthetic filter fabric. Underlying engineered materials detain and filter pollutants prior to infiltration into underlying soils or discharge to a conventional storm drain system through an underdrain system. Porous paving systems can preserve natural drainage patterns, enhance groundwater recharge and soil moisture, and can help establish and maintain roadside vegetation. Although a good substitute for conventional concrete and asphalt, porous paving systems are typically not suitable for heavily trafficked applications. There are several different types of porous paving systems, which are referred to here as:

- Porous Pavement Detention
- Open-Celled Block Pavers
- Open-Jointed Block Pavers
- Porous Asphalt and Porous Concrete Pavement
- Porous Turf
- Porous Gravel.



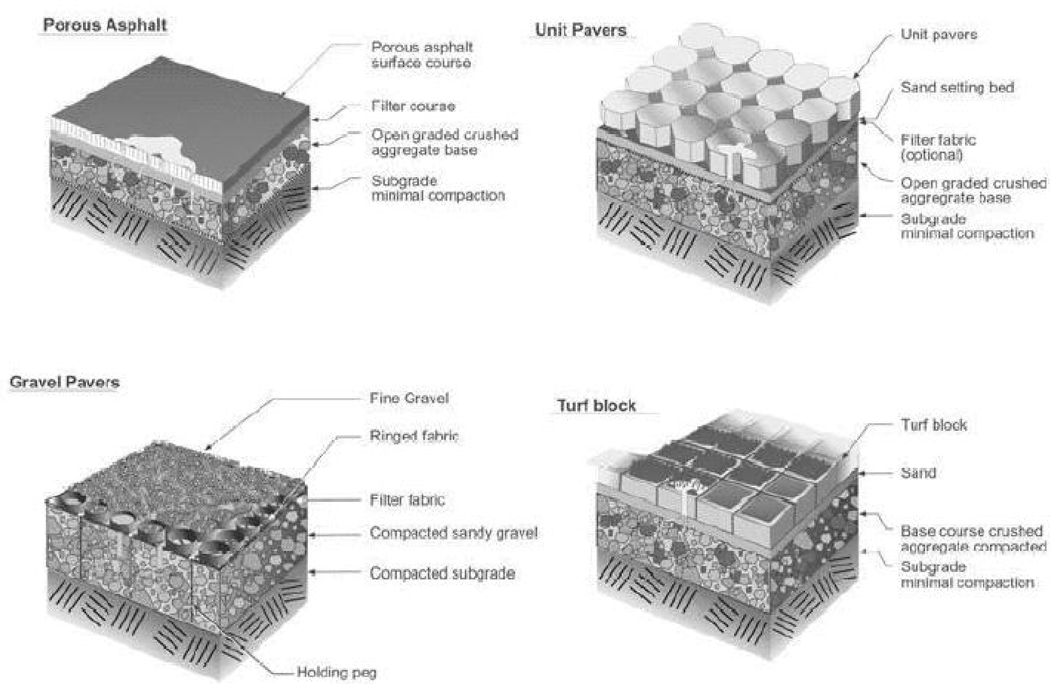
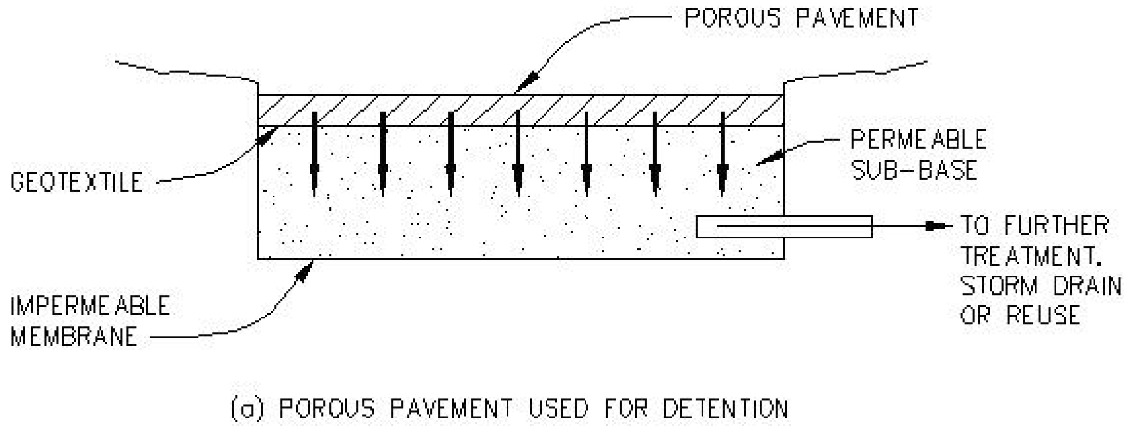



Figure 3-39: Cross-sections of Typical Porous Pavement Installations and Different Types of Porous Pavement (from Sacramento 2000)



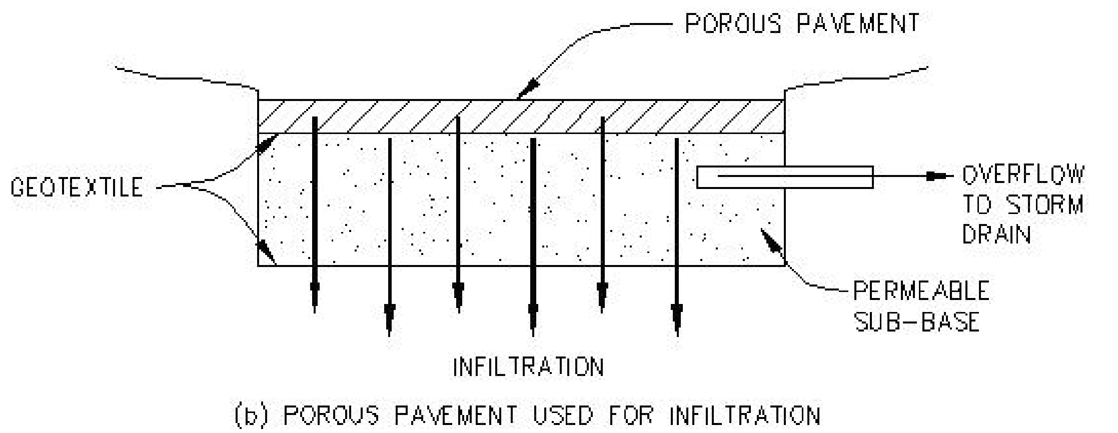




Figure 3-40: Typical Porous Pavement and Drainage Pipe Configurations for a) Filtering and Detaining Stormwater Runoff and, b) Filtering and Infiltrating Stormwater Runoff (modified from CASQA 2003)

### 3.4.4.1 Porous Pavement Detention

Porous pavement detention is an installation of open-celled block pavers that is flat and is provided with a 2-inch deep surcharge zone to temporarily store the WQv. Open-celled block pavers consist of blocks or slabs made of concrete or brick with open surface voids that penetrate their surface area. The modular blocks are placed over a porous sub-base and the openings within and between the blocks are filled with pervious materials (e.g., open-graded aggregate). Porous materials such as clean gravels placed below the porous pavement detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system.

## Applications and Advantages

Porous pavement detention can be used as a substitute for conventional pavement, but is limited to parking areas and low traffic volume roadways where little to no truck traffic is anticipated. Examples include residential driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, emergency vehicle and fire access lanes, stopping lanes on divided highways, equipment storage areas, and patios.

## Performance Data

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 70 - 90 |
| Total Phosphorus | 40 - 55 |
| Total Nitrogen | 10 - 20 |
| Total Zinc | 40 - 80 |
| Total Lead | 60 - 70 |

**Source:**

UDFCD 1999.

## Limitations

- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.
- Care must be taken when applying in commercial or industrial areas.
- May become clogged if not properly installed and maintained.
- Maintenance costs can be relatively high if the blocks frequently become clogged with sediment from offsite sources.
- Porous pavements may cause uneven driving surfaces and may be problematic for high heel shoes and ADA compliance.
- May not be suitable for areas that require wheelchair access because of the pavement texture.
- Do not install sand or pavers during rain events.

## Siting Criteria

- Porous pavement detention installations shall be installed in areas that are flat in all directions (i.e. 0% slope).
- If designed to infiltrate stormwater into underlying soils, porous pavements are considered indirect infiltration systems. Therefore apply site screening, infiltration testing

(if the project is 20 acres or greater), separation, and setback standards for indirect infiltration systems presented in Section 4.3.3.

**Design and Construction Criteria**

- Registered professional civil engineers shall design porous pavements.
- Calculate the Water Quality Volume ($WQ_v$) per the methods presented in Section 4.4.2 to determine the minimum required surface area for the porous pavement detention:

$$\text{Minimum surface area} = WQ_v/0.17\text{ft}$$

- Sub-base layers shall be capable of bearing an appropriate load without deforming.
- Pervious pavements shall be the last thing to install during construction or redevelopment.
- Open-celled block pavers shall have a minimum surface area void space of 20 percent.
- Use an open-graded aggregate base course to provide a permeable reservoir.
- When designing the base course, or base reservoir, to detain the water quality volume, select the appropriate porosity[4] value for the material used.
- Strength and durability of materials under saturated conditions must be considered.
- When installing the base course, it must be compacted as it is placed in lifts.
- A bedding layer should be laid over the base course as level bedding for the blocks consisting of relatively small open-graded aggregate meeting criteria for a filter layer, or “choke layer.
- Appropriate gradations of aggregate material must be used to minimize the migration of particles from one layer to the next. If this cannot be achieved, a woven geotextile shall be used under the bedding layer above the base course to minimize migration. A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal can be used.
- For aggregate fill in the cells, material shall consist of open-graded sand and can be the same material as the bedding material.
- A concrete perimeter wall shall be installed to confine the edges of the block installation. The perimeter wall shall be 6 inches thick and to extend 6 inches deeper than the base course, bedding layer, and block depth combined.
- Direct sediment-laden runoff away from the porous pavements.
- Filter fabrics shall be placed on the bottom and sides of the sub-base layer.



[4] Porosity is the ratio of void space volume to the total volume of soil or rocks. Generally the higher the soil porosity, the greater the ability to hold, transmit and infiltrate water.

- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure.

- To allow infiltration and minimize clogging, the filter fabric shall be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.

- Follow pavement manufactures specifications.

- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.

- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.

- The storage capacity of the stone reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the Water Quality Volume (WQV) as discussed in Section 4.4.2.

**Inspection and Maintenance Requirements**

- Accumulated debris and litter removal as needed.

- Maintenance such as vacuuming is required to minimize clogging of the pervious surface.

- Inspect sand filter routinely and after storm events to insure proper infiltration and drainage.

- Frequently inspect the pavement to insure proper infiltration and drainage during the first wet season, and then once a year following that time.

- Replacement of surface sand filter layer may occur when runoff does not infiltrate readily into the surface.

**References**

Balades et al. 1995. Permeable Pavements: Pollution Management Tools, Water Science and Technology. Vol. 32, No. 1, pp. 49-56, 1995.

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Newman et al. 2002. Oil Bio-Degradation in Permeable Pavements by Microbial Communities, Water Science and Technology. Vol. 45, No. 7, pp. 51-56, 2002.

Pratt et al. 1999. Mineral Oil Bio-Degradation within a Permeable Pavement: Long Term Observations, Water Science and Technology. Vol. 39, No. 2, pp. 103-109, 1999.

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### 3.4.4.2 Open-Celled Block Pavers

Open-celled block pavers, also known as modular block pavers, consist of blocks or slabs made of concrete or brick with open surface voids that penetrate their surface area. The modular blocks are placed over a porous sub-base and the openings within and between the blocks are filled with pervious materials (e.g., open-graded aggregate). Porous materials such as clean gravels placed below the porous pavement detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system. This type of surface reduces runoff from paved areas and the ponding that typically occurs in parking lots during and after storm events.

**Applications and Advantages**

Open-celled block pavers can be used as a substitute for conventional pavement, but shall be limited to parking areas and low traffic volume roadways where little to no truck traffic is anticipated. Examples include residential driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, emergency vehicle and fire access lanes, stopping lanes on divided highways, equipment storage areas, and patios as well as alternative to conventional paving in areas where tree protection and preservation is a concern.

**Performance Data**

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 70 - 90 |
| Total Phosphorus | 40 - 55 |
| Total Nitrogen | 10 - 20 |
| Total Zinc | 40 - 80 |
| Total Lead | 60 - 70 |

**Source:**

UDFCD 1999.

**Limitations**

- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.
- Care must be taken when applying in commercial or industrial areas.
- May become clogged if not properly installed and maintained.
- Maintenance costs can be relatively high if the blocks frequently become clogged with sediment from offsite sources.
- Porous pavements may cause uneven driving surfaces and may be problematic for high heel shoes and ADA compliance.
- May not be suitable for areas that require wheelchair access because of the pavement texture.
- Do not install sand or pavers during rain events.

**Siting Criteria**

- Ideally, pervious pavement shall be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces. However they can also be placed on gentle slopes that do not exceed 5 percent.
- If designed to infiltrate stormwater into underlying soils, porous pavements are considered indirect infiltration systems. Therefore apply site screening, infiltration testing (if the project is 20 acres or greater), separation, and setback standards for indirect infiltration systems presented in Section 4.3.3.

**Design and Construction Criteria**

- Registered professional civil engineers shall design porous pavements.
- Sub-base layers shall be capable of bearing an appropriate load without deforming.
- Pervious pavements shall be the last thing to install during construction or redevelopment.
- Open-celled block pavers shall have a minimum surface area void space of 20 percent.
- Use an open-graded aggregate base course to provide a permeable reservoir. When designing the base course, or base reservoir, to detain the water quality volume, select the appropriate porosity value for the material used.
- Strength and durability of materials under saturated conditions must be considered.
- When installing the base course, it must be compacted as it is placed in lifts.

- A bedding layer should be laid over the base course as level bedding for the blocks consisting of relatively small open-graded aggregate meeting criteria for a filter layer, or “choke layer.

- Appropriate gradations of aggregate material must be used to minimize the migration of particles from one layer to the next. If this cannot be achieved, a woven geotextile shall be used under the bedding layer above the base course to minimize migration. A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal can be used.

- Open-celled block pavers are vibrated into place into the bedding layer.

- Filter fabrics shall be placed on the bottom and sides of the base layer.

- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure.

- To allow infiltration and minimize clogging, the filter fabric shall be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.

- Edge restraints shall be installed on compacted sub grade or base material, not on the bedding.

- For aggregate fill in the cells, material shall consist of open-graded sand and can be the same material as the bedding material. A concrete perimeter wall shall be installed to confine the edges of the block installation. The perimeter wall shall be 6 inches thick and to extend 6 inches deeper than the base course.

- Lateral-flow cut-off barriers shall be installed using a 16-mil or thicker PE or PVC impermeable membrane liner or concrete walls installed normal to flow. This minimizes flow of water downstream resurfacing at the toe of the block installation.

- Distance between cut-off barriers shall not exceed:

  $$L_{MAX} = D/(1.5*S_o)$$

  Where:

  $L_{MAX}$ = Max distance between cut-off barriers normal to flow (ft)

  D = Depth of the aggregate base course (ft/ft)

  $S_o$ = Slope of the base course (ft)

- An underdrain shall be installed where impermeable liners are installed to prevent infiltration into underlying soils or when existing site soils exhibit infiltration rates of less than 0.5 in/hr (120 min/in). Locate each underdrain pipe just upstream of the lateral-flow cut-off barrier when used.

- For rooting vegetation in the joints, planting medium shall be sandy and open-graded. In bedding and base course a limited amount of planting medium could be mixed into open-graded aggregate to deepen rooting.

- Plant grass in open-joints as plugs or broadcast seed at a reduced rate to account for concrete grids.

- All installations shall be designed and constructed to pavement manufactures specifications.

- Follow pavement manufactures specifications.

- Direct sediment-laden runoff away from the porous pavements.

- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.

- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.

- The storage capacity of the base reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the Water Quality Volume ($WQ_V$) as discussed in Section 4.4.2.

**Inspection and Maintenance Requirements**

- Open-celled block pavers shall not be washed to remove debris and sediment in the openings between pavers, rather sweeping with suction shall be utilized annually. Replace lost sand infill.

- Joints between block pavers may require occasional weed suppression.

- Pavers can be removed individually and replaced when utility work is needed.

- Top course aggregate can be removed or replaced in pavers if they become clogged or contaminated.

- Replace surface filter layer by vacuuming out sand media from blocks when it becomes evident that runoff does not rapidly infiltrate into the surface.

- For pavers planted with turf, regular turf maintenance will be necessary. However, pesticides, fertilizers and other chemicals can have adverse effects on concrete products, so their use shall be restricted.

**References**

Balades et al. 1995. Permeable Pavements: Pollution Management Tools, Water Science and Technology. Vol. 32, No. 1, pp. 49-56, 1995.

CASQA. 2003. Stormwater Best Management Practice Handbook – New Development and Redevelopment. California Stormwater Quality Association.

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UDFCD. 1999. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices. Urban Drainage and Flood Control District.



### 3.4.4.3 Open-Jointed Block Pavers

Open-jointed block pavers consist of solid block units made of concrete, clay, or stone that form an interlocking, flexible pavement surface. Open voids are created, by beveling the corners of each block or creating wider spacing between the blocks. The blocks themselves also commonly contain small voids to increase permeability. The modular blocks are placed over a porous sub-base and the openings within and between the blocks are filled with pervious materials (e.g., clean sand). The pavers are placed on a gravel sub-grade to detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system. This type of surface reduces runoff from paved areas and the ponding that typically occurs in parking lots during and after storm events.

*Photo: courtesy of ICPI*

Figure 3-41: Example of an Open Jointed Block Paver Installation

#### Applications and Advantages

Open-jointed block pavers can be used as a substitute for conventional pavement, but shall be limited to parking areas and low traffic volume roadways where little to no truck traffic is anticipated. Examples include residential driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, emergency vehicle and fire access lanes, stopping lanes on divided highways, equipment storage areas, and patios, as well as alternative to conventional paving in areas where tree protection and preservation is a concern.

**Limitations**

- Care must be taken when applying in commercial or industrial areas.
- May become clogged if not properly installed and maintained.
- Maintenance costs can be relatively high if the blocks frequently become clogged with sediment from offsite sources.
- Open jointed block pavers may cause uneven driving surfaces and may be problematic for high heel shoes and ADA compliance.

**Performance Data**

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 70 - 90 |
| Total Phosphorus | 40 - 55 |
| Total Nitrogen | 10 - 20 |
| Total Zinc | 40 - 80 |
| Total Lead | 60 - 70 |

**Source:**

UDFCD. 1999.

**Siting Criteria**

- Do not install pavers on slopes greater than 15 percent.
- If designed to infiltrate stormwater into underlying soils, porous pavements are considered indirect infiltration systems. Therefore apply site screening, infiltration testing (if the project is 20 acres or greater), separation, and setback standards for indirect infiltration systems presented in Section 4.3.3.
- May not be suitable for areas that require wheelchair access because of the pavement texture.
- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.

**Design and Construction Criteria**

- Registered professional civil engineers shall design porous pavements.
- Sub-base layers shall be capable of bearing an appropriate load without deforming.

- Do not install sand or pavers during rain events.

- Pervious pavements shall be the last thing to install during construction or redevelopment.

- Consult a qualified engineer, architect, and/or landscape architect for paver applications.

- To be installed by a qualified contractor experienced in paver applications.

- Open-jointed block pavers shall have a minimum surface area void space of 8 percent.

- Use an open-graded aggregate base course to provide a permeable reservoir. When designing the base course, or base reservoir, to detain the water quality volume, select the appropriate porosity value for the material used.

- Strength and durability of materials under saturated conditions must be considered.

- When installing the base course, it must be placed and compacted in maximum 12 inch thick lifts.

- A bedding layer should be laid over the base course as level bedding for the blocks consisting of relatively small open-graded aggregate meeting criteria for a filter layer, or "choke layer". Do not use concrete sand, which is traditionally used for interlocking concrete pavement bedding layer construction and has been shown to have low permeability.

- Appropriate gradations of aggregate material must be used to minimize the migration of particles from one layer to the next. If this cannot be achieved, a geotextile shall be used under the bedding layer above the base course to minimize migration.

- Filter fabrics shall be placed on the bottom and sides of the base layer.

- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure.

- To allow infiltration and minimize clogging, the filter fabric shall be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.

- Edge restraints are required around the perimeter and shall be installed on compacted subgrade or base material, not on the bedding.

- Do not sweep sand into the joints after the pavers are installed to fill joints as this can compromise the permeability and porosity of pavers.

- A concrete perimeter wall shall be installed to confine the edges of the block installation. The perimeter wall shall be 6 inches thick and to extend 6 inches deeper than the base course.

- Lateral-flow cut-off barriers shall be installed using a 16-mil or thicker PE or PVC impermeable membrane liner or concrete walls installed normal to flow. This minimizes water flowing downgradient and resurfacing at the toe of the block installation.

- Distance between cut-off barriers shall not exceed:

$$L_{MAX} = D/(1.5*S_o)$$

Where:

$L_{MAX}$ = Max distance between cut-off barriers normal to flow (ft)

D = Depth of the aggregate base course (ft/ft)

$S_o$ = Slope of the base course (ft)

- An underdrain shall be installed where impermeable liners are installed to prevent infiltration into underlying soils or when existing site soils exhibit infiltration rates of less than 0.5 in/hr (120 min/in). Locate each underdrain pipe just upstream of the lateral-flow cut-off barrier when used.

- For rooting vegetation in the joints, planting medium shall be sandy and open-graded. In bedding and base course a limited amount of planting medium could be mixed into open-graded aggregate to deepen rooting.

- Cut pavers with a paver splitter or masonry saw. Cut pavers shall be no smaller than one-third of the full unit size along edges subject to vehicular traffic.

- All installations shall be designed and constructed to pavement manufactures specifications.

- Direct sediment-laden runoff away from the porous pavements.

- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.

- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.

- The storage capacity of the base reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the Water Quality Volume ($WQ_V$) as discussed in Section 4.4.2.

**Inspection and Maintenance Requirements**

- Blocks shall not be washed to remove debris and sediment in the openings between pavers, rather sweeping with suction shall be utilized annually. Replace lost sand infill.

- Joints between pavers may require occasional weed suppression.

- Pavers can be removed individually and replaced when utility work is needed.

- Replace surface filter layer by vacuuming out sand media from blocks when it becomes evident that runoff does not rapidly infiltrate into the surface. If vacuuming does not adequately remove fill, blocks can be lifted and reset with new joint fill material.

- If soils swell or subside, blocks can be removed individually, the base leveled, and blocks reset.

**References**


Balades et al. 1995. Permeable Pavements: Pollution Management Tools, Water Science and Technology. Vol. 32, No. 1, pp. 49-56, 1995.

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Newman et al. 2002. Oil Bio-Degradation in Permeable Pavements by Microbial Communities, Water Science and Technology. Vol. 45, No. 7, pp. 51-56, 2002.

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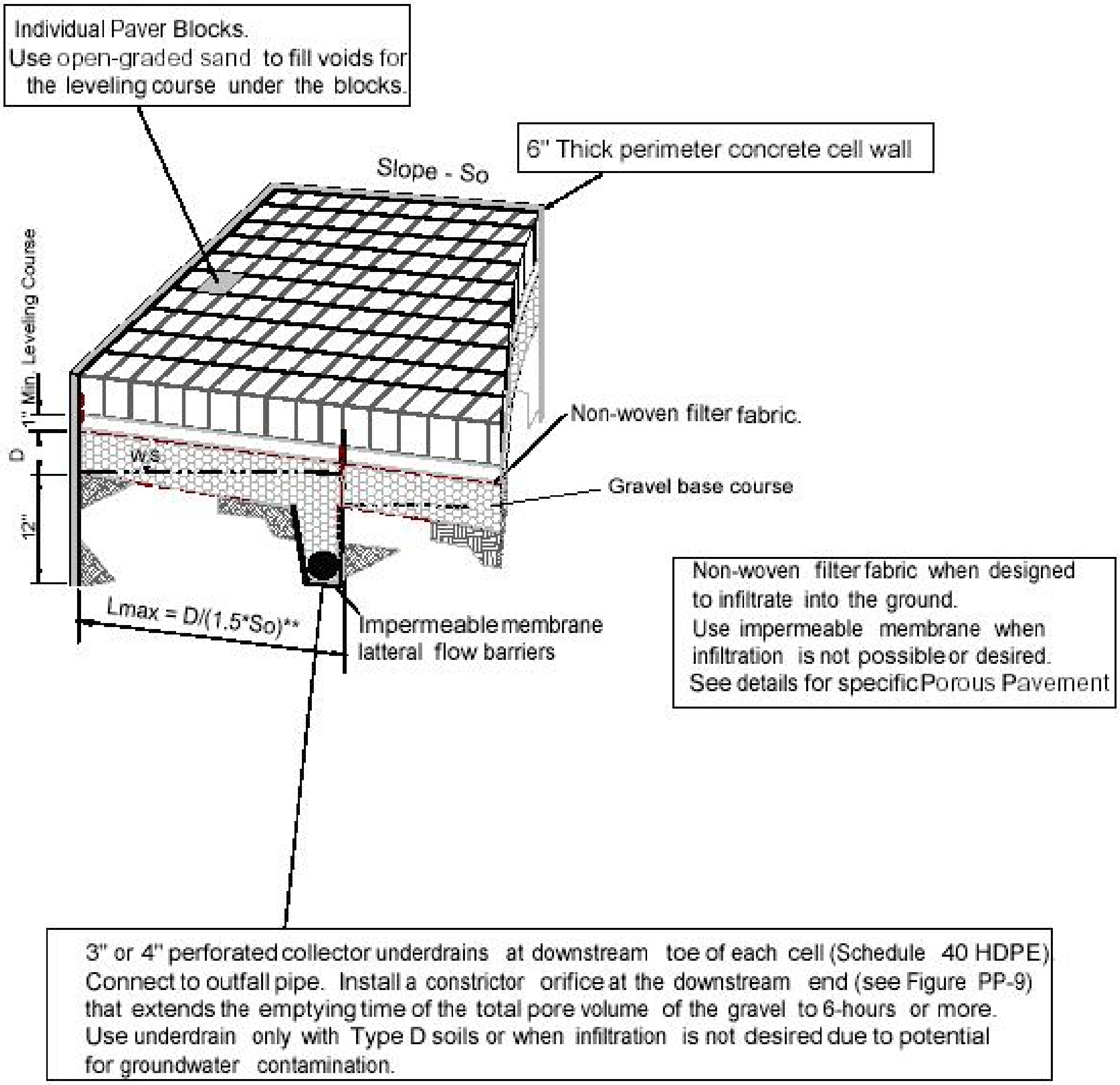


Figure 3-42: View of a Paver Block Installation Showing Perimeter Wall and Contained Cells (modified from UDFCD 2005)

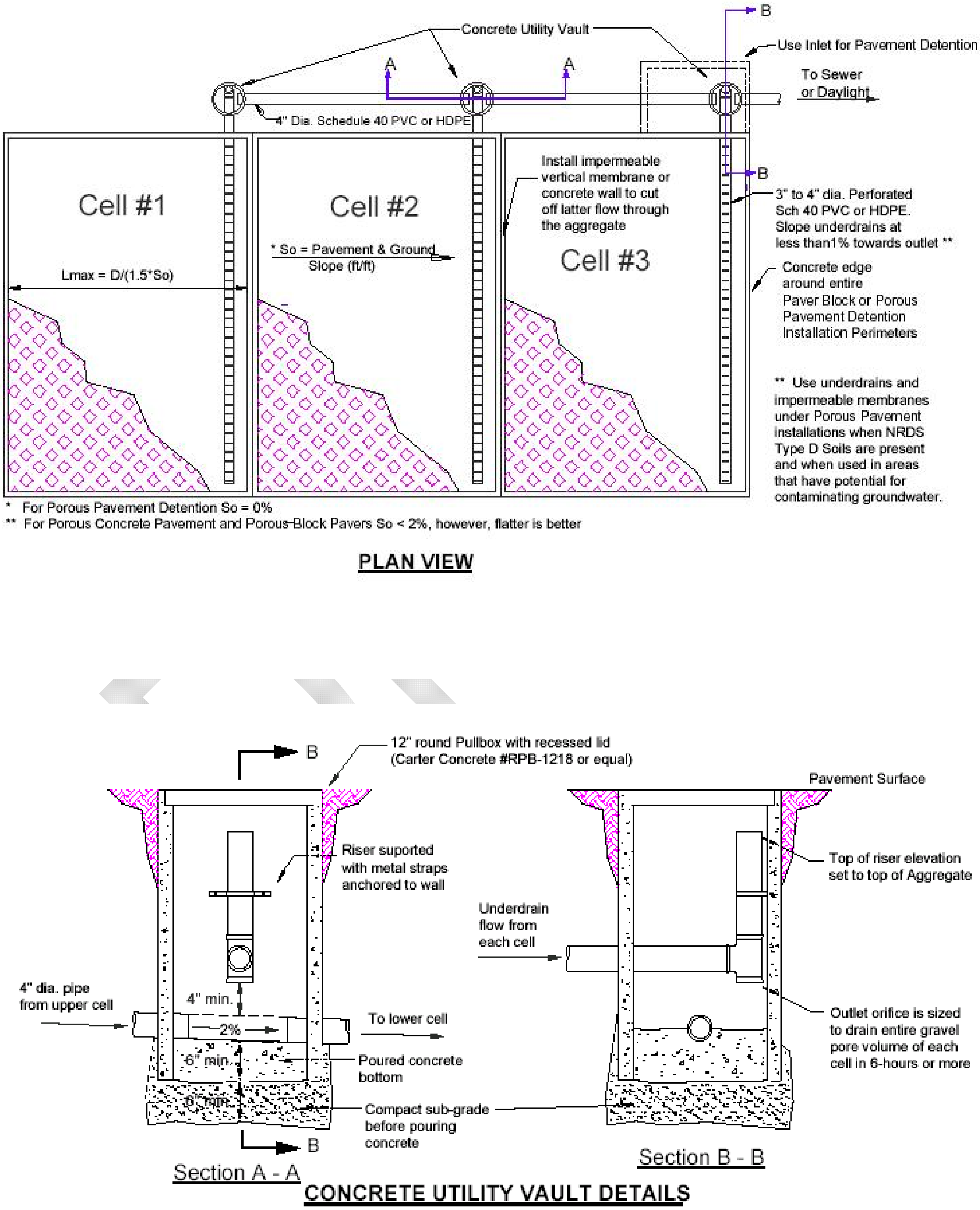


Figure 3-43: Layout for Underdrain System for Porous Pavement Installations (Modified from UDFCD 2005)

### 3.4.4.4 Porous Concrete and Asphalt

Porous concrete and asphalt both make a continuous, smooth paving surface like their impervious counterparts. However, they are made by binding open-graded aggregate, and therefore contain void spaces that allow water to pass through to a permeable sub base layer. Porous materials such as clean gravels placed below the porous concrete or asphalt detain and filter pollutants prior to infiltration into the underlying soils or discharge to an underdrain and the conventional storm drain system.

**Applications and Advantages**

Porous concrete and asphalt are ideal for light to medium duty applications such as residential access roads, residential street parking lanes, parking lot stalls in parking lots, overflow parking areas, utility access, sidewalks, bike paths, maintenance walkways/trails, residential driveways, stopping lanes on divided highways, and patios. Porous asphalt has, however, also been used in heavy applications such as airport runways and highways because its porosity creates a favorable driving surface in rainy weather.

Porous concrete and asphalt can also reduce icing hazards during winter freeze and thaw cycles as runoff will tend to infiltrate rather than freeze onto the surface of roadways, parking lots, driveways and sidewalks. (Photo source: Cahill & Associates)

**Performance Data**

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 70 - 90 |
| Total Phosphorus | 40 - 55 |
| Total Nitrogen | 10 - 20 |
| Total Zinc | 40 - 80 |
| Total Lead | 60 - 70 |

**Source:**

UDFCD 1999.

**Limitations**

- Typically not to be applied on streets where speeds exceed 30 mph or streets that experience high-traffic loads
- Not recommended for slopes over 5 percent

- Not applicable where the seasonal high groundwater table is less than 5 feet below the bottom of the gravel sub-base layer of a porous concrete or porous asphalt installation

- Sand and salt applied to porous roadways, parking lots, and sidewalks in winter can clog void spaces and render permeability ineffective if not removed annually

- Porous concrete may experience raveling if not properly installed

- Porous asphalt and concrete may become clogged if not protected from nearby construction activities, areas of bare soil without landscaping, downslope of steep, erosion-prone areas, or when not maintained

- Applications with underdrain systems are typically more expensive than conventional asphalt and concrete

- Porous asphalt and concrete shall be avoided in drainage areas with activities generate highly contaminated runoff

- Not to be applied in areas where wind erosion supplies significant amounts of windblown sediments.

**Siting Criteria**

- Pervious pavement shall be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces. However, they can also be placed on gentle slopes that do not exceed 5 percent.

- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).

- The seasonal high water table shall be more than 3 feet below the bottom of the gravel sub-base.

**Design and Construction Criteria**

- Registered professional civil engineers shall design porous pavements

- Avoid installing in high traffic areas

- Slopes shall be flat or very gentle (less than 5 percent)

- Pretreatment recommended to treat runoff from surrounding areas

- Filter fabric shall be placed on the bottom and sides of the sub base reservoir

- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure

- To allow infiltration and minimize clogging, the filter fabric shall be woven geotextile fabric layer such as SI Corporation Geode 117F or an approved equivalent
- Use an open-graded aggregate to provide open voids in the gravel sub base
- Erosion and sediment introduction from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces in base material and permeable surface
- Install porous asphalt and concrete towards the end of construction activities to minimize sediment problems
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement
- During emplacement of porous concrete, boards should be used to separate individual pours and to produce uniform seams between adjacent pours.

**Inspection and Maintenance Requirements**

- The overall maintenance goal is to avoid clogging of the void spaces
- Accumulated debris and litter shall be routinely removed as a source control measure
- Inspect porous asphalt and concrete several times during the first few storms to insure proper infiltration and drainage. After the first year, inspect at least once a year
- Permeable pavements and materials shall be cleaned with a vacuum-type street cleaner a minimum of twice a year (before and after the winter)
- Hand held pressure washers can be effective for cleaning the void spaces of small areas and shall follow vacuum cleaning
- Maintenance personnel must be instructed not to seal or pave with non-porous materials
- Pavement must not be sanded in the winter to avoid clogging the void spaces.

**References**

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### 3.4.4.5 Porous Turf Pavement

Porous turf pavement is a stabilized grass surface that can support intermittent pedestrian or vehicular traffic, underlain by an open-graded (single-sized) sandy root zone, and a permeable aggregate base course. Porous turf pavement applications should be applied when the appearance of grass is desired, but a load bearing capability of a pavement surface is needed. The turf surface can be either reinforced or un-reinforced, with reinforced turf containing synthetic reinforcement that assists the turf in resisting wear and compaction, allowing it to bear a heavier traffic load. Advantages of porous turf pavement include the appearance of a "green space" when not used for parking, as well as the benefit of a living surface which actively cools by transpiration counteracting the urban heat island effect (Ferguson 2005).

#### Applications and Advantages

Porous turf pavement is suitable for any area that desire turf application and also for parking areas with frequencies of up to once per week. Ideal settings are sports fields, overflow parking areas, church and football stadium parking lots, event parking, roadway shoulders, parking lanes, crossover lanes on divided highways, flea market parking, and maintenance roads and trails. The suitable application of these porous turf pavement applications for parking lots would be to have the vehicle movement lanes leading up to the porous turf constructed of another type of material such as porous concrete or asphalt pavement (i.e. porous turf parking pads with porous concrete or asphalt lanes). This reduces grass wear from excessive traffic on the porous turf surface, decreasing the porosity and increasing maintenance. Porous turf applications can also be multiuse facilities, for example a sports field that also serves as a special event parking lot.

## Performance Data

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 70 - 90 |
| Total Phosphorus | 40 - 55 |
| Total Nitrogen | 10 - 20 |
| Total Zinc | 40 - 80 |
| Total Lead | 60 - 70 |

**Source:**

UDFCD 1999.

## Limitations

- Not to be applied in heavily trafficked areas, grass wear can result
- Until grass is established, surface cannot be used
- Requires supplemental irrigation
- A uniformly graded vegetative cover is required to function properly
- Excessive traffic can cause soil compaction and reduce infiltration
- Weed invasion can result from thinning of grass cover
- Turning action of vehicles can be problematic for porous turf, damaging structure of the leaves and sometimes causing root damage
- May be problematic for high-heeled shoes. Smooth-soled shoes can slip on wet grass
- Grass species shall be selected based on wear tolerance and irrigation needs for specific site conditions
- Grass selection, traffic control, and good maintenance for health and vigor are all important for turf grass wear prevention and recovery.

## Siting Criteria

- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites)
- Must be installed only in settings where they will be free of traffic on a predictable schedule for maintenance

- If designed to infiltrate stormwater into underlying soils, porous pavements are considered indirect infiltration systems. Therefore apply site screening, infiltration testing (if the project is 20 acres or greater), separation, and setback standards for indirect infiltration systems presented in Section 4.3.3.

**Design and Construction Criteria**

- Registered professional civil engineers shall design porous pavements.
- Sub-base layers shall be capable of bearing an appropriate load without deforming.
- Pervious pavements shall be the last thing to install during construction or redevelopment.
- When designing the sub-base reservoir to detain the water quality volume, select the appropriate porosity value for the sub-base material used.
- Direct sediment-laden runoff away from the porous pavements.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.
- The surface course, or root zone, should consist of an aggregate meeting the gradation requirements.
- The sandy root zone shall have a thickness of 12 inches.
- A permeable aggregate base course shall be constructed. If Class C backfill is used, a woven filter fabric shall be installed between the root zone and the aggregate base course.
- To allow infiltration and minimize clogging, the filter fabric shall be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- The aggregate base course shall be at least several inches thick.
- The storage capacity of the open-graded aggregate base course depends upon local detention requirements and can be sized to capture, detain and filter the Water Quality Volume ($WQ_V$) as discussed in Section 4.4.2.
- If needed, a filter fabric or a filter layer of coarse sand 2 to 4 inches in depth can be installed between the root zone and aggregate base course.
- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure.

- Underdrains are required for installations over existing site soils with infiltration rates of 0.5 in/hr (120 min/in) or less or when an impermeable membrane liner is installed to prevent infiltration into underlying existing site soils.

- Turf shall be installed by seeding. Root zone material should be tested by a qualified lab and soil treated with appropriate lime or fertilizer as recommended for establishment success.

- Proprietary meshes, mats, and fibers are available for reinforcing turf root zones.

- Turf can also be installed in open-celled grids or pavers.

- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.

- Allow turf at least one full growing season to establish before use.

- If seeding, seed in the fall or early spring to avoid heat stress.

**Inspection and Maintenance Requirements**

- Porous turf requires regular maintenance associated with regular lawns such as irrigation, mowing, fertilization, aeration, topdressing, reseeding, disease control, insect control, and weed management.

- Soil testing should be conducted at least once every other year to determine proper fertilization, which will help to maintain turf stress tolerance.

- Routine mowing will be required in the growing season.

- Above ground biomass is important in wear tolerance, therefore high mowing can increase a grasses resistance to traffic stress. Mowing patters should also be altered regularly to limit wear from repetitive wheel action.

- Reseeding may be required to maintain a uniform turf cover.

- Topdressing material should be at least as coarse and open-graded as the root zone.

- Irrigation operations shall follow local water conservation ordinances in effect.

- Traffic routes can be spread out or rotated to give the turf time to recover between uses. Traffic control can also divert traffic away from areas which are showing signs of wear.

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### 3.4.4.6 Porous Gravel Pavement

Porous gravel pavement, or crushed aggregate, consists of a loose gravel-surface paving placed over a porous sub-base. Porous materials such as clean gravels placed below the porous pavement detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system. This type of pavement reduces runoff from paved areas and the ponding that typically occurs in parking lots during and after storm events.

#### Applications

Porous gravel pavement can be used as a substitute for conventional pavement. It is most appropriate for industrial sites and uses such as storage yards or for vehicle parking. Other examples include residential driveways, residential street parking, low vehicle movement zones such as parking lots and maintenance roads, maintenance walkways/trails, and stopping lanes on divided highways.

#### Performance Data

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 70 - 90 |
| Total Phosphorus | 40 - 55 |
| Total Nitrogen | 10 - 20 |
| Total Zinc | 40 - 80 |
| Total Lead | 60 - 70 |

**Source:**

UDFCD 1999.

### Limitations

- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.
- Care must be taken when applying in commercial or industrial areas.
- May become clogged if not properly installed and maintained.
- Porous pavements may cause uneven driving surfaces and may be problematic for high heel shoes and ADA compliance.

### Siting Criteria

- Pervious gravel pavement shall be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces. However they can also be placed on gentle slopes that do not exceed 5 percent.
- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).
- The seasonal high water table shall be more than 3 feet below the ground surface.

### Design and Construction Criteria

- Registered professional civil engineers shall design porous pavements.
- Sub-base layers shall be capable of bearing an appropriate load without deforming.
- Pervious pavements shall be the last thing to install during construction or redevelopment.
- Use a single size grading to provide open voids between sand or gravel sub-bases.
- When designing the sub-base reservoir to detain the water quality volume, select the appropriate porosity value for the sub-base material used.
- Direct sediment-laden runoff away from the porous pavements.
- Thickness of porous gravel layer shall be designed to support the traffic and vehicle loads pavement will need to carry.
- Filter fabrics shall be placed on the bottom and sides of the sub-base layer.
- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure.

- To allow infiltration and minimize clogging, the filter fabric shall be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.

- Lateral-flow cut-off barriers shall be installed using a 16-mil or thicker PE or PVC impermeable membrane liner or concrete walls installed normal to flow. This minimizes the downstream flow of water ant the resurfacing of water at the toe of the block installation.

- Distance between cut-off barriers shall not exceed:

$$L_{MAX} = D/(1.5*S_o)$$

  Where:

  $L_{MAX}$ = Max distance between cut-off barriers normal to flow (ft)

  D = Depth of the aggregate base course (ft/ft)

  $S_o$ = Slope of the base course (ft)

- Underdrains are required for installations over soils with infiltration rates less than 0.5 in/hr or when an impermeable membrane liner is needed.

- A sand filter layer is required for installations over expansive soils or when underdrains are required.

- A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal shall be placed on top of and below the sand filter layer.

- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.

- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.

- The storage capacity of the stone reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the Water Quality Volume ($WQ_V$) as discussed in Section 4.4.2.

**Inspection and Maintenance Requirements**

- Accumulated debris and litter removal as needed

- Maintenance is required to minimize clogging of the pervious surface

- Occasional weed suppression may be required

- Periodic replenishing and/or raking of displaced gravel may be required

- Inspect sand filter routinely and after storm events to insure proper infiltration and drainage

- Frequently inspect the pavement to insure proper infiltration and drainage during the first wet season, and then once a year following that time

- Replacement of surface sand filter layer may occur when runoff does not infiltrate readily into the surface

- Inspect surface gravels once a year. When inspections show accumulation of sediment and debris on top of gravel or slow infiltration, remove and replace top few inches of gravel.

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### 3.4.4.7 Open-Celled Plastic Grids

Open-celled plastic grids, also known as geocells, are manufactured plastic lattices which can be filled with aggregate or topsoil and planted with turf. Many of these systems are made from recycled plastics. The grid systems contain hollow rings or hexagonal cells from 1 to 2 inches thick and a few inches wide. Since the cells occupy very little surface area in most systems, they appear as a turf or gravel surface. Some models are also joined at the bottom by either a perforated plastic sheet or geotextile fused to the bottom of the grid which is placed on the underlying base course. It is important that this area is open for rooting of grasses. Most open-celled grid systems are flexible, so they are tolerant of swelling or freezing soils and are applicable on uneven sites.

## Applications and Advantages

Open-celled grids shall be limited to low intensity use and areas with low traffic speeds. Examples include driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, utility access, ATV and off-road bike trails, golf cart paths, emergency vehicle and fire access lanes, loading areas, and alleys.

## Performance Data

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total Suspended Solids | 70 - 90 |
| Total Phosphorus | 40 - 55 |
| Total Nitrogen | 10 - 20 |
| Total Zinc | 40 - 80 |
| Total Lead | 60 - 70 |

**Source:**

UDFCD 1999.

## Limitations

- Sharp turning on grids shall be avoided
- May be problematic for high-heeled shoes
- Irrigation of porous turf installation in open-celled grids has the potential to require heavier irrigation than normal due to the low water holding capacity of the soil in grids
- Slopes shall not exceed 5%
- Not to be applied in heavily trafficked areas or where speeds exceed 20 miles per hour.

## Siting Criteria

- Open-Celled Plastic Grids shall be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces. However they can also be placed on gentle slopes that do not exceed 5 percent.
- If designed to infiltrate stormwater into underlying soils, porous pavements are considered indirect infiltration systems. Therefore apply site screening, infiltration testing (if the project is 20 acres or greater), separation, and setback standards for indirect infiltration systems presented in Section 4.3.3.

**Design and Construction Criteria**

- Registered professional civil engineers should design porous pavements.
- Sub-base layers should be capable of bearing an appropriate load without deforming.
- Open-Celled Plastic Grids shall be the last thing to install during construction or redevelopment.
- An open-graded permeable base course shall be constructed according to manufacturers' specifications.
- The storage capacity of the open-graded aggregate base course depends upon local detention requirements and can be sized to capture, detain and filter the Water Quality Volume ($WQ_V$) as discussed in Section 4.4.2.
- Lattices come in pre-assembled panels or rolls in various dimensions, from a few square feet to rolls that can be spread out to cover large areas.
- Grids need to be anchored to the base in some applications, depending on the model, to minimize being jarred by moving traffic. Anchors may consist of plastic spikes, pins, or rods, or even boulders, logs, or wheel stops over the surface.
- A setting bed of smaller aggregate may be needed over the base course to make a uniform surface for the open-celled grids.
- Woven filter fabrics shall be placed on the bottom and sides of the base course layer.
- An impermeable liner and an underdrain system shall be included in the design of the BMP in areas where there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur, or where in the opinion of a professional registered geotechnical engineer, infiltration of stormwater may result in slope failure, foundation settlement, pavement failure or a negative impact to existing underground infrastructure.
- To allow infiltration and minimize clogging, the filter fabric shall be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- Underdrains are required for installations over soils with infiltration rates less than 0.5 in/hr or when an impermeable membrane liner is needed.

**For Open-Celled Grids filled with Aggregate**

- Aggregate fill must be open-graded Aggregate is compacted into place with a vibrating plate or roller
- Follow manufacturer's specifications for top course installation.

**For Open-Celled Plastic Grids planted with Turf**

- The planting medium should be settled into cells by vibrating or watering
- The planting medium should consist of open-graded fine aggregate.
- Seeding is preferred to sod to provide optimum infiltration rates.
- If sod is used, it shall not contain a high percentage of clay that inhibits infiltration.
- Sod should only be installed with thin-walled grid systems.
- Sod can be installed by pressing into empty cells. Sod should be cut to a depth of the grid system.
- Anchoring may protect growing grass roots and promote deeper rooting, which will add strength to pavement structure.
- An open-graded aggregate filter layer shall be used on top of the base course (do not use a geotextile filter fabric).
- Traffic shall not be allowed on the surface until after turf is established.

**Inspection and Maintenance Requirements**

- Sections can be removed and replaced for utility access and pavement repair
- Remove and replace grid segments where three or more adjacent rings are broken or damaged.

**For Open-Celled Plastic Grids filled with aggregate**

- Accumulated debris and litter removal as needed.
- Maintenance is required to minimize clogging of the pervious surface.
- Occasional weed suppression may be required.
- Periodic replenishing and/or raking of displaced gravel may be required.
- Inspect surface gravels once a year. When inspections show accumulation of sediment and debris on top of gravel or slow infiltration, remove and replace top few inches of gravel.

**For Open-Celled Plastic Grids planted with turf**

- For open-celled grids filled with turf, mechanical aeration of must be avoided, as this can damage the plastic material.

See maintenance requirements for Porous Turf.

**References**

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### 3.4.5 Green Roofs

A Green Roof is a vegetated roofing system. Green Roofs typically consists of a number of layers: a waterproofing membrane, a drainage system, root protection, growing media (soil) and vegetation. Green Roofs provide numerous environmental benefits and offer a valuable tool for integrated stormwater management.

*Photo: Jonathan Feldman*

Figure 3-43: Green Roof on Carmel Valley, CA Residence


*Photo: www.infrastructures.com*

Figure 3-44: Green Roof on a Commercial Office Building

Green Roofs have been a popular sustainable building practice to improve urban environments in Europe since the 1970s. However, it is still an immature market and evolving practice in the

United States[5]. Many terms may be used to describe Green Roof systems. The list below describes some of the related terms:

- *Ecoroof* is used to describe lightweight vegetated roof systems, implemented as a sustainable building technique that limits impacts on the natural environment.
- *Roof garden* is a term generally describes a useable garden space that includes some vegetation. This type of roof system typically requires extra structural support and consequently, costs more to build.
- *Vegetated roof* is a general term that may describe a number of Green Roof objectives.
- *Living roof* is a general term that may describe a number of Green Roof objectives.

Structurally, there are two types of Green Roofs: intensive and extensive. Extensive Green Roofs are lightweight vegetated roofs consisting of 4-8 inches of growth media (or soil), planted with hardy, drought-tolerant species to minimize additional irrigation, maintenance, cost and weight[6]. They typically require supplemental irrigation to support growth during extended dry periods.

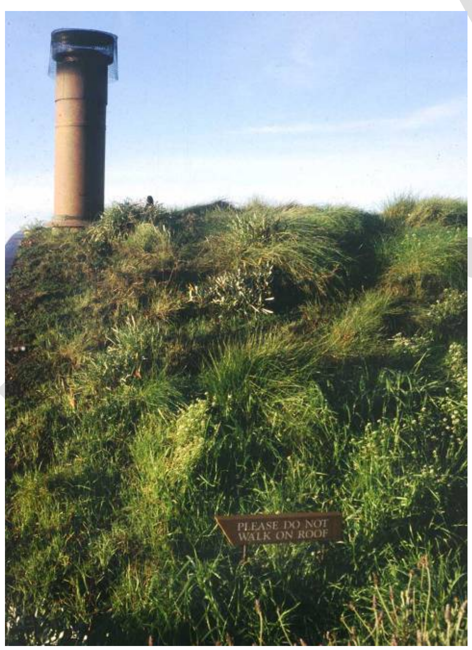


Photo: Rana Creek

Figure 3-46: Extensive Green Roof Big Sur, CA


Photo: Rana Creek

Figure 3-47: Extensive Green Roof at Post Ranch Inn, Big Sur, CA

Alternatively, *intensive* Green Roofs can be designed to support lawns, trees, and create a useable outdoor garden space; often referred to as *roof gardens*. While these amenities do not preclude environmental benefits of Green Roofs, they do require extra structural support, cost,

[5] Rozenzweig, C. et al. and Green Roofs for Healthy Cities
[6] Rozenzweig, C. et al. and City of Portland, Bureau of Environmental Services

and have functional goals in addition to sustainable building objectives. They also typically require supplemental irrigation systems.


Figure 3-48: Intensive Green Roof on a Parking Structure at Stanford University, Palo Alto, CA



**Stormwater Management**

As a stormwater management strategy, Green Roofs can help meet the following LID objectives:

- Absorbs rainfall
- Reduces urban runoff at its source
- Increases evapotranspiration
- Reduces heat island effect.

Green Roofs provide small-scale decentralized controls that collect, absorb, and increase the evaportranspiration rates of rainfall. Additionally, Green Roofs are effective in reducing the heat island effect of urbanized areas containing large impervious surfaces. By reducing the temperatures of the runoff, the thermal impacts of urban runoff on local waterways are reduced.

**Benefits**

Green Roofs provide numerous environmental, economic and social benefits listed below.

- **Absorbs rainfall at the source.** 10-100% of roof runoff is absorbed and utilized by the vegetation[7]. Peak stormwater flow rates are also reduced.
- **Improves building insulation**. This reduces heating and cooling costs and energy consumption.[8]
- **Reduces heat island effect** and the associated effects on waterway temperatures.

[7] City of Portland, Bureau of Environmental Services. Note: estimates vary depending on the climate, depth of growing media, and plant materials.

[8] Rozenzweig, C. et al.

- **Increases wildlife habitat** for birds and insects that is often scarce in urban areas.

- **Absorbs noise pollution** through soils, plants, and trapped layers of air.

- **Reduces glare** that affects adjacent buildings and habitat.

- **Increases life-span of roof** by protecting the roof's structural elements from UV rays, wind and temperature fluctuations. Green Roofs typically last twice as long as conventional roofs.[9]

- **Improves air quality** by reducing air temperatures, filtering smog, binding dust particles, and converting carbon dioxide to oxygen through photosynthesis.

- **Provides an attractive roof.** In urbanized areas, Green Roofs integrate living systems into the built environment. In less urbanized areas, Green Roofs can help blend a structure into the surrounding landscape.

## Siting Criteria

### *Regional Criteria*

As a stormwater management strategy on California's Central Coast, Green Roofs are best utilized in highly urbanized areas where there is little pervious ground surface to infiltrate and manage stormwater or on buildings with significant roof areas such as industrial facilities, warehouses, shopping centers, and office buildings. Though environmental benefits still pertain in less urbanized areas, the initial cost of Green Roof implementation may preclude their use as a stormwater management strategy in these areas because more cost effective solutions that utilize open spaces or landscaped areas may be available. Green Roofs are also utilized on the Central Coast in an effort to blend structures into the scenic landscapes and protect native plant species, such as on the Big Sur coastline.

The Central Coast's temperate climate is amenable to succulents, grasses, and native perennials that are recommended for Green Roofs. Short bursts of supplemental irrigation may be necessary to maintain a green appearance and for fire protection during the dry season.

*Photo: Rana Creek*

Figure 3-49: Green Roof at GAP Corporate Campus, San Bruno, CA

[9] Green Roofs for Healthy Cities, City of Portland, Bureau of Environmental Services, and Rosenzweig, C. et al.

### Limitations

- **Initial costs** are typically significantly more than a standard roof. However, extensive Green Roofs can be competitive on a life cycle basis.
- **Specific maintenance**, such as irrigation and cleaning out drainage features will need to be factored into the long-term building care.
- **Untraditional** design and installation may stall the permitting process. Green Roof systems are still an evolving market and practice that needs perfecting in North America.
- **Immature market and government policies**. Not yet widely understood, regional and local governments may not yet be providing economic or policy incentives to implement Green Roofs.

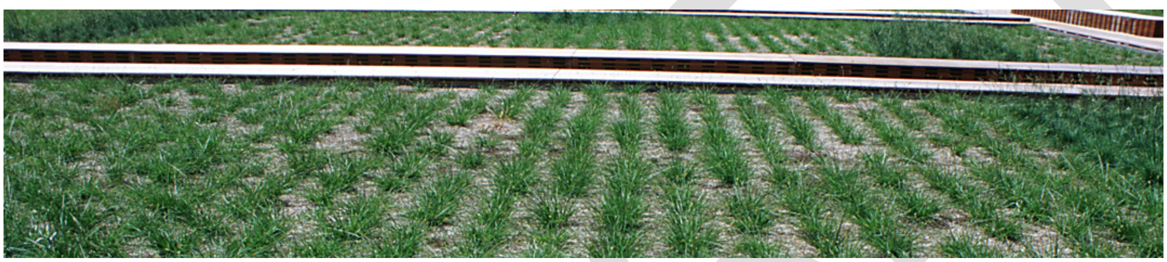

*Photo: Rana Creek*

### PROGRESSIVE POLICIES AND INCENTIVES

Numerous economic benefits can help to offset initial costs of Green Roofs including: reduced energy costs, extended roof life, increased property values. Some jurisdictions are promoting their implementation through various incentive programs such as:

- Lowered stormwater utility fees
- Increased floor to area ratios and/or density bonuses
- Faster permitting for new projects
- Energy tax credits
- Grants and subsidies for Green Roofs and energy efficient building
- LEED credits from the U.S. Green Building Council

### Design and Construction

Green Roofs can be placed on flat or pitched roof structures at slopes up to 40 percent (or 5 in 12 pitch).[10] Green Roofs can be incorporated into new construction or onto the roofs of existing buildings. Though several site factors will need to be considered, such as the aspect of the roof, the microclimate of the site, prevailing winds and the building's functions – most factors can be accommodated into a successful Green Roof design.

[10] City of Portland, Bureau of Environmental Services.

Extensive Green Roof systems are composed of several layers. The roof systems may be modular interlocking components or each layer may be installed separately. Either way an extensive Green Roof is constructed with the following basic layers (starting at the bottom): structural support, a waterproof roofing membrane (including flashing), a root barrier, drainage, a porous drainage medium layer, a filter fabric layer to contain the growing medium (soil), and plant materials and mulch. Other elements shown in the diagram below may be optional or required depending upon the conditions of the roof design.

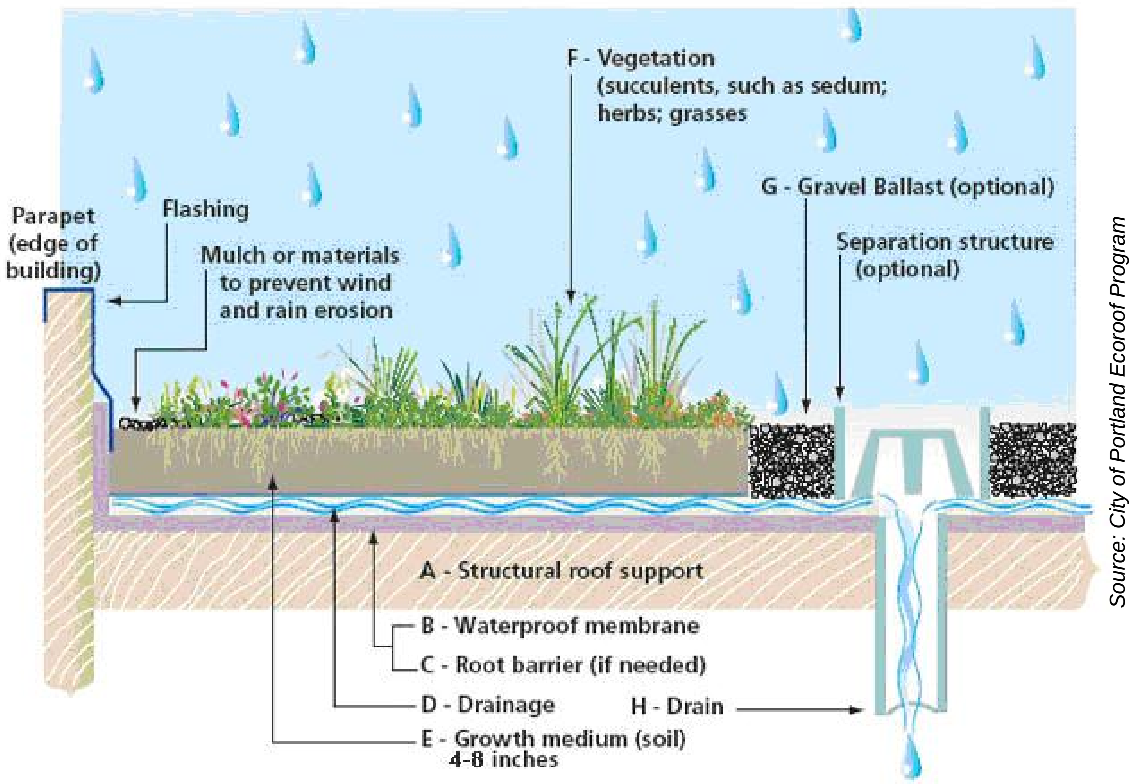


Figure 3-50: Green Roof Construction Detail Schematic

Generally, a building's structure must be able to support an additional 10-25 pounds per square foot of saturated weight, depending on the growth media and vegetation used. For New construction, the load requirement of the Green Roof can be addressed as part of the building's design process. Additional structural support may be necessary for a re-roofing project; however, many existing buildings are structurally sound enough to accommodate a Green Roof.[11] Green Roofs can be designed by architects, landscape architects, and building contractors. Since Green Roof systems include materials not found on convention roofs, it is recommended that qualified roofing contractor with Green Roof experience is chosen to install the design.[12]

[11] City of Portland, Bureau of Environmental Services.

[12] Green Roofs for Healthy Cities

Green Roofs may require maintenance beyond standard roof care. Long term management shall be factored into appropriate siting of Green Roofs.

**Inspection and Maintenance**

- Upon installation, the Green Roof system should be inspected monthly for the first year and after each large storm event for erosion, plant survival, proper drainage and water proofing
- Inspections can be reduced to a quarterly schedule once the Green Roof system has proven to work properly and vegetation is established
- If necessary, irrigate in short bursts only (3-5 minutes) to minimize runoff. Irrigation frequencies shall be established by the designer using an automated system
- Clean out drain inlets as needed.
- Weeding and mulching may be necessary during the establishment period, depending on the planting design
- Replace or fill in vegetation as needed
- Inspect soil levels semi-annually to improve plant survival and rainfall absorption
- If the vegetation used is flammable during the dry season, it shall be mowed or watered as needed to minimize fire potential.

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**Photograph Sources**

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### 3.4.6 Infiltration Basins

Infiltration basins capture stormwater runoff and allow it to infiltrate into the ground. They must be sited in flat areas that have permeable existing site soils and a sufficient depth to groundwater. They are similar to infiltration trenches, however they can use a wider variety of filter media, can be vegetated on the basin bottom and can serve larger drainage areas. Pollutants such as suspended solids, metals, nutrients, and bacteria are removed through sedimentation, adsorption, and physical filtration through permeable media and soil, thereby improving water quality. As is the case with infiltration trenches, they must be protected from sediment sources that can clog the filter media. Therefore upstream pretreatment with vegetated swales or other structural treatment controls is typically required.

**Applications and Advantages**

Infiltration systems are applied in areas with well-drained and pervious soils. They are typically applied to drainage areas ranging between 5 and 50 acres. On select sites, it is relatively easy to incorporate an infiltration basin into a site's open space design and layout. Infiltration basins are ideal for areas adjacent to roadways and near interchanges. However, they must not be used in industrial or commercial areas where hazardous or toxic materials are stored outdoors and the potential for spills is relatively high.

**Performance Data**

Infiltration basins can provide 100 percent reduction in pollutant loading directly to surface waters. Infiltration basins can also provide high pollutant removal efficiency for particulates and moderate efficiency for soluble pollutants when functioning as designed. Actual loading to the subsurface may vary significantly depending on site-specific conditions. Studies in the Pacific Northwest have shown improved long-term performance for basins developed in highly permeable soils.

The literature reported range of removal for various pollutants is as follows:

| Pollutant | Percent Removal Efficiency |
|---|---|
| Total suspended solids | 55 – 75 |
| Total Phosphorus | 45 – 55 |
| Total Nitrogen | 10 – 20 |
| Total Recoverable Zinc | 30 – 60 |
| Total Recoverable Lead | 55 – 80 |

**Source:**

UDFCD 1999.

**Limitations**

- There may be significant concerns regarding the potential to degrade groundwater
- Should not be applied where the tributary drainage area to the infiltration basin includes an automotive repair shop, a car wash, a fleet storage area (buses, trucks, etc.), a nursery or any business or operation that provides outdoor storage of hazardous or toxic materials that may impact groundwater if a spill were to occur
- Should not be applied on slopes greater than 15%
- Large drainage areas require a relatively large amount of land surface area for relatively large infiltration basins
- Tributary areas with highly erodible soils will require greater maintenance
- Not to be applied in areas with existing soil or water contamination
- Not to be applied in areas with existing clay or silty soils or in areas where imported fill soils cover existing site soils
- Difficult to maintain and restore if clogging occurs
- Infiltration trenches that incorporate piping that emplaces stormwater underground may be subject to Underground Injection Control (UIC) regulations
- If any surface dimension of the trench is less than the trench is deep, it may be considered a Class V Injection Well subject to additional UIC regulatory permitting.



**Siting Criteria**

- Infiltration basins shall not be used in areas where existing site soils have infiltration (percolation) rates of less than 1.0 in/hr (60 min/in) or greater than 2.4 in/hr (25 min/in)
- Prior to siting infiltration basins, review the Considerations for Designing Infiltration Systems presented in Section 4.3.2 and the Setbacks for Stormwater Infiltration BMPs presented in Section 4.3.3 of these standards

**Design and Construction Criteria**

- Registered professional civil engineers shall design infiltration basins
- Size the basin to capture and treat the water quality volume ($WQ_V$) using the method outlined in Section 4.4.2
- Flows in excess of the $WQ_V$ shall be diverted around the infiltration basin with an upstream diversion structure (see Section 4.5)

- The basin shall be designed to drain the entire water quality volume within 72 hours

- Sufficient technical knowledge of the vertical and lateral movement of infiltrated runoff through soil and the interaction with groundwater shall be established through a geotechnical investigation

- Installation of an inlet energy dissipation structure is recommended where inflow velocities may cause erosion of the filter media

- The basin dimensions shall be determined using the following equation:

$$A = WQ_V / (k \times t)$$

  Where:

  A = Basin invert area ($ft^2$)

  $WQ_V$ = water quality volume ($ft^3$)

  k = 0.5 x $K_h$ , where $K_h$ is the lowest field measured hydraulic conductivity (in/hr)

  t = minimum drain time (72 hours)

- Basin side slopes shall be 3H:1V or flatter

- The slope of the floor of the basin shall not exceed 5 percent

- Disturbed soils within the drainage area of the infiltration basin shall be stabilized with vegetation within one week of construction

- Install berms around the infiltration basin during construction activities to keep sediment and runoff from entering the filter media

- During construction, an easily removable filter cloth can be installed over the permeable media to minimize clogging of the basin from construction related sediments

- A large area, a flat bottom, and a dense-turf buffer zone will to improve the performance of an infiltration basin.

**Inspection and Maintenance Requirements**

- Inspect following major storm events during the first year after installation.

- Inspect annually for settling, cracking, erosion, leakage, condition of the riprap, state of the turf vegetation, and amount of sedimentation. If necessary, repair immediately.

- If the drawdown time is more than 72 hours, maintenance and replacement of the filter media is required.

- Debris and litter shall be periodically removed from the infiltration basin and vegetation shall be mowed when growth exceeds 6 inches in height.

- If bare and eroded areas are present in the drainage area directly adjacent to the infiltration basin, vegetation and/or additional stabilization methods may be required to minimize premature clogging.

- Every 5 – 10 years the area shall be tilled, fine materials removed and the base of the basin regraded.

- Infiltration basins can be joined with detention basins to improve water quality.

- Vegetation installed within the infiltration basin tends to decrease the rate of clogging.

- A pretreatment device, such as an oil and water separator, may be required in areas where petroleum hydrocarbons in stormwater are anticipated.

- If a spill occurs and hazardous materials contaminate soils, sands or gravels in an infiltration basin, the affected areas shall be removed immediately and the appropriate soils and materials replaced as soon as possible.

**References**

CASQA. 2003. Stormwater Best Management Practice Handbook – New Development and Redevelopment. California Stormwater Quality Association.

City and County of Sacramento. 2000. Guidance Manual for Onsite Stormwater Quality Control Measures.

Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, Fact Sheet – Infiltration Basin, http://www.fhwa.dot.gov/environment/ultraurb/3fs2.htm

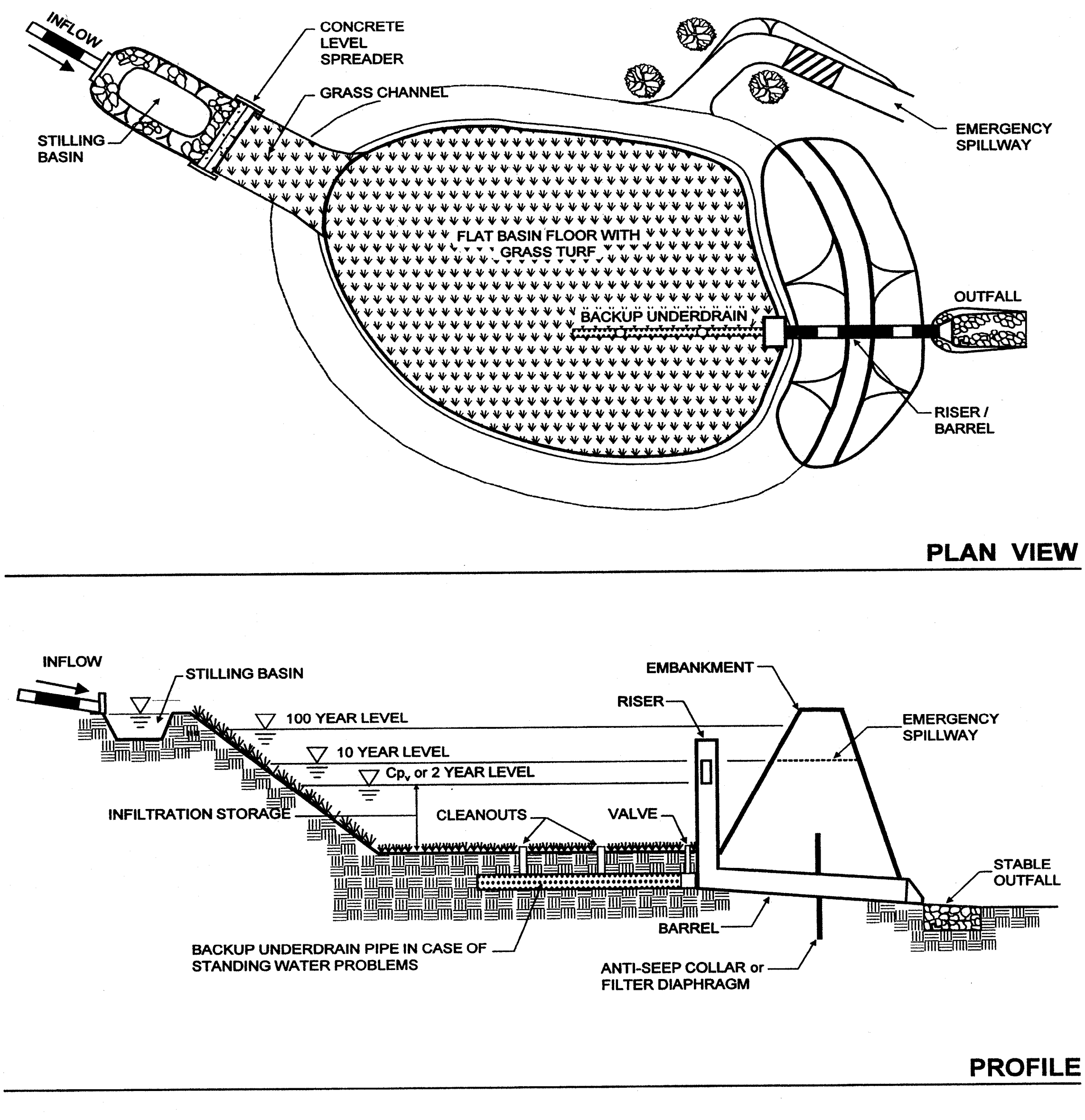


Figure 3-51: Example of a Typical Infiltration Basin Design
(modified from CASQA 2003)

## 3.5 Additional Structural Treatment Controls

Design Guidance for additional structural treatment controls such as Stormwater Ponds and Wetlands, Sedimentation Basins (a.k.a. Extended Detention Basins), Sand Filter Basins, Infiltration Basins and other treatment control BMPs can be found in the current version of the California Stormwater Quality Association (CASQA) *Stormwater Best Management Practice (BMP) Handbook for New Development and Redevelopment* (the CASQA Handbook) http://www.cabmphandbooks.com/. The primary use of the CASQA Handbook is that of a technical design guidance manual. The CASQA Handbook provides additional design guidance for the LID practices and the Integrated Management Practices (IMPs) presented in Section 3.4 above, as well as design guidance for other Structural Treatment Control BMPs (both public domain and manufactured or proprietary designs). Unless otherwise stated, methods used in the CASQA Handbook are approved for use in development design in the City of Salinas. However, when used alone, a number of the Structural Treatment Control BMPs presented in the CASQA Handbook do not meet the Regional Board's definition of MEP. Therefore, the City may allow their use to supplement LID designs and IMPs as part of a treatment train, or to provide pretreatment for an IMP (e.g. a vortex separator that provides up-gradient sediment removal for a bioretention system). In the event of any conflict between the two, the City requirements contained in this Stormwater Development Standards document supersede any recommendations of the CASQA Handbook.

# Section 4: Stormwater Design Considerations

## 4.1 How to Use This Section

The purpose of Section 4 is to provide additional guidance on typical stormwater pollutants and sources from urban development, and the design standards that are required for stormwater infiltration systems and bioretention systems. In addition, this section provides detailed information on the numeric sizing criteria that are to be applied to volume- and flow-based IMPs and other treatment control BMPs. Finally, this section provides design standards for diversion structures that may be needed to isolate IMPs and other treatment control BMPs to keep runoff from the relatively large storm events (the 5-, 20- and 100-year storms) from entering IMPs and BMPs and causing erosion, re-suspension and removal of captured sediment and other pollutants, and to prevent flooding.

## 4.2 Stormwater Pollutants and Sources

The City's current NPDES permit (Appendix C) requires that these Development Standards "*shall* consider *pollutants of concern or activities of concern in identifying appropriate BMPs for new development or significant redevelopment projects. In selecting BMPs the following shall be considered: (1) the target pollutants; (2) land use and pollutants associated with that land use type: (3) pollutants expected to be present on site at concentration that would pose potential water quality concerns; and (4) changes in flow rates and volumes resulting from the development project and sensitivity of receiving water to changes in flow rates and volumes."*

Proper selection of source controls and structural treatment controls includes the identification of anticipated pollutants of concern for proposed new development and redevelopment projects. Table 4-1 provides a general list of the types of pollutants commonly found in urban stormwater, the major sources of these pollutants, and their potential environmental impacts.

Table 4-1: Pollutants Commonly Found in Urban Runoff

| Pollutant | Major Sources | Potential Effects |
|---|---|---|
| **Nutrients**<br>• **Nitrogen**<br>• **Phosphorus** | • Fertilizers<br>• Animal waste<br>• Detergents<br>• Atmospheric deposition<br>• Leaking sewage pipes | • Lowers oxygen levels<br>• Destroys habitat<br>• Promotes algal blooms<br>• Limits recreation<br>• Interferes with navigation |
| **Pathogens**<br>• **Bacteria**<br>• **Viruses** | • Animal waste<br>• Illicit connections between storm sewers and sewage lines<br>• Leaking sewage pipes | • Poses human health risks<br>• Closes beaches<br>• Closes shellfish harvesting areas |
| **Hydrocarbons**<br>• **Oil**<br>• **Grease**<br>• **Petroleum-based products**<br>• **Polycyclic aromatic hydrocarbons (PAHs)** | • Parking lots<br>• Roads<br>• Automobile emissions<br>• Improper disposal of used motor oil<br>• Illicit connections to drain systems | • Lowers levels of dissolved oxygen in receiving waters<br>• Causes toxic impacts<br>• Damages habitat |
| **Toxic Organics**<br>• **Pesticides**<br>• **Polychlorinated biphenyls (PCBs)** | • Lawn care<br>• Agricultural lands<br>• Industrial uses<br>• Illicit connections to storm drain systems | • Causes toxic impacts<br>• Leads to human and animal reproductive abnormalities<br>• Increases animal mortality rates |
| **Sediments** | • Construction sites<br>• Agricultural lands<br>• Logged forest lands<br>• Eroded stream banks | • Increases water turbidity<br>• Alters water flows<br>• Destroys benthic habitat<br>• Blocks sunlight<br>• Attracts particulate forms of metals and nutrients |
| **Metals**<br>• **Lead**<br>• **Copper**<br>• **Cadmium**<br>• **Zinc**<br>• **Mercury**<br>• **Chromium**<br>• **Selenium**<br>• **Nickel** | • Illicit storm drain connections<br>• Automobile use – emissions, brake pad residues<br>• Atmospheric deposition<br>• Industrial activities<br>• Commercial activities | • Increases toxicity of sediment and water column<br>• Adds toxins to food chain<br>• Causes genetic defects and reproductive abnormalities; increases mortality rates among fish and wildlife<br>• Increases risks of cancer, neurological disorders, and birth defects among humans |
| **Litter** | • Human activities | • Affects aesthetics<br>• Impairs recreational uses<br>• Threatens aquatic life |
| **Chlorides** | • Outdoor storage and use of salts on roads, driveways, and sidewalks in cold areas | • Toxic to freshwater organisms |
| **Elevated Temperatures** | • Industrial sources<br>• Removal of trees next to streams and rivers<br>• Impervious surfaces and conveyances | • Threat to insects, fish, and other temperature-sensitive aquatic species |

**Sources:** Terrene Institute 1996, U.S. EPA 1995.

Table 4-2 provides a list of stormwater impacts from several common urban land uses. To evaluate pollutants of concern and the appropriate source control BMPs, LID practices, IMPs, and/or structural treatment control BMPs, the project designer should refer to Table 4-2 and consider the following:

- Land use type of the development project, and pollutants associated with that land use type,
- Materials considered likely to be present on the site that could impact stormwater quality,
- Changes in stormwater discharge flow rates, velocities, durations, and volumes resulting from the development project (e.g., increasing impervious surface area will increase flow velocity and volume), and
- Receiving-water quality, sensitivity of receiving waters to pollutants, and changes in stormwater discharge flow rates, velocities, durations, and volumes.

Significant reductions in structural treatment BMP size and investment can often be realized by controlling sources of pollutants and by implementing LID and reducing runoff that needs to be captured, infiltrated, or treated.

## Table 4-2: Anticipated and Potential Pollutants Generated by Land Use Type

| Development Type | General Pollutant Categories | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pathogens | Heavy Metals | Nutrients | Pesticides | Organic Compounds | Sediments | Trash & Debris | Oxygen Demanding Substances | Oil & Grease |
| Detached Residential Development | A | | A | A | | A | A | A | A |
| Attached Residential Development | P | | A | A | | A | A | P[(a)] | P[(b)] |
| Commercial / Industrial Development >100,000 ft[(b)] | P[(c)] | | P[(a)] | P[(e)] | P[(b)] | P[(a)] | A | P[(e)] | A |
| Automotive Repair Shops | | A | | | A[(d,e)] | | A | | A |
| Restaurants | A | | | | | | A | A | A |
| Hillside Development >5,000 ft[(b)] | | | A | A | | A | A | A | A |
| Parking Lots | | A | P[(a)] | P[(b)] | | P[(a)] | A | P[(e)] | A |
| Streets, Highways & Freeways | | A | P[(a)] | | A[(d)] | A | A | P[(e)] | A |

A = Anticipated

P = Potential

(a) A potential pollutant if landscaping exists onsite.

(b) A potential pollutant if the project includes uncovered parking areas.

(c) A potential pollutant if land use involves food or animal waste products.

(d) Including petroleum hydrocarbons.

(e) Including solvents.

**Source:** CASQA 2003.

## 4.3 Infiltration of Urban Stormwater

The term ***infiltration*** refers to the process of stormwater percolating downward into subsurface soils. Infiltration can occur through existing site soils that are not covered by impervious surfaces, or it can occur through infiltration devices designed to collect and treat urban runoff. Infiltration devices are LID practices of IMPs designed to capture and percolate urban runoff through imported permeable materials (drain rock and/or engineered soils – a mix of topsoil, sand, and compost or peat, see Section 4.3.5). If site conditions allow (e.g. the existing site soils are permeable), urban runoff percolates through infiltration devices and recharges the shallow groundwater system. Infiltration can be the most effective method to reduce the volume, flow rate, and pollutant loading of urban runoff. Pollutants within urban runoff are typically removed by infiltration devices through a variety of physical, chemical, and biological processes. Site planning and grading can minimize runoff and promote infiltration at almost any site.

LID practices and IMPs such as filter strips, swales, bioretention systems (e.g., landscape detention, tree box filters, and stormwater planters), porous paving systems and infiltration basins all work using infiltration as a means of reducing urban runoff volumes, rates and pollutant loads. These IMPs can be used on sites with native clayey soils (not conducive for infiltration) if imported permeable soils, drain rock, and underdrains are included in the design. At sites with existing soils that are more permeable (e.g. sandy soils), it may be possible to install these devices without underdrains and realize cost savings by reducing or eliminating the need to install expensive conventional underground storm drain infrastructure (e.g., reinforced concrete drop inlets and storm drain pipe).

Stormwater infiltration devices are defined in two categories – direct and indirect. ***Direct infiltration devices*** are broadly defined as facilities designed to rapidly infiltrate urban runoff into the subsurface and bypass the natural groundwater protection afforded by surface or near surface soil. Examples of direct infiltration devices include infiltration trenches and dry wells which utilize drain rock installed in trenches or borings. ***Indirect infiltration devices*** are broadly defined as facilities designed to first filter urban runoff through engineered soils prior to infiltration into subsurface soil and/or to an underdrain system. Examples of indirect infiltration devices include vegetated swales and filter strips, bioretention systems, porous paving systems, and infiltration basins.

Direct infiltration devices (e.g., infiltration trenches, drywells, etc.) can also be used on sites with permeable existing site soils, provided the potential threat to groundwater quality is assessed and found to be very low. The City limits the use of these systems due to the potential to impact groundwater quality, therefore direct injection shall only be considered where other LID practices and IMPs (e.g. vegetated swales, bioretention systems, etc.) cannot be applied <u>and</u> there is no threat to groundwater. See Section 4.3.2 for considerations when designing stormwater infiltration systems, which include but are not limited to, minimum separation from the seasonally high groundwater level to prevent groundwater contamination, setbacks from underground storage tanks (USTs) and areas with existing soil and/or groundwater contamination, and concerns with dry wells, Class V injection wells, mosquito breeding and vector control.

### 4.3.1 City of Salinas Soil and Groundwater Conditions

During the development of these standards, Kennedy/Jenks Consultants researched and mapped surface soil and shallow groundwater conditions in the Salinas area and assessed the feasibility of infiltrating urban runoff (Kennedy/Jenks Technical Memorandum No. 2, January 18, 2007). Sources of information used in this analysis included soil survey records from the Natural Resource Conservation Service (NRCS), well log records from the Monterey County Water Resources Agency (MCWRA), and shallow groundwater data from the State Water Resource Control Board's Geotracker web database and the Monterey County Health Department. The research indicated that the soils in the Salinas area are typical of an alluvial depositional environment with discontinuous (horizontal and vertical) layers and mixtures of sands, silts and clays. It also indicated that shallow restrictive layers (~1 foot thick or greater clay layers less than of 5 feet below ground surface or bgs) are relatively extensive throughout the Salinas area. The MCWRA well logs revealed that shallow restrictive clay layers also occur in areas mapped by the NRCS as having soils with moderate infiltration rates (Hydrologic Soil Group B soils). In addition, the research revealed a number of areas with shallow groundwater occurring within 10 feet bgs. These results indicate that the feasibility of infiltrating urban runoff into existing shallow subsurface soils in the Salinas area is limited due to low permeability soils, shallow restrictive layers, and the occurrence shallow groundwater.

Based on the findings of Kennedy/Jenks Technical Memorandum No. 2, policies and procedures related to the infiltration of urban runoff in the Salinas area were developed. The primary policy is that collection of site specific information must be conducted prior to the final design of stormwater infiltration practices for developments of 20 acres or more. This shall include, but not be limited to, infiltration/percolation testing of existing site soils, definition of the seasonal high groundwater table for the site, and the location of water wells and other site constraints (see Table 4-3 for additional information). Unless infiltration/percolation testing indicates existing site soils have adequate infiltration rates (0.5 inches/hr or greater), underdrains shall be specified in the design of all indirect infiltration practices such as swales, bioretention systems, and porous pavements. The City may not require infiltration/percolation testing if the designer chooses to include underdrains in preliminary and final design of indirect stormwater infiltration systems. Direct infiltration practices such as infiltration basins will require faster existing site soil infiltration rates (minimum 1.0 inches/hr or greater) because they are more prone to clogging by fine sediment and are often designed without underdrains.

### 4.3.2 Considerations for Designing Infiltration Systems

A variety of factors may limit or prevent the use of certain urban stormwater infiltration methods. If not sited, designed and maintained properly, stormwater infiltration methods can have unintended consequences including but, not limited to, groundwater contamination, stormwater seepage into building foundations which may cause settlement, stormwater seepage into the crawlspaces and basements of homes and other structures and creating favorable conditions for mold. In addition, if they are not designed and maintained to drain properly, stormwater infiltration methods hold water for extended periods of time and can create favorable breeding habitats for mosquitoes. Design consideration for stormwater infiltration methods include an assessment existing site soil infiltration/percolation properties; site slopes; depth to groundwater; expansive clays; land uses and practices within the drainage area; proximity to water resources (e.g. streams, wetlands, drinking water or irrigation wells); proximity to structures and underground utilities; and proximity to septic systems, underground storage tanks (USTs), underground utilities, and areas of known soil and/or groundwater contamination. Evaluate these factors during the design of IMPs and other treatment control BMPs to prevent undesirable consequences such as slope failures and settlement; stormwater in crawlspaces and basements, groundwater contamination; and mosquito breeding.

The following sections provide guidance on design techniques and methods that must be considered to avoid these undesirable consequences.

#### 4.3.2.1 Site Topography

Flatter sites typically provide the most viable areas for stormwater infiltration. Stormwater routed to slopes may run off rather than soak into the ground. In addition, stormwater that penetrates the soil on hillsides may resurface a short distance down the slope and may also cause geotechnical instability. For this reason, direct stormwater infiltration systems such as infiltration trenches and basins shall not be placed on slopes greater than 15 percent. In addition, indirect stormwater infiltration systems (e.g., bioretention systems) may need to incorporate impermeable liners and underdrain systems if sited near or on slopes.

Vegetated or grassy swales shall have minimum and maximum longitudinal slopes and side slopes to slow runoff and enhance infiltration/percolation and stormwater treatment potential. Per the design standards provided in Section 3.4.2.1, vegetated or grassy swales shall have minimum longitudinal slopes of 0.5 percent, maximum longitudinal slopes of 2.5 percent, and maximum side slopes of 5.0 percent.

#### 4.3.2.2 Geotechnical Considerations

Infiltration of stormwater can increase water pressure in soil pores, reducing soil strength and making slopes more susceptible to failure. It can also make foundations of nearby structures more susceptible to settling. With the exception of bioretention systems designed with impermeable waterproof membranes and underdrains (or enclosed in a concrete box with an underdrain connected to the conventional storm drain system), stormwater infiltration systems shall be set back from slopes and foundations.

#### 4.3.2.3 Stormwater in Crawl Spaces

Shallow groundwater, stormwater, and water from landscape irrigation, if not properly managed, can penetrate foundations and seep into the basements and crawl spaces of homes and other structures. Since many types of building materials contain organic matter, mold can occur in the favorable environment created in these areas. Mold in crawl spaces and basements is a concern because several species can present health risks. Commonly, stormwater and water from landscape irrigation creates mold problems in basements and crawlspaces when homeowners re-grade their property for landscaping improvements, creating a drainage pattern that redirects moisture towards the foundation of the home.

Landscaping shall be graded to direct moisture away from the foundation. A minimum grade of at least six inches fall over the first ten feet from the foundation wall is recommended to keep moisture away from foundations. In addition, foundation drains can reduce the potential for water in basements and crawl spaces. Foundation drains that extend and drain to IMPs such as swales can be expected to provide better drainage than foundation drains surrounded by native soils. Additional measures include the installation of a vapor barrier (a plastic cover over the exposed dirt of crawlspaces) to minimize moisture from coming in from the ground. Crawl spaces and basements shall also incorporate adequate cross ventilation so air will circulate freely.

Based on a literature search and an Internet list serve poll of stormwater professionals across the nation, no reported cases of water or mold in crawl spaces and basements have occurred from implementing LID practices and IMPs or structural treatment control BMPs that infiltrate stormwater. However, this could occur if a stormwater infiltration system were improperly designed or sited directly up gradient of and/or adjacent to the foundation of a home or other structure. Conformance with local building design standards and the design standards presented these standards are necessary to keep stormwater out of crawl spaces and basements in new development and redevelopment. Public education about the importance of maintaining proper grades, directing moisture away from foundations, and providing good ventilation for crawlspaces and basements can also help to minimize the potential mold problems.

#### 4.3.2.4 Depth to Groundwater

To protect groundwater quality, direct stormwater infiltration methods such as infiltration trenches and basins shall be designed with a minimum separation between the base of the imported permeable materials and the seasonally high groundwater level. The minimum separation required in these standards for direct stormwater infiltration devices is 10 feet from the bottom of the device to the seasonal high groundwater level. Indirect stormwater infiltration methods, such as bioretention basins that filter urban runoff through amended surface soils and vegetation, are allowed to have less separation (5 feet) between the base of the device and the seasonally high groundwater level because these devices provide a greater level of treatment and groundwater protection. The infiltration of stormwater near the ground surface helps increase the separation to groundwater, providing a greater filtration layer and decreasing the risk of groundwater contamination.

#### 4.3.2.5 Potential Groundwater Contamination

Direct stormwater infiltration methods (e.g., infiltration trenches, drywells, etc.) shall not be used where there is a reasonably high potential for materials or liquids to spill and be transported in runoff. These devices shall not be used at industrial or light industrial areas or near gas stations, automotive repair shops, car washes, fleet storage areas, nurseries, or other areas that provide outdoor storage, use or disposal of chemicals and materials. In addition, direct stormwater infiltration shall not occur adjacent to roadways subject to high vehicular traffic. Indirect stormwater infiltration methods, such as vegetated swales, bioretention systems, and porous pavements can potentially be used within the drainage area of the industrial and commercial land uses and roadways noted above if 1) a pretreatment device such as an oil/water separator is included in the design to capture spills and/or 2) the bioretention system includes an impermeable liner that prevents infiltration/percolation to underlying soils and an underdrain system that connects to the conventional storm drain system (to promote proper drainage) is included in the design.

If sited in areas where there is a low potential for spills, BMPs designed to infiltrate stormwater are typically very effective at removing pollutants. Numerous studies have shown that stormwater infiltration presents only a minor risk of impacting either groundwater quality or subsurface soils (Barraud et al. 1999; Dierkes and Geiger 1999; Legret et al. 1999; Pitt et al. 1994). These studies indicate that natural and amended surface soils are very effective at removing pollutants from urban stormwater runoff because concentrations are typically low and surface soils utilize a number of natural processes such as physical filtering, ion exchange, adsorption, biological processing, conversion, and uptake by plants.

However, any time stormwater runoff from developed areas is infiltrated into the soil, there is a potential for pollutant transport and impacts to groundwater quality. IMPs and other treatment control BMPs that allow for infiltration of polluted runoff can be of concern if sited, designed of constructed incorrectly. Infiltration systems are shall not be located in drainage areas where runoff is expected to contain significant concentrations of hydrocarbons, metals, toxics (e.g. pesticides) or other pollutants that may impact groundwater. Therefore infiltration systems shall **not** be located in drainage areas with industrial or vehicle service activities where there is outdoor storage or use of hazardous materials.

As discussed in Section 4.3.3, infiltration systems shall not be installed within 150 feet of drinking water wells or in areas where the seasonally high groundwater table would be within 5 to 10 feet of the bottom of a proposed system.

In areas where existing site soil infiltration rates exceed 3.0 in/hr (20 min/inch), stormwater shall be pretreated by a structural BMP device, or soil amendments shall be added to slow infiltration rates to 3.0 in/hr or less. Stormwater infiltrating directly into existing site soils that have infiltration rates exceeding 3.0 in/hr, generally do not provide adequate treatment prior to transport to groundwater, particularly in sandy soils with little to no organic matter. If a bioretention system, swale, filter strip, or porous pavement system is proposed and there is a potential for spills or highly polluted runoff to be conveyed to the infiltration system, it shall be relocated or an impermeable liner and underdrain system shall be incorporated into the design to prevent infiltration and groundwater contamination.

#### 4.3.2.6 Areas with Existing Groundwater Pollution

Stormwater infiltration shall be avoided near areas of known groundwater contamination, such as the leaking underground fuel tank (LUFT) sites listed by the Regional Board. Infiltration of stormwater near these sites can contribute to the movement and dispersion of pollutants in groundwater. Direct stormwater infiltration methods such as infiltration trenches and basins shall not be sited within 500 feet of USTs that contain fuels or other hazardous materials. Indirect stormwater infiltration methods such as swales and bioretention basins shall also not be sited within 500 feet of these areas unless they include an impermeable liner and an underdrain system that connects to the conventional storm drain system.

#### 4.3.2.7 Underground Storage Tank (UST) Sites

The Regional Board indicates that 60 - 65% of new (1998 or newer) USTs leak -- even those with double-containment, improved installation techniques, and leak detection systems. Per the Regional Board, the setback may be potentially reduced to 250 feet if the UST is located downgradient of the proposed stormwater infiltration device, the infiltration flow patterns would not influence a pollution plume, and there are no utility conduits or trenches in the vicinity that could influence the pathway of UST contaminants or infiltration water.

#### 4.3.2.8 Wells and Septic Systems

Wells (domestic- and irrigation-water supply and monitoring wells) can capture infiltrated stormwater and become contaminated when infiltration trenches and basins are sited near the wellhead. In addition, direct stormwater infiltration methods sited near septic system leach fields can promote the migration of nitrates and pathogens to groundwater. Therefore, direct stormwater infiltration methods shall be placed a minimum distance from wells and leach fields. The design guidance provided in a number of stormwater management manuals developed by the agencies noted on Table 4-3 indicates the minimum distance between wells and leach fields at 100 to 150 feet. These manuals also note that direct stormwater infiltration methods should not be sited within wellhead protection zones. Indirect stormwater infiltration methods such as swales and bioretention basins are also not typically allowed to be located near wells and septic systems unless they include an impermeable liner and an underdrain system that connects to the conventional storm drain system.

#### 4.3.2.9 Mosquito Breeding and Vector Control

Direct and indirect stormwater infiltration systems shall be designed and maintained to promote long-term performance and to minimize standing water for extended periods of time that allows mosquitoes and other vectors to breed. Per the requirements listed in Section 1.5.6 Restrictions, any retention of stormwater for more than 72 hours is considered storage, and shall be accompanied with mitigation for vectors and general sanitation. A number of other design and maintenance measures are also typically applied for vector control. These include taking steps to minimize the entry of fine sediment that may clog stormwater infiltration systems and avoiding the use of loose riprap or concrete depressions that may retain standing water.

Stagnant pools of shallow water that contain organic matter from plants and debris can provide an ideal habitat for mosquitoes and other vectors to breed. Mosquitoes that spread diseases such as West Nile Virus and other diseases are present in the Salinas area. Developed areas can increase breeding habitats for mosquitoes and other vectors when water ponds for extended periods of time. Therefore LID practices, IMPs and structural treatment control BMPs shall not hold standing water for more than 72 hours during the primary mosquito breeding season (June through October) without mitigation measures for vectors.

To minimize mosquito breeding in LID practices, IMPs, and structural treatment control BMPs, the following design and maintenance standards are required:

- Locate and design facilities to avoid entry of fine sediment, which may cause systems to clog and fail and may also result in standing water.

- Select locations that will allow flow by gravity to, through, and away from the facility. Pumps are not recommended because they are subject to failure and often require sumps.

- Design distribution piping and containment basins with adequate slopes to drain fully and minimize standing water. Take into consideration the buildup of sediment between maintenance periods.

- Compaction during grading may be needed to avoid slumping and settling, which can create depressions that will hold water. However, avoid compaction of infiltration/percolation areas.

- Avoid the use of loose riprap or concrete depressions that may hold standing water for more than 72 hours.

- Avoid barriers, diversions, or flow spreaders that may retain standing water for more than 72 hours.

LID practices, IMPs and structural treatment control BMPs that permanently retain water, such as stormwater ponds and wetlands, shall be designed and maintained based on the standards presented in this document. These standards include rock lining and steep slopes along the edge of stormwater ponds and wetlands and periodic removal of debris and vegetation. Mosquito fish (Gambusia sp.) that eat mosquito larvae can also be introduced to stormwater ponds and wetlands to provide an additional method of control.

Nationally, LID practices, IMPs and structural treatment control BMPs that include landscaping and depressed areas that temporarily pond water have only been shown to breed mosquitoes when these facilities were not designed correctly, not properly planted, not maintained adequately, or were not infiltrating properly. In bioretention basins, proper infiltration rates are attained through the use of engineered soils with good permeability and proper plant composition. Proper design and routine maintenance will minimize ponding for periods long enough to allow for mosquito breeding. Routine maintenance is necessary to maintain soil infiltration rates and minimize invasion of undesirable species such as cattails, which can increase the chances of standing water and therefore, mosquito breeding potential. Vegetated swales and extended detention basins that include rock lined low flow channels and underdrain systems typically minimize the development of stagnant pools of water, particularly in areas that receive persistent runoff from turf and landscaping irrigation. Low flow channels shall be designed with a minimum continuous grade of 0.5 percent. Those that do not include underdrain systems may require more frequent maintenance to minimize ponding water from standing longer than 72 hours.

#### 4.3.2.10 Dry Wells and Class V Injection Wells

Shallow dry wells, infiltration galleries, and subsurface drain fields that release stormwater or other fluids directly below the land surface are considered Class V injection wells and may be subject to regulation by the U.S. EPA and the Safe Drinking Water Act. By definition, a Class V injection well is any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension. An underground infiltration gallery that receives urban runoff from a pipe, or a series of pipes, is also considered a Class V injection well. These types of facilities are considered stormwater disposal systems, not treatment systems, and have impacted groundwater quality in a number of communities across the nation. The U.S. EPA is concerned that there may be a dramatic increase in the use of Class V injection wells as a result of NPDES stormwater permit requirements to implement BMPs.

When not allowed to filter through surface soils and plant roots, stormwater contaminated with sediments, hydrocarbons, nutrients, metals, salts, fertilizers, pesticides, bacteria, or other pollutants can contaminate groundwater supplies, resulting in costly treatment alternatives and possibly the closure of private drinking water and irrigation wells. However, when stormwater is allowed to temporarily pond in an open basin that is exposed to the atmosphere, is wider than it is deep, and infiltrates stormwater through engineered soils and gravel, the system is not considered a Class V injection well and typically presents little risk to groundwater quality. The LID practices, IMPs, and structural treatment control BMPs presented in this document are not considered Class V injection wells and should not present a threat to groundwater quality if sited and designed correctly.

### 4.3.3 Design Standards for Stormwater Infiltration BMPs

Stormwater infiltration BMPs include practices designed to directly and indirectly infiltrate urban runoff through surface soils to groundwater to minimize pollutants from entering surface waters. Direct infiltration practices include infiltration basins and trenches. Indirect infiltration practices include vegetated swales, bioretention systems, and porous pavements. Any time urban runoff is allowed to infiltrate to the subsurface, there is some potential for pollutant transport and groundwater contamination. In addition, if not designed correctly and maintained appropriately, stormwater infiltration systems can hold standing water for extended periods of time, potentially creating mosquito breeding habitats. Table 4-3 presents the allowable infiltration rates, limits on standing water, and separation and setback standards for stormwater infiltration BMPs established to protect groundwater quality and assist with vector control in the Salinas area, in the Salinas area. For comparison purposes, Table 4-3 also notes some similar standards that Monterey County has adopted for septic systems. This information is provided because design standards for stormwater infiltration systems shall be similar to those required for the permitting septic system leach fields. Although there is currently little available documentation about groundwater impacts from infiltration of stormwater, there are numerous documented cases of nitrate contamination of aquifers by septic systems.

## Table 4-3: City of Salinas Stormwater Infiltration System Design Standards

| Recommended Design Standards | Direct Infiltration Practices[a] | Indirect Infiltration Practices[b] | Agencies with Similar Design Standards | Monterey County Septic System Requirements[c] |
|---|---|---|---|---|
| Allowable Infiltration Rates[d] | Min 1.0 in/hr (60 min/in) Max 3.0 in/hr (20 min/in) | Min 0.5 in/hr (120 min/in)[e] max 3.0 in/hr (20 min/in) | CASQA, CCCWP, CWP, TMSWMP | min 1.0 in/hr (60 min/in) max 12.0 in/hr (5 min/in) |
| Standing Water[f] | < 72 hrs | < 72 hrs | CASQA, CCCWP | NA |
| Groundwater Separation | ≥ 10 ft | ≥ 5 ft | Boise, CASQA, CCCWP, CWP, UDFCD, WDOE | ≥ 10 ft |
| Bedrock Separation | ≥ 10 ft | ≥ 5 ft | Boise, CASQA, CCCWP, CWP, UDFCD, WDOE | ≥ 10 ft |
| Water Well Setback | ≥ 150 ft | ≥ 100 ft[g] | Boise, CASQA, CCCWP, CWP, TMSWMP, WDOE | ≥ 250 ft |
| Surface Water Setback | ≥ 100 ft | ≥ 50 ft[g] | Boise, CCCWP, TMSWMP | ≥ 100 ft |
| Septic System Setback[h] | ≥ 150 ft | ≥ 100 ft[g] | CCCWP | NA |
| Groundwater Contamination Setback[i] | ≥ 500 ft | ≥ 500 ft[g] | CCCWP | Distance not specified[j] |
| Underground Fuel Tank Setback[k] | ≥ 500 ft | ≥ 500 ft[g] | CCCWP | Not specified |
| Building and Bridge Foundation Setback | ≥ 100 ft up slope and ≥ 20 ft down slope | ≥ 100 ft up slope and ≥ 20 ft down slope[g] | CASQA, IDEQ, TMSWMP, WDOE | ≥ 10 ft |
| High Use Roadway Setback[l] | Prohibited | ≥ 20 ft | CCCWP | NA |
| Basement and Crawl Space Setback | ≥ 100 ft up slope and ≥ 20 ft down slope | ≥ 100 ft up slope and ≥ 20 ft down slope[7] | IDEQ, TMSWMP, WDOE | ≥ 10 ft |
| Property Line Setback[m] | ≥ 5 ft | ≥ 5 ft | PBES | ≥ 10 ft |
| Slope Setback[n] | 100 ft from the top of slopes >15% | 50 ft from the top of slopes >15% | WDOE | Prohibited where slopes exceed 30%[o] |

*Notes on following page.*

**Notes:**

(a) Direct infiltration practices include infiltration trenches; infiltration basins; and any structure designed to infiltrate stormwater into the subsurface and bypass the natural groundwater protection afforded by surface or near-surface soils.

(b) Indirect infiltration practices include swales, bioretention systems, and porous pavements. The root systems of vegetated swales and bioretention systems (e.g., rain gardens) typically maintain soil permeability. Vegetated systems may require supplemental irrigation during extended dry periods.

(c) Monterey County Code 15.20.060 Septic tank system/gray water system permits and 15.20.070 Standards and Specifications.

(d) If testing results indicate that native soil infiltration rates are less than the minimum value, direct infiltration practices are not allowed, and indirect infiltration systems are required to be installed in underdrains or subdrains. If testing results indicate that native soil infiltration rates are higher than the maximum value, additional pretreatment and evaluation of potential impacts to groundwater should be conducted.

(e) A lower minimum design infiltration rate is allowed for indirect infiltration practices such as swales and bioretention systems because the roots of the vegetation incorporated into these practices generally maintain the permeability of native and imported soils. Direct infiltration practices can clog if the stormwater is not pretreated to remove fine sediment. Porous paving systems should consider underdrain systems when native soil infiltration rates are less than 1.0 inch/hour (60 minutes/inch).

(f) Additional design standards and maintenance requirements apply for mosquito and vector control (see Monterey County Code for Mosquito Abatement and Vector Control).

(g) Indirect infiltration practices may be placed within the setback limits or directly adjacent to the structures noted above if an impermeable surface and an underdrain system prevent infiltration to the underlying soils within the setback limits.

(h) Setback applies to septic system leach fields.

(i) Setback applies to areas of known groundwater contamination.

(j) Monterey County Code 15.20.060 Section I: No septic tank/gray water system permit shall be issued in any area where continued use of onsite systems constitutes a pubic health hazard, or where there is an existing or threatened condition of water pollution, contamination, or nuisance.

(k) Setback applies to known underground fuel tank sites.

(l) Main roadways with average daily traffic (ADT) of 25,000 or more and ADT of 15,000 or more on any intersecting or minor roadways.

(m) Variances may be awarded for infiltration systems located in the City right of way (ROW) or for systems designed to treat more than one property.

(n) A qualified geotechnical and/or structural engineer shall determine site-specific requirements whenever site slopes exceed 7 percent.

(o) Monterey County Code 15.20.070: New septic tank systems are prohibited in areas where the natural ground slope exceeds thirty (30) percent unless a variance is granted by the Regional Board.

**Abbreviations and Acronyms:**

Boise - City of Boise, ID.
CASQA - California Stormwater Quality Association.
CCCWP - Contra Costa Clean Water Program, CA.
CWP - Center for Watershed Protection.
IDEQ - Idaho Department of Environmental Quality.
PBES - Portland Bureau of Environmental Services, OR.
TMSWMP - Truckee Meadows Stormwater Management Program (Reno, Sparks, Washoe Co, NV).
UDFCD - Urban Drainage and Flood Control District, Denver, CO.
WDOE - Washington State Department of Ecology.

### 4.3.4 Site Screening and Infiltration Testing Requirements

If a stormwater infiltration practice[13] is proposed as part of a development strategy to reduce the flow rate, volume, and pollutant loading of urban runoff[14], the following site screening and testing procedures shall be applied to new and redevelopment projects 20 acres or greater:

a) A boring or test pit shall be installed at the location of the proposed stormwater infiltration practice. The boring shall be advanced to a minimum depth of 15 ft or to refusal. The boring or test pit shall be used to identify seasonally high groundwater (e.g., staining) and potential shallow restrictive soil layers (e.g., bedrock or clayey soils).

b) If seasonally high groundwater or bedrock occurs more than 10 ft below the depth of the bottom of the proposed direct stormwater infiltration practice (e.g., an infiltration basin or trench), proceed to Step d). Direct stormwater infiltration shall not be allowed if seasonally high groundwater or bedrock occurs less than 10 ft below the depth of the bottom of a proposed direct stormwater infiltration practice.

c) If seasonally high groundwater or bedrock occurs more than 5 ft below the depth of the bottom of a proposed indirect stormwater infiltration practice (e.g., a swale, a bioretention system, or a porous pavement), proceed to Step d). Indirect stormwater infiltration shall not be allowed if seasonally high groundwater or bedrock occurs less than 5 ft below the depth of the bottom of a proposed indirect stormwater infiltration practice.

d) If the site meets the minimum criteria for separation from seasonally high groundwater and bedrock noted above (e.g., ≥5 ft for indirect infiltration BMPs and ≥10 ft for direct infiltration BMPs), infiltration/percolation testing shall be conducted at the location of the proposed stormwater infiltration practice. The test shall be conducted at the depth of the bottom of the proposed stormwater infiltration practice (e.g., at the interface between the bottom of the drain rock layer and the excavated site soils, where percolation into existing site soils will occur).

e) The minimum infiltration/percolation testing method acceptable for use in the City of Salinas (City) is the method currently specified by the Monterey County Health Department (MCHD) for the permitting of septic system leach fields in the Salinas area. The infiltration/percolation test shall be conducted in accordance with the MCHD procedures, using the appropriate data collection forms. The data forms and testing results shall be supplied to the City of Salinas Development & Engineering Services Department for review and approval. Equivalent testing procedures may be allowed by the City upon the approval of the City Engineer.

f) The acceptable range of infiltration/percolation rates for stormwater infiltration practices is 0.5 in/hr to 3.0 in/hr (120 min/in to 20 min/in).



[13] Stormwater infiltration practices include direct infiltration systems such as infiltration basins and trenches and indirect infiltration practices such as swales, bioretention systems, and porous pavements.

[14] Per Regional Board Order No. R3-2004-0135, Priority Projects in the City of Salinas (see Section 1.4.1) are required to reduce the rate, volume, and pollutant loading of urban runoff to the Maximum Extent Practicable (MEP).

g) If testing results indicate infiltration/percolation rates are less than 0.5 in/hr (120 min/inch), an underdrain system shall be incorporated into the design to minimize standing water for extended periods of time that may allow mosquitoes and other vectors to breed. Infiltration/percolation rates less than 0.5 in/hr typically indicate existing site soils are poorly drained clayey or silty soils that are prone to extended ponding.

h) If testing results indicate infiltration/percolation rates are greater than 3.0 in/hr (20 min/inch), stormwater should be fully pretreated prior to infiltration to minimize potential groundwater contamination. Addition of soil amendments to slow infiltration and allow adequate treatment and processing of stormwater may also be considered. Infiltration/percolation rates greater than 3.0 in/hr typically indicate existing site soils are sandy soils with little to no silt and/or clay. Infiltration of stormwater into soils with relatively high infiltration rates (≥5 in/hr), without proper pretreatment and/or the addition of soil amendments to slow infiltration can result in groundwater contamination.

   a) Seasonally high groundwater levels, soil infiltration rates, depth to bedrock, and depth and thickness of shallow restrictive layers shall be evaluated, verified, and certified by a California registered professional engineer, geotechnical engineer, geologist, hydrogeologist, or other qualified professional as approved by the City Engineer.

   b) A faster maximum design infiltration rate up to 12.0 in/hr (5 min/in) may be allowed for some stormwater infiltration practices if conditions exist such that the drainage area for the device has a low pollutant loading and spill potential, and there is a low potential for groundwater contamination. Stormwater infiltration into underlying soils with infiltration rates between 3.0 and 12.0 in/hr shall be approved by the City Engineer. Stormwater infiltration is not allowed into site soils with infiltration rates greater than 12.0 in/hr.

   c) Site conditions that might allow a slower or faster maximum design infiltration rate or a reduction in the separation to seasonally high groundwater or bedrock should be evaluated, verified, and certified by a California registered professional engineer, geotechnical engineer, geologist, hydrogeologist, or other qualified professional and approved by the City Engineer.

Refer to Section 3.4 for additional information on the design of swales, bioretention systems, porous pavements and other IMPs. The fact sheets in these sections provide numerous design variations; the advantages and limitations of each IMP; siting, design and construction criteria; inspection and maintenance requirements; and examples from other communities.

### 4.3.5 Bioretention System Design Criteria

As noted previously, bioretention systems[15] are considered indirect infiltration devices. If site conditions and constraints allow, urban runoff can percolate through bioretention systems and into subsurface soil. Where site conditions and constraints prevent the infiltration of urban

15 Bioretention systems include landscape detention basins, tree box filters, and stormwater planters. See Section 3.3 for additional information on these LID practices.

runoff into the subsurface, impermeable barriers and underdrains can be incorporated into the design of bioretention systems. If a bioretention system is proposed as part of a development strategy to reduce the rate, volume and pollutant loading of urban runoff[16], the following design criteria shall be applied:

1. Bioretention shall consist of the following components:
   - A depressed ponding area located below the grade of an adjacent impervious surface[17];
   - Planted vegetation and a mulch layer;
   - A layer of engineered soil mix consisting of well mixed clean sand, certified compost or peat moss, and topsoil with a minimum thickness of 18 inches;
   - Depending on underlying soil conditions and site constraints, an underdrain system[18] may be required to drain the ponding area within 72 hours.
   - An optional permeable filter fabric liner[19] or an impermeable liner[20] that separates existing site soils from the engineered soil mix.
2. The depressed ponding area or "Low Planting Zone" shall allow urban runoff to temporarily pond for 72 hours or less at a depth of approximately 6 to 12 inches. The depressed area shall be sized to capture and treat the Water Quality Volume ($WQ_V$) using the method outlined in Section 4.4.2. Vegetation planted in the "Low Planting Zone" shall be capable of being inundated for extended periods of time. Appendix G presents the LID Planting Zones and Plant list to be used in the design of bioretention systems.
3. The vegetation selected for bioretention systems shall follow the guidelines outlined in the "Salinas Planting Zone and Plant List for LID Practices" presented in Appendix G. The plant

[16] Per Regional Board Order No. R3-2004-0135, Priority Projects in the City of Salinas are required to reduce the rate, volume and pollutant loading of urban runoff to the Maximum Extent Practicable (MEP).

[17] Stormwater planters designed to treat runoff from elevated impervious surfaces such as roofs and parking structures may be placed above the grade of an adjacent impervious surface such as sidewalks and driveways.

[18] The requirement to include an underdrain system as part of the design of a bioretention system depends on the infiltration/percolation rates of the underlying soils determined during the initial site screening procedures outlined in the "Site Screening / Infiltration Testing Requirements" (Section 4.2.1). As noted in this section, an underdrain system consisting of a perforated pipe in the gravel sub-base layer (e.g. drain rock, pea gravel, and filter fabric) is required if testing results indicate infiltration/percolation rates in existing site soils underlying the proposed infiltration practice are less than 0.5 in/hr (120 min/inch). Underdrains are also required in closed bioretention systems (e.g. bioretention systems that do not drain to underlying site soils) such as tree box filters and stormwater planters enclosed within concrete boxes without drain holes.

[19] To allow infiltration and prevent clogging, the filter fabric shall be a woven geotextile fabric layer, such as SI Corporation Geotex 117F or an approved equivalent.

[20] An impermeable liner may be required in some circumstances to protect groundwater quality, to prevent stormwater from migrating under structures or into utility corridors, and to separate stormwater from expansive clays.

list provides appropriate local plant species for the 'Low', 'Mid' and 'High Planting Zones' of bioretention systems, vegetated swales and flood control detention basins.

4. The engineered soil mix shall be well mixed and contain the following:

- 50-60% clean sand
- 5-20% certified compost or peat moss
- 20-30% topsoil

a) The sand shall be clean washed ASTM C-33 sand free of deleterious material. The sand shall be rinsed with potable water prior to installation and construction of the bioretention system. Recycled wash water from concrete ready mix operations and other sources shall not be used to wash the sand because it typically has a high pH.

b) The engineered soil mix shall be tested prior to installation for pH, Organic matter and P-index and meet the following criteria:

i. pH range: 5.5 to 6.5

ii. Organic matter: Greater than 1.5

iii. P-index: 4 to 12

c) The definitions of materials that qualify as certified compost and peat moss are as follows:

**Compost** is produced by the controlled biological decomposition of organic material. Certified compost[21] is a form of compost that has been sanitized through the generation of heat and 'processed to further reduce pathogens' (PFRP), as defined by the U.S. EPA (Code of Federal Regulations Title 40, Part 503, Appendix B, Section B). It is further stabilized to the point that it is beneficial to plant growth and does not contain any pathogens harmful to human health. Certified compost is an organic matter source that has the unique ability to improve the chemical, physical, and biological characteristics of soils or growing media. It contains plant nutrients but is typically not characterized as a fertilizer. Certified compost shall be tested regularly with a frequency based on production volumes and applicable State and/or Federal regulations. Certified compost shall be analyzed for the following properties:

– pH

– Soluble salts

[21] Compost made from leaves collected during the fall season is preferable for urban runoff pollutant removal because the nutrient content in the leaves is typically low (the compost has a low P-index). During the fall, nutrients in the leaves are transferred to the branches and roots of trees in anticipation of winter. The low nutrient content effectively prevents the leaching of excess nutrients into the bioretention system effluent. Other compost types, particularly those that include animal manure, have been observed to leach nutrients into the effluent of bioretention systems, resulting in increased concentrations of nitrogen and phosphorous, greater than observed in the urban runoff influent.

- Nutrient content (total N, $P_2O_5$, $K_2O$, Ca, Mg)?
- Moisture content
- Organic matter content
- Bioassay (maturity)
- Stability (respirometry)
- Particle size (report only)
- Pathogens (fecal coliform or Salmonella)
- Trace metals (Part 503 regulated metals).

**Peat Moss** or Sphagnum is a genus of between 150-350 species of mosses commonly called peat moss, due to its prevalence in peat bogs. Members of this genus can hold large quantities of water inside their cells; some species can hold up to 20 times their dry weight in water. This water retention property is one reason why peat moss is commonly sold as a soil amendment. Peat moss can acidify surrounding soils by taking up cations such as calcium and magnesium and releasing hydrogen ions. This property makes peat moss effective at urban runoff pollutant removal.

d) The topsoil shall be a sandy loam or loamy sand of uniform composition, containing no more than 5% clay, free of stones, stumps, roots, or similar objects greater than one inch, brush, or any other material or substance which may be harmful to plant growth, or a hindrance to plant growth or maintenance. The topsoil shall be free of plants or plant parts of Bermuda grass or others as specified by the City of Salinas Urban Forester. The soil mix shall also contain no toxic substances harmful to plant growth or that can be leached into the bioretention system effluent and detected at a concentration greater than observed in the urban runoff influent.

5. The Engineered Soil Mix shall be well mixed and consist of clean sand, certified compost or peat moss, and topsoil per specifications 4 a), b), c) and d) noted above.

6. If a gravel sub-base layer is incorporated into the design, it shall consist of clean coarse aggregate (drain rock and/or pea gravel). Recycled wash water shall not be used to wash the aggregate because it typically has a high pH. The aggregate shall be rinsed with potable water prior to installation and construction of the bioretention system.

Bioretention systems can function in a “2-step” fashion. Urban runoff can be conveyed to the first stage of a bioretention system with a minimum capacity to capture and treat a 0.6-inch rain event from the basin drainage area (e.g., the Water Quality Volume or $WQ_V$). Overflow from the first stage bioretention system can be conveyed into a larger detention or retention basin during larger storm events for flood control. The bioretention features noted above may not be required for larger flood control detention or retention basins. However, when practicable or where necessary to provide adequate treatment, these bioretention features may be considered in larger detention or retention basins and may be required in some areas.

## 4.4 Numeric Sizing Criteria

The Salinas NPDES Permit requires numeric sizing criteria for both volume- and flow-based treatment control BMPs. Volume-based treatment control BMPs are designed to reduce the volume of stormwater runoff. Examples of volume-based treatment controls include extended detention basins, infiltration basins and trenches, and bioretention basins. Flow-based treatment controls are designed to reduce the flow rate of stormwater runoff. Examples of flow-based treatment control BMPs include swales and filter strips. The following sections discuss an analysis of local rainfall records and the methods to be used to size volume- and flow-based treatment control BMPs in the Salinas area, and the rainfall depth and intensity to be applied to these methods, respectively.

### 4.4.1 Salinas Design Storm Criteria

A precipitation frequency analysis was conducted using hourly precipitation data for the Salinas Municipal Airport obtained from the National Climatic Data Center (NCDC). Hourly data was only available for this station from 1948 to 1951, and 1998 to 2006[22] (e.g., the period of record). Runoff producing storm events were considered to be 0.05 inches or greater in depth, with a 6 hour dry period between storms. Based on these parameters there were a total of 354 storms and the 85th percentile storm had a rainfall depth of 0.6 inches. Figure 4-1 presents a graph of the 85th percentile runoff producing storm event, which is equivalent to the value to be used when calculating the water quality volume ($WQ_V$) for volume-based treatment control BMPs in the Salinas area. A similar analysis of rainfall intensity was conducted using the data recorded during the period of record. The analysis indicated that the 85th percentile hourly rainfall intensity for the City of Salinas is 0.11 inches/hour. Figure 4-2 presents a graph of the 85th hourly rainfall intensity for the Salinas area. The Salinas NPDES Permit indicates that flow-based treatment control BMPs must be designed to infiltrate or treat the maximum flow rate produced by a rain event equal to two times the 85th percentile hourly rainfall intensity. Therefore a rainfall intensity of 0.22 inches/hour is the value to be used when calculating the water quality flow ($WQ_F$) for flow-based treatment control BMPs in the Salinas area.



[22] According to the Western Regional Climate Center (WRCC), the record ended in 1951 when the gauge was removed. The station was reportedly inactive between 1952 and 1998 and became active again in September 1998 when new automated equipment was installed. The 2006 data utilized for this analysis was from January to June

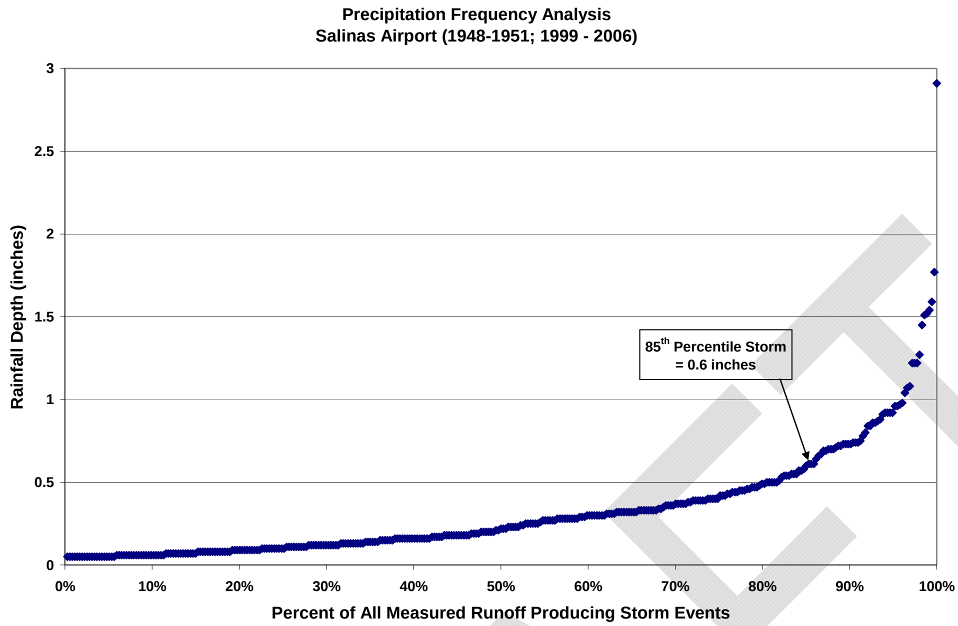


Figure 4-1: Precipitation Frequency Analysis Indicating the 85th Percentile Runoff Producing Storm Event for the Salinas Area (Source: Kennedy/Jenks Consultants)

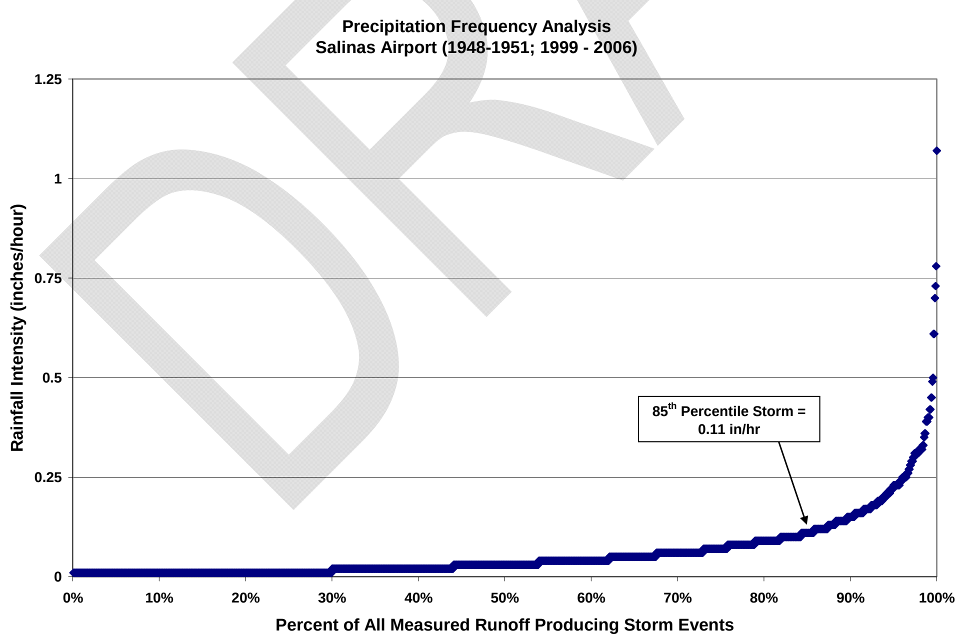


Figure 4-2: Precipitation Frequency Analysis Indicating the 85th Percentile Rainfall Intensity for the Salinas Area (Source: Kennedy/Jenks Consultants)

### 4.4.2 Volume-based Treatment Control BMPs

The Salinas NPDES Permit indicates that volume-based treatment control BMPs must be designed to infiltrate or treat the calculated volume obtained using one of the following methods:

- The volume of runoff produced by the 24-hour 85$^{th}$ percentile storm event (based on local rainfall records) using the maximized stormwater quality capture volume method (WEF/ASCE method 1998)
- An equivalent numeric sizing criteria as approved by the City Engineer.

As discussed in the previous section, the rainfall depth associated with the 24-hour 85$^{th}$ percentile storm is 0.6 inches. The maximized stormwater quality capture volume (WEF/ASCE method 1998) for volume-based treatment control BMPs is as follows:

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

$$P_o = (aC)P_6 = WQ_V$$

Where

$C$ = the runoff coefficient

$i$ = watershed imperviousness ratio which is equal to the percent total imperviousness divided by 100

$P_o$ = maximized detention volume (inches) = $WQ_V$

$a$ = regression constant for BMP draw down time (for 24 hours, a = 1.582; for 48 hours, a = 1.963)

$P_6$ = mean annual runoff producing rainfall depth based on local rainfall records (inches)

As noted above $P_6$ = 0.6 inches for the City of Salinas.

### 4.4.3 Flow-based Treatment Control BMPs

The Salinas NPDES Permit indicates that flow-based treatment control BMPs must be designed to infiltrate or treat the maximum flow rate produced by a rain event equal to two times the 85$^{th}$ percentile hourly rainfall intensity based on local rainfall records (CASQA method 2003). An approved equivalent numeric sizing criteria can also be adopted by the City.

The CASQA method utilizes the commonly applied Rational Formula ($Q = CIA = WQ_F$):

Where

$WQ_F$ = flow rate (ft$^3$/sec)

C = the runoff coefficient

I = rainfall intensity (inches/hour)

A = drainage area (acres).

As discussed in Section 4.4.1, the rainfall intensity associated with the 24-hour 85$^{th}$ percentile storm is 0.11 inches/hour. Therefore two times the 85$^{th}$ percentile hourly rainfall intensity is 0.22 inches/hour. The runoff coefficients that shall be used to calculate the $WQ_F$ for BMPs in the City of Salinas are presented Table 4-4.

Additional information about calculating the $WQ_F$ can be found in Section 5.5.2 of the California Stormwater BMP Handbook for New Development and Redevelopment (www.cabmphandbooks.com).

Table 4-4: Runoff Coefficients (C factor) For BMP Design*

| Surface | "C" Factor |
|---|---|
| Roofs | 1.0 |
| Concrete/Asphalt/Other pavement | 1.0 |
| Grouted Unit Pavers | 1.0 |
| Pervious Concrete | 0.6 |
| Pervious Asphalt | 0.6 |
| Unit Pavers, Tight Pack | 1.0 |
| Unit Pavers, with Gaps | 0.8 |
| Crushed Aggregate | 0.4 |
| Grass Turf (sod) | 0.7 |
| Grass (Seed or Clump) | 0.35 |
| Other landscaping | 0.35 |

*Reduced C factors for alternative surface designs to be approved by the City Engineer

## 4.5 Diversion Structures

Depending on the design, diversion structures can be required to prevent urban runoff from the relatively large storm events (the 5-, 20- and 100-year storms) from entering LID practices, IMPs, and structural treatment controls and causing erosion, re-suspension and removal of captured sediment and other pollutants, and to prevent flooding. Implementing one or both of the following techniques typically accomplishes capture or isolation of the water quality flow ($WQ_F$) or water quality volume ($WQ_V$):

- Use of diversion structures, such as weirs, orifices or pipes, to divert the $WQ_F$ or $WQ_V$ into an off-line structural treatment control or LID practice. The diversion structure is typically located at or upstream of the inlet to the BMP (Figures 4-3 and 4-4).

- Bypassing flows in excess of the $WQ_F$ or $WQ_V$ using weirs, orifices or pipes within in-line structural treatment controls and routing these flows to the conventional storm drain system or another treatment control BMP (Figures 4-5 and 4-6).

Since conventional storm drainage systems are typically constructed to convey flows from the relatively large storm events (the 5-, 20- and 100-year storm peak flows) without regard for treatment, the design engineer shall ensure there is sufficient capacity in the diversion structure to accommodate overflows. Therefore, the engineer shall establish the design capacity of the storm drain system when designing diversion structures and structural treatment controls for stormwater quality enhancement. The following pages provide examples of diversion structures and procedures for sizing various diversion structures for flow and volume-based treatment controls BMPs.

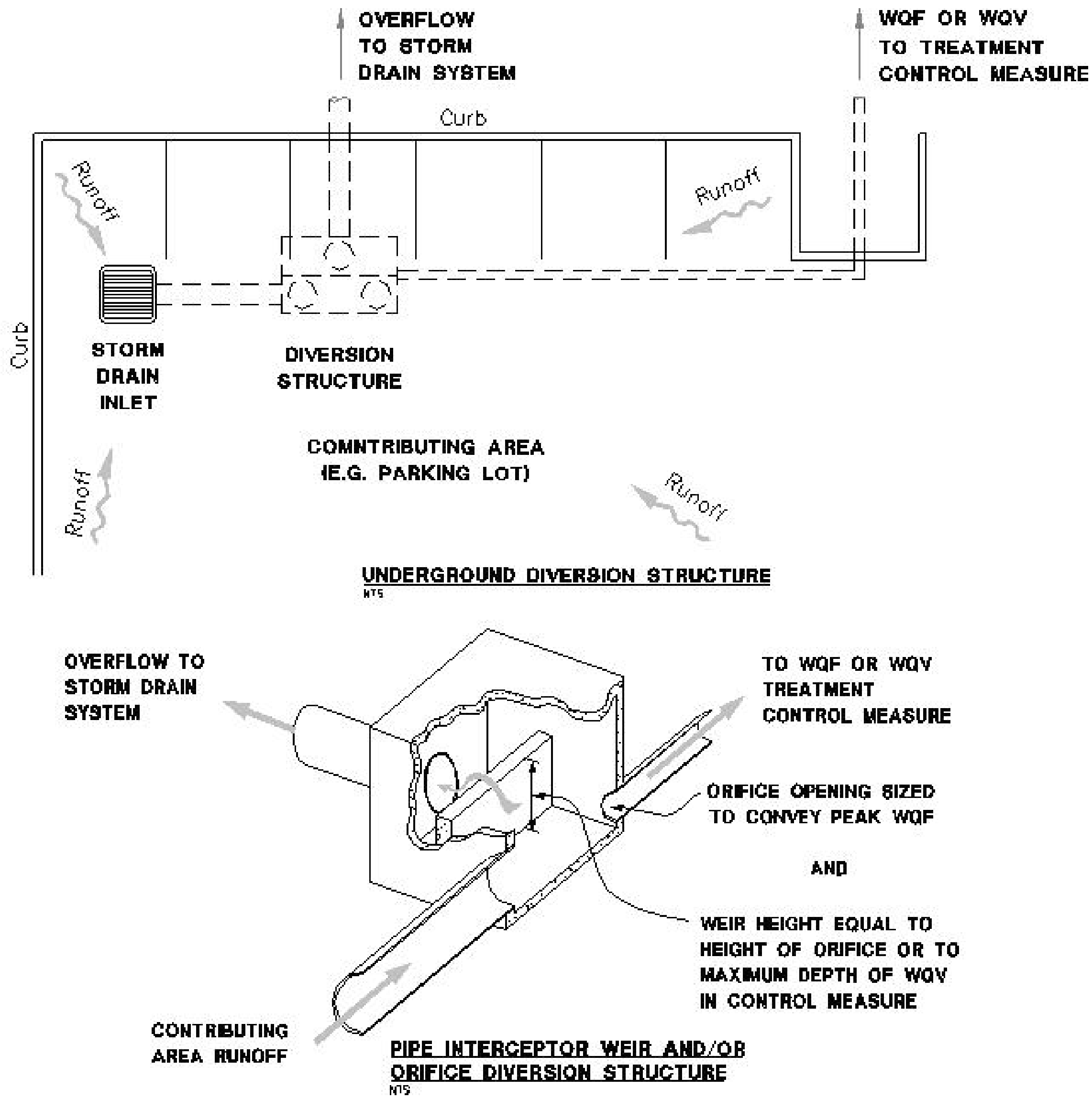


Figure 4-3: Example of an Underground Pipe Interceptor Weir and/or Orifice Diversion Structure for $WQ_F$ or $WQ_V$ T Treatment Control Measures

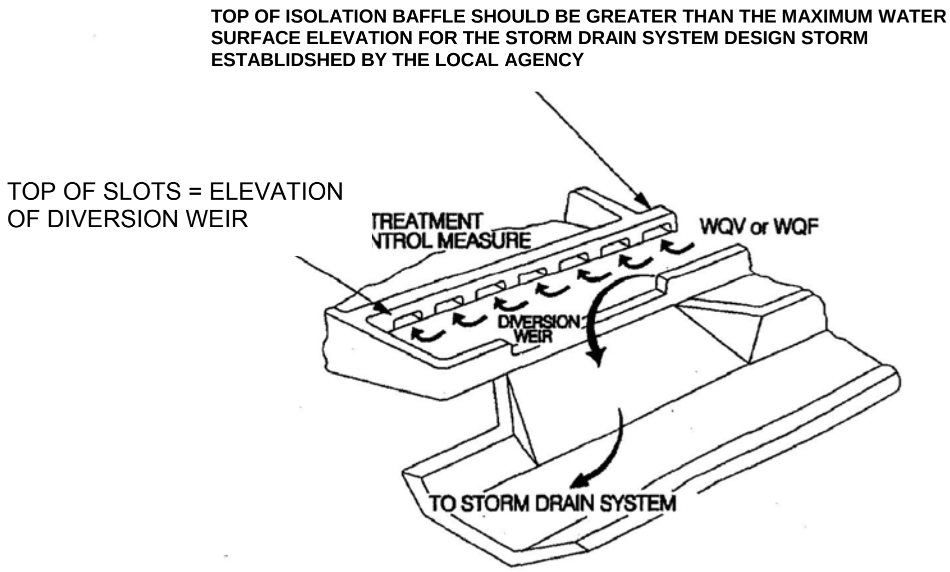


Figure 4-4: Example of a Surface Channel Diversion Structure for Flow or Volume-based Treatment Controls (modified from City of Austin 2003)

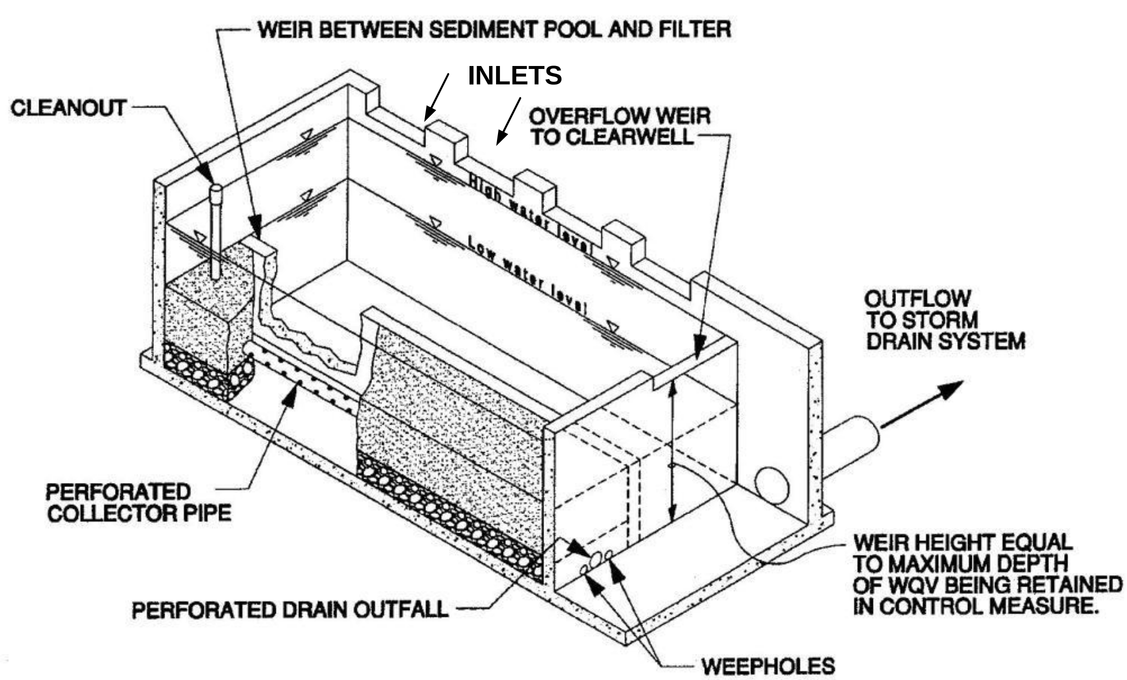


Figure 4-5: Example of an In-line Underground Sand Filter with an Overflow Weir (City of Sacramento 2000)

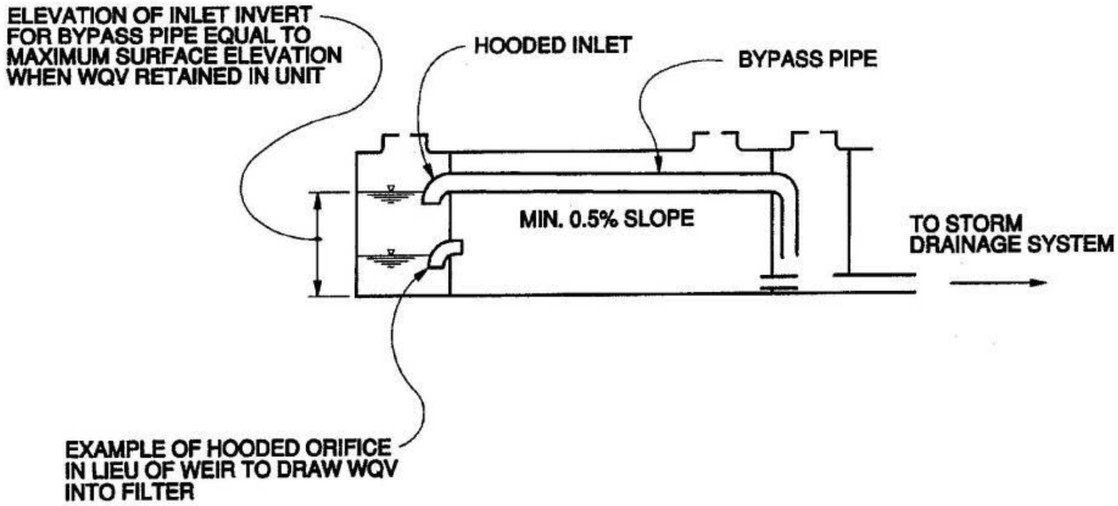


Figure 4-6: Example of an In-line Treatment Control Measure with a Bypass Pipe (City of Sacramento 2000)

### 4.4.4 Weirs for Flow-Based Treatment Controls

Weirs can be used as an engineered, flow-based treatment control to reduce the flow of stormwater during a rain event. Design considerations are outlined below:

1) Establish the design capacity of the storm drain system at the point of diversion.

2) Determine the $WQ_F$ for the proposed LID practice or structural treatment control BMP using the equations presented in Section 4.4.3.

3) Determine the depth of flow in the storm drain system at the $WQ_F$ using the Manning's equation.

$$WQ_F = (1.49/n)AR^{2/3}S^{1/2}$$

Where: $WQ_F$ = water quality peak flow rate (cfs)

1.49 = conversion factor for English units

n = Manning roughness coefficient (dimensionless)

A = cross sectional area of the storm drain pipe or channel ($ft^2$)

R = hydraulic radius of the storm drain pipe or channel (ft)

S = slope of the pipe or channel (ft/ft)

Nomographs or computer programs can also be used to determine the depth of flow.

4) Set the weir height (H) at the flow depth determined in step 3.

5) Use the following equation for a rectangular broad-crested weir to determine weir length (L).

$$Q_{SD} = CLh^{1.5}$$

Where:

$Q_{SD}$ = the peak flow rate for the storm drain system (cfs)

C = the weir coefficient

L = the effective horizontal length of the weir (ft)

h = the depth of flow above the crest of the weir (ft)

6) Ensure sufficient head is available in the design of the weir structure to accommodate overflow from the larger storm events.

The weir or discharge coefficient “C” for a broad-crested weir accounts for factors such as the flow approach velocity. It has been determined experimentally to range between 2.67 and 3.05. A value of C = 3.0 is typically used for the design for the design of detention overflow structures, spillways and diversion structures (Stahre and Urbonas 1990). Table 5-4 provides a list of Manning roughness coefficients (n) for various channel-lining materials.

### 4.4.5 Weirs for Volume-Based Treatment Controls

Weirs can also be used to control the volume of stormwater that is discharged during and after a storm event. While it does not reduce the volume of water, it can control the rate of which water is released. Design considerations are outlined below:

1) Establish the design capacity of the storm drain system at the point of diversion.

2) Determine the $WQ_V$ for the proposed LID practice or structural treatment control BMP using the equations noted in Section 4.4.2.

3) Using the design and construction criteria provided in the BMP fact sheets; determine the water level height in the treatment control measure when the entire $WQ_V$ is retained within the structure.

4) Set the weir height (H) at the water level height determined in step 3.

5) Use the equation for a rectangular broad-crested weir (noted above) to determine weir length (L).

6) Design weir with low-flow capabilities so that no ponding occurs behind the weir.

7) Ensure sufficient head is available in the design of the weir structure to accommodate overflow from the larger storm events.

### 4.4.6 Orifices for Volume-Based Treatment Controls

1) Establish the design capacity of the storm drain system at the point of diversion

2) Determine the $WQ_V$ for the proposed LID practice or structural treatment control BMP using the equation in Section 4.4.2

3) Using the design and construction criteria provided in the BMP fact sheets; determine the water level height in the treatment control measure when the entire $WQ_V$ is retained within the structure

4) Set the invert elevation of the orifice at the water level height determined in step 3

5) Establish the size of the orifice opening using the following equation:

$$Q_{SD} = C_d A(2gh_d)^{1/2}$$

Where: $Q_{SD}$ = capacity of the storm drain system from step 1 (cfs)

$C_d$ = orifice coefficient = 0.65 (dimensionless)

A = orifice area ($ft^2$)

g = acceleration of gravity (32.2 $ft/sec^2$)

$h_d$ = height of water above mid-point of orifice (ft)

6) Ensure sufficient head is available in the treatment control BMP to accommodate flows from larger storm events through the orifice.

In addition to providing a bypass for the amount of water that exceeds the $WQ_V$, orifices can be used within volume based treatment controls in place of weirs or pipes to minimize floatables from entering the conventional storm drain system.

### 4.4.7 Bypass Pipes for Volume-Based Treatment Controls

1) Repeat steps 1 through 3 under Designing Orifice Diversions for Volume-Based Treatment Controls.

2) Size the bypass pipe to the design capacity of the storm drain system ($Q_{SD}$). Assuming the bypass pipe flows full at $Q_{SD}$, use the following version of the Manning's equation:

$$D = \left( \frac{2.159 Q_{SD} n}{S^{1/2}} \right)^{3/8}$$

Where: D = diameter of the bypass pipe (ft)

$Q_{SD}$ = capacity of the storm drain system (cfs)

n = Manning's roughness coefficient (dimensionless)

S = slope of the pipe or channel (ft/ft).

3) Ensure sufficient head is available in the treatment control BMP to accommodate flows from larger storm events through the bypass pipe.

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# Section 5: Storm Drain and Flood Control Design

## 5.1 Purpose

The purpose of this section of the Stormwater Development Standards is to provide criteria for design of stormwater infrastructure. The requirements contained herein supersede the 2004 City Design Standards and are in addition to Flood Damage Prevention standards. Chapter 9, Article VI of the Salinas Municipal Code includes Flood Damage Prevention standards related to FEMA requirements.

The following design criteria are intended to address various issues with historic criteria, the unique nature of the regional drainage system, and the application of LID techniques. Historic criteria include design of pipe systems to convey a 5-year or 20-year design storm, and detention to limit the post-development 100-year runoff to the 10-year pre-development rate. Most of the City of Salinas is tributary to the Reclamation Ditch drainage system. The Reclamation Ditch drainage system includes historic lakes that act as detention basins that greatly reduce peak discharges that would otherwise occur from the area of Salinas to Monterey Bay. The implications of effective implementation of LID can also be factored into storm drain design.

Drainage design criteria are presented for drainage collection system features and for measures to mitigate impacts on existing drainage systems. Drainage collection system features are required to satisfy roadway drainage requirements and to convey excess flows from LID features to receiving waters (for example, Carr Lake, Santa Rita Creek, or the Reclamation Ditch. Detention basins are required where necessary to limit discharges to the capacity of the existing collection system or to mitigate for increasing discharges into the receiving waters. Criteria for basins designed primarily for sediment control (such as the temporary basins recommended in the City's Stormwater Master Plan) are not covered by these Standards.

## 5.2 Receiving Waters

The majority of the City drains to the Reclamation Ditch system. Only the southwest portion of the City drains directly to the Salinas River. Gabilan, Natividad, and Alisal Creeks drain into historic lakes that are drained by the Reclamation Ditch. The Reclamation Ditch system includes Smith Lake, Heinz Lake and Carr Lake along the ditch within the City. Other portions of the City drain into Markeley Swamp or the Santa Rita Storage Area, both of which are also tributary to the Reclamation Ditch.

The Reclamation Ditch system is very complex and is generally deficient in capacity. Extensive flooding occurred in February 1998 during what has been estimated to be approximately a 25-year storm event. The City and Monterey County Water Resources Agency (MCWRA) are working together to develop funding programs and projects to correct existing deficiencies and accommodate future development. The complexities of the system make it challenging to identify appropriate mitigation and corrective measures.

One of the most significant complications is that the detention that may be necessary to mitigate for increased discharges into the existing storm drainage collection system can aggravate regional flooding conditions. This cause and effect scenario can be explained by the function of Carr Lake in context of the timing of flows from its entire 100 square mile tributary watershed relative to the timing of flows from local development.

Essentially, detaining flows that originate close to Carr Lake can cause these flows to be released into Carr Lake at a time closer to when peak flows from the upper watershed arrive. Therefore, detention of flows in areas tributary to Carr Lake could possibly cause water levels in Carr Lake to be higher than if no detention were to be used.

In some situations, development may not be required to include detention to release post development 100-year runoff at no more than the peak pre-development 10-year discharge. Requirements to obtain a waiver are listed in Section 5.5.4 Computer Simulation Method.

The complexities of the regional drainage system make it impractical to demonstrate that on-site improvements fully mitigate for off-site impacts to receiving waters. Therefore, whether or not a project is required to include detention would not provide direct cause for demonstrating any offset to any drainage system mitigation fees.

## 5.3 Conflicts

The City of Salinas makes no representation that the design practices or recommendations in these Design Standards (or in the publications listed as references and in the bibliography) meet all existing applicable codes or standards. It is up to the project engineer to design an appropriate combination of measures to meet all of the requirements. Where conflicts occur between stormwater management practices and existing codes and standards, municipal staff will work with the applicant to identify one or more regulatory or design solutions that can satisfy all applicable requirements.

Discuss with municipal planning staff any potential conflicts you note in the Stormwater Development Standards. By doing so, it may be possible to resolve the issue prior to final design. This will help avoid the need for redesign and re-submittal of final plans and associated project delays.

## 5.4 General

Stormwater runoff shall be minimized from development and significant redevelopment using the LID planning and source control techniques of Section 2:, and the LID designs and practices for both volumetric and qualitative stormwater control of Section 3:. Surface flows and flows collected in pipes in excess of those retained within LID features and the IMPs of Section 3.4 must be managed to limit flooding and erosion. The criteria presented herein shall be applied to drainage facility design for these excess flows. Conservative assumptions shall be made regarding the effectiveness of LID techniques, such as lowest realistic long-term infiltration rates and highest reasonable initial water levels in storage areas, for the purpose of calculating discharges for drainage facility design.

LID techniques may be designed to limit the difference between pre-development and post-development hydrology, particularly during more frequent storm events. With implementation of LID techniques, frequent storms that may not have generated any runoff in the pre-project condition should continue to not generate any runoff in the post-project condition. However, above some threshold, which would depend on site conditions, runoff from the site must be expected. Therefore, reasonable assumptions must be made regarding the effectiveness of LID techniques to determine design discharges during more severe storm events.

Methods used to calculate runoff from areas that include LID designs and IMPs shall address all actual impervious areas directly and the effectiveness of specific mitigation measures individually. Calculation methods are described in Section 5.5, Hydrology – Surface Runoff.

Storm drainage facilities shall conform to the City's Stormwater Master Plan (2004 version) and the City's Standard Specifications except as noted herein or as approved or directed by the City Engineer. The determination of storm runoff and required facilities shall be as outlined herein or in the City of Salinas Stormwater Master Plan (2004 version), or specific alternative methods approved by the City Engineer. The City's Stormwater Master Plan (2004 version) can be found at: http://www.ci.salinas.ca.us/MtcSvc/StormWater-NPDES/StormDrainMstrPlan.pdf.

The storm drainage system shall follow existing surface drainage patterns as much as possible, within the constraints of the development needs and City requirements. The existing major creeks in the City (Gabilan Creek, Natividad Creek, Santa Rita Creek) and the Reclamation Ditch shall be maintained in their existing state, or enhanced in accordance with approved plans, to the maximum extent practical.

Closed conduit storm drainage facilities for flows from new development tributary to the creeks or to detention/retention areas shall typically be reinforced concrete with pipe strength of Class 3, 4, or 5 RCP or high density polyethylene pipes HDPE-DR 26. At the option of the City Engineer, use of cast-in-place concrete pipes may be approved. The last closed conduit storm drain segment from any outfall day-lighting into an open channel to the first junction structure upstream from the outfall, and for a minimum distance of 50 feet, must be concrete for stability reasons. New drainage ditches or open channel conveyance shall only be used if approved by the City Engineer.

Detention of excess stormwater runoff flows from new development or redevelopment shall be mitigated as specified herein.

The design of storm drainage facilities is subject to final determination and approval of the City Engineer.

## 5.5 Hydrology – Surface Runoff

### 5.5.1 Pipeline Design Criteria

A (twenty) 20-year design storm shall be used for design of conduits and inlets in commercial and industrial areas and for main trunk lines. Main trunk lines are defined as those drainage systems having a tributary area of more than 25 acres. A five (5) year design storm shall be used for design of residential and local drainage facilities.

### 5.5.2 Calculation Methodology

These Design Standards allow for the use of the Rational Method for peak flow calculations for drainage areas of 25 acres or less, but require a City approved computer simulation method that performs volumetric flow routing for larger areas and evaluation of detention basin facilities. Because LID measures typically involve detention and infiltration, appropriate approved computer simulations must be used to demonstrate their effectiveness at reducing peak discharges and runoff volumes. Therefore, the only typical application of the Rational Method will be for roadway collection systems upstream from a treatment measure or for applications where bioretention is included at each inlet, but the effectiveness of the bioretention system at reducing the 5- or 20-year storm may not be included in drainage facility design in the public right-of-way.

Two methods are described in this section to estimate peak runoff for storm drainage facility sizing:

- Rational Method for drainage areas of twenty 25 acres or less. At the option of the City Engineer, the Rational Method may be used for larger areas.

- Computer simulation method for drainage areas of any size, but generally required for developments larger than twenty-five acres. Computer simulation method that includes storage routing shall be used for all detention basin designs.

### 5.5.3 Rational Method

The "Rational Method" can be used to determine peak discharges for drainage areas of twenty 25 acres or less. At the option of the City Engineer, use of the Rational Method may be approved for larger drainage areas.

The "Rational Method” approach is represented by the formula:

$$Q = CiA$$

Where:

Q - Design peak runoff/discharge in cubic feet per second (cfs) Design peak runoff/discharge in cubic feet per second (cfs)

C - Coefficient of runoff, representing the ratio of runoff to rainfall.

I - Average rainfall intensity expressed in inches per hour for a duration equal to the time of concentration.

A - Size of the tributary drainage area in acres.

**Time of concentration:**

- Time of concentration is defined at the sum of the initial time of concentration and the travel time to the point at which flows are being calculated.

- The initial time of concentration is the time required for water to flow overland to the first concentration point at which flow becomes channelized such as at a street gutter and along the gutter to the most upstream inlet. For typical residential developments, the initial time of concentration includes a roof to gutter time of 5 minutes plus travel time along a gutter that depends on slope and length.  Detailed calculations, based on expected flow times with LID features full of water to the depth expected during a severe storm event, can be used to calculate initial times of concentration.

- A minimum time of concentration of fifteen (15) minutes is used. A minimum time of concentration should not be confused with an initial time of concentration.

- Actual times of concentration along the conduit are calculated based on the initial time of concentration plus the travel time in the conduit. The minimum time of concentration is used until the actual time of concentration exceeds the minimum time of concentration.

Modified rainfall intensity curves for the City of Salinas, as shown herein (Figure 5-1) shall be used for runoff computations.

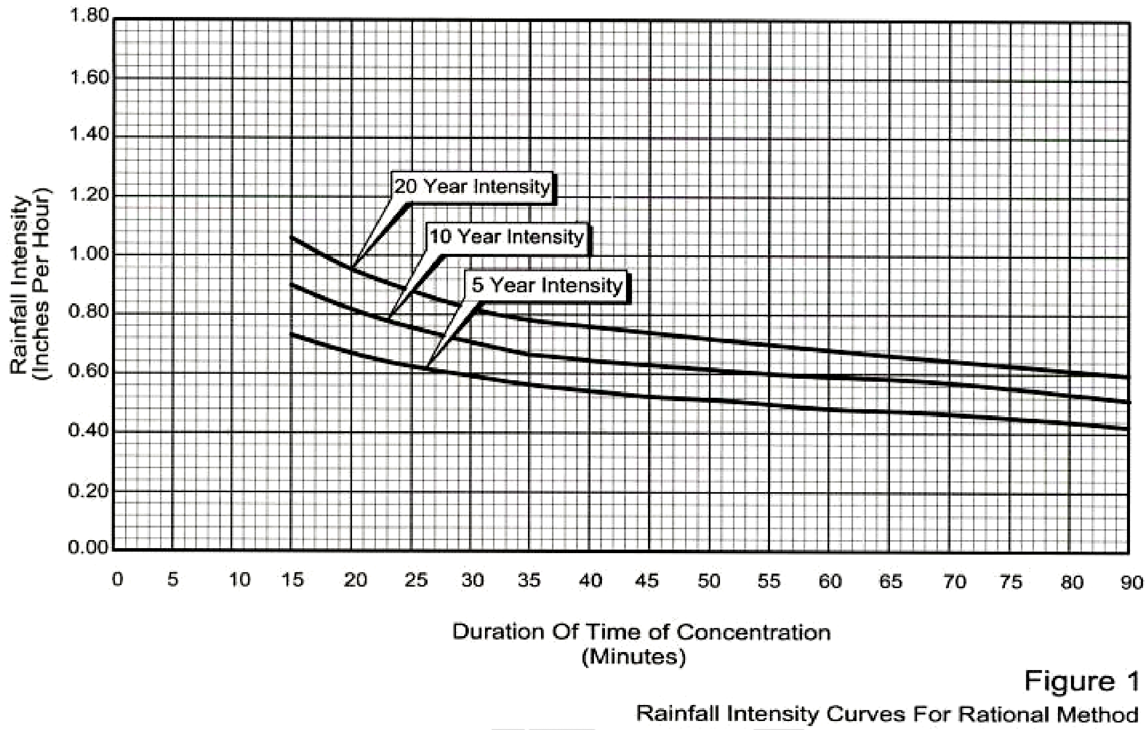


Figure 5-1: Rainfall Intensity Curves for Rational Method

Rational Method calculations require estimating runoff coefficients that represent the fraction of incident rainfall that becomes surface runoff. Actual runoff coefficients vary with many factors including antecedent rainfall, ground slope, and rainfall intensity. Therefore, a runoff coefficient that may be appropriate for design of a flow based water quality feature may not be appropriate for local storm drainage facility design such as for a storm drain receiving runoff from 20 acres.

For all cases, the applicable runoff coefficients shall be determined based on ultimate build-out land use. However, requirements for undeveloped upstream areas to incorporate on-site detention should also be considered, where appropriate. (Design shall consider the higher of existing and future flows and shall address the potential for sediments from upstream areas to impact the system.) For preliminary studies, approximate runoff coefficients may be based on estimates using of ultimate land use designations from the City's latest General Plan. A weighted runoff coefficient may be calculated based on the percentage of the different land uses in the tributary drainage area with minimum runoff coefficients as shown below.

For final design calculations, runoff coefficients shall be based on estimates of impervious area for the build-out conditions based on a weighted runoff coefficient of 0.90 for the tributary impervious area and 0.15 for the tributary pervious area. For the purposes of calculated peak discharges from 5-year storms and less frequent events, all impervious area, whether effective impervious area or not, shall be treated the same.

Table 5-1: Planning Study Rational Method Runoff Coefficients

| Land Use | Percent Impervious | Runoff Coefficient |
|---|---|---|
| Existing Residential: | | |
| Low Density | 30-50 | 0.4 |
| Medium Density | 50-60 | 0.5 |
| High Density | 60-80 | 0.6 |
| New Residential: | | |
| Low Density | 50-70 | 0.5 |
| Medium Density | 60-80 | 0.6 |
| High Density | 70-90 | 0.7 |
| All Commercial Use | 90-100 | 0.8 |
| Light Industry and Research | 70-80 | 0.7 |
| General Industry | 90-100 | 0.8 |
| Schools, Public & Semipublic Facilities | 40-60 | 0.4 |
| Parks and Open Space | 10-20 | 0.2 |

### 5.5.4 Computer Simulation Method

A computer simulation model can be used to estimate peak runoff and shall be used to perform volumetric routing for detention basins. Both existing and ultimate build-out land uses shall be evaluated for the analysis. Land use designation shall be obtained from the City's latest General Plan.

The City's current Stormwater Master Plan used the HYDRA model. The key hydrologic and hydraulic parameters for the HYDRA model shall be as described in the Master Plan report and summarized below. Appropriate use of these parameters can be applied to other models as well:

Percent impervious values for existing conditions shall be from Table 3-5 in the Stormwater Master Plan, or estimates based on aerial photographs if the engineer determines that the typical values in the Table are not appropriate to the specific location being studied. Table 3-5 may be used for planning studies to determine ultimate impervious areas. Site planning documents shall be used to estimate impervious areas for final design.

A six (6-hour) duration storm shall be used for computer simulations to determine design discharges in storm drains, as shown below:

Table 5-2: Six (6) Hour Duration Storm For Storm Drains

| Time Interval (h:mm) | Five (5) Year Storm | | Ten (10) Year Storm | | Twenty (20) Year Storm | |
|---|---|---|---|---|---|---|
| | Cumulative Rainfall Amount (inches) | Rainfall Intensity (in/hrs) | Cumulative Rainfall Amount (inches) | Rainfall Intensity (in/hrs.) | Cumulative Rainfall Amount (inches) | Rainfall Intensity (in/hrs) |
| 0:00-0:15 | 0.02 | 0.07 | 0.02 | 0.80 | 0.02 | 0.09 |
| 0:15-0:30 | 0.03 | 0.07 | 0.04 | 0.08 | 0.05 | 0.09 |
| 0:30-0:45 | 0.06 | 0.10 | 0.07 | 0.12 | 0.08 | 0.14 |
| 0:45-1:00 | 0.09 | 0.10 | 0.10 | 0.12 | 0.11 | 0.14 |
| 1:00-1:15 | 0.11 | 0.10 | 0.13 | 0.12 | 0.15 | 0.14 |
| 1:15-1:30 | 0.15 | 0.14 | 0.17 | 0.16 | 0.19 | 0.18 |
| 1:30-1:45 | 0.18 | 0.14 | 0.21 | 0.16 | 0.24 | 0.18 |
| 1:45-2:00 | 0.21 | 0.14 | 0.25 | 0.16 | 0.29 | 0.18 |
| 2:00-2:15 | 0.26 | 0.17 | 0.30 | 0.20 | 0.34 | 0.23 |
| 2:15-2:30 | 0.30 | 0.17 | 0.35 | 0.20 | 0.40 | 0.23 |
| 2:30-2:45 | 0.35 | 0.21 | 0.41 | 0.24 | 0.47 | 0.27 |
| 2:45-3:00 | 0.40 | 0.21 | 0.47 | 0.24 | 0.54 | 0.27 |
| 3:00-3:15 | 0.46 | 0.24 | 0.54 | 0.28 | 0.62 | 0.32 |
| 3:15-3:30 | 0.57 | 0.43 | 0.67 | 0.50 | 0.76 | 0.57 |
| 3:30-3:45 | 0.74 | 0.70 | 0.89 | 0.90 | 1.02 | 1.05 |
| 3:45-4:00 | 0.87 | 0.50 | 1.02 | 0.50 | 1.16 | 0.57 |
| 4:00-4:15 | 0.98 | 0.43 | 1.14 | 0.50 | 1.30 | 0.55 |
| 4:15-4:30 | 1.03 | 0.21 | 1.20 | 0.24 | 1.37 | 0.27 |
| 4:30-4:45 | 1.07 | 0.17 | 1.25 | 0.20 | 1.43 | 0.23 |
| 4:45-5:00 | 1.11 | 0.17 | 1.30 | 0.20 | 1.49 | 0.23 |
| 5:00-5:15 | 1.15 | 0.14 | 1.34 | 0.16 | 1.53 | 0.18 |
| 5:15-5:30 | 1.17 | 0.10 | 1.37 | 0.12 | 1.57 | 0.14 |
| 5:30-5:45 | 1.19 | 0.07 | 1.39 | 0.08 | 1.59 | 0.12 |
| 5:45-6:00 | 1.20 | 0.03 | 1.40 | 0.04 | 1.60 | 0.08 |



Detention basins are sized to accommodate the more stringent (higher) storage volume that would be needed under either of the following conditions: 1) to limit discharge to the 10-year pre-development rate, and store the difference between the 10-year pre-development and 100-year post-development runoff; or 2) to limit discharge to the available capacity of the downstream drainage facilities.

A 24-hour rainfall distribution shall be used to design detention basins to limit peak discharges unless a longer discharge is necessary to demonstrate that the basin has reached 100-year peak stage. Rainfall for 24-hour storm analyses shall follow the SCS Type 1A. An appropriate rainfall and calculation time interval shall be selected that consider the time of concentration for the site. The 24-hour rainfall depths for the 10- and 100-year storms are 2.5 and 3.7 inches, respectively.

The model developed for the MCWRA Zone 9 and Reclamation Ditch Drainage System Operations Study (Schaaf & Wheeler 1999) shall be used as a basis for evaluating impacts on receiving waters. The Zone 9 Model is based on the U.S. Army Corps of Engineers December 1955 rainfall distribution, balanced to fit regional statistics, with a storm duration of 72 hours. Refer to Appendix B of the MCWRA Zone 9 Study for more information. Modeling to determine impacts on the receiving waters shall generally be required to obtain a variance from the detention standards and shall clearly isolate impacts from the “with” and “without” or “proposed variance” detention from other changes. A waiver may be granted if it is demonstrated to the satisfaction of the City Engineer that:

1. The local drainage system from the proposed development to the regional system (Carr Lake, Reclamation Ditch, Markeley Swamp and Santa Rita Storage Area) will not be negatively,

2. Impacts to the drainage system will be minimized through the implementation of Low Impact Development measures, and

3. Inclusion of detention would make regional drainage problems more severe based on the design 3-day, 100-year storm.

Loss rates and other calculation parameters and methodology applied to design shall be consistent with the MCWRA Zone 9 Study or the 2004 Stormwater Master Plan, or City Engineer approved alternative. In no case shall composite loss rate values (SCS Curve Numbers) be applied. Runoff from pervious and impervious areas shall be calculated independently. Some parameters from the 2004 Stormwater Master Plan are included herein.

Soil infiltration rates are used as a parameter to account for losses between rainfall and runoff due to percolation of rainfall into the soil. The infiltration rates of the major soils within the City, as shown below, shall be used. Information on soil types within the development shall be obtained form the U.S. Natural Resources Conservation Service (formerly Soil Conservation Service) or from soils reports and infiltration tests prepared for the development.  Soil information is also available at http://websoilsurvey.nrcs.usda.gov/app/.

Table 5-3: Infiltration Rates From City's Stormwater Master Plan

| | Infiltration Rate | | |
|---|---|---|---|
| Hydrologic Soil Group | Maximum (in/hr) | Minimum (in/hr) | Soil Associations Within City |
| A | 6 | 2 | Sandy xerothents |
| B-High [a] | 6 | 2 | Arroyo Seco gravelly loams |
| B-Low | 2 | 0.6 | Chualar loams, Elder sandy loam |
| C | 0.6 | 0.2 | Rincon clay loams, Salinas loam, Salinas clay loam |
| D | 0.2 | 0.06 | Antioch very fine sandy loams, Clear Lake clays, Diablo clays, Placentia sandy loams [b] |

**Notes:**

(a) The Soil Survey classifies the Arroyo Seco gravelly foams as Group B. However, the infiltration rates for these soils are those of Group A. For the model analysis, the higher infiltration rates will be used for these soils.

(b) Antioch very fine sandy loams and Placentia sandy loams are classified as Group D due to a hard pan layer located at a depth of approximately thirteen (13) inches and twenty-one (21) inches, respectively. The soil layer above the hard pan has a higher infiltration rate similar to Group B. However, under saturated conditions, the percolation rate would be that of Group D.

Analysis may be performed using the methodology of the 2004 Stormwater Master Plan, which uses the Horton Equation. For this method, the falling off of the infiltration rate from the maximum to the minimum value during the storm is an exponential decay function. The rate of decrease of the infiltration rate depends on the initial soil moisture content at the start of the storm, with saturate soils having higher runoff. As was used in the 2004 Stormwater Master Plan, a decay rate of 0.00115 per second shall be used.

Depression storage represents an initial loss caused by such phenomena as surface ponding, surface wetting, interception and evaporation. The following depression storage values shall be used as average values for the tributary drainage area:

Pervious Areas 0.18 inches

Impervious Areas 0.06 inches

Losses from interception storage by vegetation and evaporation-transpiration are minimal during rainy season conditions, and can be ignored for analysis purposes.

## 5.6 Hydraulic Considerations

Storm drains (pipes, culverts, closed conduits) shall be sized with adequate capacity to convey the peak design flow with the hydraulic gradeline below ground level. Open channels shall be designed with a minimum of one (1) foot freeboard for peak design flow.

A minimum mainline pipe size of fifteen (15) inch diameter is required for all storm drains. A twelve (12) inch diameter may be used for catch basin laterals, provided it has adequate capacity and will have a one (1) percent minimum slope.

Gradients of pipes shall be sufficient to provide a velocity not less than two (2) feet per second or more than eight (8) feet per second when flowing full. End lines serving a single inlet shall have a one (1) percent minimum slope; although slope should be maximized to minimize maintenance efforts.

Manning's formula for gravity flow shall be used in computing capacity of drainage facilities. The roughness coefficient (n) for friction losses shall be as follows:

Table 5-4 Roughness Coefficients

| Type of Facility | n |
|---|---|
| Concrete Pipe | |
| • Under 24” diameter | 0.015 |
| • Over 24” diameter | 0.013 |
| Concrete-lines interceptor V-Ditches (typically 1-foot depth) | 0.017 |
| Reinforced Concrete Box Culvert | |
| • Cast-in-Place | 0.015 |
| • Pre-Cast | 0.014 |
| Natural Channels | |
| • Straight bank with some weeds & stones | 0.035 |
| • Straight bank very weedy reaches | 0.070 |
| • Winding with some weeds & stones | 0.045 |
| • Winding very weedy reaches | 0.125 |
| Earthen Channels- smooth, geometric | 0.030 |
| Concrete-lined Channels | |
| • Smooth troweled | 0.015 |
| • Rough | 0.017 |
| HDPE PIPE (ADS N-12 or equal) | 0.012 |

Drainage inlet type and spacing shall be governed by the capacity of the drainage channel/gutter as well as the capacity of the inlet itself. Generally, channel flow lengths between inlets should be less than one thousand (l,000) feet, with a flowline grade of not less than thirty-six hundredth (0.36) of a percent. Actual spacing shall consider roadway ponded widths and inlet capacity. Valley gutters may only be used with the authorization of the City Engineer. In designing a structure, the inlet capacity of the pipe draining the inlet structure and the inlet configuration itself shall be considered. Flows shall not encroach into the travel lanes during the design storm event. Inlet bypass flows shall be considered in street flow evaluations.

Manholes or structures providing access to the pipe should be constructed at all changes in pipe size and angle points. Manhole spacings should not exceed six hundred (600) feet. Manholes are required at all lateral pipe junctions with new and existing mains, unless the main pipeline is three times or greater in diameter than the joining pipe. Where grades permit, one-tenth (0.1) of a foot drop in manholes should be included where there is no appreciable change in direction, and two-tenth (0.2) foot drop where turns occur.

Pipelines may be laid on curves by using beveled pipe sections and/or by deflections of straight pipe in accordance with pipe manufacturer's recommendations.

Siphons shall not be used at any location within the storm drainage system.

Special consideration shall be given to the design criteria for major trunk lines and outfalls, pumping stations and areas historically subject to flooding. Design criteria for flood prone lands shall be in accordance with these standards and specifications, and with the standards of the Monterey County Water Resources Agency. Requirements for stormwater detention/retention are discussed in Section 5.8.

For the protection of properties under flooding conditions, flood relief structures, channels or other drainage facilities shall be constructed to accommodate floodwater depths exceeding nine (9) inches above gutter flowline.

The backwater effects of Carr Lake, the Reclamation Ditch and the major creeks shall be taken into account by specifying at a minimum the beginning water surface elevations in those water bodies, as obtained from the most recent version of FEMA's Flood Insurance Study, and the FEMA FIRM maps, including subsequent Letters of Map Amendment (LOMAs), and Letters of Map Revision (LOMRs) that have revised the original FIRM maps.

The ten (10) year beginning water surface elevations shall be used for those pipe networks designed to convey the five (5) year runoff, and the twenty-five (25) year water beginning surface elevations shall be used for those pipe networks designed to convey the twenty (20) year runoff. The starting point for the hydraulic gradeline calculation shall be where the subdivision's storm drainage discharges to a creek, channel or detention area.



## 5.7 Floodway And Floodplain Requirements

A Flood Insurance Study and Flood Insurance Rate Map (FIRM) have been prepared for the City by the Federal Emergency Management Agency (FEMA). In addition, there have been subsequent Letters of Map Amendment (LOMAs) and Letters of Map Revision (LOMRs) that have revised the original FIRM maps. Regulations for new construction, subdivisions, utilities, and the regulatory floodway as stipulated in the study, map, and floodplain ordinance are applicable to storm drainage improvements within the floodplain/floodway.

## 5.8 Detention/Retention Requirements

New development and redevelopment shall provide stormwater detention or retention to mitigate increases in stormwater discharges. This shall be done only after stormwater runoff volume minimization using planning techniques such as minimization of impervious surfaces and Low Impact Development requirements of the City have been implemented.

Regional detention basin locations, as identified in the City's Stormwater Master Plan or approved Precise/Specific Plans, shall be implemented when development occurs in new areas. The requirement for detention/retention may be waived only with approval of the City Engineer.

Drainage system design shall also be in accordance with Monterey County Water Resources Agency detention criteria for new development discharging to Carr Lake or its tributaries, and to the Reclamation Ditch system unless a variance is obtained. The Monterey County criteria for stormwater detention is to limit discharge to the ten (10) year pre-development rate, and store the difference between the ten (10) year pre-development and one hundred (100) year post-development runoff for development upstream of North Main Street and/or West Laurel Drive/US 101.

A detention basin has a small outlet, and flow returns to the downstream drainage system at a low rate. A retention basin has no outlet, and water leaves only by evaporation or percolation into the ground. Unless otherwise approved by the City Engineer, detention basins shall be used rather than retention basins due to the proximity of major drainage channels, and the relatively low soil permeability (slow percolation characteristics) in much of the City.

The required storage volume shall be determined using a twenty-four (24) hour duration design storm, a discharge rate that does not exceed the available downstream capacity, and is conformance with the Monterey County criteria described above. Basin outlets shall be provided to release incoming flows to downstream facilities at less than the ten (10) year pre-development rate, but not greater than the capacity of the downstream facilities.

Detention basins with engineered fill embankments shall have an uncontrolled spillway to protect the embankments. A minimum of 2 feet of freeboard shall remain at 1.5 times the 100-year peak discharge rate. A defined overland release path is required for the 100-year peak discharge rate for situations where the entire basin volume is in cut. A surface route for overflows downstream from the basin shall be provided to minimize the potential for damage in the even that basin capacity is exceeded.

Where appropriate, basin design shall incorporate features that provide stormwater quality benefits for excess flows, while still meeting flood control needs. The California Stormwater Best Management Practice Handbook for New Development and Redevelopment (California Stormwater Quality Association, January 2003) shall be used as the basis for design of the stormwater quality features. Basins shall include a de-silting chamber or sediment forebay. Where appropriate, basins shall provide adequate detention time for runoff from the small storm events that have the greatest impact on water quality, as specified in the Handbook.

Detention basins shall be designed to drain within a maximum of forty-eight (48) to seventy-two (72) hours to minimize mosquito/vector control problems. The City Engineer may approve detention basins designed to drain in 96 hours if it is demonstrated that a more restrictive outlet is necessary to meet downstream flow rate constraints.

## 5.9 Design Submittal Requirements

The design engineer shall submit a design report on the proposed storm drainage system improvements. This report shall include:

The hydrologic calculations, facility sizing, and hydraulic gradeline calculations for proposed facilities and where they drain into existing facilities. Hydrologic and hydraulic calculations shall meet the requirements specified in this section. If a computer model is used, a description of the model, the hydrologic and hydraulic parameters used for the analysis, the analysis findings, and printouts of the computer input and output files for the proposed improvements shall be documented and provided to the City Engineer.

Profiles of each existing and proposed storm drain shall be submitted with the calculations. The profile shall show the following information: beginning water surface elevation and location for hydraulic calculations; storm drain invert and soffit; diameter; design flow; design hydraulic gradeline; existing ground line; proposed ground line if applicable; and locations of street intersections and connections with other storm drains or channels. A plan view map shall also be provided for off-site profiles.

For detention/retention basins, the storage volume calculations, a plan view map showing the location of the basin, a conceptual cross-section showing the depth, and a description of any stormwater quality features to be incorporated into the basin design shall be provided.

A description of the Low Impact Development techniques and measures that will be employed and any additional stormwater quality best management practices (control measures) that will be used, and a plan view map showing their location shall be provided.