EXHIBIT 7.III

TECHNICAL GUIDANCE DOCUMENT (TGD)

FOR THE PREPARATION OF CONCEPTUAL/PRELIMINARY AND/OR PROJECT WATER QUALITY MANAGEMENT PLANS (WQMPs)

in SOUTH ORANGE COUNTY

Version 1.1

Major release date: September 28, 2017 (Version 1.0)

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Version Notes:

This version of the of the TGD (Version 1, Version 1.1, etc.) is intended to be used to support project development in South Orange County. In combination with the Model WQMP, this document is intended to serve as the "Model BMP Design Manual" for South Orange County pursuant to the requirements of the San Diego Regional MS4 Permit (Order No. 2013-0001 as amended by Orders 2015-0001 and 2015-0100).

THIS DOCUMENT IS NOT FOR USE IN NORTH ORANGE COUNTY AT THIS TIME. A subsequent reissuance of this TGD is anticipated in the future to support project development in North Orange County upon adoption of the 5th Term MS4 Permit in the North Orange County Region. To aid in the future incorporation of the North Orange County MS4 Permit into this TGD once the new permit is adopted, placeholders have been incorporated throughout the TGD for the subsections, figures, tables, and appendices specific to North Orange County.

CHANGE LOG

9/28/2017 – Version 1

Original publication of 2017 TGD to comply with 2015 MS4 Permit.

12/21/2018 – Version 1.1 - minor, slip-sheet update

Section 1.1.4 - Corrected an error related to permit applicability in Laguna Hills and Laguna Woods.

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Technical Guidance Document

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ACRONYMS

BMP – Best Management Practice
CEQA - California Environmental Quality Act
CMF – Cartridge Media Filtration
CWA – Federal Clean Water Act
DAMP – Drainage Area Management Plan
DCIA – Directly Connected Impervious Area
DCV – Design Capture Volume
DCF – Design Capture Flow
DWF – Dry Weather Flow
DEDB – Dry Extended Detention Basin
ESA – Environmentally Sensitive Area
ET – Evapotranspiration
HCOC – Hydrologic Condition of Concern
HMP – Hydromodification Management Plan
HSC – Hydrologic Source Control
EIATA – Effective Irrigated Area to Tributary Area
IRWMP – Integrated Regional Water Management Plan
LID – Low Impact Development
LIP – Local Implementation Plan
MEP – Maximum Extent Practicable
MS4 – Municipal Separate Storm Sewer System
NOC – North Orange County (Region 8- SARWQCB Jurisdictional Area)
NPDES – National Pollutant Discharge Elimination System
NPP – Non-Priority Project
NTS – Natural Treatment Systems
OCWD – Orange County Water District
POC – Pollutant of Concern
RWQCB – Regional Water Quality Control Board
SARWQCB – Santa Ana Regional Water Quality Control Board
SDRWQCB – San Diego Regional Water Quality Control Board
SJBA – San Juan Basin Authority
SOC – South Orange County (Region 9 -SDRWQCB Jurisdictional Area)
SSMP – Standard Stormwater Mitigation Plan
TGD – Technical Guidance Document
TMDL – Total Maximum Daily Load
TUTIA – Toilet Users to Impervious Area
WMA – Watershed Management Area
WMAA – Watershed Management Area Analysis
WQ – Water Quality
WQIP – Water Quality Improvement Plan
WQMP – Water Quality Management Plan

GLOSSARY OF KEY TERMS

Agronomic Demand – the amount of irrigation required to meet plant water needs, accounting for inefficiencies in irrigation.

Alternative Compliance Program – In general, refers to a program through which qualifying project applicants may participate in alternative compliance options in lieu of implementing some or all on-site structural BMP requirements. Specific criteria and attributes of alternative compliance programs vary by region.

Assessment of Susceptibility (to Hydrologic Conditions of Concern) – an assessment of the receiving water(s) of a project to determine whether downstream water courses, water bodies, and/or stormwater conveyance infrastructure would potentially be impacted by changes in hydrologic regime.

Average Annual Capture Efficiency (a.k.a. capture efficiency) – the estimated percent of long term average annual runoff volume that is managed/controlled by a BMP. Target capture efficiency serves as one element of the performance criteria for LID and treatment control BMPs.

Biofiltration BMP – A class of BMPs that use dense vegetation and biologically-active amended soils to detain and treat runoff from impervious areas. Treatment is through filtration, infiltration, adsorption, ion exchange, and biological uptake of pollutants.

Biotreatment BMP[1] – A sub-category of structural treatment control BMPs that employ biological uptake, transformation, or degradation of pollutants as their principal mechanism(s) of pollutant removal. Although a portion of the design capture volume or flow may incidentally infiltrate, evaporate, or evapotranspire, the principal of operation involves the discharge of the treated storm water after detention in a densely-vegetated basin and/or passing through porous, biologically-active medium, dense vegetation or both. Biofiltration BMPs are a kind of biotreatment BMP.

Biofiltration volume (see also "pre-filter and pore storage volume") – the volume of storage in biofiltration BMPs, measured from the lowest treated discharge elevation of the BMP up to BMP overflow elevation; this volume includes surface storage and pore storage but does not include the volume that would be retained in the BMP and discharged to infiltration, ET, or uses.

Biotreatment Volume – see biofiltration volume.

Bypass – runoff that is routed around a BMP or passes through the BMP with minimal treatment. Bypass generally occurs when the inflow volume or flowrate has exceeded the BMP capacity and the BMP is completely full.

Capture Efficiency – see *average annual capture efficiency*.

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[1] Biotreatment BMPs that do not also meet the definition of a "biofiltration BMP" are not considered LID BMPs; they may be considered treatment control or pretreatment BMPs.

Capture Efficiency Method – a BMP sizing method based on capturing a specified percentage of the average annual stormwater runoff volume from a project as determined with continuous flow modeling or via nomograph methods developed from continuous simulation modeling.

Conceptual Project WQMP - a Project WQMP prepared at the planning phase of projects subject to discretionary approval; intended to describe, at the earliest possibly phase in the development process, the BMPs that will be implemented and maintained throughout the project (functionally equivalent to a Preliminary Project WQMP; nomenclature varies by local jurisdiction).

Conforming BMP – A structural BMP that substantially conforms to one of the BMP types in the BMP fact sheets and has been designed using generally-accepted engineering methods.

Design Capture Storm Depth – the 85^{th} percentile, 24-hr storm depth at the project site; varies by location within the County.

Design Capture Volume (DCV)– the volume of storm water runoff resulting from the design capture storm depth.

Design Criteria – requirements that serve as the basis for designing a BMP to meet performance criteria. Design criteria may encompass BMP sizing and other characteristics of BMP design.

Drainage Area Management Plan (DAMP) – The specific water pollutant control elements of the Orange County Stormwater Program are documented in the Drainage Area Management Plan (DAMP), which is the Permittees' primary policy, planning and implementation document for municipal NPDES Stormwater Permit compliance.

Drawdown – the process of discharging water from a BMP. Drawdown results in emptying of the BMP over time following a storm event and results in creation of storage volume for subsequent storm events.

Drawdown Rate – the rate at which water discharges from a BMP, making storage volume available for subsequent storm events.

Drawdown Time – the time it takes to drain a BMP from brim full. Drawdown time may need to be calculated separately for the retention volume of the BMP and the biotreatment volume of the BMP in order to support design calculations if both types of volume exist. These separate measures are referred to as the "retention drawdown time" and "biotreatment drawdown time".

Environmentally Sensitive Area - areas such as those designated in the Ocean Plan as Areas of Special Biological Significance or waterbodies listed on the CWA Section 303(d) list of impaired waters (See full definition in **Section 2.3.4)**.

Evapotranspiration (ET) - the loss of water to the atmosphere by the combined processes of evaporation (from water, soil and plant surfaces) and transpiration (from plant tissues). As used in this TGD, ET refers to one or both of these processes.

Evapotranspiration BMP (aka ET BMP) – a class of retention BMPs that discharges stored volume predominantly to ET; some infiltration may occur. ET includes both evaporation and transpiration, and ET BMPs may incorporate one or more of these processes.

Final Project WQMP – a Project WQMP submitted at the ministerial approval phase prior to final approval of a grading or building permit; expected to reflect the detail available at the time of project ministerial-level approval.

Harvest and Use – The process of capturing rainwater or stormwater runoff, storing it, and making it available for subsequent use. This process is performed by Harvest and Use BMPs.

Harvest and Use BMP (aka Rainwater Harvesting BMP) – a class of retention BMPs that captures rainwater or stormwater runoff and stores it for subsequent use.

Hydrocollapse - a sudden collapse of granular soils caused by a rise in groundwater dissolving or deteriorating the inter-granular contacts between the sand particles

Hydrologic Condition of Concern (HCOC) – a combination of upland hydrologic conditions and stream biological and physical conditions that presents a condition of concern for physical and/or biological degradation of a stream.

Hydrologic Source Control (HSC) - a class of LID BMPs integrated with site design that retain stormwater runoff and reduce the volume (and potentially rate) of stormwater discharge to the downstream system. HSCs are differentiated from retention and biotreatment classes of LID BMPs by their higher level of integration with a site. They are not sized according to engineering design criteria, and they do not typically result in a distinct facility. Consequently, they are usually regarded as site design practices, as opposed to structural treatment control BMPs. An example includes routing roof runoff into adjacent landscaped areas.

Hydromodification – Changes in runoff and sediment yield caused by land use modifications.

Hydromodification Control – Management techniques which reduce the potential for hydromodification impact.

Hydromodification Impact – The physical response of stream channels to changes in runoff and sediment yield caused by land use modifications

Infiltration BMP – a class of retention BMPs that discharges stored volume predominantly to infiltration/deeper percolation; some evapotranspiration may also occur.

In-stream Control – Modification of a receiving channel as a technique for managing hydromodification impacts. The modifications are usually done for the purposes of allowing the channel to accept changes in hydrology while minimizing impacts to beneficial uses.

Irrigation Area Ratio – a ratio describing the agronomic irrigation demand for harvested stormwater as a fraction of the tributary area to the stormwater storage device.

Irrigation Efficiency – the ratio of plant irrigation needs met to the amount of irrigation water applied. A value of 0.75 implies that 1 inch of irrigation water must be applied to satisfy 0.75

inches of plant water needs. The balance is lost directly to evaporation or to deeper percolation below the root zone.

LID BMP – a BMP that provides retention or biotreatment as part of an LID strategy – these may include HSCs, retention, and biotreatment BMPs. Biotreatment BMPs that do not meet the definition of biofiltration are not considered LID BMPs in the SOC MS4 permit.

LID Site Design – The component of an LID approach that relates to the way in which a site is laid out to achieve strategic stormwater management and resource management objectives. Site design practices work synergistically with LID BMPs, treatment control, and hydromodification control strategies. Example practices include minimizing impervious areas and locating pervious areas such that impervious areas can drain to pervious areas.

Liquefaction - a seismically-induced geological hazard that can result in damage to structures as a result in reduction in bulk volume of saturated granular soils.

Local Implementation Plan (LIP) - The Local Implementation Plan (LIP) describes how the DAMP is being implemented by individual permittees under the MS4 Permit. The DAMP provides a foundation for the description and detail of how the Orange County Stormwater Permittees commonly implement model programs designed to prevent pollutants from entering receiving waters to the maximum extent practicable (MEP). The LIP is designed to supplement the DAMP and each city and the County have developed a comprehensive LIP that is specific to their jurisdiction.

Nonconforming BMP – Any structural BMP that does not substantially conform to one of the BMP types in the BMP fact sheets.

Non-Infiltration Biotreatment BMP – A biotreatment BMP that is designed to avoid infiltration or does not provide appreciable infiltration.

Non-Priority Project - a new development or redevelopment project that has a nexus to stormwater quality but does not meet the thresholds to be considered a Priority Project described in **Section 1.2** of the TGD.

On-site LID Practices – LID practices that are implemented within the project boundary.

Other Pollutants of Concern – a pollutant which is expected to be generated by the project's land uses for which there is no 303(d) listing or TMDL in place for any receiving water of the project.

Partial Infiltration Biotreatment BMP – a biotreatment BMP that includes incidental infiltration and has been designed to maximize volume reduction via infiltration and ET in those conditions where partial infiltration is feasible.

Performance Criteria – specific measurable or verifiable requirements against which the performance of a system is compared to assess conformance with applicable requirements. There are three separate types of performance criteria: 1) LID, 2) treatment control, and 3) hydromodification control. These performance criteria are evaluated individually although they can be interrelated. It is possible to meet one and not meet the others. This is synonymous with "performance standard."

Preliminary Project WQMP – a Project WQMP prepared at the planning phase of projects subject to discretionary approval; intended to describe, at the earliest possible phase in the development process, the BMPs that will be implemented and maintained throughout the project (functionally equivalent to a Conceptual Project WQMP; nomenclature varies by local jurisdiction).

Pre-filter Volume (see also "biofilter volume") – the volume of storage in biofiltration BMPs, measured from the lowest treated discharge elevation of the BMP up to BMP overflow elevation; this volume includes surface storage and pore storage but does not include the volume that would be retained in the BMP and discharged to infiltration, ET, or uses.

Primary Pollutant of Concern - A pollutant which is expected to be generated by the project's land uses for which there is a 303(d) listing or TMDL in place for any receiving water of the project.

Priority Development Project – See Priority Project. The term "priority development project" is used in the South Orange County MS4 Permit, but for the purpose of this document, only the term "Priority Project" is used.

Priority Project – a new development or redevelopment project meeting the thresholds described in **Section** 1.2 of the TGD.

Project Water Quality Management Plan (Project WQMP) - a project submittal that describes the Best Management Practices (BMPs) that will be implemented and maintained throughout the life of a project. This term is used in this TGD to describe Conceptual/Preliminary and Final Project WQMPs.

Retention BMP – a class of LID BMPs including infiltration BMPs, evapotranspiration BMPs, and harvest and use BMPs whose design does not allow the discharge of stormwater runoff to the storm drainage system or surface water up to the DCV; these BMPs either infiltrate, evapotranspire, or allow for storage and later use of the retention volume.

Retention Volume – the volume of storage in retention and biotreatment BMPs that would be retained and discharged to infiltration, ET, or uses as the BMP drains. All storage volume is retention volume in retention BMPs. In biotreatment or biofiltration BMPs, retention includes water held below the lowest treated discharge elevation and in suction storage in soil pores

Site Design – a stormwater management strategy that emphasizes conservation and use of existing site features to reduce the amount of runoff and pollutant loading that is generated from a project site. Site design practices compliment LID BMPs, treatment control, and hydromodification control strategies. Example practices include clustering development, minimizing impervious areas, and locating pervious areas such that impervious areas can drain to pervious areas.

Sizing Criteria – specific design criteria related to BMP size that serve as a basis for meeting performance criteria.

Source Control – a class of preventative measures intended to prevent the introduction of pollutants into stormwater.

Standard Stormwater Mitigation Plan (SSMP) – see Project WQMP

Structural BMP Requirements – refers to the portion of WQMP requirements that apply only to Priority Projects, including LID BMPs sized for the DCV (or equivalent), treatment control BMPs (if applicable), and hydromodification control (if applicable).

Susceptibility – a channel's lack of ability to resist physical response due to hydromodification

Treated Discharge – water that is discharged from a BMP to the storm drain or receiving water after treatment (see *treatment*).

Treatment – removal of pollutants from stormwater discharges. Treatment is provided by LID and treatment control BMPs. Levels of treatment vary by BMP types. Volume reduction via infiltration or ET is considered to be a type of treatment.

Treatment Control BMP – a structure designed to treat pollutants in stormwater runoff and release the treated runoff to surface waters or a storm drain system, but is not a biotreatment BMP. Examples include sand filters and cartridge media filters. In the SOC Permit, this category of BMPs is referred to as "Flow Thru Treatment Control BMPs."

Water Quality Improvement Plan – a requirement of the Fifth Term MS4 permit in SOC which provides an adaptive management pathway for Copermittees to select and address the highest priority water quality issues through an iterative process.

Water Quality Management Plan – see *Project Water Quality Management Plan*

Watershed Management Area (WMA) - Watershed Management Areas (WMAs) are used in the countywide Water Quality Strategic Plan as the structure for water resource management. The eleven watersheds in Orange County are grouped by similar characteristics into three Watershed Management Areas: North, Central, and South County.

Watershed Management Area Analysis (WMAA) – an element of the Water Quality Improvement Plan in SOC.

2-year, 24-hour Event – a 24-hour storm event expected to be equaled or exceeded, on average, every 2 years. As defined for Orange County by the Orange County Hydrology Manual.

EQUIVALENT TERMINOLOGY USAGES IN THIS TGD

The 5th Term SOC MS4 Permit uses certain terminology that is different than the 4th Term SOC MS4 Permit and is different from previous versions of this Technical Guidance Manual. The purpose of this section is to list the terms used in this TGD and the equivalent terms found in the 5th Term SOC MS4 Permit.

Site Design BMPs – In this document, this term is specifically used to refer to BMPs that relate to how a site is designed. In the SOC MS4 Permit, many of these practices are found under a heading of Low Impact Development, however these are not referred to as LID BMPs in this document.

Structural Treatment BMPs – This refers to a class of BMPs that is designed to a specific sizing standard and operates to remove pollutants from stormwater via combinations of hydrologic losses (e.g. infiltration, ET, harvest and use) and treatment processes (e.g., filtration, biological update, conversion). This is synonymous with "Stormwater Pollutant Control BMPs" used in the SOC MS4 Permit. Structural Treatment BMPs must be selected according to a prioritization hierarchy where retention BMPs are the highest priority, followed by biofiltration BMPs, followed by treatment control BMPs. Retention BMPs and biofiltration BMPs are LID BMPs, while treatment control BMPs are not.

LID BMPs – This term is used to refer specifically to a subset of structural treatment BMPs including retention BMPs, biofiltration BMPs, and hydrologic source controls. These BMPs have a specific numeric sizing basis and are used for controlling pollutants in stormwater runoff.

Retention BMPs – The first priority class of LID BMPs. Includes infiltration and harvest and use BMPs, both of which may also be supported by evapotranspiration.

Biotreatment/Biofiltration BMPs – The second priority class of LID BMPs. The SOC Permit uses only the term biofiltration. Biofiltration is a narrower term than biotreatment. Biofiltration is always biotreatment, but biotreatment is only biofiltration if it meets the narrower definition and criteria to be considered biofiltration. Biotreatment BMPs that do not meet the definition of biofiltration BMPs may only be used as a treatment control BMP or a pretreatment BMP, not to fulfill LID requirements.

Treatment Control BMPs – This term refers to a specific subset of structural treatment BMPs that is not a retention or biotreatment BMP. This is synonymous with "flow thru treatment control BMP" used in the SOC MS4 Permit.

Structural BMP Requirements – The set of requirements related to LID BMPs, treatment control BMPs (if applicable), hydromodification control BMPs (if applicable), and alternative compliance associated with these requirements that are required for Priority Projects but are not required for non-Priority Projects.

SECTION 1. INTRODUCTION AND PROJECT APPLICABILITY CRITERIA

1.1. Orientation and How to Use this Document

This Technical Guidance Document (TGD) is intended to assist project applicants and agency staff with developing and reviewing designs that address **post-construction** urban runoff and stormwater pollution from **new development and significant redevelopment projects** in the portion of the County of Orange within the San Diego Permit Region (See **Section 1.1.4**).

This document includes technical guidance to:

- Determine which requirements are applicable to a project,
- Develop Project Water Quality Management Plan (WQMPs) that incorporate and comply with applicable requirements,
- Conduct supporting investigations and calculations, and
- Design Best Management Practices (BMPs) that are identified to be applicable to the project.

The following sections provide brief guidance related to the contents of this document and how it can be used.

1.1.1. What is a WQMP?

A Water Quality Management Plan is a land development project submittal that describes the post-construction BMPs that will be implemented and maintained throughout the life of a project. This term is used in this TGD to describe Conceptual/ Preliminary and Final Project WQMPs. A WQMP does not describe construction-phase stormwater management approaches.

1.1.2. What types of projects require WQMPs?

Development projects meeting triggers to be considered “Priority Projects” are required to develop a WQMP. Not all development projects require WQMPs. Some may require Non-Priority Project (NPP) checklists (or alternative local mechanisms for demonstrating conformance). Projects that do not have a nexus to stormwater pollution or meet other specific definitions do not require any stormwater-related plans. All users should consult **Section 1.2** to determine what type of plan is required for their project.

1.1.3. Why is a WQMP required?

Preparation and implementation of WQMPs for Priority Projects is required by municipal National Pollutant Discharge Elimination System (NPDES) permits held jointly by the

Permittees as part of implementation of the Clean Water Act. These permits are issued to the Permittees by the State of California through the Regional Water Quality Control Boards. In the County of Orange, these permits include an MS4 Permit covering North Orange County (Santa Ana Region - Order No. R8-2009-0030) and an MS4 Permit covering South Orange County (San Diego Region; R9-2013-00021 as amended by R9-2015-0001 and R9-2015-0100). These are referred to as the North Orange County (NOC) Permit and the South Orange County (SOC) Permit in this document. This version of the TGD is applicable only for projects in the SOC permit region at this time. Upon adoption of the 5th Term NOC MS4 Permit, this TGD will be updated to incorporate requirements for projects in NOC.

1.1.4. Which MS4 Permit Applies to a Project Site?

The division between regions generally follows El Toro Road. This follows the watershed divide between the San Diego Creek, Santiago Creek, and Newport Coast watersheds to the north (each in NOC) and the Aliso Creek and Laguna Coast watersheds to the South (both in SOC).

Jurisdictions that have land area in both permit regions are assigned to permit regions as follows:

- When the 5th Term North OC MS4 Permit goes into effect, the Cities of **Laguna Hills** and **Laguna Woods** will be solely covered by the **SOC MS4 Permit** for the purpose of land development stormwater management requirements. Until that time, the Cities of Laguna Hills and Laguna Wood are within both regions depending on the location of the development project within the City.
- When the 5th Term North OC MS4 Permit goes into effect, the **City of Lake Forest** will be covered solely within the **NOC MS4 Permit**. Until that time, the City of Lake Forest is within both regions depending on the location of the development project within the City.

Table 1-1 identifies the division of permit areas.

Table 1-1: Division of Permit Areas

Jurisdictions within Santa Ana Region (NOC)	Jurisdictions within San Diego Region (SOC)	Jurisdictions within both the NOC and SOC Regions
City of Anaheim City of Brea City of Buena Park City of Costa Mesa City of Cypress City of Fountain Valley City of Fullerton City of Garden Grove City of Huntington Beach City of Irvine City of La Habra City of La Palma City of Lake Forest* City of Los Alamitos City of Newport Beach City of Orange City of Placentia City of Santa Ana City of Seal Beach City of Stanton City of Tustin City of Villa Park City of Westminster City of Yorba Linda	City of Aliso Viejo City of Dana Point City of Laguna Beach City of Laguna Niguel City of Mission Viejo City of Rancho Santa Margarita City of San Clemente City of San Juan Capistrano	County of Orange Orange County Flood Control District City of Laguna Hills[1] City of Laguna Woods[1] City of Lake Forest[2]

[1] When the 5th Term North OC MS4 Permit goes into effect, the Cities of Laguna Hills and Laguna Woods will be solely covered by the SOC MS4 Permit. Until that time, the Cities of Laguna Hills and Laguna Wood are within both regions depending on the location of the development project within the City.

[2] When the 5th Term NOC MS4 Permit goes into effect, the City of Lake Forest will be covered solely within the NOC MS4 Permit. Until that time, the City of Lake Forest is within both regions depending on the location within the City.

1.1.5. Who reviews WQMPs?

A Project WQMP is reviewed by the local MS4 Copermittee that has development project review jurisdiction over the location of the project. This may include one of the 34 cities in Orange County or the County of Orange. Specific review steps and procedure are described in the Model WQMP and/or the reviewing jurisdiction's Local Implementation Plan.

1.1.6. How should a WQMP be developed?

The minimum standards and content for WQMP development are presented in the **Model WQMP**. **Section 2** of this TGD presents a stepwise process for WQMP development and includes references to the other TGD sections and appendices to assist with each step. This stepwise process is not mandatory, but it is intended to support the collection of appropriate information at each project phase and provide standard approaches for developing designs making decisions. Additionally, the reviewing agency can provide a WQMP Template to assist in organizing information in a consistent format. Where deviations from recommended processes and criteria are determined to be necessary for a project, the **SOC Model WQMP** should be consulted to determine the underlying standards that must be met in Project WQMP development.

1.1.7. When should a WQMP first be prepared?

An approved Conceptual or Preliminary WQMP[2] should be completed as part of the first phase of project approval. For significant and discretionary projects (most projects), the Conceptual or Preliminary WQMP should be approved prior to the discretionary approval of the overall project (e.g., a city council or Board of Supervisors approval). **It is strongly encouraged to begin stormwater quality planning and Conceptual or Preliminary WQMP preparation at the earliest stages of project site layout and preliminary design.** Preparation of a compliant WQMP requires that applicant be able to describe how the site layout was developed to maximize the feasibility of low impact development (LID) BMPs. Developing the Conceptual or Preliminary WQMP early in the site layout process helps prevent having to revise the site layout in later phases of the project to accommodate LID BMPs. A Final Project WQMP builds upon the Conceptual or Preliminary WQMP and is required as part of the grading and building permit application process (see next section).

[2] A Preliminary WQMP and Conceptual WQMP refer to the same document, but different nomenclature is used in different jurisdictions.

1.1.8. What is the difference between a Conceptual/Preliminary and Final Project WQMP?

There are two primary differences: (2) the phase of approval they accompany, and (2) the level of detail they contain.

A **Conceptual/Preliminary WQMP** accompanies discretionary approval of the project, or the first phase of approval, if the project is not subject to discretionary approval. The level of detail that is appropriate varies by project. In general, the Conceptual/Preliminary WQMP should provide enough detail to demonstrate that the project will conform to applicable standards and demonstrate that the approach for conforming is reasonable and feasible. It may not be appropriate or necessary to describe detailed BMP designs at this phase. Certain aspects of the conceptual design may be contingent on obtaining additional, more detailed information, such as infiltration tests at specific locations.

A **Final Project WQMP** accompanies the grading and building permit application process. At this phase, the level of detail in the WQMP must be consistent with the level of detail found in the detailed design and construction plans. The plans must be construction ready, and the WQMP must definitively describe how the proposed construction plans conform to applicable standards. It is typical for additional site investigation information, focused at specific BMP locations, to be available to support the Final Project WQMP that may not have been available for the Conceptual/Preliminary WQMP.

1.1.9. What requirements are associated with a Project WQMP?

New development and significant redevelopment projects that qualify as Priority Projects are required to prepare a Project Water Quality Management Plan (Project WQMP) which describes the practicable and enforceable controls the Priority Project will use to demonstrate and maintain conformance with four major sets of requirements:

- **Site Design** – approaches and practices for configuring a site that reduce stormwater runoff volume, reduce pollutant loads to receiving waters, protect sensitive areas, and allow more feasible placement of LID BMPs.
- **Source Control** – approaches for reducing the introduction of pollutants into stormwater and eliminating dry weather urban runoff.
- **Pollutant Treatment** – requirements intended to remove pollutants from stormwater, including use of LID BMPs (first priority) and treatment control BMPs (second priority). These BMPs must be designed to specific numeric sizing standards and selected according to a hierarchy as described in this TGD and the in Model WQMP.
- **Hydromodification Control**– requirements intended to reduce the potential for site hydrologic modifications to cause downstream channel erosion, potentially including

additional or larger BMPs than required for pollutant treatment. These requirements only apply where channels are susceptible to erosive impacts and are based on specific numeric sizing criteria as described in this TGD and in the Model WQMP.

These requirements apply to all Priority Projects except where a specific requirement is demonstrated to be not applicable. Additionally, a WQMP must provide an Operation and Maintenance (O&M) plan and assign O&M responsibility for ongoing operation of BMPs into perpetuity.

1.1.10. What requirements are associated with a Non-Priority Project?

Non-Priority Projects must incorporate applicable site design and source control BMPs but are not required to implement pollutant treatment or hydromodification BMPs. A NPP checklist can be used to guide and document the incorporation of these BMPs. Local jurisdictions may provide alternative templates or checklists to document the site design BMPs and source control BMPs that were incorporated.

1.1.11. How should a project applicant use this TGD?

This TGD is not intended to be read from "cover to cover." Additionally, there is no "right or wrong" way to use this TGD. However, a suggested approach includes:

- Start consulting this TGD early in the project development process at a time when stormwater management objectives can be considered in overall site layout and design.
- Use **Section 1.2** to determine project categorization and determine if a WQMP is required
- Review **Sections 1.3** and **1.4** as an introduction to the types of stormwater BMPs and the underlying principles for selecting and designing these BMPs
- Use the stepwise process described in **Section 2** to begin to develop a WQMP. This section includes cross references to the other sections of the TGD that are applicable to the project.
- Based on the references from **Section 2** that apply to the project, consult other sections and appendices, as needed.
- Use the worksheets from the TGD (consolidated in **Appendix M**) to document decisions.
- Use a WQMP template acceptable to the reviewing jurisdiction as the structure upon which to organize the WQMP

For guidance on specific topics, the Table of Contents may be used to hyperlink to relevant sections of the document or relevant appendices.

1.1.12. How do the various planning documents relate to each other?

There are five documents that describe requirements and provide guidance for developing Project WQMPs or NPPs. These documents are listed in **Table 1-2**. Additionally, the respective

MS4 Permits are expected to serve as a reference in cases not specifically addressed by these documents.

Table 1-2. Intended Purpose and Integration of Planning Documents

Document	Intended Purposes
South Orange County Model WQMP (DAMP Section 7.II)	Describes core performance criteria underlying the development of Project WQMPs. Describes requirements that are specific to the South Orange County Permit Region. Describes requirements and procedures for WQMP development, review, approval, verification, and ongoing implementation.
Technical Guidance Document (DAMP Section 7.III) (serves North and South Orange County)	Provides technical guidance for: • Determining applicability of requirements. • Developing Project WQMPs that incorporate applicable requirements. • Conducting and documenting associated investigations and calculations. • Designing BMPs that meet applicable requirements. Provides examples and worksheets.
Hydromodification Management Plan for South Orange County (DAMP Section 7.IV)	Provide technical guidance for developing hydromodification management designs for projects in South Orange County
WQMP Template	Provides a standardized format, organizational structure, and embedded guidance for developing a project WQMP for a Priority Project.
Non-Priority Project Checklist	The local jurisdictions may use a checklist or alternative template for NPPs to support identification and documentation of applicable BMPs.

1.2. Project Categorization to Determine Applicable Requirements

1.2.1. Overall Project Categories

Development and redevelopment activities that are permitted with City and County planning and building departments can include a wide range of activities. Not all activities require post-construction stormwater management planning, even when approval from City and County planning and building departments are required. Development and redevelopment activities fall under three categories for the purposes of determining their post-construction stormwater requirements:

Priority Projects: A project that meets the Priority Project criteria described in **Section 1.2.4**. These projects require a Project WQMP unless the project is, in its entirety, necessary to mitigate an emergency.

Non-Priority Projects: This category includes activities that do not meet the requirements to be considered a Priority Project but have a potential for stormwater pollution that is non-negligible. Additional guidelines for defining Non-Priority Projects is found in **Section 1.2.4.**

Other Projects: This category includes development or redevelopment activities that are not exposed to stormwater, do not include new potential sources of pollutants to stormwater, or do not meet the minimum requirements to be considered a Non-Priority Project or Priority Project. No documentation of post-construction stormwater planning is required for these types of activities.

Projects as a whole may be either Priority Projects, Non-Priority Projects, or Other Projects. It is prohibited for projects to be subdivided into elements and with these elements individually categorized. The project categorization must be based on the "whole of the action" that is reasonably foreseen and/or proposed.

Under certain conditions and limitations, some site activities may be exempted from stormwater management requirements. Specific exemptions are discussed in **Section 1.2.4**.

1.2.2. General Criteria for Defining Priority Projects

In the MS4 Permit, Priority Projects categories are defined based on the total area affected by the project, quantity of new or replaced impervious area, project type, and/or design features. To determine classification, the project applicant shall review each Priority Project category, defined in **Section 1.2.4**[3]. If any of the categories match the project, the entire project is a Priority Project. For example, if a project feature such as a parking lot falls into a Priority Project category, then the entire development footprint including project components that otherwise would not have been designated a Priority Project on their own (such as other impervious components that did not meet Priority Project size thresholds, and/or landscaped areas), will be subject to Priority Project requirements. Note that size thresholds for impervious surfaces created or replaced vary based on land use, land characteristics, and whether the project is a new development or redevelopment project. Therefore, all definitions must be carefully reviewed.

[3] **Section 1.2.4** includes requirements specific to the SOC permit region. **Section 1.2.3** is included as a placeholder for requirements from the NOC permit region upon approval of the 5th term NOC MS4 Permit.

The following terms are relevant to interpret these categories:

> **Existing impervious surface area:** The amount of impervious surface that exists on the site prior to the proposed development action.
>
> **Created impervious surface:** New impervious surface that will be created as part of new development or redevelopment where there was previously pervious surface.
>
> **Added impervious surface:** Synonymous with "created impervious surface."
>
> **Replaced impervious surface:** New impervious surface that will be placed where there is existing impervious surface that is being removed as part of a redevelopment action.
>
> **Removed impervious surface:** Impervious surface that exists before the project that will be removed and left pervious after the project.
>
> **Maintained impervious surface:** Impervious surface that will be subject to routine maintenance. This only applies to portions of a site that are outside of the defined project boundary and where the maintenance activity is not a condition of project approval. See Section 1.2.5.6 for examples intended to clarifying this.

Note that Priority Project categories are primarily based on created, added, or replaced impervious surface rather than removed impervious surface.

1.2.3. Specific Criteria for Priority Project Categories in North Orange County

[Placeholder for NOC-specific content upon adoption of the 5th Term NOC MS4 Permit]

1.2.4. Specific Criteria for Priority Project Categories in South Orange County

A project meeting one or more of the following criteria is a Priority Project unless the project is, in its entirety, necessary to mitigate an emergency.

(a) New development projects that create 10,000 square feet or more of impervious surfaces (collectively over the entire project site). This includes commercial, industrial, residential, mixed-use, and public development projects on public or private land.

(b) Redevelopment projects that create and/or replace 5,000 square feet or more of impervious surface (collectively over the entire project site on an existing site of 10,000 square feet or more of impervious surfaces). This includes commercial, industrial, residential, mixed-use, and public development projects on public or private land.

(c) New and redevelopment projects that create and/or replace 5,000 square feet or more of impervious surface (collectively over the entire project site), and consist primarily of one or more of the following uses:

(i) 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 (Standard Industrial Classification (SIC) code 5812). Information and an SIC search function are available at **https://www.osha.gov/pls/imis/sicsearch.html.**

(ii) Hillside development projects. This category includes development on any natural slope that is twenty-five percent or greater.

(iii) Parking lots. This category is defined as a land area or facility for the temporary parking or storage of motor vehicles used personally, for business, or for commerce.

(iv) Streets, roads, highways, freeways, and driveways. This category is defined as any paved impervious surface used for the transportation of automobiles, trucks, motorcycles, and other vehicles.

(v) Automotive repair shops. This category is defined as a facility that is categorized in any one of the following SIC codes: 5013, 5014, 5541, 7532-7534, or 7536-7539. Information and an SIC search function are available at **https://www.osha.gov/pls/imis/sicsearch.html**.

(vi) Retail gasoline outlets. This category includes Retail gasoline outlets that meet the following criteria: (a) 5,000 square feet or more or (b) a projected Average Daily Traffic of 100 or more vehicles per day.

(d) New or redevelopment projects that create and/or replace 2,500 square feet or more of impervious surface (collectively over the entire project site), and discharge directly to an Environmentally Sensitive Area (ESA). "Discharging directly to" includes flow that is conveyed overland a distance of 200 feet or less from the project to the ESA, or conveyed in a pipe or open channel any distance as an isolated flow from the project to the ESA (i.e. not comingled with flows from adjacent lands).

Note: ESAs are defined in **Section 2.3**. For projects adjacent to an ESA, but not discharging to an ESA, the 2,500 sq-ft threshold does not apply as long as the project does not physically disturb the ESA and the ESA is upstream of the project.

(e) New or redevelopment projects that result in the disturbance of one or more acres of **total** land (impervious and pervious) and are expected to generate pollutants post-construction.

Note: This category is intended to apply to sites where there is a permanent change in site use that does not include addition of impervious cover but is expected to generate runoff volume greater than existing condition and/or pollutant loads greater than existing condition. Projects creating less than 5,000 sf of impervious surface and where any added landscaping does not require regular use of pesticides and fertilizers, such as a slope stabilization project using native plants, are excluded from this category. Calculation of the square footage of disturbance need not include linear pathways that are for infrequent vehicle use, such as for emergency or maintenance access or for bicycle or pedestrian use, if they are built with pervious surfaces or if they sheet flow to surrounding pervious surfaces.

1.2.4.1. Specific Exclusions and Clarifications in South Orange County

Redevelopment does not include routine maintenance activities, such as trenching and resurfacing associated with utility work; pavement grinding; resurfacing existing roadways, sidewalks, pedestrian ramps, or bike lanes on existing roads; and routine replacement of damaged pavement, such as pothole repair.

Additionally, the following categories of projects may be exempted from being defined as Priority Projects at the discretion of the permittee with jurisdiction over project review:

a) New or retrofit paved sidewalks, bicycle lanes, or trails that meet the following criteria:
    i. Designed and constructed to direct storm water runoff to adjacent vegetated areas, or other non-erodible permeable areas; OR
    ii. Designed and constructed to be hydraulically disconnected from paved streets or roads; OR
    iii. Designed and constructed with permeable pavements or surfaces in accordance with USEPA Green Streets guidance.
b) Retrofit or redevelopment of existing paved alleys, streets or roads that are designed and constructed in accordance with the USEPA Green Streets guidance.

Guidance for incorporating required features to potentially qualify for these exemptions is found in **Section 2.9** of this TGD.

1.2.4.2. Criteria for Redevelopment of a Portion of a Site in South Orange County (50% Rule)

The following provisions apply to cases where a portion of a site is redeveloped:

a) Where redevelopment results in the creation or replacement of impervious surface in an amount of less than fifty percent of the surface area of the previously existing development, then the structural BMP performance requirements described in this TGD (pollutant treatment and hydromodification) apply only to the creation or replacement of impervious surface, and not the entire development; or
b) Where redevelopment results in the creation or replacement of impervious surface in an amount of more than fifty percent of the surface area of the previously existing development, then the structural BMP performance requirements of this TGD apply to the entire development.

This TGD interprets the term “surface area” in this subsection to mean impervious surface area.

It must be noted that if a portion of the site does not require treatment per bullet (a) above but cannot be hydrologically separated from the areas being treated (i.e. comingles), then the comingled runoff from this area also needs to be treated.

Example:

- An existing 1.2 acre site contains 0.8 acres of impervious surface.
- A redevelopment project would add 0.2 acres of impervious surface, replace 0.3 acres of impervious surface, and remove 0.1 acres of impervious surface, and bringing the total impervious surface to 0.9 acre.
- The added or replaced impervious surface is 0.5 acres.
- Comparing 0.5 acres to the existing impervious surface area of 0.8 acres yields a value of 62%. This is greater than 50%. Structural BMP requirements apply to the entire impervious surface area of the site and any other area that comingles with this area prior to treatment.

1.2.5. Special Considerations and Common Issues with Project Categorization

The following subsections provide clarification on common issues encountered in project categorization.

1.2.5.1. Tabulating Total Quantity of Imperviousness versus Net Change

Categories are defined by the total quantity of "added or replaced" impervious surface, not the **net change** in impervious surface.

For example, consider a redevelopment project that adds 7,500 square feet of new impervious surface and removes 4,000 square feet of existing impervious surface. The project has a net increase of 3,500 square feet of impervious surface. However, the project is still classified as a Priority Project because the total added or replaced impervious surface is 7,500 square feet, which is greater than the 5,000 square foot threshold.

1.2.5.2. Defining a Project and a Site

The definition of what is meant by the project must be clearly defined in the Project WQMP and must be consistent with the project description used in other aspects of discretionary approvals or subsequent administrative approvals.

With respect to the location of treatment (i.e., on-site or off-site), the limits of the project boundary, as defined in the project description, define the site.

The definition of an existing developed site extends beyond the limits of the project boundary of the currently proposed project. This may be important in evaluating the "50 percent rule" to determine what portion of the existing site requires treatment. In this case, the site-specific information is necessary. As a general rule, the existing developed site is reasonably defined as:

- The tax lot(s) where the project will occur (appropriate in cases where the project will occur within a small number of tax lots and there was not a common plan of development that involved more than one tax lot at the time of original development)
- The finest scale of development approval for the original development (appropriate where there was a common plan of development at the time of the original development and the proposed project will cross multiple tax lots)

1.2.5.3. Accounting for the Use of Pervious Pavement Surfaces

Where development projects incorporate permeable pavement surfaces, these surfaces may be tabulated as pervious in the tabulation of impervious area in determining Priority Project categorization. Such projects may not trigger being Priority Projects. Such projects must be required to maintain these permeable surfaces into perpetuity, so a Non-Priority Project Water Quality Plan must be developed and maintained for the site.

1.2.5.4. Small Projects with Driveways and/or Parking Lots

The MS4 permit defines lower impervious areas thresholds for projects that support driveways, parking lots, and roads (5,000 sq-ft) than exist for new development projects (10,000 sq-ft). Many projects include some portion of these uses, but this does not necessarily reduce the impervious area threshold to 5,000 sq-ft for these projects. These values should be tested independently:

- Is the total parking lot area greater than 5,000 sq-ft of impervious surface?
- Is the total road or driveway area greater than 5,000 sq-ft impervious surface?
- Is the total impervious area greater than 10,000 sq-ft of impervious surface?

If any of these tests is positive, the project is a Priority Project. If all are negative, then the project is a Non-Priority Project.

For example:

- If a project has a new 4,000 sq-ft driveway, 2,000 sq-ft parking lot, and 3,000 sq-ft of other imperviousness, then the project is not a Priority Projects.
- If a project has a 6,000 sq-ft driveway and 3,000 sq-ft of other imperviousness, then the project is a Priority Project because the driveway exceeds 5,000 sq-ft.

1.2.5.5. Priority Projects that Involve Improvements in Existing Right of Ways

The MS4 permit establishes specific approaches for new or retrofit paved sidewalks, bicycle lanes, or trails, and retrofit or redevelopment of existing paved alleys, streets or roads that are different from what would apply to an ordinary development or redevelopment project (see **Section 1.2.4.1**). However, it is possible that a development or redevelopment project would involve off-site improvements in existing right of ways within its project description (e.g., turn lane addition). These improvements would encounter similar constraints to projects that are purely right of way projects. In such a case, it is acceptable to apply different standards and approaches for the area within the existing right-of-way and outside of the existing right-of-way. The whole of the project must be considered in determining PDP categorization (i.e., it should not be treated as two separate projects).

Example:

- A project proposes to add or replace 8,000 sq-ft of impervious surface, of which 7,000 would be within a private parcel and 1,000 would be to add a turn lane within the public right-of-way.

Applicability determination:

- The whole of the project (all 8,000 sq-ft) would be used to classify this as Priority Project. It would not be appropriate to consider the turn lane to be a separate project to avoid Priority Project thresholds for that element.
- The portion within the private parcel would be treated per the standard LID, pollutant treatment, and hydromodification standards defined in Section 2.4 through 2.6 of this TGD.
- The portion within the right-of-way would implement USEPA Green Streets guidance per Section 2.9.

1.2.5.6. Routine Maintenance Activities Concurrent with Priority Project Activities

A common issue is delineating whether an activity is routine maintenance (see **Section 1.2.4.1**) or a priority development project. It is possible that a routine maintenance activity could occur simultaneously and in close proximity to a priority project on a given site. Proximity and timing do not necessarily have a bearing on whether the routine maintenance activity can be exempted. The key test is whether the activity being considered routine maintenance is a necessary condition of approval of the priority project or is otherwise an integral part of the project description of the priority project. If this is the case, then the if the maintenance activity is part of the project and does not qualify for an exemption from priority project status.

Example:

- A site is being redeveloped to remove an existing building, add a new building, and add new site improvement features, including walkways, and parking.
- Simultaneously, a paved parking lot within the site, adjacent to the project, will be ground down (not exposing subbase material) and resurfaced.

- The parking lot maintenance work is being done simultaneously with the redevelopment project so that both efforts can be performed as part of the same contractor mobilization.
- Only the redevelopment project requires discretionary approval and grading and building permits. The parking lot maintenance work is not part of the project description that is being considered for discretionary approval.

Applicability determination:

- It is appropriate to exclude the parking lot maintenance from the project and therefore exclude it from the tabulation of impervious surface being added or replaced.
- In determining whether this area will need to be treated, the "50% rule" should be checked (See **Section 1.2.4.2**). The parking lot being maintained should be considered "existing impervious surface," and not tabulated as "added" or "replaced" impervious surface.

1.3. Types and Applicability of Stormwater Best Management Practices

This TGD describes BMP strategies for meeting the four major sets of requirements in the WQMP (See **Section 1.1.9**). BMP requirements are divided into four primary categories to reflect the four major sets of requirements as described in **Table 1-3**.

Table 1-3. Categories of BMP Requirements and Project Type Applicability

BMP Requirement	Description	Examples (partial list)	Applicability by Project Type
Site Design	Approaches and practices for configuring a site that reduce pollutants and volumes of stormwater runoff, protect natural resources, and allow more feasible placement of LID BMPs. Certain types of site design BMPs, known as HSCs, can have quantifiable benefits for sizing associated with Priority Projects.	Buffers on riparian areas and slopes Revegetation and decompaction of pervious area Disconnection of impervious area	Non-Priority Projects and Priority Projects
Source Control	Approaches for reducing the introduction of pollutants into stormwater and eliminating dry weather urban runoff.	Covered garbage areas Storm drain stenciling Community car wash area	Non-Priority Projects and Priority Projects
Pollutant Treatment	Requirements intended to remove pollutants from stormwater, including use of **LID BMPs** (first priority) and **treatment control BMPs** (second priority). These BMPs must be designed to specific numeric sizing standards and selected according to a hierarchy. Pollutant treatment BMPs may be located within a project site or in off-site locations subject to certain criteria.	Bioretention Biofiltration Sand Filters	Priority Projects
Hydromodification Control	Requirements intended to reduce the potential for site hydrologic modification to cause downstream channel erosion, potentially including additional or larger BMPs than required for pollutant treatment. These requirements only apply where channels are susceptible to erosive impacts and are based on specific numeric sizing criteria.	Detention ponds Flow duration control ponds	Priority Projects only where the project drains to susceptible stream channel

1.4. BMP Selection and Integration Principles

The development of WQMPs should be based on three underlying principles:

1. Integration of BMP types into a holistic system of stormwater management is expected to yield the highest performance and most efficient design.
2. The use of BMP types that are effective, applicable, and feasible for a project, based on a realistic assessment of reliable site data is expected to improve overall performance and reduce the rate of failure and needed rehabilitation.
3. BMPs should be selected and designed for resiliency, adaptability, and ability to be operated and maintained into perpetuity.

These principles are explained further below and have been considered throughout this TGD.

1.4.1. Integration of BMP Types

While this TGD established four separate sets of BMP requirements, the types of BMPs are intended to be synergistic and function as an integrated system. Examples of synergy include:

- Site design BMPs can have quantifiable benefits on reducing runoff volume that can result in smaller structural LID, treatment control, and hydromodification BMPs.

- Source control BMPs help reduce high intensity pollutant sources, thereby reducing maintenance burden on pollutant treatment BMPs, reducing the list of pollutants of concern that pollutant treatment BMPs must address, and improving the overall quality of stormwater leaving the site.

- Site design and source control BMPs can both help reduce the quantity of dry weather flows (e.g., irrigation excess, air conditioner condensate, car wash water) and lessen nuisance issues from persistent flows into pollutant treatment BMPs and/or lessen the need for structural measures (e.g., a lift station) to eliminate these flows.

- LID BMPs that are adequately sized fully address pollutant treatment standards, thereby eliminating the need for any treatment control BMPs.

- LID BMPs and hydromodification BMPs can be integrated into the same facility or treatment train, where the hydrologic benefits provided by the LID BMP portion of the system serves as part of complying with hydromodification requirements.

The design approaches in **Section 2**, **Section 4**, **Section 5** and **Appendix B** provide more details and examples of how multiple BMP types can be integrated.

1.4.2. Use of Effective, Applicable and Feasible BMPs

The MS4 Permits require BMPs to be selected from a hierarchy that favors retention BMPs, then biotreatment BMPs that achieve some volume reduction, then biotreatment BMPs without volume reduction, and then non-LID treatment control BMPs. The LID hierarchy is discussed in more detail in **Section 2.5** and **Section 4**, but the general hierarchy is described in **Figure 1-1**.

Figure 1-1: General Hierarchy of LID BMPs[4]

Retention BMPs

Example: Bioretention without underdrains (or plugged underdrains)

↓

Biotreatment BMPs that Achieve Partial Infiltration

Example: Bioretention with underdrain and gravel sump storage

↓

Biotreatment BMPs without Incidental Infiltration

Example: Bioretention with an underdrain and liner

↓

Treatment Control BMPs

Example: Media filter

This hierarchy must be observed in a manner consistent with the Maximum Extent Practicable (MEP) standard that underlies the MS4 Permit. However, this hierarchy must not be interpreted by applicants or reviewers as a mandate to use BMPs types that cannot be reliably supported by site information and/or are not appropriate for the project type. A BMP that is selected from a

[4] Biotreatment BMPs that do not also meet the definition of a "biofiltration BMP" are not considered LID BMPs in South Orange County; they may be considered treatment controls or pretreatment BMPs.

higher level of the hierarchy based on unreliable information and does not perform to acceptable standards or leads to property or environmental damage is unacceptable. The WQMP development process must equally seek to use higher priority BMPs and also ensure that the BMPs that are used are reliably supported, safe, and do not pose risks that cannot be reasonably mitigated.

A principal role of this TGD is to describe the processes and criteria to ensure that the LID hierarchy is incorporated into project WQMPs to the maximum extent practicable (MEP) **and** whichever BMP type is selected is adequately confirmed to be effective and safe in its proposed use, or an option is available to adapt the BMP design to ensure that this is met.

1.4.3. Focus on Resiliency, Adaptability and Long Term O&M

WQMPs are planning and design documents that describe a system of BMPs that must work in the post construction phase and be maintainable into perpetuity. Foremost, the designer and reviewer must acknowledge that information about the site that is available at the design phase is inherently imperfect and also may change during construction or via evolution of site condition and uses over time. This is particularly important for designs that rely solely on infiltration, which is dependent on an infiltration rate that must be estimated during the planning and design phases of the project. Infiltration rates may vary by orders of magnitude within a small area of a site or with depth, and can be very sensitive to variations in compaction that can result during construction.

In contrast to previous versions of this document, this TGD includes greater emphasis on ensuring that systems are selected and designed to be more resilient and adaptable to actual conditions, encouraging the use of confirmation testing during the construction phase, and including design features to facilitate long term O&M that is needed to sustain performance. This includes:

- Providing BMP selection and design options for cases where infiltration conditions are marginal and/or inherently uncertain prior to completion of construction activities.

- Describing how data that are obtained between the planning phase (Conceptual WQMP) and design phase (Final WQMP) can be incorporated into design refinements and/or adaptations.

- Providing design recommendations for BMPs that enable adaptation during or after the construction process.

- Providing design criteria and checks to identify and address cases that pose elevated risk of clogging for infiltration, biofiltration, and filtration types of BMPs.

- Providing design recommendations for BMPs that enable them to be inspected and maintained.

The selection process and criteria for LID BMPs is detailed in **Section 2.5** and **Section 4**. BMP fact sheets are included in **Appendix G**.

1.5. Limits in Scope of the Technical Guidance Document

To help make this document relevant for the majority of users, the guidance is tailored primarily to projects that will comply with applicable requirements via on-site LID and hydromodification BMPs (as applicable). Options for on-site LID BMPs include highly space efficient options such as proprietary biotreatment BMPs, such that the frequency that a project will demonstrate infeasibility of on-site approaches and be required to seek alternative approaches is quite limited. The following primary limitations apply:

Alternative Compliance Options. Pathways for alterative compliance are contingent on the development of jurisdictional frameworks. At this time, alternative compliance options are not discussed in this TGD, but are discussed in the **Model WQMP**.

Regional BMPs. Regional BMPs can be acceptable options, with a set of associated criteria. These criteria are provided in the **Model WQMP**. This TGD provides general guidance for adapting LID BMPs to larger scales, but does not focus on Regional BMPs. The design and permitting process for regional BMPs is anticipated to be project-specific and would typically be conducted to meet the underlying criteria described in the **Model WQMP** but would not necessarily follow the standardized process described in this TGD.

In-stream hydromodification BMPs. This option may be available for hydromodification control under specific conditions. This option is anticipated to be very rarely implemented by an individual Priority Project without significant permittee involvement. Each design and permitting process is anticipated to be project-specific. Therefore, this TGD does not attempt to provide guidance for this option.

Groundwater, Soil, and Geotechnical Analysis Methods. This TGD identifies the need for qualified professionals to investigate groundwater, soil, and/or geotechnical factors and the key metrics or types of recommendation that are needed to support project development. However, it does not seek to prescribe specific methods that must be used. It is expected that the qualified professional shall apply discretion to determine appropriate methods, subject to reviewer approval.

BMP Design Standards. This TGD attempts to clearly describe what is meant by each BMP type, provide a reasonably comprehensive set of criteria, and the rationales for these criteria. However, this TGD also provides flexibility for designer preference and project-specific adaptations. Variations on these designs are permissible, and additional design references may need to be consulted. BMP design criteria should be interpreted as standard guidelines, not strict limits.

Non-Priority Project BMPs. This TGD can be used as a reference for site design and source control approaches applicable for NPPs. However, this TGD presents a process that is focused specifically on Priority Projects and does not attempt to present the much-abbreviated process that an NPP would follow. NPPs can typically refer to an NPP checklist available from a local jurisdiction for guidance. The local jurisdiction may use a checklist or alternative method to identify and document applicable requirements.

1.6. Organization of the Technical Guidance Document

TGD Body

- **Section 1** introduces the purpose of the document, methods for project priority categorization, and the underlying principles of this TGD.
- **Section 2** contains stepwise guidance on how to develop BMP plans and prepare each section of the WQMP.
- **Section 3** provides guidance for site design principles and practices.
- **Section 4** provides guidance on pollutant treatment BMPs, including BMP selection, sizing, and design guidance for LID and treatment control BMPs.
- **Section 5** provides guidance for design approaches for hydromodification control BMPs.
- **Section 6** provides guidance for the type, functionality, and selection of Source Control Measures, both structural and non-structural.

TGD Appendices

- **Appendix A** provides examples of integration of LID and hydromodification requirements into BMPs in the NOC permit area [PLACEHOLDER ONLY].
- **Appendix B** provides examples of integration of LID and hydromodification requirements into BMPs in the SOC permit area.
- **Appendix C** describes methods for investigating groundwater-related issues and provides groundwater-related infiltration feasibility criteria.
- **Appendix D** provides guidance for evaluating infiltration rates and determining safety factors for infiltration feasibility screening and design.
- **Appendix E** contains guidance on standardized hydrologic calculations and sizing methods for LID and treatment control BMPs including worksheets, examples, and stepwise sizing methodologies. It also contains guidance methodologies for checking clogging risk, minimum BMP footprint areas, and approaches for space-constrained sites.
- **Appendix F** summarizes harvest and use demand calculations and design considerations.
- **Appendix G** provides concise fact sheets for 20 LID and treatment control BMPs and 7 hydrologic source control BMPs in addition to 3 fact sheets on soil amendments and other media. References to more extensive design guidance is also provided.

- **Appendix H** provides the technical basis for green roof design criteria.
- **Appendix I** - NOT IN USE
- **Appendix J** describes the criterion for acceptance of proprietary BMPs.
- **Appendix K** provides approved methods for quantifying hydrologic conditions of concern in the North Orange County permit area [PLACEHOLDER ONLY].
- **Appendix L** provides guidelines for applying the South OC HMP for development of hydromodification designs. [PLACEHOLDER ONLY, CURRENTLY]
- **Appendix M** provides links to worksheets that are referenced throughout the TGD. [PLACEHOLDER ONLY, CURRENTLY]
- **Appendix N** contains exhibits to support preparing a Project WQMP.

SECTION 2. TECHNICAL GUIDANCE FOR PREPARING PROJECT WQMPS

2.0 Section Orientation and Stepwise Process

This section provides a recommended stepwise process for developing Conceptual/Preliminary and Final Project WQMPs. This section is intended to be the core reference for users developing WQMPs. This section explains when the other guidance in this TGD is applicable and should be consulted.

Why use a stepwise process?

- **Stormwater management is site- and watershed-specific.** Of primary importance in WQMP development is that planning and design decisions be based on adequate and reliable data. A stepwise process helps to organize data collection efforts and make clear the intended outcomes of these efforts.
- **WQMP development can involve multiple disciplines and multiple phases**. A structured process helps develop a common understanding across design and review staff about what decisions are necessary at each phase and what are the intended outcomes of investigations and calculations.
- **It is critical that decisions be documented to provide the basis for decisions about site design, BMP selection, and BMP design.** A structured process helps organize this information in a more standardized format and makes it easier to review.
- **Knowledge of a site and the resulting proposed BMP plans inherently improve over time.** Following a process helps provide a point of reference for how to incorporate and adapt decisions and designs to new information as it becomes available.

Table 2-1 provides an orientation to this stepwise approach.

Sections 2.1 through **2.8** are organized to mirror the respective Section 2.1-2.8 of the **Model WQMP**. The **Model WQMP** is intended to describe the expected content and underlying performance criteria associated with each aspect of WQMP development. Section 2.1 through 2.6 are organized to mirror Sections 1 through 6 of the WQMP Template. The WQMP Template is intended to provide a standardized structure and format for WQMP preparation.

This TGD provides methods and guidance to aid project applicants through development of each of these sections of the Project WQMP. These steps can be followed for both the Conceptual/Preliminary WQMP (planning phase) and the Final Project WQMP (design phase), with certain steps being geared towards one or the other or requiring more detail for the Final Project WQMP as additional information is acquired. These steps are designated in **Table 2-1** below as (*Planning Phase*) and (*Design Phase*).

Table 2-1. WQMP Preparation Steps, Key Efforts, and Expected Outcomes

Step	WQMP Preparation Step	Section Reference (click to jump)	Key Efforts	Key Expected Outcomes

1	Determine discretionary permits and water quality conditions	2.1	• Review of previous approval:
			  ○ Prior WQMPs
			  ○ Environmental clearance (e.g., CEQA)
			  ○ Other
				Fully characterize requirements that apply to stormwater management, potentially beyond those prescribed by the MS4 Permit, Model WQMP and TGD

2	Describe the project	2.2	• Provide the legal description of the project • Inventory certain site features and land uses	• Fully characterize what is meant by the "project" • Provide information to support subsequent steps

3	Assess the site and the watershed	2.3	• Summarize key aspects of existing site information and proposed plans
			• Compile and interpret available mapped and tabular data
			• Investigate the site relative to infiltration and harvesting feasibility to:
			  ○ Determine areas with greatest potential feasibility
			  ○ Determine tentative feasibility at BMP locations (*Planning Phase*)
			  ○ Identify needed future investigation (*Planning Phase*)
			  ○ Confirm or adapt BMP-specific design parameters and feasibility findings (*Design Phase*)
				• Describe the existing and proposed conditions of the site
				• Describe how the site connects to the off-site drainage system
				• Identify and characterize the water bodies to which the site discharges
				• Determine Pollutants of Concern
				• Determine whether Hydrologic Conditions of Concern apply
				• Document a comprehensive evaluation of conditions related to the feasibility of stormwater infiltration and harvesting (*Planning Phase)*
				• Document BMP-specific design investigations at BMP locations (if needed) to establish design parameters (*Design Phase*)

Step	WQMP Preparation Step	Section Reference (click to jump)	Key Efforts	Key Expected Outcomes
4	Develop the site design and drainage plan	2.4	• Develop the layout of the site and the conceptual drainage plan • Incorporate site design approaches and BMPs into overall project site design • Identify and reserve locations for site design BMPs and structural BMPs in the drainage plan • Identify structural BMP locations • Delineate "Drainage Management Areas" (DMAs) • Iteratively refine site design, drainage plan, and BMP locations as new information is available and as designs become more detailed	• Identify and incorporate applicable site design BMPs • Identify and incorporate applicable source control BMPs • Document the site configuration approaches that were used to maximize the feasibility of BMPs that include infiltration and harvesting • Establish the BMP locations and "Drainage Management Area" delineations as the foundation for BMP selection and sizing
5	Select, size, and design LID BMPs for each DMA (if applicable)	2.5	Apply site investigation data and drainage plan data to: • Determine the LID BMP category that is applicable to each DMA • Select a BMP from the applicable category • Determine the required size of the BMP • Compare sizing to available space to determine the need for design adaptation or alternate BMP selection • Determine the conceptual (*Planning Phase)* and detailed (*Design Phase*) BMP designs	Planning Phase: • Tentative BMP selection for each DMA • BMP sizing requirements for each DMA • Tentative confirmation that required sizes will be provided • Documentation and calculations for each DMA • Conceptual BMP design Design Phase: • Confirmed BMP types and design parameters • Final required size based on final DMA characteristics • Documentation and calculations for each DMA • Final BMP design

Step	WQMP Preparation Step	Section Reference (click to jump)	Key Efforts	Key Expected Outcomes
6	Select, size, and design hydromodification BMPs for each Point of Compliance (if applicable)	2.6	• Define points of compliance for hydromodification criteria • Conduct hydrologic analyses and iterative BMP design adaptation to develop a design that meets applicable hydromodification criteria • Determine the conceptual (*Planning Phase)* and detailed (*Design Phase*) BMP designs	Planning Phase: • Integrated structural BMP design and sizing that meets both LID and hydromodification control requirements • Documentation of hydromodification sizing calculations for each point of compliance • Conceptual BMP design Design Phase: • Integrated structural BMP design and sizing that meets both LID and hydromodification control requirements • Documentation of hydromodification sizing calculations for each point of compliance • Final BMP design
7	Prepare the Project WQMP and BMP plan	2.7	Assemble the results of step 1 through 6 into a compliant Project WQMP	Planning Phase: • Document the conceptual BMP plan • Document that appropriate BMPs are selected • Provide tentative confirmation that required sizes will be provided Design Phase: • Document the final BMP plan • Document confirmation that BMPs are selected per hierarchy, are protective of property and environment, and are maintainable. • Provide a definitive comparison of required size versus as-designed size

Step	WQMP Preparation Step	Section Reference (click to jump)	Key Efforts	Key Expected Outcomes
8	Prepare the Operation and Maintenance (O&M) Plan	2.8	Identify the following for each BMP: • Maintenance responsibility and funding source • Inspection requirements • Routine, periodic, and corrective maintenance requirements and triggers • Documentation requirements	Funded, implementable, enforceable, and transferrable plan for perpetual O&M of all BMPs included in the WQMP. Only required as part of the Final Project WQMP.

Frequent Questions

Does this approach need to be followed precisely?

No, it is expected that most projects will adapt the details of this approach based on project-specific considerations. As with every aspect of this TGD, the intent is to provide recommended guidelines for how to meet the minimum criteria described in the **Model WQMP**. The applicant and reviewer have discretion to deviate from these guidelines with appropriate rationale provided that minimum criteria are met.

Is this a linear process?

In reality, most design processes are iterative. It is expected that there will be feedback loops in this process, and the acquisition of additional data or design adjustments as part of design refinement may prompt revisiting earlier steps.

Why is the feasibility of infiltration important in WQMP development?

Determining where and to what degree infiltration is feasible is among the most important questions that guide WQMP development. Retention (i.e., control of the DCV without surface discharge) is the highest priority type of LID BMP and must be used unless demonstrated to be infeasible. Infiltration is the most significant retention process that may be feasible in typical cases. Additionally, biotreatment must be designed to maximum volume retention, including incidental infiltration and evapotranspiration. However, there are a number of factors that limit infiltration to being only partially feasible or not feasible in any amount. This influences BMP selection and sizing. It also can have an effect on integrating hydromodification management into BMP designs.

Do all of the potential infiltration feasibility criteria associated with Step 5 (2.5: LID BMP Selection and Design) need to be evaluated?

Not necessarily. Because the LID BMP hierarchy prioritizes infiltration, infiltration feasibility needs to be evaluated. However, infiltration feasibility criteria are numerous, including infiltration rates, groundwater depths, groundwater quality protection, geotechnical hazards, and other factors. Any individual feasibility criterion can control a decision not to infiltrate. So, if a single criterion shows that infiltration is infeasible, there is no need to evaluate any other criteria. However, if infiltration will be used, then the acceptability of this decision must be adequately supported through evaluation of each criterion.

Can regional maps be used to support infiltration feasibility decisions?

At the planning phase, regional maps (**Appendix N**) can serve as tools for understanding what constraints may exist. However, these maps are considered to be adequately reliable to support final decisions for only a subset of projects and conditions. Additional information on the use of regional maps for infiltration feasibility investigations is provided in **Section** 4.2.

What is meant by "planning phase" and "design phase" in these steps?

This is loosely associated with the Conceptual/Preliminary WQMP and Final Project WQMP phases. However, it does not need to be associated on a 1-to-1 basis. For a small project where more precise site design is being included in the Conceptual/Preliminary WQMP application, both planning and design phases may be conducted prior to the Conceptual/Preliminary WQMP

In general, at the planning phase, the purpose of site design, investigation, and BMP sizing is to demonstrate that:

- The site has been configured in a way that considers stormwater management objectives;
- Differences in infiltration feasibility across the site have been estimated and incorporated into this layout and proposed BMP locations, to the extent feasible;
- Appropriate site-specific data has been used to tentatively classify the site in terms of infiltration and harvesting feasibility and hydromodification requirements and appropriate LID BMPs and hydromodification BMPs have been selected; and
- The space allocated or committed for BMPs is adequate for the BMP sizes estimated to be needed.

In general, at the design phase, the purpose of site design, investigation, and BMP sizing is to demonstrate that:

- The BMP types and designs at each specific location are supported by design phase investigations; and
- The BMP sizes that are designed are equal to or greater to what is provided.

It can be seen that the methods and burden of proof associated with site investigation and associated BMP design is different at the planning phase. This is especially true for projects of a larger scale where there is more flexibility to establish the layout of the project site and where planning phase investigations must inherently be done at a different scale and degree of confidence than design phase investigations.

Are two phases of investigation always necessary?

No. The applicant is responsible for the meeting the following burdens of proof:

- Reliable information has been obtained and adequately considered in site layout and BMP selection consistent with the LID hierarchy; and

- The selected BMPs are designed to be effective, and protective of property and the environment based on information that applies to the exact location of the BMP.

There are two common cases where a second phase may not be needed:

- If the initial investigation conducted to support conceptual design obtains defensible design-level tests at the specific location of the proposed BMPs that carry through detailed design, then it is not necessary to do additional testing.
- If planning phase investigations definitively conclude that full infiltration is not feasible, then it is not necessary to conduct design phase investigations to demonstrate this again. This finding supports the selection of BMPs that do not rely solely on infiltration, therefore BMP design is resilient to whatever actual infiltration rates are eventually present at BMP locations.

Regardless of the need for additional investigation, a Conceptual/Preliminary WQMP followed by a Final Project WQMP will be required in most cases.

Does this process allow BMP types to be changed between the planning and design phase?

Yes. BMP types or design configuration must be changed if design phase investigations or analyses at the BMP locations do not support the initial BMP selection and conceptual design. In cases where planning level investigations form the basis for discretionary approvals, the Conceptual/Preliminary WQMP needs to recognize the commitment for further BMP-site-specific testing and identify the range of design contingencies or adaptations that could result. The consideration of these potential contingencies in the discretionary approval provides the envelope of approval for these adjustment to be made, with adequate supporting information, in the design phase.

2.1. Step 1: Document Discretionary Permits and Water Quality Conditions

Section 1 of the WQMP should list the discretionary permit(s) applicable to the project and provide the site address or lot and tract/parcel map number describing the property.

Information from Prior Approvals. List, verbatim, any Water Quality Conditions arising from prior approvals, including the condition requiring preparation of a WQMP, if applicable. Water Quality Conditions may be included as mitigation measures in California Environmental Quality Act (CEQA) documents for the project. For example, a Mitigation Monitoring and Report Program (MMRP) adopted in a certified Environmental Impact Report (EIR) may include Project Design Features (PDFs), Standard Conditions (SCs), and Mitigation Measures (MMs) related to water quality protection.

A Conceptual/Preliminary WQMP should be prepared for the project in the preliminary planning stages, for example, as a technical appendix in an EIR. At this phase, there may be relatively few prior approvals and prior conditions of note. Through the EIR process or equivalent, and through the review and approval of the Conceptual/Preliminary WQMP, it is common for conditions of approval to be added.

The Conceptual/Preliminary WQMP must be used as a source of information for the Final Project WQMP. The project description and stormwater control approaches must be substantially consistent with the Conceptual/Preliminary WQMP, otherwise an additional discretionary approval process may be necessary. In order to demonstrate consistency, Section 1 of the Final Project WQMP should discuss whether there are any substantial differences compared to the Conceptual/Preliminary WQMP and the significance of these differences.

If the project is part of a common plan of development where regional BMPs have been installed as part of an earlier phase, then these regional facilities should be described here, including the planning and design documents related to their construction.

Watershed-based plans. Watershed planning efforts may also result in special conditions that must be considered in WQMP development for Priority Projects. The following watershed-based plans should be reviewed for requirements that may affect the selection of best management practices (BMPs) for the project:

> ***Water Quality Improvement Plans (South Orange County).*** A Water Quality Improvement Plan has been developed as required by the SOC MS4 permit. WQIPs provide an adaptive management pathway for Copermittees to select and address the highest priority water quality issues in receiving waters through an iterative process. Within this process, the pollutants of highest priority are identified for each region. Additionally, strategies have been identified and will be implemented, which may be related to land development projects. These may exceed the provisions described in the **Model WQMP** and TGD.

Watershed Management Plans (North Orange County). [Placeholder for section to be developed].

2.2. Step 2: Document the Project Description

This section provides guidance for documenting the project descriptions as part of completing Section 2 of the WQMP template. This section of the Conceptual/Preliminary or Project WQMP should provide the information listed below. The purpose of this information is to:

- Legally define what is meant by the "project" for the purpose of discretionary and subsequent approval; and
- Provide a general introduction to proposed development patterns, land uses, site activities as they relate to determining applicable stormwater management provision.

This section should not provide a detailed description of the existing or proposed site. That information will be catalogued in more detail as part Step 3: Site and Watershed Characterization.

The project description section of the WQMP should include:

- Project location, parcel numbers, and legal address, as applicable;
- Legal boundaries of the proposed project;
- Project acreage;
- Proposed land uses and site activities, including associated quantification (e.g., acreages, units);
- Off-site improvements as part of the overall project action; and
- General description of site grading and drainage modifications as part of proposed development.

Describe the ownership of all portions of the project and site. State whether any infrastructure will transfer to public agencies (City, County, Caltrans, etc.). State if a homeowners or property owners' association will be formed that will be responsible for the long term maintenance of the project's stormwater facilities.

The information in this section must match the legal project description that is being considered as part of discretionary approval.

2.3. Step 3: Characterize the Site and Watershed

This section provides guidance for conducting site and watershed characterization as part of completing Section 3 of the WQMP template and supporting subsequent decisions about the BMP plan. The purpose of this section of the WQMP is to provide data to support site design, drainage design and BMP selection. This step consists of the following sub-tasks discussed in the subsections below:

- Characterize site conditions;
- Characterize proposed site development activities;
- Identify receiving waters;
- Determine Pollutants of Concern (POCs); and
- Determine if HCOCs apply.

2.3.1. Characterize Site Conditions

The WQMP must describe the existing condition of the site. At a minimum, the following information summarized in **Table 2-2** must be catalogued.

Table 2-2. Expected Activities and WQMP Content for Investigation of the Existing Site

Expected Activities/Content	Rationale
Identify sensitive environmental features and hydrologic features that currently exist at the site.	The WQMP must document that the site was designed in a way to minimize impacts to these features.
Identify drainage patterns, including points of run-on and run-off from the project site.	These are important constraints in developing post-development drainage plans. For infill and redevelopment site, the existing developed grade and points of connection to the storm sewer system may not be able to be changed significantly during development.
Quantify existing impervious cover.	This is important to evaluate the "50% rule" in determining the priority status of a project.
Characterize existing topography.	The change in topography proposed as part of development (e.g., cut/fill) can be relevant for BMP selection.
[Planning level; all sites] Describe soil, groundwater, geotechnical, and/or utility issues (as applicable) at a level of detail and site specificity adequate to support the tentative determination of infiltration feasibility for all portions of the site where it may be reasonably practical to site LID BMPs.	BMP selection based on the LID hierarchy must be adequately documented based on "substantial evidence." The level of effort and the range of factors needed to satisfy this burden of proof is expected to vary from project to project depending on the size and complexity of the project and the features of the site.

Expected Activities/Content	Rationale
[Design level; only if full infiltration BMPs are used] Provide additional or modified description of soil, groundwater, geotechnical, and/or utility issues (as applicable) at specific BMP locations adequate to support the design and construction of BMPs.	If full infiltration BMPs are used, the design of BMPs must be fully supported by site-specific information at the precise location of the BMP site.

The following sections provide guidance for satisfying this minimum content in the characterization of the existing site condition. The specific recommendations contained in this section are not intended to prevent the consideration of site-specific factors or substitute for the need to exercise sound engineering judgment. In addition, the recommendations made in this section are intended to be applied to the extent that they are necessary to meet minimum site-assessment requirements. These recommendations are not intended to imply that each of these analyses must be conducted for every project if an equally reliable source of information is available in place of any of these analyses or if the analysis outcome is obvious and can be documented based on simpler analysis methods. For example, if groundwater is known to be very deep based on regional surveys or other available information, it is not necessary to conduct an evaluation of the exact elevation of the water table or the potential for groundwater mounding.

2.3.1.1. Topography, Drainage Patterns, and Infrastructure

The planning and design phase of most projects should begin with a topographic and environmental survey of the project site. Based on this information, the WQMP should describe, as applicable:

- Overview of site topography
- Site elevations ranges and slopes
- Presence, locations, and extents of slopes over 15 percent
- General surface drainage patterns
- Specific points of concentrated runoff onto and off of the site
- Acreage and imperviousness of land upstream of each point of concentrated or sheet flow run-on
- Existing storm drain infrastructure and points of connection from the site
- Existing impervious surfaces
- Adjacent infrastructure to remain in service after project development (e.g., roads, foundations)
- On-site or adjacent utilities (within 100 feet)

2.3.1.2. *Groundwater Considerations*

Site groundwater conditions at the site must be investigated in a manner adequate to support the selection of LID BMPs consistent with the LID BMP selection hierarchy described in **Section 2.5**. This investigation must be conducted for all locations of the site where it is reasonably possible to site LID BMPs. Guidance on specific methods and criteria for evaluating the feasibility of infiltration related to groundwater consideration is provided in **Appendix C.**

Groundwater Levels

The depth to seasonal high groundwater table (normal high depth during the wet season) beneath the project may preclude infiltration if the groundwater table is too close to the surface. Depth to seasonal high groundwater level should be estimated as the average of the annual minima (i.e., the shallowest recorded measurements in each water year, defined as October 1 through September 30) for all years on record. If groundwater level data are not available or not considered to be representative, seasonal high groundwater depth can be determined using field data, regional surveys, or geologic reports of the site. If regional groundwater is known to be very deep, then these methods may suffice for investigation of groundwater levels depending on the needs and circumstances of the project. If regional groundwater levels are relatively shallow, then the groundwater depth at the site can be determined by redoximorphic analytical methods combined with temporary groundwater monitoring for November 1 through April 1 at the proposed project site. **Appendix C** provides guidance for determining the depth to seasonally high groundwater table and the potential magnitude of groundwater mounding that could occur below infiltration BMPs.

Groundwater and Soil Contamination

In areas with known groundwater and soil pollution, infiltration may need to be avoided if it could contribute to the movement or dispersion of soil or groundwater contamination or adversely affect ongoing clean-up efforts. Mobilization of groundwater contaminants may also be of concern where contamination from natural sources is prevalent (e.g., marine sediments, selenium-rich groundwater), to the extent that data is available. If infiltration is under consideration in areas where soil or groundwater pollutant mobilization is a concern, a site-specific analysis must be conducted to determine where infiltration-based BMPs can be used without adverse impacts. It is possible that a certain amount of stormwater infiltration would not be detrimental, or could be beneficial. See **Appendix C** for specific guidance on assessing groundwater and soil contamination to ensure that project drainage plans do not contribute to movement or dispersion of groundwater contamination or interfere with groundwater cleanup activities

Protection of Groundwater Quality

Research conducted on the effects on groundwater from stormwater infiltration by Pitt et al. (1994) indicate that the potential for contamination due to infiltration is dependent on a number of factors including the local hydrogeology and the chemical characteristics of the pollutants of concern. Chemical characteristics that influence the potential for groundwater impacts include mobility, soluble fractions, and concentration. Pollutants that have high mobility (low adsorption potential to soil), a high soluble fraction (most of the pollutant is dissolved rather than particulate), and/or have a high concentration in urban runoff have an elevated risk for groundwater contamination. As a class of constituents, trace metals tend to adsorb onto soil particles and are filtered out by the soils. This has been confirmed by extensive data collected beneath stormwater detention/retention ponds in Fresno (conducted as part of the Nationwide Urban Runoff Program (Brown & Caldwell, 1984)) that showed that trace metals tended to be adsorbed in the upper few feet in the bottom sediments. Bacteria are also filtered out by soils. More mobile and soluble pollutants, such as chloride and nitrate, have a greater potential for impacting groundwater.

Appendix C provides criteria for infiltration related to protection of groundwater quality, including:

- Minimum separation from groundwater, including guidance for calculating mounding potential;
- Categorization of infiltration BMPs by relative risk of groundwater contamination;
- Pollutant sources in the tributary watershed and pretreatment requirements;
- Setbacks from known plumes and contaminated sites; and
- Guidelines and triggers for review by applicable groundwater management agencies and/or well permitting agencies.

Groundwater Aquifer Recharge

Infiltration of stormwater can provide the benefit of recharging groundwater aquifers if hydrogeological conditions are conducive and the site is located over an aquifer. As feasible, infiltration BMPs should be located in areas where infiltration would be most beneficial for groundwater recharge. The site characterization should attempt to identify areas where infiltration would have the greatest benefit for groundwater aquifer recharge. Generally, a greater fraction of infiltrated water reaches groundwater aquifers in cases where there is a relatively direct hydrogeological connection between the surface and an aquifer.

Groundwater/Surface Water Interactions

Groundwater discharge to surface water is generally a primary source of dry weather base flows in perennial stream systems. Intermittent and ephemeral systems are often characterized by groundwater discharge during portions of the year and streams losing flow to groundwater during other portions of the year. In Southern California, due to the Mediterranean climate, intermittent and ephemeral systems are very common. These systems may be sensitive to minor changes in groundwater levels which could result from increased infiltration compared to the existing condition. In such systems, increases in groundwater levels could potentially increase the duration of dry weather base flows in intermittent and ephemeral drainages. These changes may have significant impacts on riparian habitat and geomorphology. If intermittent or ephemeral drainages are located adjacent to and down-gradient of the project, the application of infiltration BMPs could potentially impact these drainages, which could result in a finding of infeasibility for infiltration. The Conceptual/Preliminary or Project WQMP should provide analyses to support this finding. Consultation with the local groundwater agency may also help inform this analysis.

Coordination with Groundwater and Well Permitting Agencies

Certain infiltration activities should be coordinated with the applicable groundwater management agency, such as the Orange County Water District, to ensure groundwater quality is protected. It is recommended that coordination be initiated as early as possible during the Preliminary/Conceptual WQMP development process, as part of the CEQA process (preferred) or otherwise. See **Appendix C** for specific guidance as well as a template letter to facilitate groundwater agency consultation.

Certain infiltration BMPs, including dry wells and infiltration galleries trigger USEPA Class V Underground Injection Control (UIC) definitions and require registration via USEPA Region 9. The infiltration BMP Fact Sheets (**Appendix G**) identify BMPs that are potentially categorized as Class V Injection Wells and provide guidelines for registering these BMPs.

Dry wells are classified as Class V wells and fall under the California Well Standards (Bulletin 74-81) and the Orange County Well Ordinance (No. 2607). This requires design per specific standards and a specific separate permitting process beyond what is required for WQMPs. See Appendix G.3, Fact Sheet INF-4.

2.3.1.3. *Soil and Geologic Infiltration Characteristics*

Soil and geologic conditions at the site must be investigated in a manner adequate to support the selection of LID BMPs consistent with the LID BMP selection hierarchy described in **Section 2.5**. This investigation must be conducted for all locations of the site where it is reasonably possible to site LID BMPs. Guidance on specific methods for measuring or estimating infiltration rates at the planning and design phases of project are described in **Appendix D.**

At the planning phase of a project, this investigation should result in, as applicable:

- Narrative description of soil conditions at the site, including information such as texture class, NRCS hydrologic soil group.
- Narrative description of geologic conditions underlying the site, including information such as texture class, degree of consolidation.
- Locations of infiltration testing conducted at the project site.
- Raw results and professional interpretation of infiltration tests conducted at the project site.
- Locations and logs of borings at the project site that are relevant for interpretation of infiltration feasibility.

- Identification of areas of the site that fall within estimated observed infiltration rate thresholds indicative of likelihood of full or partial stormwater infiltration (See **Section 4.2.2** and **Appendix D** for definitions of "observed infiltration rate", "feasibility screening infiltration rate", and "design infiltration rate"):
    - Areas with an observed infiltration rate > 4 inch per hour – these areas have the highest potential for full infiltration BMPs.
    - Areas with an observed infiltration rate 0.6 to 4 inches per hour – these areas may support full infiltration BMPs, but conditions may be marginal and require more thorough analysis or contingency planning as part of BMP selection.
    - Areas with an observed infiltration rate 0.1 to 0.6 inches per hour – these areas may support incidental infiltration, but not likely full infiltration.
    - Areas with an observed infiltration rate less than 0.1 inches per hour – these areas likely do not support appreciable levels of incidental infiltration.
- A geotechnical investigation report containing investigation methods and interpretation of findings.
- Characterization of surface soils to determine presence, locations, and extents of critical course sediment, as further defined in the **South Orange County HMP.** Maps of critical course sediment yield areas are included in **Appendix N**. (Note: this provision applies only to projects which have an HCOC, see **Section 2.3.5.**)

In addition, available geologic or geotechnical reports on local geology should be reviewed to identify relevant features such as depth to bedrock, rock type, lithology, faults, and hydrostratigraphic or confining units. These geologic investigations may also identify shallow water tables and past groundwater or soil contamination issues that are important for BMP design (see below). Geologic investigations may provide an assessment of whether soil infiltration properties are likely to be uniform or variable across the project site.

At the design phase of the project, if infiltration BMPs will be used, the investigation of soils and geology should also include:

- Infiltration testing at the location and elevation of the proposed infiltrating surface consistent with an acceptable design-phase testing method described in **Appendix D**;
- Interpretation of infiltration testing result consistent with the guidance provided in **Appendix D**; and
- Stamped geotechnical report documenting and certifying findings.

Note that if the presence of another infiltration feasibility factor (e.g., groundwater limitation) controls the categorization of infiltration feasibility, no testing or site characterization may be needed to meet the minimum requirements.

2.3.1.4. Geotechnical Considerations

Infiltration of stormwater can cause geotechnical issues in certain conditions, including: (1) settlement through collapsible soil, (2) expansive soil movement, (3) slope instability, and (4) an increased liquefaction hazard. Stormwater infiltration temporarily raises the soil moisture and groundwater level near the infiltration facility, such that the potential geotechnical conditions are likely to be of greatest significance near the area of infiltration and diminish with distance. If infiltration BMPs are considered, a geotechnical investigation should be performed for the infiltration facility to identify potential geotechnical issues and geological hazards that may result from infiltration and identify potential mitigation measures.

Increased water pressure in soil pores reduces soil strength. Decreased soil strength can make foundations more susceptible to settlement and slopes more susceptible to failure. In general, infiltration-based BMPs must be set back from building foundations or steep slopes. Recommendations for each site should be determined by a licensed geotechnical engineer based on soil boring data, drainage patterns, and the current requirements for stormwater treatment. Implementing the geotechnical engineer's requirements is essential to prevent damage from increased subsurface water pressure to surrounding properties, public infrastructure, sloped banks, and even mudslides.

It must be noted that reliance on geotechnical engineering recommendations does not relieve the project applicant of attempting to identify locations for BMPs that satisfy the recommended setbacks and still allow the opportunity for infiltration.

Geotechnical recommendations should consider the following factors.

Collapsible Soil

Typically, collapsible soil is observed in sediments that are loosely deposited, separated by coatings or particles of clay or carbonate, and subject to saturation. Infiltration of stormwater may result in a temporary rise in the groundwater elevation. This rise in groundwater could change the soil structure by dissolving or deteriorating the intergranular contacts between the sand particles, resulting in a sudden collapse, referred to as hydrocollapse. This collapse phenomenon generally occurs during the first saturation episode after deposition of the soil, and repeated cycles of saturation are not likely to result in additional collapse. If infiltration is considered, it is important to evaluate the potential for hydrocollapse during the geotechnical investigation. The magnitude of hydrocollapse is proportional to the thickness of the soil column where infiltration is occurring; in most instances, the magnitude of hydrocollapse will be small. Regardless, if infiltration BMPs are considered, the geotechnical engineer should evaluate the potential effects of hydrocollapse and, if necessary, specify mitigation and monitoring measures.

Expansive Soil

Expansive soil is generally defined as soil or rock material that has a potential for shrinking or swelling under changing moisture conditions. Expansive soils contain clay minerals that expand in volume when water is introduced and shrink when the water is removed or the material is dried. When expansive soil is present near the ground surface, a rise in groundwater from infiltration activities can introduce moisture and cause these soils to swell. Conversely, as the groundwater surface falls after infiltration, these soils will shrink in response to the loss of moisture in the soil structure. The effects of expansive soil movement (swelling and shrinking) will be greatest on near surface structures such as shallow foundations, roadways, and concrete walks. Basements or below-grade parking structures can also be affected as additional loads are applied to the basement walls from the large swelling pressures generated by soil expansion. If infiltration BMPs are considered, the geotechnical investigation should identify if expandable materials are present near the proposed infiltration facility, and if they are, evaluate if the infiltration will result in wetting of these materials and any potential mitigation measures.

Slopes

Slopes near infiltration facilities can be affected by the temporary rise in groundwater. The presence of a water surface near a slope can substantially reduce the stability of the slope from a dry condition. If infiltration BMPs are considered near a slope, groundwater mounding analysis should be performed to evaluate the rise in groundwater around the facility. If the computed rise in groundwater approaches nearby slopes, then a separate slope stability evaluation should be performed to evaluate the implications of the temporary groundwater surface. The geotechnical and groundwater mounding evaluations should identify the duration of the elevated groundwater and assign factors of safety consistent with the duration (e.g., temporary or long-term conditions).

Liquefaction

Soil liquefaction is a phenomenon in which saturated granular materials experience a reduction in bulk volume and a loss of bearing capacity induced by seismic motion. Soil liquefaction can also result in instabilities and lateral spreading in embankments and areas of sloping ground.

Saturation of the subsurface soils above the existing groundwater table may occur as a result of stormwater infiltration. If infiltration BMPs are considered, the potential for liquefaction should be assessed. If this assessment shows that potential for liquefaction exists, appropriate geotechnical analyses should be conducted to determine the level of stormwater infiltration that can be safely tolerated.

2.3.1.5. *Reporting of Groundwater, Soil and Geotechnical Investigations*

For simple cases that have a clear basis for rejecting infiltration, separate reporting of groundwater, soil and geotechnical investigations may not be necessary. For example, for projects that can document and confirm the presence of a limiting constraint within the WQMP, a supplemental report is not necessary. However, in cases where findings regarding infiltration feasibility and/or design involve data analysis and/or measurements that are beyond a standard civil engineering discipline, a separate report or set of reports prepared under the supervision of a qualified professional may be required. In any case, the documentation must present findings based on substantial evidence that are adequate to support defensible responses to the feasibility criteria described in **Section 2.5**, as applicable.

2.3.2. Characterize the Proposed Site Development Activities

The WQMP must describe the proposed condition of the site. At a minimum, the following information summarized in **Table 2-3** must be catalogued. To the extent that this data is shown in drainage plan exhibits developed in subsequent sections, it is not necessary to have a separate exhibit in this section of the WQMP.

Table 2-3 Expected Activities and Content for Description of the Proposed Site

Expected Activities/Content	Rationale
Identify sensitive environmental features and hydrologic features that will be preserved at the site.	The WQMP must document that the site was designed in a way to minimize impacts to these features; certain site design BMPs are applicable to protection of these features.
Identify proposed drainage patterns, including points of run-on and run-off from the project site.	These factors may represent constraints in siting BMPs. Run-on must be considered in sizing and crediting of BMPs as described in Section 2.5.
Characterize and quantify proposed land uses, land use activities, and applicable industrial codes.	Land uses, land use activities, and industrial codes are relevant to defining pollutants of concern and determining applicable source control measures.
Characterize specific pollutant source areas.	Specific pollutant source areas are relevant to identifying applicable source control measures.
Characterize the spatial extent, magnitude, and locations of significant proposed cut and fill.	A description of proposed fill is relevant to the evaluation of infiltration feasibility. If BMPs will be located in fill, the infiltration rate of the BMPs cannot be known prior to construction, and a full infiltration approach is not acceptable.
Characterize potential harvested water demands in the proposed condition.	Harvested water demand can be screened based on the overall project land uses to evaluate whether an LID approach based on harvesting may be feasible.

The following guidelines apply for information that should be collected and summarized.

2.3.2.1. Project Land Uses

Provide the following information:

- For the entire project, list and describe the proposed land uses, the area of each land use, and the estimated imperviousness for each land use.

- List and show on a figure where facilities will be located and what activities will be conducted:

    - List what kinds of materials and products will be used (if known), how and where materials will be received and stored (if applicable), and what kinds of wastes will be generated (if any).
    - Describe all paved areas, including the type of parking areas.
    - Describe all landscaped areas and open space areas (if any).

- For commercial and industrial projects:

    - Provide the Standard Industrial Classification (SIC) Code which best describes the facilities operations.
    - Describe the type of use (or uses) for each building or tenant space (if known).
    - If the project includes food preparation, cooking, and eating areas, specify the location and type of area.
    - Describe delivery areas and loading docks (specify location, design, if below grade, and types of materials expected to be transferred).
    - Describe outdoor materials storage areas (describe and depict location(s), specify type(s) of materials expected to be stored).
    - Describe activities that will be routinely conducted outdoors.
    - Describe any activities associated with equipment or vehicle maintenance and repair, including washing or cleaning.
    - Indicate the number of service bays or number of fueling islands/fuel pumps, if applicable.

- For residential projects:

    - For a single dwelling unit, describe the unit and project site.
    - For a tract, list the range of lot and home sizes.
    - Describe all community facilities such as laundry, car wash, swimming pools, parks, open spaces, tot lots, etc.

2.3.2.2. *Post Development Drainage Characteristics*

The Project WQMP should generally describe the proposed drainage for the site, including the following:

- Will the site connect to a storm drain system or discharge directly into a receiving water body?
- If the site will connect to a storm drain system, name the locations for the connection(s).

2.3.2.3. *Property Ownership/Management*

Describe the ownership of all portions of the project and site. State whether any infrastructure will transfer to public agencies (City, County, Caltrans, etc.). State if a homeowners or property owner's association will be formed that will be responsible for the long-term maintenance of the project's stormwater facilities.

2.3.2.4. *Potential Harvested Water Demands*

The project proponent may choose to implement harvest and use BMPs to capture stormwater from the site and use it for demands such as irrigation and toilet flushing. Harvest and use BMPs for stormwater management require that there is sufficient demand for the harvested water so that the water can be used in a reasonable time. To support subsequent assessment of harvest and use feasibility, this section of the WQMP should describe the types and magnitudes of potential harvested water demands. **Appendix F** contains methods and guidance for calculating the potential harvested water demand for a range of scenarios.

2.3.3. Identify Receiving Waters

Name every receiving water to which the project will discharge. Name the direct receiving water body for the project site and list each subsequent water body until reaching the ocean. If the project will connect to the storm drain, determine where the storm drain system discharges into a receiving water body and each subsequent downstream receiving water. For assistance in mapping the receiving water bodies, see the maps provided in **Appendix N**.

2.3.4. Determine Pollutants of Concern

Urban runoff from a developed site has the potential to contribute pollutants to the municipal storm drain system and ultimately to the tributary receiving waters during both dry and wet weather. Pollutants that are commonly associated with urban development include suspended solids/sediment, nutrients, metals, pathogens, oil and grease, toxic organic compounds, and trash and debris. Additionally, non-permitted non-stormwater discharges that are allowed to leave the project site can also convey pollutants and are a water quality condition of concern. Pollutants of concern are separated into two types:

Primary Pollutants of Concern: Defined as pollutants that are expected to be generated by the project at levels of concern and are identified as an impairment of any downstream water body. Additionally, pollutants or conditions identified as contributing to a Highest Priority Water Quality Condition per the Water Quality Improvement Plan are a primary pollutant of concern regardless of the potential for them to be generated from the project.

Other Pollutants of Concern: Defined as pollutants identified as expected to be generated from the project at levels of concern, but for which downstream waterbodies are not listed as impaired.

The WQMP shall identify the pollutants and other water quality conditions of concern for the project. Specifically, the WQMP shall:

- Determine pollutants expected to be generated or have the potential to be generated from the project based on land uses and specific features (See **Section 2.3.4.2**).
- Identify water quality impairments and/or priority receiving water quality conditions in the water bodies that receive runoff from the site, directly or indirectly, and all downstream water bodies (See **Section 2.3.4.3**)
- Identify environmentally sensitive areas that relate to the project (See **Section 2.3.4.4**)
- Identify primary pollutants or conditions of concern and identify other pollutants or conditions of concern (See **Section 2.3.4.5**).

The following sections provide guidance and resources for determining the pollutants of concern.

2.3.4.1. Pollutant Categories

Pollutants and water quality conditions of concern can be grouped into the following eight general categories:

- ***Suspended Solids / Sediment***: consist of soils or other surficial materials that are eroded and then transported or deposited by wind, water, or gravity. Excessive sedimentation can increase turbidity, clog fish gills, reduce spawning habitat, lower young aquatic organisms' survival rates, smother bottom dwelling organisms, and suppress aquatic vegetation growth. Sediments in runoff also transport other pollutants that adhere to them, including trace metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and phosphorus. Sediment also reduces storage and clogs media and soils in BMPs which impacts BMP performance. The largest source of suspended solids / sediment is typically erosion from disturbed soils.
- ***Nutrients/Eutrophication:*** includes the macro-nutrients nitrogen and phosphorus. They commonly exist in stormwater in the form of mineral salts or organic matter dissolved or suspended in stormwater. Excessive discharge of nutrients to water bodies and streams can cause eutrophication, including excessive aquatic algae and plant growth,

loss of dissolved oxygen, release of toxins in sediment, and significant swings in hydrogen ion concentration (pH). Primary sources of nutrients in urban runoff are fertilizers, illicit connections to sanitary sewers, trash and debris, pet waste, and eroded soils. Urban areas with improperly managed landscapes can be substantial sources.

- ***Metals:*** includes certain metals that can be toxic to aquatic life if concentrations become high enough to stress natural processes. Metals of concern include cadmium, chromium, copper, lead, mercury, and zinc among others. Lead and chromium have been used as corrosion inhibitors in primer coatings and are also raw material components in non-metal products such as fuels, adhesives, paints, and other coatings. Copper and zinc are typically associated with building materials, including galvanized metal and ornamental copper, and automotive products, including tires and brake pads. Humans can be impacted from contaminated groundwater resources, and bioaccumulation of metals in fish and shellfish. Environmental concerns regarding the potential for release of metals to the environment have already led to restricted metal usage in certain applications, for example lead additives in gasoline. The primary source of metals in urban stormwater is typically commercially available metal products and automobiles.
- ***Pathogens (Bacteria and Viruses)/Human Health Risk***: include harmful bacteria and viruses, which are ubiquitous microorganisms that thrive under a range of environmental conditions. Water containing excessive pathogenic bacteria and viruses, particularly from human sources, can create a harmful environment for humans and aquatic life. This has been identified as a Highest Priority Water Quality Condition in coastal waters in South Orange County. Typically, in Southern California, indicator bacteria are used as a surrogate of pathogens because there are many different pathogens, and the methods required to detect and monitor them are much more complex than those used for indicator bacteria. Indicator bacteria are fecal bacteria that originate from human or animal wastes, so their presence may indicate the present of pathogens.
- ***Oil and Grease***: are characterized as high-molecular weight organic compounds. Elevated oil and grease content can decrease the aesthetic value of the water body, as well as the water quality. Introduction of these pollutants to water bodies may occur due to the wide uses and applications of some of these products in municipal, residential, commercial, industrial, and construction areas. Primary sources of oil and grease are petroleum hydrocarbon products, motor products from leaking vehicles, esters, oils, fats, waxes, and high molecular-weight fatty acids.
- ***Toxic Organic Compounds***: include organic compounds (pesticides, solvents, hydrocarbons) which at certain concentrations constitute a hazard to humans and/or aquatic organisms. Stormwater coming into contact with organic compounds can transport excessive levels of organics to receiving waters. Dirt, grease, and grime retained in cleaning fluid or rinse water may also adsorb levels of organic compounds that are harmful or hazardous to aquatic life. Sources of organic compounds include landscape maintenance areas, vehicle maintenance areas, waste handling areas, and potentially most other urban areas.

- ***Trash and Debris –*** includes trash, such as paper, plastic, and various waste materials that can typically be found throughout the urban landscape, and debris which includes waste products of natural origin which are not naturally discharged to water bodies such as landscaping waste, woody debris, etc. The presence of trash and debris may have a significant impact on the recreational value of a water body and upon the health of aquatic habitat. Trash and debris also tend to clog stormwater infrastructure and can be a source of other pollutants as they break down.
- ***Dry Weather Flows –*** Dry weather flows (e.g., irrigation overspray, air conditioner condensate, car wash water) have the potential to impact riparian beneficial uses by contributing to an unnatural flow regime in inland streams. This condition has been identified as a Highest Priority Water Quality Condition in inland receiving waters in South Orange County.

2.3.4.2. Expected Pollutants Based on Project Land Use Activities

This section describes how to determine expected pollutants based on project land use activities. Pollutants in stormwater runoff are typically related to land use activities, which means that the project's site uses provide some indication of the pollutants that may be present in runoff from the project site. Pollutants that are expected to be generated or have a potential to be generated from a project based on the project's land use activities must be identified using **Table 2-4**, as applicable**.** The identification of expected pollutants must always be based on the land use activities proposed. In addition, site-specific conditions must also be considered for potential pollutant sources, such as pollutants generated from specific process on-site, legacy pesticides or nutrients in site soils as a result of past agricultural practices or hazardous materials in site soils from industrial uses. Hazardous materials that have been remediated and do not pose a current or future threat to stormwater quality are not considered a pollutant of concern.

Municipal projects should determine expected pollutants based on the pollutant generating activities associated with the project using Table 5.5 in Section 5 of the Orange County DAMP (www.ocwatersheds.com/Documents/2003_DAMP_Section_5_Municipal_Activities.pdf).

Table 2-4: Anticipated and Potential Pollutants Generated by Land Use Type

Priority Project Categories and/or Project Features	General Pollutant Categories							
	Suspended Solid/ Sediments	Nutrients	Heavy Metals	Pathogens (Bacteria/ Virus)	Pesticides	Oil & Grease	Toxic Organic Compounds	Trash & Debris
Detached Residential Development	E	E(1)	N	E	E(1)	E	N	E
Attached Residential Development	E	E(1)	N	E	E(1)	E(2)	N	E
Commercial/ Industrial Development	E(1)	E(1)	E(2)	E(3)	E(1)	E	E	E
Automotive Repair Shops	N	N	E	N	N	E	E	E
Restaurants	E(1)(2)	E(1)	E(2)	E	E(1)	E	N	E
Hillside Development >5,000 ft^2	E	E(1)	N	E	E(1)	E	N	E
Parking Lots	E	E(1)	E	E(4)	E(1)	E	E	E
Streets, Highways, & Freeways	E	E (1)	E	E(4)	E(1)	E	E	E
Retail Gasoline Outlets	N	N	E	N	N	E	E	E

E = expected to be of concern
N = not expected to be of concern

(1) Expected pollutant if non-drought tolerant landscaping exists on-site. Where landscaping is drought tolerant and is depressed within planting areas, nutrients and pesticides are not expected at levels of concern.
(2) Expected pollutant if the project includes uncovered parking areas, otherwise not expected.
(3) Expected pollutant if land use involves food or animal waste products, otherwise not expected.
(4) Bacterial indicators are routinely detected in pavement runoff.
(5) Expected if outdoor storage or metal roofs, otherwise not expected.

2.3.4.3. *Identifying Water Quality Impairments, TMDLs, and Highest Priority Water Quality Conditions*

The presence of impairments and TMDLs has an important role in the identification of pollutants of concern and therefore selection of BMPs for the project. Therefore, it is important to identify impairments and TMDLs as part of Section 3 of the Project WQMP.

Table 2-6 lists the impaired waterbodies within the South Orange County permit area that are included on the 2010 303(d) list. The 303(d) listings for the San Diego Region (South Orange County permit area) were scheduled to be updated in the 2016 Integrated Report. As of the writing of this document, only the 2010 Integrated Report with the 2010 303(d) listings has been approved by USEPA for the San Diego Region. **Project proponents should consult the most recent EPA-approved 303(d) list to identify whether the project's proximate and downstream receiving water bodies are listed as impaired.** The WQMP should document the 303(d) list that was consulted. The most recent EPA-approved 303(d) list is located on the State Water Resources Control Board website[5] **Table 2-7** lists TMDLs that have been adopted and are being implemented in the Orange County Watersheds as of March 2016.

In South Orange County Water Quality Improvement Plan identifies the highest priority water quality conditions for receiving waters. A highest priority water quality condition is considered to be a priority pollutant or condition, even if that pollutant or condition is not typically generated from that land use type. Highest priority water quality conditions include:

> **Pathogen Health Risk:** Applies to coastal waters, including any inland water that discharges to coastal waters. Pathogens and indicator bacteria should always be categorized as a primary pollutant of concern.
>
> **Unnatural Water Balance/Flow Regime:** Applies to all inland receiving waters. Dry weather discharges from projects should always be classified as a primary water quality condition of concern for areas that drain to inland receiving waters. Additionally, if a subsequent update of the Water Quality Improvement Plan determines that stormwater infiltration is responsible for unnatural water balance in a specified area, then this may be a basis for determining infeasibility of infiltration in that the specified area.
>
> **Geomorphic Impacts/Stream Erosion:** This is relevant to any channel that is susceptible to hydromodification impacts as described in **Section 2.3.5**. Priority Projects discharging to susceptible reaches are required to meet hydromodification control criteria.

Highest priority water quality conditions may change over time with revisions of the Water Quality Improvement Plan.

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[5] http://www.swrcb.ca.gov/water_issues/programs/#wqassessment

Table 2-5: Summary of the Approved 2010 303(d) Listed Water Bodies and Associated Pollutants of Concern for North Orange County

[Placeholder for future addition after adoption of the 5th Term NOC MS4 Permit]

Table 2-6: Summary of the Approved 2010 303(d) Listed Water Bodies and Associated Pollutants of Concern for South Orange County

Region	Water Body	Bacteria Indicators/ Pathogens	Metals	Nutrients	Pesticides	Toxicity	Trash	Sediment	Other Organics	Other Inorganics
Region 9 San Diego	Aliso Creek (Mouth)	X								
	Aliso Creek (20 Miles)	X	X	X		X				
	Arroyo Trabuco Creek			X	X	X				
	Dana Point Harbor		X			X				
	English Canyon		X		X	X			X	
	Laguna Canyon Channel					X				
	Oso Creek (at Mission Viejo Golf Course)									X
	Oso Creek (lower)		X			X				
	Pacific Ocean Shoreline, Aliso HSA at Aliso Beach (Middle and Mouth)	X								
	Pacific Ocean Shoreline, Dana Point HSA	X								
	Pacific Ocean Shoreline, Laguna Beach has at Main Beach	X								
	Pacific Ocean Shoreline, Lower San Juan HSAs	X								
	Pacific Ocean Shoreline, San Clemente HA	X								
	Pacific Ocean Shoreline, Tijuana HU	X								
	Prima Deshecha Creek		X	X				X		
	San Juan Creek	X	X	X	X	X				
	San Juan Creek (mouth)	X								
	Segunda Deshecha Creek			X		X		X		

On October 11, 2011, the 2010 303(d) list was approved by USEPA Region 9. Project proponents should consult the most recent 303(d) list located on the State Water Resources Control Board website[6].

[6] http://www.swrcb.ca.gov/water_issues/programs/#wqassessment

Table 2-7: Summary of the Status of TMDLs for Waterbodies in Regions 8 (NOC) and 9 (SOC).

Region	Water Body	Pollutant				
		Bacteria Indicators/ Pathogens	Metals	Nutrients	Pesticides	Turbidity/ Siltation
Region 8 Santa Ana (NOC) (Included as a placeholder only until adoption of the 5th Term NOC MS4 Permit)	Newport Bay, Lower	Implementation Phase	Technical TMDLs	Implementation Phase	Technical TMDLs	Implementation Phase
	Newport Bay, Upper (Ecological Reserve)	Implementation Phase	Technical TMDLs	Implementation Phase	Technical TMDLs and Implementation Phase	Implementation Phase
	San Diego Creek, Reach 1		Technical TMDLs	Implementation Phase	Technical TMDLs and Implementation Phase	Implementation Phase
	San Diego Creek, Reach 2		Technical TMDLs	Implementation Phase		Implementation Phase
	Coyote Creek/San Gabriel River		Technical TMDLs[1]			
Region 9 San Diego (SOC)	Pacific Ocean Shoreline: Laguna Beach HSA, Aliso HSA, Dan Point HSA, Lower San Juan HSA, San Clemente HSA	Implementation Phase				
	Pacific Ocean Shoreline: Dana Point Harbor at Baby Beach	Implementation Phase				
	Aliso Creek	Implementation Phase				
	San Juan Creek	Implementation Phase				
	Pacific Ocean Shoreline: Doheny State Beach	In Progress				

[1]This TMDL was adopted by the Los Angeles Regional Water Quality Control Board (Region 4), however it applies to the areas of Orange County that drain to Coyote Creek and San Gabriel River.

2.3.4.4. *Determining Environmentally Sensitive Areas and Areas of Special Biological Concern*

To assist developers in determining the presence of ESAs such as areas designated in the Ocean Plan as Areas of Special Biological Significance (ASBS) or waterbodies listed on the CWA Section 303(d) list of impaired waters, The County of Orange has prepared watershed maps that identify each ESA (**http://ocwatersheds.com/documents/wqmp**).

A Priority Project may potentially impact a water body considered to be an ESA if this project is:

- Within or adjacent to, or
- Discharges pollutants directly to an ESA.

For the purposes of these procedures, the following terms are defined:

- *Adjacent* -located within 200 feet of the listed water body.
- *Discharging directly to* -discharge from a drainage system that is composed entirely of flows from the subject facility or activity, i.e., discharge from an urban area that comingles with downstream flows prior to discharging to an ESA is not subject to this requirement.

An ESA exists if any of the following designations have been applied to the water body of concern:

- Clean Water Act 303(d) listed impaired water body based on **most recent approved 303(d) list.**
- Areas designated as Areas of Special Biological Significance by the SWRCB in the Water Quality Control Plan for Ocean Waters of California (**California Ocean Plan**)
- Water bodies designated with the RARE beneficial use by the SWRCB in the Water Quality Control Plans for the San Diego Region (**Region 9 Basin Plans**)
- Water bodies located within areas designated under the California Department of Fish and Game's Natural Community Conservation Planning (NCCP) Program as preserves or equivalent in subregional plans (**https://www.wildlife.ca.gov/Conservation/Planning/NCCP**)
- Areas designated as Critical Aquatic Resources in the Orange County Drainage Area Management Plan (**DAMP**)
- Any other equivalent ESAs that contain water bodies that have been identified by the local jurisdiction to be of local concern.

The maps available at the OC Watersheds website may be used to assist in the identification and classification Priority Projects in order to determine if they potentially impact an ESA. (**http://ocwatersheds.com/documents/wqmp**)

2.3.4.5. *Selecting the Pollutants of Concern for the Project*

Compare the list of pollutants for which the receiving waters are impaired or for which TMDLs have been adopted with the pollutants anticipated to be generated by the land uses included in the project (as identified in **Table 2-4**). In SOC, in addition to the pollutants generated by the land uses included in the project, identify the highest pollutant of concern from the WQIP applicable for the location of the project.

Primary Pollutants of Concern are any pollutants anticipated to be generated by the project using **Table 2-4** that have also been identified as causing impairment of project receiving waters (**Table 2-6)** or for which a TMDLs is in place (**Table 2-7)**. Note that this applies to all receiving waters between the point of discharge from the project and the ocean. In addition, a highest priority water quality condition from the Water Quality Improvement Plan is also a primary pollutant of concern, even if it is not expected to be generated at levels of concern by land uses included in the project.

Other pollutants of concern are those pollutants anticipated to be generated by the project using **Table 2-4** that have not been identified as causing impairment in the project's receiving waters. In addition, pollutants that may affect the performance of BMPs (e.g. sediment) should be considered when selecting pretreatment and designing BMPs.

In addition to the process described in this section, primary pollutants of concern may also be identified through the environmental impact assessment for the project (e.g., project-specific pollutant evaluations in CEQA EIRs). Watershed planning documents should also be reviewed for identification of specific implementation requirements that address pollutants of concern as discussed in **Section 2.1.**

Guidance on selecting LID and treatment control BMPs to address pollutants of concern is provided in **Section 4.2**.

2.3.5. Determine Potential Hydrologic Conditions of Concern

The physical response of stream channels to changes in catchment runoff and sediment yield caused by land use modifications is referred to as hydromodification. Unless managed, hydromodification can cause channel erosion, migration, or sedimentation, as well as biologic impacts to streams.

2.3.5.1. *Primary Basis for Determining Potential HCOCs*

This section of the WQMP (Section 3.5) shall identify whether there are potential HCOCs. This section does not need to determine whether hydromodification controls are needed to address the HCOC; it simply determines whether HCOCs need to be considered as part of Step 6 (**Section 2.6**) or whether this design requirement can be disregarded.

The determination of potential HCOCs is made primarily based on whether there are channels downstream that are susceptible to hydromodification.

For phased projects, the determination of potential HCOCs and subsequent analysis to address HCOCs should be done for the overall project and for each phase as it is approved, cumulative of the current phase and previously completed phases. More guidance on phased projects is provided in Section 4.8 of the **Model WQMP**.

North Orange County

[Placeholder for future addition after adoption of the 5th Term NOC MS4 Permit]

South Orange County

Per Provision E.3.c.(2)(d), priority projects are categorically exempted from hydromodification requirements where the project discharges to:

1. Existing underground storm drains discharging directly to water storage reservoirs, lakes, enclosed embayments, the Pacific Ocean, or one of the channel types described below;
2. Conveyance channels whose bed and bank are concrete lined all the way from the point of discharge to water storage reservoirs, lakes, enclosed embayments, or the Pacific Ocean; or
3. An area identified by the Copermittees as appropriate for an exemption by the optional Watershed Management Area Analysis incorporated into the Water Quality Improvement Plan.

The most recent approved version of the Watershed Management Area Analysis shall be consulted to determine the list of reaches that are exempted per bullet #3 above. The map of exempted reaches from the WMAA have been incorporated into **Appendix N.7**. If waterbodies are not potentially susceptible to hydromodification impacts, an HCOC does not exist and hydromodification does not need to be considered further.

2.3.5.2. Potential Project-Specific Exemptions in North Orange County

[Placeholder for future addition after adoption of the 5th Term NOC MS4 Permit]

2.3.5.3. Potential Change of WMAA Exemption Maps in South Orange County

Revisions to the determination of susceptibility of stream or channel reaches may be pursued by an MS4 permittee via an amendment to the Watershed Management Area Analysis. Should the MS4 permittee pursue an amendment to the hydromodification susceptibility maps and/or list of exempted reaches via this pathway, a technically defensible analysis of stream susceptibility is necessary. This analysis requires review as part of the Consultation Panel process as part of the Annual Update of the Water Quality Improvement Plan.

2.4. Step 4: Develop Site Design and Drainage Plan

The purpose of this section of the Conceptual/Preliminary or Project WQMP is to develop the site design and drainage plan incorporating all applicable site design BMPs and source control BMPs and to determine the locations for structural BMPs by dividing the site into separate drainage management areas (DMAs).

2.4.1. Regulatory Criteria Applicable to Site Design and Drainage Planning

The MS4 Permits do not establish specific criteria for site design and drainage planning. However, in order to support subsequent phases of BMP planning, every project must engage in a site design and drainage planning phase related specifically to stormwater quality management and hydromodification management (if applicable). Specifically, the documentation of the site design and drainage plan must demonstrate that the following underlying criteria are met:

- BMPs are provided to remove pollutants from runoff prior to its discharge to any receiving waters, and are located as close to the source as possible.
- Structural BMPs must not be constructed within any Water of the United States.
- All site design BMPs and source control BMPs that are applicable and feasible for the project must be identified and implemented.
- Water quality and hydromodification management (if applicable) must be considered at the earliest practical phase of project development. As part of this requirement, the plan must explain how the locations determined for LID BMPs were identified to support the use of higher priority LID BMP types that maximize retention of stormwater.
- Space constraints and overriding considerations in site layout and BMP locations must be presented based on technical justifications.

2.4.2. Expected WQMP Content

The expected activities and WQMP content associated with this effort are described in **Table 2-8**. In practice, the process of site design and drainage planning (Step 4, this section), LID BMP selection and sizing (Step 5, **Section 2.5**), and hydromodification BMP selection and sizing (Step 6, **Section 2.6**) are iterative and interdependent. Approaching them in isolation is unlikely to result in efficient designs. Additionally, there are many potential approaches for conducting these three steps depending on the nature of the site, characteristics of the project, and designer preferences. This section is intended to identify expected content and provide suggested approaches. It is not intended to be interpreted as the only acceptable approach.

Table 2-8. Expected Activities and WQMP Content for Development of Site Design and Drainage Plan

Expected Activities/Content	Rationale
Subdivide the site into discrete DMAs (single DMA may be acceptable for simpler sites)	DMAs are generally defined at the BMP scale and must be used as the spatial basis for structuring the drainage plan.
Describe the properties of each DMA, including: • Impervious cover • Land uses • Areas of potential elevated pollutant generation within DMA • Topographic features of significance • Sensitive environmental features or natural drainage features of significance • Infiltration feasibility of the DMA consistent with the phase of WQMP being prepared	Defining these parameters at a DMA level allows BMP approaches to be determined appropriate to each part of the site. This base description helps provide the rationales for how DMAs were subdivided. An overall site-level description of these parameters does not provide adequate spatial discretization, except for simple sites.
Describe the type, location, and spatial extent of site design BMPs associated with each DMA. Provide an explanation for why a certain site design BMP was not applicable if it was not used (See Section 3).	Approaches and features must be assigned to specific locations based on DMA characteristics.
Describe the type, location, and spatial extent of source control BMPs associated with each DMA. Provide an explanation for why a certain source control BMP was not applicable if it was not used (See Section 6).	Approaches and features must be assigned to specific locations based on DMA characteristics.
Identify structural BMP locations and tributary area.	This provides the underlying structure for structural BMPs as part of Step 5 and 6.

Expected Activities/Content	Rationale
Include a site-level narrative description of the rationale for the site plan and drainage plan, including: • Rationale for why any site design approaches were not employed • Rationales used for subdividing the site into DMAs • How the placement of structural BMPs sought to improve the feasibility of retention BMPs and allow adequate space to avoid subsequent findings of spatial constraints • Overriding factors requiring compromise in site design or structural BMP locations	While there are no specific numeric criteria for site design, all applicable and feasible site design BMPs must be implemented. This section must clearly explain how stormwater management was incorporated into the project at the earliest possible time in a manner consistent with the intents of the MS4 Permit and Model WQMP. Where a site is constrained by overriding factors, this should be explained holistically here rather than only identifying space constraints in subsequent steps in the context of individual BMP locations. It is often not possible to evaluate the validity of infeasibility and space constraint claims at the scale of individual BMPs without a clear introduction to site scale planning and constraints.

2.4.3. Guidelines and Techniques for Site Design and Drainage Planning

As discussed above, the actual approach used by designers to develop site designs and drainage plans is dependent on designer preference, the characteristics of the site, and the characteristics of the project. The following sections do not define a specific approach for meeting the minimum criteria described in the Model WQMP; rather they are intended to provide helpful guidelines and suggestions.

2.4.3.1. *Types of Site Design BMPs*

Site design approaches and BMPs are described in **Section 3**. Site design BMPs that should be implemented wherever applicable include, but are not limited to:

- Maximize Natural Infiltration Capacity and Groundwater Recharge (where appropriate),
- Preserve Existing Drainage Patterns and Time of Concentration,
- Protect Existing Vegetation and Sensitive Areas,
- Minimize Impervious Area,
- Disconnect Impervious Areas,
- Minimize Construction Footprint, and
- Re-vegetate Disturbed Areas

Refer to the Bay Area Stormwater Management Agencies Association (BASMAA) **Start at the Source** manual for more guidance on LID site design practices beyond those in **Section 3**.

2.4.3.2. Types of Source Control BMPs

Source control BMPs and approaches are described in **Section 6**. Source control BMPs are specific to pollutant generating source areas and activities. As part of site design, the designer should review the list and description of source control BMPs and describe which source control BMPs are applicable and how they will be incorporated into the site design.

2.4.3.3. Defining and Delineating DMAs

Drainage management areas (DMAs) provide an important framework for feasibility screening, BMP prioritization, and storm water management system configuration. BMP selection, sizing, and feasibility determinations must be made at the DMA level; therefore, delineation of DMAs is highly recommended at the conceptual site planning phase and is mandatory for completing the project design and meeting submittal requirements.

There is not a precise process for defining DMAs. However, in order to be useful for developing the water quality management approach and documenting conformance, there are several guidelines for DMAs:

- DMAs are defined based on the proposed drainage patterns of the site and the BMPs to which they drain.
- During the early phases of the project, DMAs shall be delineated based on site drainage patterns and possible BMP locations identified in the site planning process.
- DMAs are primarily used as a tool for identifying the BMPs proposed at the site and performing calculations to show that they are adequately sized. The designer should anticipate the scales and locations at which BMPs will be applied and tailor DMA delineations to these BMPs.
- DMAs should not overlap and should be similar with respect to BMP opportunities and feasibility constraints.
- More than one DMA can drain to the same BMP. However, because the BMP sizes are determined by the runoff from the DMA, a single DMA may not drain to more than one BMP. See **Figure 2-1**.
- Some DMAs may be self-retaining (i.e. produce no runoff for the 85th percentile 24-hour storm event) through the use of hydrologic source controls (HSCs) discussed in **Section 4.3.1** and will not require an LID BMP.
- Where it is possible to isolate potential sediment sources associated with natural or non-pollution generating areas of the site, this is strongly recommended to help avoid sediment loading to BMPs and preserve the natural flow of sediment from these areas of the project site.

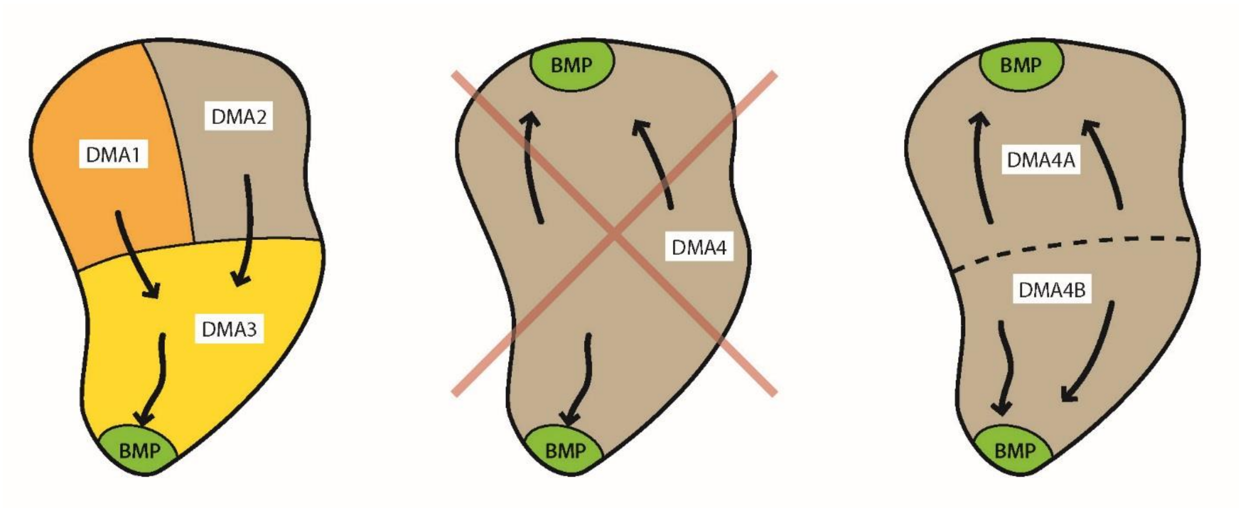

Figure 2-1. DMA Delineation

2.4.3.4. Differences in Delineations between Conceptual/Preliminary and Final Project WQMPs

The primary difference between Conceptual/Preliminary and Final Project WQMPs is the detail and resolution of drainage delineations and the specificity with which individual BMPs are located. At the conceptual/preliminary approval level, it may be acceptable to define an overall BMP strategy for a homogeneous DMA and use a "sizing factor" type of approach. For, example, a 2-acre parking lot could be identified as being treated by bioretention with a sizing factor equivalent to 4% of the tributary drainage area. The adequacy of the sizing factor could be established and the overall space allocation could be established without subdividing individual drainage areas to each BMP at the discretion of the reviewer. However, at the Final Project WQMP phase, each BMP must be specifically delineated and sized based on BMP-specific calculations. Similarly, the specific locations of site design and source control BMPs must be shown in Final Project WQMPs but may be more generally described in Preliminary/Conceptual BMPs at the discretion of the reviewer.

2.4.3.5. Space Requirements and Recommended Allowances for Structural BMPs

Perhaps the most important aspect of site planning is allowing sufficient space for LID BMPs and hydromodification BMPs (if applicable) in areas that can physically accept runoff and have good potential for allowing retention or partial retention of stormwater. Simple rules of thumb are presented in **Table 2-9** to help allow sufficient space in preliminary site layout. **Table 2-9 cannot be used to determine the required footprint for the purpose of BMP sizing, and is to be used only for estimating the amount of space required for structural BMPs during preliminary site layout.**

Each of these values is dependent on site-specific factors. More detailed methodologies for sizing LID and hydromodification BMPs and determining required footprints are described in subsequent steps. In general, the size allocations for LID BMPs are a function of:

- Reliable infiltration rate – higher, reliable infiltration rates will tend to allow somewhat deeper BMPs with smaller footprints and vice versa; a higher factor of safety is recommended for systems where investigation is less thorough, there is less redundancy, or where systems are underground and less maintainable. These conditions will tend to require larger surface areas.
- Adaptability – where systems, such as underground systems, cannot be adapted with a supplemental treated discharge to accommodate infiltration rates less than planned, a higher factor of safety is required and this results in a larger footprint.
- Sediment loads and pretreatment – lower sediment loads, better pretreatment, and/or the presence of vegetation helps reduce potential for clogging and allows somewhat deeper systems and smaller footprints.
- Vertical constraints of a site – where the profile of BMPs must be relatively shallow due to vertical constraints, this can increase footprint.
- The size allocation for hydromodification BMPs in SOC is primarily a function of soil type and the depth of the detention system that is allowable based on site constraints.

Some of these factors can and should be addressed as part of site investigation and BMP design to help result in footprint requirements that are toward the lower end of the ranges presented in **Table 2-9**. Additional guidance is provided in **Section 4** and **Appendix E**.

Table 2-9. Approximate (Rule of Thumb) Space Requirements for Structural BMPs for the Purposes of Preliminary Site Layout

BMP Type	Percent of Tributary Impervious Area Recommended in Site Design Allowance as "Rule of Thumb"	
	Well Drained Soils (> 2.0 in/hr)	Moderately Drained Soils (0.6 to 2.0 in/hr)
LID Surface Infiltration OR LID Subsurface Infiltration with Filtration Pretreatment or Rooftop Only Drainage	2.5 to 5	4 to 8
LID Subsurface Infiltration with Hydrodynamic or Settling Pretreatment	4 to 8	Not recommended
LID Biotreatment/biofiltration	2.5 to 5 percent of tributary impervious area	
LID Harvest and Reuse	1-2 percent of tributary area (based on cistern 4 to 8 feet tall, indoor or outdoor)	

NOC – Hydromodification – Redevelopment Projects	Typically satisfied as part of BMPs for LID
NOC – Hydromodification – New Development Projects	May require approximately 2x size to increase volume reduction (first priority), or greater depth (second priority), if increased volume reduction is not feasible, or combination of increased footprint and depth to maximize volume reduction and match peak flowrates
SOC – hydromodification	Typically, 2x to 5x LID size, however detention compartments may be subsurface

2.4.3.6. *Influence of Infiltration Feasibility Findings and Recommended Setbacks on Drainage Planning*

As introduced above, one of the primary goals of LID site design is to identify and set aside areas that are more likely to be feasible for retention BMPs. In this regard, a clear understanding of feasibility constraints and recommended setbacks from the site investigation conducted in Step 3 (**Section 2.3**) is critical and should be clearly cross-referenced in the narrative about how DMAs and BMP locations were established. Where feasible, the site plan should demonstrate a clear priority for siting BMPs in areas that are outside of recommended setbacks and allow for infiltration or partial (incidental) infiltration, respectively, as the first and second priority, respectively.

2.4.3.7. *Influence of Hydromodification Requirements on Drainage Planning*

Hydromodification requirements can mandate a larger BMP volume as reflected in the site area allowances recommended in **Section 2.4.3.5** and detailed in **Section 2.6** and **Section 5**.

Given that hydromodification requirements can be met via detention rather than retention or biotreatment, this provides the designer with the option of meeting this larger control volume designing separate detention systems or creating additional components/larger sizes within LID BMPs.

There is no preference for volume reduction versus flow duration control for hydromodification compliance, so a detention-based centralized system or larger LID BMPs are equally permissible.

Hydromodification requirements include provisions to avoid critical course sediment areas and allow critical course sediment to continue to be transported from the site. This mandates that DMAs be configured to avoid treating the runoff from critical course sediment areas and may require that certain natural drainage courses be preserved. This is also a good approach to help avoid premature clogging of BMPs.

2.4.3.8. *Self-Mitigating and Self-Retaining Areas*

Self-mitigating or self-retaining areas are an important outcome of effective site design. By hydrologically isolating areas that do not have impervious cover and do not generate pollutants at levels of concern, these areas do not need to be treated and do not require structural BMPs. This is especially beneficial if these areas are also potential sediment sources. By keeping these sediment sources out of infiltration or filtration BMPs, required factors of safety can be reduced. Similarly, self-retaining areas can eliminate or lessen the need for downstream structural BMPs. These areas are defined as follows:

Self-mitigation areas: DMAs that have no impervious cover and are not managed with the use of fertilizers or pesticides and are hydrologically disconnected from other DMAs (i.e., do not flow to BMPs).

Self-retaining areas: DMAs that produce no runoff during the 85th percentile, 24-hour storm event through application of HSCs. The isopluvial maps in **Appendix N** are to be used to determine the 85th percentile, 24-hour storm depth.

2.4.3.9. *Alternatives to the Use of DMAs*

The MS4 Permit does not specifically require a unit known as a "DMA." While use of this common term/concept is strongly recommended, alternative units of drainage planning could be used at the discretion of the reviewer provided that they meet the same objectives.

2.5. Step 5: Select, Size, and Design LID BMPs for Each Drainage Management Area

At the core of WQMP development are three requirements for LID BMPs that apply to all Priority Projects:

- **BMP Selection**: LID BMPs must be selected to maximize volume retention and pollutant reduction according to a specific hierarchy.
- **BMP Sizing:** LID BMPs must be sized to capture and retain the Design Capture Volume (DCV); where biotreatment is used for a portion of the DCV that is not retained, specific additional sizing criteria apply for biotreatment components. Note that biotreatment BMPs must meet the requirements to be called biofiltration BMPs in order to be used to fulfill LID requirements.
- **BMP Design:** LID BMPs must be designed per accepted engineering standards to provide safe and reliable operation, avoid premature failure or nuisance conditions, and allow for inspection and maintenance activities without entrainment of captured pollutants or disruption of functionality.

For each DMA that is not self-retaining or self-mitigating, structural LID BMPs are required. Selecting the appropriate LID BMP type and determining the required size to meet LID requirements are functions of the site conditions, the information gathered as discussed in Step 3 (**Section 2.3**), and the site design and drainage planning conducted as part of Step 4 (**Section 2.4**).

This section describes the underlying criteria that need to be met by LID BMP plans and the content that is expected to be included in Project WQMPs as part of providing adequate demonstrations that LID BMP criteria have been met. More detailed technical guidance and criteria related to LID BMPs are consolidated in **Section 4** of this TGD and multiple supporting appendices.

Where hydromodification criteria also apply, the design of systems to comply with LID and hydromodification requirements can be integrated. Therefore, it is strongly recommended that both Step 5 and 6 be consulted prior to beginning efforts on BMP selection and sizing. **Appendix B** can also be consulted to help understand how LID and hydromodification requirements can be integrated.

2.5.1. LID Selection and Sizing Criteria

The criteria for LID selection and sizing are provided below.

First Priority – Full Retention

LID BMPs must be implemented that are designed to retain stormwater onsite (i.e., intercept, store, infiltrate, evaporate, and/or evapotranspire) and meet one of the following equivalent criteria[7]:

> Capture and retain the volume of stormwater runoff produced from a 24-hour 85th percentile storm event (DCV)[8] and demonstrate that this DCV is drawn down within 48 hours or less following the end of precipitation.
>
> OR
>
> Demonstrate via use of nomographs or continuous simulation that BMPs will retain 80 percent of average annual runoff volume via either volume-based, flow-based, or combined approaches.

[7] The basis for the equivalency of these sizing criteria is provided in **Appendix E.5**.

[8] Isopluvial maps showing the 85th percentile, 24-hour storm depth are provided in **Appendix N**. Sizing methods described in **Appendix E** provide references to how to use the results of these isopluvial maps as part of performing sizing calculations.

[Guidance: Where HSCs are applicable, they can be accounted to reduce the DCV of the retention BMP.]

Second Priority – Biotreatment with Maximized Retention

Where it is demonstrated based on substantial evidence that it is not feasible to fully infiltrate the DCV or equivalent per the first priority criteria above, but incidental (i.e., partial) infiltration is determined to be feasible, LID BMPs must be implemented that are designed to meet the following criteria:

1) Maximize volume and pollutant retention through the incorporation of all of the following design elements that apply:

a) Use of all applicable HSCs, and
b) Use of retention compartments within BMPs, including gravel storage below the lowest point of treated discharge, amended soils and other features designed to achieve similar processes.

[Guidance: As a target, BMPs should be designed to provide static retention storage equivalent to one-third of the DCV or achieve retention of 40 percent of average annual runoff volume.]

AND

2) Size biotreatment[9] components of the BMP to meet one of the following equivalent criteria[10]:

a) Treat 1.5 times the portion of the DCV that is not reliably retained through the use the volume reduction measures described above.
OR
b) Retain or treat 80 percent of average annual runoff volume, and apply a multiplier of 1.5 to the resultant required volume and footprint.
OR
c) Design a biofiltration BMP that has a static biofiltration volume (bowl volume plus media pore spaces) of at least 0.75 times the portion of the DCV not retained through the use of the volume reduction measures described above.

[Guidance: Option (a) and (b) do not have a specific static storage volume requirements and allow routing to be considered; Option (c) specifies a minimum static storage volume and does not require or allow routing to be considered.]

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[9] In order to meet LID requirements, biotreatment BMPs must meet the requirements to be called biofiltration BMPs.

[10] The basis for the equivalency of these sizing criteria is provided in **Appendix E.5**.

[Guidance: Where HSCs are applicable, they can be accounted to reduce the DCV that is the basis for biotreatment sizing.]

Third Priority – Biotreatment with Negligible Retention

Where it is demonstrated based on substantial evidence that it is not feasible to infiltrate any appreciable volume, LID BMPs must be implemented that are designed to meet the following criteria:

1) Maximize volume retention through the incorporation of all applicable HSCs.

[Guidance: Due to their more distributed nature, some HSCs may allow incidental volume reduction in marginal conditions where no volume reduction is permissible within LID BMPs.]

AND

2) Size biotreatment[11] BMPs to meet one of the following equivalent criteria[12]:

d) Treat 1.5 times the DCV.
OR
e) Treat 80 percent of average annual runoff volume, and apply a multiplier of 1.5 to the resultant required volume and footprint.
OR
f) Design a biofiltration BMP that has a static biofiltration volume (bowl volume plus media pore spaces) of at least 0.75 times the DCV.

[Guidance: Option (a) and (b) do not have a specific static storage volume requirements and allow routing to be considered; Option (c) specifies a minimum static storage volume and does not require or allow routing to be considered.]

[Guidance: Where HSCs are applicable, they can be accounted to reduce the DCV that is the basis for biotreatment sizing.]

Application of LID Criteria at a Regional Scale

While the majority of projects will comply with these criteria on-site, the MS4 Permit provides pathways for use of regional BMPs located outside of the project site that may serve areas larger than the project and/or removed from the project site. The criteria and guidance provided in this section are written to be most useful for projects that comply with LID requirements within

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[11] In order to meet LID requirements, biotreatment BMPs must meet the requirements to be called biofiltration BMPs.

[12] The basis for the equivalency of these sizing criteria is provided in **Appendix E.5**.

the project site. Specific criteria for regional BMPs are provided in Section 3 of the **Model WQMP.** General guidance for design of LID BMPs at a larger scale is provided in **Section 4.4.7**.

Lower Priorities and Alternative Pathways

If LID BMPs are demonstrated to be not feasible or not feasible for the full sizing criteria based on substantial evidence, Section 2.5 of the **Model WQMP** describes additional and alternative pathways that may apply. This may include:

- Use of treatment control BMPs or biotreatment BMPs, and/or
- Retrofits of offsite locations, and/or
- Participation in an alternative compliance program.

Specific criteria for use of these approaches are not discussed in this TGD.

2.5.2. LID Selection and Sizing Process

The LID selection and sizing process is based on determining the infiltration feasibility condition for the BMP location and selecting an individual type of BMP that is compatible with that feasibility condition. This process specifically does not require the applicant to assemble a system of multiple LID BMPs from different levels of the LID hierarchy in order to meet the sizing criteria.

The overall simplified process for LID BMP selection and sizing is depicted in **Figure 2-2**. A more detailed version of this process is depicted in **Figure 4-1**.

This process involves the following steps:

1. Determine the feasibility conditions for infiltration and harvest and use associated with each BMP location and its tributary DMA based on feasibility criteria described in **Section 4.2**. The applicable infiltration feasibility categories include:

    - *Full infiltration*: It is feasible to infiltrate the full DCV without foreseen issues.
    - *Partial infiltration*: It is not feasible to infiltrate the full DCV due to limited infiltration rates or limited space, however incidental infiltration of a portion of the DCV would be possible without significant risk.
    - *No infiltration*: It is not feasible to infiltrate in any appreciable quantity due to demonstrated physical limitation or risk.

    These categories are defined based on applicable criteria in **Section 4.2.2**. Stormwater harvesting is categorized as either required or optional based on the criteria in **Section 4.2.3**. In almost all cases, harvest and use will be optional.

2. Determine and document any demonstrated space constraints at each BMP location based on considerations identified in **Section 4.2.4**.

3. Select BMPs from a menu associated with each feasibility category as identified in **Table 2-10** and detailed in **Section 4.3**, with modification for demonstrated space constraints, as appropriate.

4. Size the selected BMP based on methods specific to the BMP type identified in **Section 4.3** and detailed in **Appendix E**. Target footprint sizing factors related to volume reduction and/or clogging lifespan goals may apply as described in **Section 4.4**, **Appendix E**, and the BMP fact sheets to which they apply.

5. Design BMPs based on the BMP-specific criteria contained in the BMP Fact Sheets in **Appendix G**. Optionally, BMP designs may be adapted while still conforming to the general design criteria contained in **Section 4.4**.

6. Where necessary, conduct design- phase and/or construction-phase investigations to confirm or adapt BMP selection and design. Return to earlier steps, as needed, to incorporate new information.

A more detailed description of this process and supporting criteria are provided in **Section 4**.

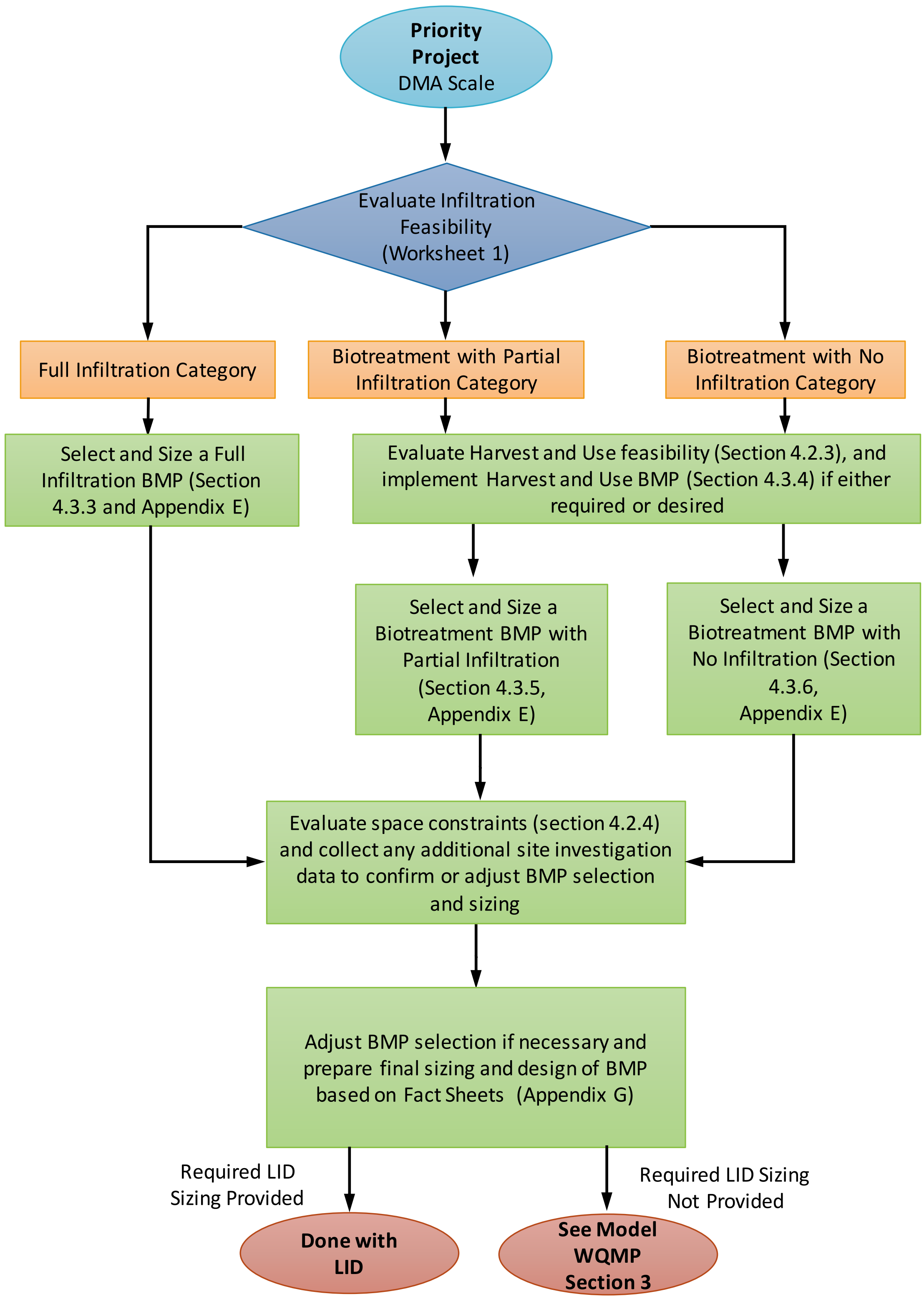

Figure 2-2. Overview of LID BMP Selection Process

Table 2-10. Menu of LID BMPs Appropriate for Each Infiltration Feasibility Category

Infiltration/Harvesting Category	BMP Types Compatible with Infiltration Category
Full Infiltration	INF-1: Infiltration Basin INF-2: Infiltration Trench INF-3: Bioretention with no Underdrain INF-4: Drywell INF-5: Permeable Pavement (concrete, asphalt, and pavers) INF-6: Underground Infiltration
Biotreatment with Partial Infiltration *BMP selection must also be based on pollutants of concern* *Only BIO-1 and BIO-5 can meet the definition of biofiltration in South Orange County. BIO-2, BIO-3, and BIO-4 may only be used as treatment control BMPs in SOC.*	*First check for full harvest and use feasibility. If not required, then choose from:* BIO-1: Bioretention with raised underdrain discharge elevation (internal water storage) BIO-2: Swales with amended soils and shallow infiltration sump (adjustable sump preferred) BIO-3: Filter strip with amended soils BIO-4: Dry extended detention basin with amended soils, vegetation, and shallow infiltration sump (adjustable sump preferred) BIO-5: Proprietary biotreatment with supplemental retention *Upstream retention options:* Hydrologic source controls, cisterns, permeable pavement, *Downstream options:* Shallow infiltration chambers, trenches, or dry well for a portion of the DCV *Where demonstrated space constraints exist:* BIO-1: Bioretention with raised underdrain with compact sizing factor BIO-5: Proprietary biotreatment
Biotreatment without Infiltration *BMP selection must also be based on pollutants of concern* *Only BIO-6 and BIO-7 can meet the definition of biofiltration in South Orange County. BIO-8, BIO-9, and BIO-10 may only be used as treatment control BMPs in SOC.*	*First check for harvest and use feasibility. If not required, then choose from:* BIO-6: Bioretention with Underdrain and Impervious Liner/Minimal Volume Reduction BIO-7: Proprietary Biotreatment BIO-8: Wet Detention Basin BIO-9: Constructed Wetland BIO-10: Other Biotreatment BMPs with an Impervious Liner

2.5.3. Expected WQMP Contents

WQMPs must demonstrate conformance to the specific narrative and numeric criteria related to LID BMP selection and sizing as described above. Additionally, in order to facilitate consistent review, certain minimum content is necessary in the WQMP. **Table 2-11** identifies the minimum criteria and content that must be included in the WQMP.

Table 2-11. Expected WQMP Content for LID BMP Selection and Sizing

Expected WQMP Content	Rationale
Describe and support the preliminary feasibility category for infiltration and harvest and use for each identified BMP location, including the technical basis for this categorization for each location based on substantial evidence. BMPs must be categorized into one of the following categories in each set: Infiltration • Full infiltration • Incidental infiltration • No infiltration Where full infiltration is not feasible, the feasibility of harvest and use needs to be evaluated.	The WQMP must translate the findings of site investigation and BMP locations to a categorization of infiltration and harvesting feasibility based on "substantial evidence" as the principle basis for selection of BMPs. **Section 2.5.2** explains these categories. This TGD takes the approach that retention is maximized when BMPs are selected from a menu of BMPs that has been determined to be appropriate for each feasibility category.
Describe and provide supporting information for any overriding space constraints, approved site uses, of other technical factors that substantiate the need to use more compact BMPs than applicable BMP defaults; describe and support at the DMA scale.	Default footprints apply to certain BMP types to ensure that volume reduction is appropriately maximized and the chance of premature clogging is reduced. Deviation from these defaults requires that the project applicant to explain and provide specific details regarding the space constraints that are claimed. Acceptance of these explanations is at the discretion of the reviewer.
Identify the selected LID BMP for each DMA, including any HSCs, used as part of numeric sizing.	The WQMP must clearly identify the suite of BMPs that is used to achieve numeric conformance with LID sizing criteria.
Calculate and document the required size versus the provided size to demonstrate conformance with LID performance criteria.	The WQMP must clearly describe how the proposed suite of BMPs achieves numeric conformance with LID sizing criteria.

Expected WQMP Content	Rationale
Describe the design of the BMP for each DMA, consistent with the inputs used as part of sizing (e.g., depths of compartments, elevations of outlets).	The WQMP must describe the BMP design in adequate detail to confirm that appropriate inputs and assumptions are used in sizing calculations.
Describe any additional investigation that is required following approval of the subject WQMP and the design contingencies that could result from potential findings from these investigations.	At the Conceptual/Preliminary WQMP phase, it may be necessary to identify the need for additional information to fully confirm final designs. If there are design contingencies associated with this information, these contingencies must be defined and disclosed in the Conceptual/Preliminary WQMP as part of discretionary approval so that these adaptations can be made within the design or construction phase, as necessary.
If LID and Hydromodification requirements are addressed within a single BMP system, the WQMP must describe how the operation of the system to meet these two standards does not interfere with the ability of the BMP to conform to applicable LID criteria.	While it is possible to integrate the design of BMPs, it still is necessary to demonstrate conformance to each sizing and design standard separately.
For Final WQMP Only, utilizing any additional information obtained following discretionary approval:	
Confirm or revise the feasibility category of the BMP and adapt design within the “envelope” of the allowable contingencies that were established as part of discretionary approval.	The BMPs that are proposed must be proven to be effective and safe; if additional data changes the determination, then the contingencies identified in the Conceptual/Preliminary WQMP must be activated or the project must revisit discretionary approval.
Calculate and document the required size versus the size and design that is provided as part of detailed design and construction plans.	The Final WQMP must verify required size versus the actual designed size.
Identify whether in situ, as constructed infiltration testing is needed to confirm as-constructed design and/or determine the need for design adaptations.	Some projects may require as-constructed infiltration testing, particularly if testing prior to construction could not be done with adequate rigor or if there was significant earthwork.

2.5.4. Detailed Guidance on LID BMP Selection, Sizing and Design

Section 4 of this TGD provides more detailed guidance on selection, sizing and design of LID BMPs to support the development of LID BMP plans that conform to the minimum criteria and expected content identified above.

2.5.5. Frequent Questions

2.5.5.1. What is meant by "substantial evidence" in determining feasibility conditions?

Substantial evidence is defined as "Facts, reasonable assumptions predicated on facts, or expert opinion supported by facts. Substantial Evidence does not include argument, speculation, unsubstantiated opinion or narrative, or evidence which is clearly erroneous or inaccurate" (Public Resources Code Section 21080(e)). Specific criteria and recommended acceptable methods to provide substantial evidence are provided in Section 4.3 and referenced appendices.

2.5.5.2. When would a feasibility condition change between discretionary approval and final design approval?

This could happen if additional information became available about infiltration rates or other aspects of the site that was not known as part of discretionary approval. However, if there are significant unknown factors as part of discretionary approval, these need to be disclosed and the Conceptual/Preliminary WQMP should describe the approaches that would be used to adapt to new information as it becomes available. This would allow adaptation of designs while still being within the "envelope" of approval established in discretionary approval. However, if new information significantly changes the water quality management approach outside of what was anticipated as part of discretionary approval, then the project may need to go through discretionary approval again.

2.5.5.3. Why is infiltration feasibility the primary factor in BMP selection?

Where soils have any significant permeability, the amount of volume loss to infiltration is expected to well exceed evapotranspiration and harvesting in most cases. This makes the investigation of infiltration feasibility the most important factor in selecting BMPs that maximize volume reduction.

2.5.5.4. If the full DCV is retained, is it still necessary to use all applicable HSCs?

No, it is not necessary. However, other applicable site design measures still need to be incorporated. In conditions where biotreatment with partial infiltration or biotreatment with no infiltration is used, all applicable HSCs must be used as part of maximizing volume reduction.

2.5.5.5. *Under what conditions is a project required to use harvest and use BMPs?*

Criteria for harvest and use feasibility are provided in **Section 4.2.3**. In general, except in cases with unusually high harvested water demand, it is not required (but is allowable) to consider harvest and use.

2.5.5.6. *Can harvest and use BMPs be used even if they are not required?*

Yes, even if harvest and use is determined to be not required, it can still be used as part of a water quality management approach. The LID sizing methods described in **Appendix E** allow for accounting of partial capture provided by harvest and use systems upstream of other LID BMPs.

2.5.5.7. *Are there different processes and criteria for small and large projects?*

The overall LID selection process is the same for all projects. However, small projects, as defined in **Section 4.2.2.6** are permitted to apply alternative investigation methods in some cases to avoid excessive cost impacts. Small projects may also be more likely to prepare a more precise design as part of the Conceptual/Preliminary WQMP phase.

2.6. Step 6: Select, Size and Design Hydromodification BMPs

This steps only applies if the project has potential HCOCs, as determined as part of Step 3 (**Section 2.3.5**).

Where HCOCs exist, applicable hydromodification criteria must be met by either:

- Demonstrating that the BMPs provided to conform with LID BMP requirements also provide hydrologic performance necessary to meet HCOC criteria;
- Adapting or augmenting the design of LID BMPs so that the combined stormwater management systems conform to both LID and hydromodification criteria; or
- Providing separate systems that conform to hydromodification criteria and do not modify the LID BMPs selected and sized as part of Step 5.

This section describes the underlying criteria that need to be met by combined LID plus hydromodification BMP plans and the content that is required to be included in WQMPs as part of providing adequate demonstrations. More detailed technical guidance and criteria related to hydromodification BMPs is consolidated in **Section 5** of this TGD and multiple appendices.

2.6.1. Hydromodification Management Criteria

Hydromodification management criteria are described below. It is notable that hydromodification requirements must be met at each "point of compliance" for the project rather than the scale of individual DMAs which is the scale at which LID BMPs are evaluated. This may establish different scales of analysis and control than LID BMPs. Defining points of compliance is explained in **Section 5.2.1**. In all cases, adaptations to LID BMPs to serve hydromodification purposes must not interfere with the operations of these BMPs for pollutant control. The performance criteria to eliminate or mitigate HCOCs are explained separately in the following sections.

For phased projects that involved tiered approvals, HCOCs should be evaluated for the overall project and also for each phase at the time it is approved. Each phase should consider the cumulative effect of the current phase and any previously constructed phases. At the completion of each phase, the overall project must be in compliance with all applicable requirements.

2.6.1.1. North Orange County Performance Criteria

[Placeholder for future addition after adoption of the 5th Term NOC MS4 Permit]

2.6.1.2. South Orange County Performance Criteria

In SOC, hydromodification management criteria, methods, and tools are defined in the Hydromodification Management Plan (Exhibit 7.IV). The underlying criteria described in the HMP include:

Hydrologic management requirement: All Priority Projects must ensure, at each point of compliance, that the post-project runoff flow rates and durations do not exceed pre-development[13], naturally occurring, runoff flow rates and durations by more than 10%, for flow rates from 10% of the 2-year flowrate up to the 10-year flowrate. (See HMP Section 3). This must be evaluated using the South Orange County Hydrology Model (SOHM) which is a continuous simulation model.

Source sediment management requirement: Priority projects must avoid critical sediment yield areas known by the Copermittee or identified in the Watershed Management Area Analysis (see maps of potential critical coarse sediment yield areas in **Appendix N.8**), or implement measures that allow critical coarse sediment to be discharged to receiving waters, such that there is no impact to the receiving water. If a priority new development project is located within a potential critical coarse sediment area per **Appendix N.8** of this TGD, see Section 4 of the HMP for guidance on site-specific evaluation of critical coarse sediment.

Project applicants are required to consult the HMP to determine the specific criteria and methods that apply. Additionally, project applicants are required to use the SOHM available from the County WQMP website to conduct hydrologic analyses.
http://media.ocgov.com/gov/pw/watersheds/documents/wqmp/

2.6.2. Design Resources and Examples

Section 5 provides additional guidance and example approaches for developing hydromodification designs and integrating designs with LID BMP designs. **Appendix B** includes conceptual design examples where LID and hydromodification are integrated.

2.6.3. Expected WQMP Content

Table 2-12 describes expected WQMP content to describe the hydromodification design approach and demonstrate conformance to applicable criteria.

[13] In South Orange County, predevelopment is defined as the naturally occurring condition prior to development. Where a site has been graded, the as-graded topography of the site can be considered as the pre-development condition, but without any impervious surfaces and with typical natural vegetation.

Table 2-12. Expected WQMP Content for Hydromodification Design. (Content for NOC included only as placeholder for future update of this TGD upon adoption of the 5th Term NOC MS4 Permit)

Permit Region	Expected WQMP Content	Rationale
Both	Identify points of compliance.	Points of compliance are the primary basis for analyzing hydromodification compliance.
Both	Identify and describe BMPs or BMP systems used as part of complying with hydromodification requirements.	BMP systems must be fully described in WQMPs.
SOC	Describe the pre-development (natural) and post-development drainage characteristics to each point of compliance, including: slope, soils, drainage patterns, imperviousness, BMPs.	In SOC, the pre-development (natural) condition is the baseline condition for compliance.
SOC	Document findings from SOHM modeling of pre-development and post-development conditions and attach modeling report including model output.	In SOC, the use of SOHM is required to evaluate conformance with applicable hydrologic management criteria.
SOC	Identify critical course sediment areas and approaches for avoiding or mitigating these areas.	Conformance with this criterion is required for development projects in SOC.
Both	Describe the hydromodification BMP design, how it integrates with LID design, and why it does not interfere with LID operation.	The WQMP must describe the design in adequate detail to confirm that modeling accurately represents the BMP and area draining to the point of compliance.
Both	Document how any contingencies in infiltration or harvesting feasibility or design parameters will be addressed in hydromodification designs.	If there is a possibility that the feasibility categorizations or related design parameters (e.g., design infiltration rate) may change in subsequent investigation, describe how this affects hydromodification design and the related contingencies that are applicable.

2.7. Step 7: Prepare WQMP and Associated Exhibits

This section provides guidance for assembling the results of Step 1 through 6 into a Project WQMP and preparing associated exhibits.

2.7.1. Expected WQMP Content

The expected content associated each WQMP section is described in **Sections 2.1 through 2.6** above (corresponding to Section 1 through 6 of the WQMP template). The WQMP template provides embedded instructions for organizing and documenting this information. Deviations from the expected content may be acceptable at the discretion of the reviewer provided that the underlying criteria are met and the approach for documenting this in the WQMP is clear and technically defensible

2.7.2. Site Plan and Drainage Plan Sheet Set

In addition to the written and tabular sections of the WQMP, exhibits are required to illustrate site conditions, the drainage plan, proposed BMPs, and other information. At the Conceptual/Preliminary WQMP level, the following content is expected to be shown in exhibits. At the reviewer's discretion, the expected content for a Final Project WQMP may also be required at the time of Conceptual/Preliminary WQMP submittal.

2.7.2.1. *Expected Content for Conceptual/Preliminary WQMP Exhibits*

1) Project location map that shows and identifies each of the downstream receiving water(s) of the project, any 303(d) listed or TMDL water bodies, and any hydromodification susceptible water bodies.
2) Existing conditions site map that identifies drainage patterns, key topographic features, environmentally sensitive features, natural drainage courses, and other relevant information identified in **Section 2.3.1**.
3) Project site plan that identifies proposed site conditions including the characteristics such as land uses / activities and other relevant information identified in **Section 2.3.2**.
4) Project site plan that identifies all conditions relevant to infiltration feasibility findings (if applicable), such as, but not limited to, surficial soil properties, depth to groundwater, and geotechnical hazards, locations of infiltration testing, factors influencing demonstrated space constraints or vertical constraints.
5) Drainage plan that delineates each drainage management area, shows stormwater management infrastructure and storm drains, identifies the locations and extents of source control and site design BMPs, and identifies the location and type(s) of structural LID and hydromodification control BMPs, as applicable.
6) Conceptual design schematics or designs for structural BMPs in adequate detail to document design parameters relevant to sizing calculations.
7) Description and conceptual location of features that will facilitate inspection and O&M (e.g., access roads, monitoring ports).

2.7.2.2. *Additional Expected Content for Final Project WQMP Exhibits*

1) Detailed locations and extents of each site design and source control BMP, as applicable.

2) Detailed delineations to each proposed structural BMP.
3) Drainage and BMP plans must be overlain with final proposed condition precise grade plans at the same scale.
4) Detailed grading contours of all structural BMPs that have surface storage, clearly indicating surface elevations, overflow elevations, and freeboard elevations.
5) BMP details for all structural BMPs, including inlets, outlets, structures, bioretention media, planting, underdrains, aggregate layers, and other relevant information, as applicable.
6) Specific models and dimensions of proprietary products, where acceptable and used.
7) Identification of specific design features that will facilitate inspection and O&M.

2.8. Step 8: Prepare O&M Plan (Final Project WQMPs Only)

As specified in Provision E.3.d.(4), this TGD provides the long-term maintenance criteria for each structural BMP. This section provides guidance for preparing O&M plans that include long term maintenance requirements and responsibilities. BMP fact sheets in **Appendix G** include maintenance criteria for each structural BMP.

The sustained performance of BMPs over time depends on ongoing and proper maintenance. In order for this to occur, detailed operation and maintenance plans are needed that include specific maintenance activities and frequencies for each type of BMP. In addition, these should include indicators for assessing when "as needed" maintenance activities are required.

Structural BMPs require on-going inspection and maintenance into perpetuity to preserve the intended retention, pollution control, and/or flow control performance. BMPs capture pollutants, sediment, and debris transported by stormwater. These must be periodically removed in order for the BMP to maintain the capacity of the structural BMP to process storm water and capture pollutants from storm events. Structural BMPs that incorporate infiltration or filtration are prone to clogging over time which can result in flooding, standing water, and reduced BMP performance.

A detailed O&M Plan must be developed prior to issuance of construction, grading, building, site development, or other applicable permits. After construction, a final O&M plan should reflect actual constructed structural BMPs to be maintained including photographs and as-built plans. The O&M Plan must be available on-site with the BMPs for inspection by Copermittees.

2.8.1. Expected O&M Manual Contents

As part of the Final Project WQMP, an O&M Plan must be developed that details O&M responsibilities and activities. Expected contents of the O&M Plan are identified in **Table 2-13**.

Table 2-13. Expected O&M Manual Content

Expected O&M Manual Content	Rationale/Guidance
Description of the final structural BMP plan that matches the Final Project WQMP (subsequently updated to match as-built condition).	In preparing the O&M Plan, it should be assumed that portions of the WQMP will be recorded with the property, but will not necessarily be consulted by staff responsible for implementing the O&M Plan; the O&M Plan should serve a stand-alone purpose.
Identification and contact information of the responsible party(ies) for maintenance.	A responsible party must be identified and contact information must be included.
Identification of the required qualifications and any training required for personnel who will perform maintenance.	Where certain activities require specific training or qualifications, the required qualifications must be clearly identified.
Identification of the funding mechanism and associated supporting information to demonstrate adequacy of funding to cover anticipated and potential expenses.	The O&M Plan must demonstrate adequate funding and the source of funding.
Description of any unusual, excessively-costly, or hazardous O&M activities required for the proposed BMPs.	Such activities need to be fully disclosed so that the acceptability of these activities can be evaluated by the Copermittee and understood by the responsible party.
Regular inspection activities, frequency, and documentation requirements.	These are core elements of an effective and complete O&M Plan.
Description of routine and planned maintenance activities, frequency (if scheduled) or triggers (if initiated based on inspection findings), and documentation requirements.	
Description of foreseen rehabilitation activities, anticipated frequency, triggers for conducting activities, and the planning/approval/documentation process required to conduct rehabilitation.	
Process for identifying, diagnosing, and correcting issues resulting from damage, unusual wear, unforeseen conditions, etc.	

Expected O&M Manual Content	Rationale/Guidance
Spill response and notification requirements.	

2.8.2. Operation and Maintenance Activities

Operation and maintenance activities typically associated with different BMP types are included in the BMP fact sheets in **Appendix G**. Site-specific conditions may require additional maintenance activities or adjustments to the activities and frequencies in the fact sheets. The justification for any deviations from the fact sheets should be described in the O&M Plan.

For the purpose of consistent description of activities, the following definitions should be used in the development of O&M Plans:

Routine O&M Activities – Activities conducted at regularly scheduled intervals to sustain long-term performance of each BMP, including inspections and normal upkeep. This category also includes activities conducted on an as-needed basis, prompted by inspections, to correct conditions that are anticipated to occur with normal operations of a BMP.

Rehabilitation Activities – Activities conducted to replace or rehabilitate system components at the end of their usable life. While the need for eventual rehabilitation is an expected event, this is distinct from Routine O&M because it may require more significant redesign and reconstruction efforts. The O&M Manual should seek to estimate the expected design life and the triggers for when a system has reached the end of its usable life.

Corrective Activities. Activities conducted to resolve major issues that are not anticipated. Because these are not anticipated, it is not possible for an O&M Manual to have pre-defined remedies. Rather, the O&M Manual should establish a process for identifying a major issue that requires correction, diagnosing the issue and its underlying causes, determining the appropriate corrections, obtaining permits, if applicable, and appropriately documenting any changes to the design that result.

Emergency Response Activities – Activities related to emergencies, including spills, which may require immediate action and notifications.

Training Activities – Activities to train maintenance staff.

Documentation and Reporting – Protocols for documentation, reporting, and document retention.

2.8.2.1. *Phases of Maintenance*

Where applicable, the O&M Plan should define the phases of maintenance and any differences in activities or frequency that relate to initial establishment or reestablishment following rehabilitation. For vegetated systems and media-based systems, it may be appropriate to define one or more of the following periods:

> **Immediate post-construction or major rehabilitation** (2 months to 1 year after construction) – During this phase, the system is stabilizing and there may be limitations to placing the system into full service. After initial construction, the contractor may still be under warrantee to maintain the system.
>
> **Short-term (2-3 years post-construction or major rehabilitation).** This is a period when plants are establishing and initial system conditioning processes (e.g., media settling, soil structure development) are occurring. During this period, more frequent inspections may be needed. Additionally, maintenance activities can be more frequent and intensive, depending on the needs of the BMP. This regime may also need to be reinstated if major replanting occurs at any point in the facility lifespan.
>
> **Long-term (after end of short-term phase).** This period begins after full establishment of vegetation and upon adequate observations of typical functions. The intention of the long-term maintenance period is to provide sufficient and sustained maintenance to maximize functionality and performance for the life of the BMP while avoiding unnecessary costs. Observations during the short-term period may result in updates to frequencies or activities associated with long-term maintenance.

These phases are not required to be defined in O&M plans, but are encouraged where maintenance needs are expected to evolve over the life of the facility.

2.8.3. Roles and Responsibilities

The responsible parties that should be defined for each O&M Plan are defined as follows:

- **Facility Owner** – The Facility Owner is the party who is ultimately responsible for the functionality of the facility. The maintenance agreement will identify the facility owner for each facility, including the timing of any ownership transitions.
- **Responsible Party** - The Responsible Party is the party that shall have direct responsibility for the maintenance of the facilities included within this plan. This party shall be the designated contact with inspectors and lead maintenance personnel. The Responsible Party shall sign self-inspection reports and any correspondence regarding the verification of inspections and required maintenance. The Responsible Party will establish a system to delegate general inquiries to the appropriate maintenance personnel concerning the

operation and maintenance of the facilities. The Responsible Party reports directly to the Facility Owner and operates and manages the facilities on the Facility Owner's behalf.

- **Designated Emergency Respondent** - The Designated Emergency Respondent is the party responsible for directing activities and communications during emergencies such as clogged drains, broken irrigation pipes, hazardous spill responses etc., that would require immediate response should they occur during off-hours. It is the responsibility of the Designated Emergency Respondent to communicate the emergent situation with the Responsible Party as soon as possible.
- **Key Maintenance Personnel** –Key Maintenance Personnel are the designated lead field manager(s) or supervisor(s) who directly oversee and delegate the maintenance activities, maintains the scheduling, and coordinates activities between all personnel.

2.8.4. Maintenance Mechanisms

Maintenance mechanisms are part of the O&M Plan that assign responsibility for maintenance of the BMPs and describe a funding mechanism. Maintenance mechanisms may be provided either through the local jurisdiction through a maintenance agreement or by the project applicant. Ownership and maintenance responsibility for structural BMPs should be discussed at the beginning of the project planning, typically at the pre-application meeting with the planning and zoning agency. Provisions to finance and implement maintenance of BMPs can be a major stumbling block to project approval, particularly for small residential subdivisions. The following are alternative mechanisms that may be used to provide on-going maintenance for the BMPs included in the Project WQMP.

Project proponent agreement to maintain stormwater BMPs: The local jurisdiction may enter into a contract with the project proponent obliging the project proponent to maintain, repair and replace the stormwater BMP as necessary into perpetuity. Security of a funding mechanism with a "no sunset" clause may be required.

Assessment districts: The local jurisdiction may approve an Assessment District or other funding mechanism created by the project proponent to provide funds for stormwater BMP maintenance, repair and replacement on an ongoing basis. Any agreement with such a District shall be subject to the Public Entity Maintenance Provisions below.

Lease provisions: In those cases where the local jurisdiction holds title to the land in question, and the land is being leased to another party for private or public use, the local jurisdiction may assure stormwater BMP maintenance, repair and replacement through conditions in the lease.

Conditional use permits: For discretionary projects only, the local jurisdiction may assure maintenance of stormwater BMPs through the inclusion of maintenance conditions in the conditional use permit. Security may be required. Some jurisdictions include requirements to implement approved WQMPs in their municipal code.

Alternative mechanisms: The local jurisdiction may accept alternative maintenance mechanisms if such mechanisms are as protective as those listed above.

Public entity maintenance: The local jurisdiction with the responsibility for WQMP approval may approve a WQMP that identifies a public or acceptable quasi-public entity (e.g., the City, the County, or County Flood Control District, an existing assessment district, an existing utility district, or a conservation conservancy) as assuming responsibility for operation, maintenance, repair and replacement of the BMP. Unless otherwise acceptable to individual local agencies, public entity maintenance agreements shall ensure estimated costs are front-funded or reliably guaranteed (e.g., through a trust fund, assessment district fees, bond, letter of credit or similar means). In addition, the local jurisdictions may seek protection from liability by appropriate releases and indemnities.

The project proponent must demonstrate that it will transfer the BMP maintenance to another public entity subject to the following provisions. The project proponent will negotiate maintenance requirements with the entity that it is proposing to accept maintenance responsibilities within its jurisdiction; and negotiate with the resource agencies responsible for issuing permits for the construction and/or maintenance of the facilities. If necessary, the public entity will also demonstrate through the CEQA review or the public entity's public review process that it can accept the maintenance responsibility. If a public entity is named as the responsible maintenance entity, then the local jurisdiction must include that entity in its CEQA review process as a Responsible Agency where applicable. The local jurisdiction must be identified as a third party beneficiary empowered to enforce any such maintenance agreement within their respective jurisdictions.

2.9. Incorporating USEPA Green Streets Guidance to the MEP

This section provides guidance for preparation of a Project WQMP that incorporates USEPA **Managing Wet Weather with Green Infrastructure: Green Streets** in a manner consistent with the MEP standard. Interpretation of this guidance specific to green street projects in Orange County are included here. Most of the guidance for completing the Project WQMP described in **Sections 2.1 through 2.8** is generally applicable to green street projects. This section provides specific guidance about how this guidance should be adapted for LID and hydromodification requirements for qualifying projects.

2.9.1. Regulatory Context

2.9.1.1. North Orange County

[Placeholder for future addition after adoption of the 5th Term NOC MS4 Permit]

2.9.1.2. *South Orange County*

Per the SOC MS4 Permit, the following category of project may be exempted from being defined as Priority Projects at the discretion of the permittee with jurisdiction over project review:

> "Retrofitting or redevelopment of existing paved alleys, streets or roads that are designed and constructed in accordance with the USEPA Green Streets guidance."

This waives the need for a Project WQMP. However, to ensure that the project incorporates features that qualify it for this exemption, an analogous planning document should be developed and kept on file. This section provides guidance that can be used to develop such a document.

2.9.2. Site and Watershed Assessment Considerations for Applicable Green Streets Projects

Site and watershed assessment for applicable Green Streets projects includes many of the same considerations as described in **Section 2.3**. In addition to those elements described in **Section 2.3**, specific elements which should be given special consideration in the site assessment process for applicable Green Streets include:

- **Ownership of land adjacent to right of ways.** The opportunity to provide stormwater treatment may depend on the ownership of land adjacent to the right-of-way. Acquisition of additional right-of-way and/or access easements may be more feasible if land bordering the project is owned by relatively few land owners.
- **Location of existing utilities.** The location of existing storm drainage utilities can influence the opportunities for Green Streets infrastructure. For example, stormwater planters can be designed to overflow along the curb-line to an existing storm drain inlet, thereby avoiding the infrastructure costs associated with an additional inlet. The location of other utilities will influence the ability plumb BMPs to storm drains, therefore, may limit the allowable placement of BMPs to only those areas where a clear pathway to the storm drain exists.
- **Grade differential between road surface and storm drain system.** Some BMPs require more head from inlet to outlet than others; therefore, allowable head drop may be an important consideration in BMP selection. Storm drain elevations may be constrained by a variety of factors in a roadway project (utility crossings, outfall elevations, etc.) that cannot be overcome and may override stormwater management considerations.
- **Longitudinal slope.** The suite of LID BMPs which may be installed on steeper road sections is more limited. Specifically, permeable pavement and swales are more suitable for gentle grades. Other BMPs may be more readily terraced to be used on steeper slopes.
- **Potential access opportunities.** A significant concern with installation of BMPs in major right of ways is the ability to safely access the BMPs for maintenance considering traffic

hazards. The site assessment should identify vehicle travel lanes and areas of specific safety hazards for maintenance crews and subsequent steps of the Project WQMP preparation process should attempt avoid placing BMPs in these areas.

2.9.3. Site Design and Drainage Plan for Applicable Green Streets Projects

Applicable Green Streets projects should apply the following LID site design measures to the MEP in the drainage plan as specified in the local permitting agency's codes:

- Minimize street width to the appropriate minimum width for maintaining traffic flow and public safety.
- Add tree canopy by planting or preserving trees/shrubs.
- Use porous pavement or pavers for low traffic roadways, on-street parking, shoulders or sidewalks.
- Integrate traffic calming measures in the form of bioretention curb extensions.

2.9.4. Selecting LID BMPs for Green Streets Projects

Infiltration feasibility should be conducted for green streets projects as described in **Section4.2.2**, with specific attention to protection of groundwater quality as discussed in **Appendix C** and the structural integrity of the adjacent road bed.

Applicable Green Streets projects should select BMPs consistent with the Green Streets guidance. The fundamental tenants of the approach described by the USEPA Green Streets guidance include:

- Selecting LID BMPs to the opportunities of the site and to attempt to address pollutants of concern and HCOCs;
- Developing innovative stormwater management configurations integrating "green" with "grey" infrastructure; and
- Sizing BMPs opportunistically to provide stormwater pollution reduction to the MEP, accounting for the many competing considerations in right of ways.

Table 2-14 provides an inventory of LID BMPs which may be appropriate for applicable Green Streets projects. The performance criteria for applicable green streets projects do not require retention BMPs to be considered to the MEP before considering biotreatment and treatment control BMPs. A formal process of BMP prioritization and selection is not required for applicable Green Streets projects, however infiltration infeasibility criteria still apply. Only feasible BMPs may be selected.

BMPs should be prioritized based on a comparison of drainage area characteristics to the opportunity criteria listed in **Table 2-14**. The USEPA Green Streets guidance describes how some of these BMPs may be used in combination to achieve optimal benefits in runoff reduction and water quality improvement. Specific examples and applications for residential streets, commercial streets, arterials streets, and alleys are provided in the USEPA guidance.

The drainage patterns of the project should be developed so that drainage can be routed to areas with BMP opportunities before entering storm drains. For example, if a median strip is present, a reverse crown should be considered, where allowed, so that stormwater can drain to a median swale. Likewise, standard peak-flow curb inlets should be located downstream of areas with potential for stormwater planters so that water can first flow into the planter, and then overflow to the downstream inlet if capacity of the planter is exceeded. It is more difficult to apply green infrastructure after water has entered the storm drain.

Conceptual drainage plans for redevelopment projects should identify tributary areas outside of the project site that generate runoff that comingles with on-site runoff. The project is not required to treat off-site runoff; however treatment of comingled off-site runoff may be used to off-set the inability to treat areas within the project for which significant constraints prevent the ability to provide treatment.

Table 2-14: Potential BMPs for Applicable Green Streets Projects

BMP Type	Opportunity Criteria for Applicable Green Streets Projects
Street Trees, Canopy Interception	• Access roads, residential streets, local roads and minor arterials • Drainage infrastructure, sea walls/break waters • Effective for projects with any slope • Trees may be prohibited along high speed roads for safety reasons or must be setback behind the clear zone or protected with guard rails and barriers
Stormwater Curb Extensions / Stormwater Planters	• Access roads, residential streets, and local roads with parallel or angle parking and sidewalks • Can be designed to overflow back to curb line and to standard inlet • Shape is not important and can be integrated wherever unused space exists • Can be installed on relatively steep grades with terracing
Bioretention Areas	• Low density residential streets without sidewalks • Requires more space than curb extensions/ planters, most feasibly implemented in combination with minimized road widths
Permeable Pavement	• Parking and sidewalk areas of residential streets, and local roads • Should not receive significant run-on from major roads • Should not be subject to heavy truck/ equipment traffic • Light vehicle access roads
Permeable Friction Course Overlays	• High speed roadways unsuitable for full depth permeable pavement • Suitable for parking lots and all roadway types
Vegetated Swales (compost amended were possible)	• Roadways with low to moderate slope • Residential streets with minimal driveway access • Minor to major arterials with medians or mandatory sidewalk set- • Access roads • Swales running parallel to storm drain can have intermittent discharge points to reduce required flow capacity
Filter strips (amended road shoulder)	• Access roads • Major roadways with excess ROW • Not practicable in most ROWs because of excessive width requirements
Proprietary Biotreatment	• Constrained ROWs • Typically have small footprint to tributary area ratio • Simple install and maintenance • Can be installed on roadways of any slope • Can be designed to overflow back to curb line and to standard inlet

Table 2-14: Potential BMPs for Applicable Green Streets Projects

BMP Type	Opportunity Criteria for Applicable Green Streets Projects
Infiltration Trench	• Constrained ROWs • Can require small footprint where soils are suitable • Low to moderate traffic roadways • Infiltration trenches are not suitable for high traffic roadways • Requires robust pretreatment
Cartridge Media Filters	• Highly constrained ROW with little available surface area • Installed in underground vaults, manholes, or catch basins • Require minimum available head loss • Simple installation and maintenance
WSDOT Media Filter Drains	• See : http://www.ecy.wa.gov/programs/wq/stormwater/newtech/use_designations/MFDwsdotGULD.pdf

2.9.5. LID BMP and Hydromodification Sizing for Applicable Green Streets Projects

Applicable green street projects are not required to meet the same sizing requirements for LID and hydromodification BMPs as other projects, but they are required to attempt to meet these standards to the MEP. The following steps are used to size both LID BMPs and hydromodification BMPs for applicable Green Streets projects:

1. Delineate drainage areas tributary to BMP locations and compute imperviousness.
2. Look up the recommended LID sizing method for the BMP selected in each drainage area using **Appendix E**.
3. Attempt to provide the calculated LID sizing criteria for the selected BMPs using the methods in **Appendix E**.
4. Determine if an HCOC exists using the methods described **Section 2.3.5**.
5. Determine if LID sizing criteria satisfy hydromodification criteria to mitigate any HCOCs.
6. Attempt to mitigate any remaining HCOCs using hydromodification BMPs according to **Section 5**.
7. If LID or hydromodification sizing criteria cannot be achieved, document the constraints that override the application of BMPs, and provide the largest portion of the sizing criteria that can be reasonably provided given constraints.
8. Design BMPs per the guidance provided in the BMP Fact Sheets (**Appendix G**).

Even if BMPs cannot be sized to meet the LID and/or hydromodification criteria, it is still essential to design the BMP inlet, energy dissipation, and overflow capacity for the full tributary area to ensure that flooding and scour is avoided. It is strongly recommended that BMPs which are designed to less than their target design volume be designed to bypass peak flows.

2.9.6. Alternative Compliance Options for Applicable Green Streets Projects

Applicable green streets projects are not required to meet alternative compliance options if stormwater management controls described in this section, or equivalent, are installed in a manner consistent with the MEP standard.

SECTION 3. SITE DESIGN PRINCIPLES AND TECHNIQUES

3.1. Introduction

This section focuses on LID site design practices; structural LID BMPs are discussed in **Section 4**. LID site design practices are required to be implemented wherever feasible and applicable on all Priority Projects. LID site design practices are also required for Non-Priority Projects, wherever feasible and applicable.

The primary objective of site design principles and techniques is to reduce the hydrologic and water quality impacts associated with land development. The benefits derived from this approach include:

- Reduced size of downstream BMPs and conveyance systems;
- Reduced pollutant loading; and
- Reduced hydromodification impacts to receiving streams.

Site Design Principles and Techniques include the following design features and considerations:

- Site planning and layout;
- Vegetative protection, revegetation, and maintenance;
- Slopes and channel buffers;
- Techniques to minimize land disturbance;
- LID BMPs at scales from single parcels to watershed: and
- Integrated Water Resource Management Practices

Detailed descriptions for each of these Site Design Principles and Techniques are presented in the following sections.

3.2. Site Planning and Layout

3.2.1. <u>Minimize Impervious Area</u>

One of the principal causes of the environmental impacts of development is the creation of impervious surfaces. Impervious cover can be minimized through identification of the smallest possible land area that can be practically impacted or disturbed during site development. Below is a partial list of techniques that can reduce the amount of impervious area that will be created as part of a project. It is important to note that local land use ordinances and building codes may dictate minimum requirements for road widths, building setbacks and accessibility requirements which may not be overridden. However, in certain situations, it may be possible to modify local codes and ordinances or for a project proponent to obtain a waiver to promote less impervious area, such as allowing narrower road widths, sidewalks on one side of the street, shared driveways, reciprocal parking, and reduced building set-backs. Some strategies for minimizing impervious surfaces may serve multiple functions by supporting other local planning objectives such as providing traffic-calming measures and promoting walkable and healthy communities.

3.2.1.1. Limit Overall Coverage of Paving and Roofs

This can be accomplished by designing compact, taller structures, narrower and shorter streets and sidewalks, smaller parking lots (fewer stalls, smaller stalls, and more efficient drive lanes), and indoor or underground parking. Examine site layout and circulation patterns and identify areas where landscaping can be substituted for pavement.

3.2.1.2. Detain and Retain Runoff Throughout the Site

On flatter sites, it typically works best to intersperse landscaped areas and integrate small scale retention practices among the buildings and paving. On hillside sites, drainage from upper areas may be collected in conventional catch basins and piped to landscaped areas and BMPs in lower areas. Or use low retaining walls to create terraces that can accommodate BMPs.

3.2.1.3. Example Planning Phase Techniques

- Build vertically rather than horizontally - add floors to minimize building footprint.
- Cluster development to reduce requirements for roads and preserve green space.
- Minimize lot setbacks (which in turn minimize driveway lengths).
- Reduce road widths to minimum necessary for emergency vehicles.
- Utilize shared driveways.

3.2.1.4. Example Design Phase Techniques

- Install sidewalks on only one side of private roadways to the extent allowed by accessibility requirements.
- Use alternative materials such as permeable paving blocks or porous pavements on driveways, sidewalks, parking areas, etc. Practices should be selected such that they do not present health and safety hazards, such as tripping hazards.
- Create smaller parking spaces intended for compact cars.

3.2.1.5. Example Construction Phase Techniques

- Minimize unnecessary compaction where possible, especially in locations where infiltration BMPs will be constructed. The infiltrative capacity of soils can be greatly reduced when they are compacted, often to the point that they perform similarly to impervious surfaces. Where possible, remediate compacted soils.
- Minimize construction footprint.

- Preserve existing vegetation and trees as feasible.

3.2.2. Maximize Natural Infiltration Capacity

A key component of LID is taking advantage of a site's natural infiltration and storage capacity. This will limit the amount of runoff generated, and therefore the need for mitigation BMPs. A site soils/geology assessment will help to define areas with higher potential for infiltration and surface storage.

These areas are typically characterized by:

- Principally Hydrologic Soil Group A or B soils and in some cases Group C soils.
- Mild slopes or depressions.
- Historically undeveloped areas.

3.2.2.1. Example Planning Phase Techniques

- Avoid placing buildings or other impervious surfaces on highly permeable areas.
- Cluster buildings and other impervious areas onto the least permeable soils.

3.2.2.2. Example Design Phase Techniques

- Where paving of permeable soils cannot be avoided, loss of infiltration capacity can be minimized by using permeable paving materials.
- Where possible, incorporate soil amendments and/or retentive grading to make areas self-containing and minimize runoff

3.2.2.3. Example Construction Phase Techniques

- Minimize construction footprint.
- Minimize incidental and unnecessary compaction where it is not necessary to meet the applicable grading code requirements.

3.2.3. Preserve Existing Drainage Patterns and Time of Concentration

Integrating existing drainage patterns into the site plan will help maintain a site's predevelopment hydrologic function. Preserving existing drainage paths and depressions will help maintain the time of concentration and infiltration rates of runoff, decreasing peak flows. The best way to define existing drainage patterns is to visit the site during a rain event and to directly observe runoff flowing over the site. If this is impossible, drainage patterns can be inferred from topographic data, though it should be noted that depression micro-storage features are often not accurately mapped in topographic surveys. Analysis of the existing site drainage patterns during the site assessment phase of the project can help to identify the best locations for buildings, roadways, and stormwater BMPs.

Where possible, add additional depression “micro” storage throughout the site’s landscaping that mimics natural drainage patterns. Mild gradients can be used to extend the time of concentration, which reduces peak flows and increases the potential for additional infiltration. While risk of serious flooding must be minimized, the persistence of temporary “puddles” during storms is beneficial to infiltration. If a site is visited during dry weather, these areas can sometimes be identified by looking for surficial dried clay deposits.

Use drainage as a design element. Use depressed landscape areas, vegetated buffers, and bioretention areas as amenities and focal points within the site and landscape design. Bioretention areas can be almost any shape and should be located at low points. When configured as swales, bioretention areas can detain and treat low runoff flows and also convey higher flows.

3.2.3.1. Example Planning Phase Techniques

- Avoid channelization of natural streams.
- Establish set-backs and buffer areas from natural streams.
- Where natural streams will be converted to engineered streams, provide sinuosity to increase the time of concentration.
- Develop an effective conceptual drainage plan.

3.2.3.2. Example Design Phase Techniques

- Avoid channelization of natural streams.
- When designing channels, use mild slopes and increase channel roughness to extend time of concentration.
- When possible, use pervious channel linings to maximize opportunity for infiltration.
- Use vegetated, un-hardened conveyance elements.
- Intersperse localized retention features throughout site.

3.2.3.3. Example Construction Phase Techniques

- Minimize construction footprint.

Micro-scale on-lot retention is a component of preserving existing drainage patterns and times of concentration. Micro-scale on-lot retention is a HSC for the purpose of this TGD. A BMP fact sheet for localized on-lot retention is found in **Appendix G**. The fact sheet describes recommended design criteria and methods of quantifying the the water quality benefit of this practice.

3.2.4. Disconnect Impervious Areas

Runoff from ‘connected’ impervious surfaces commonly flows directly to a paved surface (driveway, sidewalk, or to the curb line) and from there to the stormwater collection system with no opportunity for infiltration into the soil. For example, roofs and sidewalks commonly drain onto parking lots, and the runoff is conveyed by the curb and gutter to the nearest storm inlet. Runoff from numerous impervious drainage areas may converge, combining their volumes, peak runoff rates, and pollutant loads. Disconnecting impervious areas from conventional stormwater conveyance systems allows runoff to be collected and managed at the source or redirected onto pervious surfaces such as vegetated areas. This reduces the amount of directly connected impervious area (DCIA), reduces the peak discharge rate by increasing the time of concentration, maximizes the opportunity for infiltration by reducing the velocity of flows, provides for greater contact time with the soil, and maximizes the opportunity for ET during transport.

Disconnection practices may be applied in almost any location, but impervious surfaces must discharge into a suitable receiving area for the practices to be effective. Information gathered during the site assessment will help determine appropriate receiving areas. Typical receiving areas for disconnected impervious runoff include landscaped areas and/or LID BMPs (i.e., filter strips or bioretention). Runoff must not flow toward building foundations or be redirected onto adjacent private properties. Setbacks from buildings or other structures may be required to ensure soil stability. Consult with the project geotechnical engineer to identify areas where infiltration can be accommodated.

It is important to bear in mind that water flows downhill; therefore receiving areas must be located down gradient from runoff discharges. In a residential setting, this could mean that roof runoff discharges to either the front yard or the back yard, depending on the site configuration. As compared to conventional development, some potential techniques for redirecting flows to vegetated areas may require local design standards to be revisited or a waiver obtained.

3.2.4.1. Example Planning Phase Techniques

- Plan site layout and mass grading to allow for runoff from impervious surfaces to be directed into distributed permeable areas such as turf, recreational areas, medians, parking islands, planter boxes, etc.
- Use vegetated swales for stormwater conveyance instead of traditional concrete pipes.
- Avoid channelization of natural on-site streams.

3.2.4.2. Example Design Phase Techniques

- Provide permeable areas within medians and parkways that are designed to accept runoff from adjacent areas (i.e. via curb cuts).
- Construct roof downspouts to drain to pervious areas such as planter boxes or adjacent landscaping. This approach is further described in **Section 4**.
- Use permeable paving materials such as paving blocks or porous pavements on driveways, sidewalks, parking areas, etc.

To minimize stormwater-related impacts, apply the following design principles to the layout of newly developed and redeveloped sites:

- Define the development envelope and protected areas, identifying areas that are most suitable for development and areas that should be left undisturbed.
- Set back development from creeks, wetlands, and riparian habitats.
- Preserve established trees as practicable (see **Section 3.3**)

Impervious area disconnection is characterized as a HSC for the purpose of this TGD. BMP fact sheets for localized on-lot retention and impervious area dispersion are found **Appendix G**. These fact sheets include recommended design criteria and methods of quantifying the benefits of impervious area disconnection.

3.3. Vegetative Protection, Selection Revegetation, and Soil Stockpiling

3.3.1. Protect Existing Vegetation and Sensitive Areas

A thorough site assessment will identify any areas containing dense vegetation or well-established trees. When planning the site, avoid disturbing these areas. Soils with thick, undisturbed vegetation have a much higher capacity to store and infiltrate runoff than do disturbed soils. Reestablishment of a mature vegetative community can take decades. Sensitive areas, such as wetlands, streams, floodplains, or intact forest, should also be avoided. Development in these areas is often restricted by federal, state and local laws.

Vegetative cover can also provide additional volume storage of rainfall by retaining water on the surfaces of leaves, branches, and trunks of trees during and after storm events. This capacity is rarely considered, but on sites with a dense tree canopy it can provide additional volume mitigation.

3.3.1.1. Example Planning Phase Techniques

- Establish set-backs and buffer zones surrounding sensitive areas.
- Incorporate established trees into site layout.

3.3.1.2. Example Design Phase Techniques

- Design site to deter human activity within sensitive areas (i.e. fences, signs, etc.).

3.3.1.3. Example Construction Phase Techniques

- Provide and maintain highly visible flagging and/or fencing around sensitive areas or vegetation that is to be protected.

3.3.1.4. *Example Occupancy Phase Techniques*

- Establish use/access restrictions to sensitive areas.

3.3.2. Revegetate Disturbed Areas

Maximizing plant cover protects the soil and improves ability of the site to retain stormwater, minimize runoff, and help to prevent erosion. Plants have multiple impacts on downstream water quality. First, the presence of a plant canopy (plus associated leaf litter and other organic matter that accumulates below the plants) can intercept rainfall, which reduces the erosive potential of precipitation. The Street Trees/Canopy Cover Fact Sheet provided in **Appendix G** facilitates quantification of the retention benefits of canopy cover. With less eroded material going to receiving waters, turbidity, chemical pollution, and sedimentation are reduced. Second, a healthy plant and soil community can help to trap and remediate chemical pollutants and filter particulate matter as water percolates into the soil. This occurs through the physical action of water movement through the soil, as well as through biological activity by plants and the soil microbial community that is supported by plants. Third, thick vegetative cover can maintain and even improve soil infiltration rates.

When selecting plants for re-vegetation, preference should be given to native vegetation, which is uniquely suited to the local soils and climate. However, consideration of the location of the plants in the landscape with regards to wildfire safety can sometimes make the use of native species unsuitable. The Orange County Fire Authority requires "fuel modification zones" adjacent to development and restricts species of plant that may be used in these zones. Additional information can be found by contacting local Master Gardeners or seeking the advice of local plant nurseries, which will have specific knowledge of plants suitable for your particular application. The Las Pilitas Nursery in Santa Margarita has compiled a detailed database of California native plants which is accessible online at: **http://www.laspilitas.com/comhabit/california_communities.html**. The website can be used to aid in determining the correct plant communities by searching by either ZIP code or town. In cases where use of native vegetation is impractical or impossible, use of non-natives adapted to similar climate regimes, such as the Mediterranean, may be appropriate. This strategy will maximize the successful establishment of plantings, and minimize the need for supplemental irrigation.

3.3.3. Soil Stockpiling and Site Generated Organics

The regeneration of disturbed topsoil can take years under optimal conditions, and sometimes can take many decades (Brady and Weil, 2002[14]). Proper stockpiling, storage, and reapplication of disturbed topsoil can greatly accelerate this process. Improper soil storage and restoration

[14] The Nature and Properties of Soils, 13th Edition, Nyle C. Brady, Ray R. Weil, 2002.

can significantly decrease the biological activity of the soil, decrease the successful establishment of plantings, and increase the ability of undesirable invasive species to dominate the disturbed landscape. Proper stockpiling generally includes protecting the stockpile to prevent excessive compaction and covering the stockpile to prevent significant erosion and leaching of nutrients.

Soil stockpiling and the use of in situ grubbed plant material and duff as mulch or soil amendments is encouraged. This will reduce the need for importation of top soil to improve soil quality, and will encourage reestablishment of soil flora and fauna after site disturbance. Successful soil stockpiling and reuse begins in the early stages of project planning.

The use of topsoil harvested from the local site can improve the productivity and rate of re-vegetation of a disturbed site. In addition to stockpiled soil, vegetative material grubbed from the site and free of invasive species can be tilled back into the soil to increase organic content.

Restoration of disturbed areas using native soils which have been properly stockpiled during the construction phase of the project is the preferred method of post construction soil restoration. Proper assessment of the site during the design phase of the project is critical to maintaining soil quality, both structural and biological, during the period the soil is stockpiled. Determination of the volume of soil to be stockpiled and designating an area large enough on site to accommodate the stockpiled soil should be considered early in project design.

Consideration must be given to maintenance of the flora and fauna present in the stockpiled soil in addition to its physical condition. Improper storage such as soil that is too wet or stockpiled too deeply, can render what were active biological soil communities sterile. This will severely impact the ability of the soil to support a healthy plant community. If necessary, a local soil scientist familiar with regional soils can provide testing services to evaluate soil condition prior to and after construction and recommend appropriate remediation steps to restore the soil's predevelopment ability to infiltrate stormwater runoff and support a healthy plant community.

Additional information about the impact of soil stockpiling can be found in the following document which was prepared for the District 11 office of the California Department of Transportation:

Restoration in the California Desert - **http://www.sci.sdsu.edu/SERG/techniques/topsoil.html**

3.3.4. Firescaping

Fire is a part of the ecosystems of Southern California. Over the years, wildfires have repeatedly destroyed homes and caused loss of life. In response to this natural phenomenon, extensive research has been done and, in the interest of public safety, guidelines have been codified into law. When considering any planting or re-vegetation plan, consideration must be given to minimizing the risks of fire with proper plant selection and maintenance. Keep in mind that all plants are flammable given the right conditions; selection and maintenance of plants to mitigate flammability go hand-in-hand. A plant with a low flammability rating which is allowed to accumulate dead wood or excessive levels of duff in and around the plant will have a significantly elevated risk of flammability.

California law (Public Resources Code 4291) requires a minimum 100-foot space around homes on level ground to protect the structure and provide a safe area for firefighters. If a home is located on a slope, additional distance is required and plant spacing, selection, and design must be modified to maintain proper fire safety margins.

A four zone system has been developed to create a maximum buffer around structures located in high risk wildfire zones. Each zone has very specific landscaping and management requirements to minimize flammability of the landscape. The four zones are broken down as follows:

- Zone One – The garden or clean and green zone
- Zone Two – The greenbelt or reduced fuel zone
- Zone Three – The transition zone
- Zone Four – Native or Natural Zone / Open Space

The landscape plant selection and design for any bioretention or re-vegetation project should be compliant with the requirements of the specific zone in which it will be located. For assistance in determining the correct zone plant selection and spacing, contact your local fire department or insurance company for assistance.

3.3.5. Water Efficient Landscaping

As water use, the frequency of drought, and the impact of organic waste generated from landscape management increases in California, methods to deal with these problems have been developed. Water efficient landscaping, also called "drought tolerant landscaping", California-friendly landscaping, or "native landscaping", or "xeriscaping", has become a widely-accepted alternative to traditional landscape design in dry areas.

Water efficient landscaping is a landscape design and plant selection scheme that is used to minimize required resources and waste generated from a landscape. Defined as "quality landscaping that conserves water and protects the environment" the principles of water efficient landscaping should be employed in any project that creates or restores the landscape. Consulting local resources, such as your local county extension agent, Master Gardeners, Landscape Architects, or local garden centers and nurseries, will help to select plant material suitable for a specific geographic location.

Water efficient landscaping is based on seven principles:

- Soil analysis
- Planning and design

- Appropriate plant selection
- Practical turf areas
- Efficient irrigation
- Use of mulches
- Appropriate maintenance

Water efficient landscaping has many benefits which include:

- Reduced water use
- Decreased energy use
- Reduced heating and cooling costs resulting from optimal placement of trees and plants
- Minimal runoff from both stormwater and irrigation resulting in reduction of sediment, fertilizer and pesticide transport
- Reduction in yard waste that would normally be landfilled
- Creation of habitat for wildlife
- Lower labor and maintenance costs
- Extended life of existing water resources infrastructure.

A water efficient landscape can reduce outdoor water consumption by as much as 50 percent without sacrificing the quality and beauty of landscaped areas. It is also an environmentally sound landscape, requiring less fertilizer and fewer chemicals. Water efficient landscape is also low maintenance, saving time, effort, and money.

Street trees/canopy cover are elements of vegetative protection, revegetation, and maintenance and are characterized as a HSC for the purpose of this TGD. A BMP fact sheet for street trees/canopy interception is found in **Appendix G**. Fact sheets include recommended design criteria and methods of quantifying the benefits of street trees/canopy interception.

The selection and design of vegetative-based LID BMPs that are specifically sized to treat the DCV is discussed further in **Section 4**.

3.4. Slopes and Channel Buffers

Project plans should include site design BMPs to decrease the potential for erosion of slopes and/or channels. The following design principles should be considered, and incorporated and implemented where determined applicable and feasible by the Permittee:

1. Convey runoff safely from the tops of slopes.
2. Avoid disturbing steep or unstable slopes.
3. Avoid disturbing natural channels.
4. Install permanent stabilization BMPs on disturbed slopes as quickly as possible.
5. Vegetate slopes with native or drought tolerant vegetation.
6. Control and treat flows in landscaping and/or other controls prior to reaching existing natural drainage systems, unless infiltration would cause geotechnical hazards.

7. If hydromodification control is not provided before discharge to the channel, install permanent stabilization BMPs in channel crossings as quickly as possible, and ensure that increases in runoff velocity and frequency caused by the project do not erode the channel.
8. Install energy dissipaters, such as riprap, at the outlets of new storm drains, culverts, conduits, or channels that enter unlined channels in accordance with applicable specifications to minimize erosion. Energy dissipaters should be installed in such a way as to minimize impacts to receiving waters.
9. Instead of discharging to steep reaches, consider collecting and conveying runoff to downgradient discharge points.
10. On-site conveyance channels should be lined, where appropriate, to reduce erosion caused by increased flow velocity due to increases in tributary impervious area. The first choice for linings should be grass or some other vegetative surface, since these materials not only reduce runoff velocities, but also provide water quality benefits from filtration and infiltration. Irrigation demand of vegetated systems should be considered. If velocities in the channel are large enough to erode grass or other vegetative linings, rock, riprap, concrete soil cement or geo-grid stabilization may be substituted or used in combination with grass or other vegetation stabilization.
11. Other design principles which are comparable and equally effective.

These practices should be implemented, as feasible, consistent with local codes and ordinances. Projects involving an alteration to bed, bank, or channel of a Water of the US may require approval of regulatory agencies with jurisdiction over water bodies, (e.g., the U.S. Army Corps of Engineers, the Regional Boards and the California Department of Fish and Game).

3.5. Techniques to Minimize Land Disturbance

Minimizing the amount of site clearing and grading can dramatically reduce the overall hydrologic impacts of site development. This applies primarily to new construction but the principles can be adapted to retrofit and infill projects as well.

Soil compaction resulting from the movement of heavy construction equipment can reduce soil infiltration rates by 70-99% (Gregory et al, 2006)[15]. Even low levels of compaction caused by light construction equipment can significantly reduce infiltration rates. In addition, compaction can destroy the complex network of biota in the soil profile that support the soil's ability to capture and mitigate pollutants. Soil compaction severely limits the establishment of healthy root systems of plants that may be used to revegetate the area. For these reasons, it is very important to avoid unnecessary damage to soils during the construction process. The use of

[15] Gregory, J.H.; Dukes, M.D.; Jones, P.H.; and G.L. Miller, 2006. Effect of urban soil compaction on infiltration rate. *Journal of Soil and Water Conservation 2006 61(3):117-124 Online at:* **http://abe.ufl.edu/mdukes/pdf/stormwater/Gregor-et-%20al-JSWC-compaction-article.pdf**

clearly defined protection areas will help to preserve the existing capacity of the site to store, treat and infiltrate stormwater runoff.

3.5.1.1. Example Planning Phase Techniques

- Many of the planning techniques identified in the above sections will help minimize the construction footprint.

3.5.1.2. Example Construction Phase Techniques

- Minimize the size of construction easements.
- Locate material storage areas and stockpiles within the development envelope.
- Limit ground disturbance outside of areas that require grading.
- Identify and clearly delineate access routes for the movement of heavy equipment.
- Establish and delineate vegetation and soil protection areas.
- Avoid compaction or heavy equipment on sites designated for infiltration BMPs.

Additional techniques for minimizing disturbance and protecting or restoring site conditions during construction phase include:

Establish Vegetation and Soil Protection Areas

Vegetative protection areas (e.g. stream, river, lake and other watercourse buffers, vegetation protection areas, existing trees) should be clearly delineated with highly visible fencing materials to prevent incursion of equipment or the stockpiling of materials during construction. Tree trunks should be sheathed during construction to prevent or minimize damage to the bark.

Use of Mulch and Load Distributing Matting

Mulch blankets can be used to protect soil from compaction during construction. The use of timbers or other types of load distributing materials can also be used to limit the effect of heavy equipment movement on the site.

Pre / Post Construction Soil and Plant Treatments

Consideration should be given to pre-construction treatment of the soil to mitigate the stresses on existing shrubs and trees. This can include soil aeration and specific fertilization protocols that would encourage plant vitality. A local restoration ecologist should be engaged well in advance of the start of construction to develop a plan based on specific site conditions since some of these practices are carried out prior to construction.

Inspection Guidelines and Procedures

Management of soil, water, and vegetation protection measures during the construction process will only be effective if it is carefully implemented and meticulously policed during all phases of construction. Significant damage can be done in a short timeframe, and the cost of damage remediation tends to be far greater than the cost of avoiding it. Areas intended for infiltration should be treated especially carefully. Avoid the use of heavy machinery or discharge of sediment-laden runoff in these areas. Heavy machinery will compact the soils and fine grained materials in sediment will reduce the soil's infiltration capability.

Techniques implemented on the construction site to minimize the construction footprint should be included in the project documentation. Contractors working on the project should review and agree to comply with them while working on the jobsite. Construction site inspections should include inspection of such protocols to ensure they are maintained throughout construction.

3.6. Integrated Water Resource Management Practices

Selection and incorporation of site design principles into new development and significant redevelopment projects, whether on-site or off-site can have significant multiple benefits on a subwatershed, watershed and county-wide basis. For example, Orange County Water District is supportive of regional infiltration BMPs as an approach to retaining more urban runoff in the groundwater basin. As another example, the San Diego Creek Natural Treatment System (NTS) Master Plan (**www.irwd.com/environment/natural-treatment-system.html**) includes, among other concepts, constructed wetlands integrated with flood control facilities. These types of facilities would provide retention and biotreatment as well as treatment of retrofit dry weather flows while maintaining the original flood control functionality of the basin. Wetland facilities also provide habitat for many bird species, including endangered species, can provide aesthetic benefits, and in some cases may also provide recreational benefits. Finally, LID and hydromodification control BMPs may provide significant flood control benefits, therefore the system design processes described in this TGD should be coordinated with flood control design (not covered by this TGD) to most efficiently support both functions.

SECTION 4. LID BMP SELECTION AND DESIGN

4.1. Introduction

This section provides additional detail on LID BMP selection, sizing, and design to support Step 5 (**Section 2.5**) of this TGD and Section 5 of the Project WQMP.

> **Section 4.2** describes the criteria for determining the feasibility of harvest and use and infiltration associated with each BMP location. This is intended to support the identification of the appropriate category of LID BMP to use in each DMA.
>
> **Section 4.3** provides additional detail about each category of LID BMP, including guidance for how they can be incorporated into designs, references for sizing methods, and references to BMP Fact Sheets for design criteria.
>
> **Section 4.4.** identifies and provides guidance on the general and specific design criteria associated with LID BMPs. If a standard BMP approach from the BMP Fact Sheets is selected, this section does not need to be consulted as these design criteria have been incorporated into the of the criteria described in the BMP Fact Sheets. However, the guidance and criteria in **Section 4.4** are relevant as a guide where deviations or project-specific adaptions of the fact sheets are proposed.

This section is not intended to stand alone. It is intended to be used within the overall framework for site investigation, site design, drainage planning, and LID selection described in **Section 2.5**.

4.2. LID BMP Selection

This section expands on and supports the BMP selection process that is summarized in **Section 2.5.2.**

4.2.1. Detailed Process for LID BMP Selection

A standard process and criteria for selection of on-site LID BMPs is detailed in this section. This process and criteria is intended to apply to the majority of project cases. Standardization of the selection process helps ensure a consistent basis for project development. For projects using on-site LID BMPs (the majority of projects), the selection process in this section is applicable. Criteria for the use of less common compliance pathways, including treatment control BMPs, off-site BMPs, and alternative approaches are detailed in the Model WQMP and are not covered in this section.

This process is based on complying with applicable MS4 requirements for LID BMP selection as detailed in Section 2.5 of the **Model WQMP** and **Section 2.5.1** of the TGD. It is also based on the underlying principles described in **Section 1.4**. In this regard, this section adds some practical provisions and guidelines for BMP selection and design intended to improve reliability and resiliency that exceed the minimum requirements of the permit. **Figure 4-1** describes the specific decision steps and TGD references to support these determinations and associated documentation. This is a more detailed version of **Figure 2-2**.

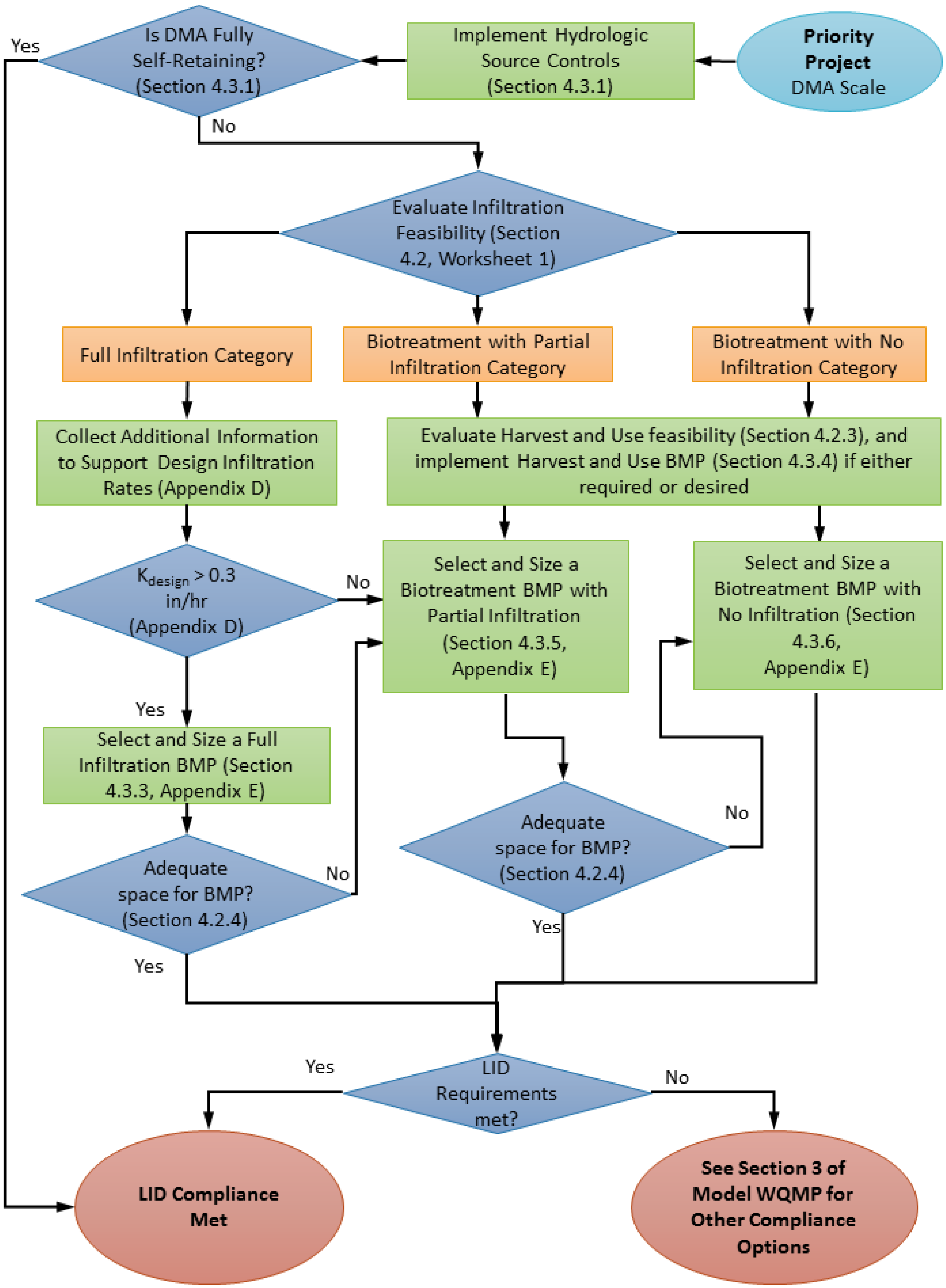

Figure 4-1: LID BMP Selection and Sizing Flow Chart

4.2.2. Infiltration Feasibility Criteria

Determining the feasibility of infiltration at each DMA and BMP location is the most critical factor in appropriate, effective, and safe BMP implementation. In minor cases, the feasibility of harvest and use (**Section 4.2.3**) may also influence BMP selection.

Based on the feasibility of infiltration at the site using the information collected about the site (**Section 2.3**), each DMA and structural BMP location should be categorized into one of three categories defined qualitatively below. Feasibility is a function of the physical ability to infiltrate stormwater and the risk of impacts to property, people, or the environment introduced by stormwater infiltration.

Table 4-1. Definition of Infiltration Feasibility Categories

Infiltration Feasibility	Physical feasibility		Risk of Impacts
Full Infiltration	Infiltration capacity at the BMP location(s) are measured and found to be reliable to support full infiltration of the DCV.	AND	The use of full infiltration of the DCV does not introduce risk of impacts to property, people, or the environment that cannot be reasonably mitigated.
Biotreatment with Partial Infiltration	Infiltration capacity is measured or estimated using acceptable methods and is not reliable to support infiltration of the DCV (or reliability cannot be reasonably determined).	AND	The use of biotreatment BMPs that provide partial infiltration of stormwater does not introduce risk of impacts to property, people, or the environment that cannot be reasonably mitigated.
Biotreatment without Infiltration	There is no reasonable opportunity to achieve appreciable infiltration of a portion of the DCV.	OR	Any degree of infiltration would pose risk of impacts to property, people, or the environment that cannot be reasonably mitigated.

4.2.2.1. *General Criteria*

Evaluation of infiltration feasibility must consider the following factors, as applicable:

- The physical rate at which water will reliably infiltrate and the ability to reasonably determine this. This is a function of soil properties, physical groundwater conditions, proposed fill, and other factors (See **Section 4.2.2.2**).

- Protection of groundwater from contamination as a result of stormwater infiltration. This includes assessment of pollutant sources in stormwater, treatment capacity of BMPs and soils, and existing soil or groundwater contamination (See **Section 4.2.2.3**).
- Geotechnical risk or hazards that are expected to arise from stormwater infiltration. (See **Section 4.2.2.4**)
- Groundwater balance and associated issues such as change in flow regime of water bodies, conflicts with water rights, or risk of increase of inflow and infiltration in to sanitary sewers. (See **Section 4.2.2.5**)

Each of these factors must be based on "substantial evidence" consistent with CEQA. Substantial evidence is defined as "Facts, reasonable assumptions predicated on facts, or expert opinion supported by facts. Substantial evidence does not include argument, speculation, unsubstantiated opinion or narrative, or evidence which is clearly erroneous or inaccurate" (Public Resources Code Section 21080(e)). Specific criteria and acceptable methods recommended to provide substantial evidence are provided in the following subsections and referenced appendices. Where deviations from these recommendations and methods are proposed, the applicant must clearly describe how the approach employed meets the definition of substantial evidence.

In evaluating each factor, reasonable approaches must also be considered for how the project could improve the feasibility of infiltration through site design, BMP design, or other project development aspects. Examples of reasonable and unreasonable mitigation approaches for improving the feasibility of infiltration are identified in each of the following subsections.

Only those factors necessary to provide adequate technical support for BMP selection are required to be considered. For example, if a single factor is investigated and determined to disallow any level of infiltration, then it is not necessary to investigate and consider other factors.

The overall framework allows that certain determinations may be made based on the use of regional maps supported by available site data rather than requiring site investigations. This is generally applicable for small projects only, as defined in **Section 4.2.2.6**.

As new information becomes available through more detailed site investigation efforts, or through construction-phase testing, this information must be incorporated into selection of BMPs.

Worksheet 1 provides a basis for categorizing each DMA into one of the three infiltration feasibility categories. The infiltration infeasibility criteria are listed below. More specific guidance on determining infiltration infeasibility related to groundwater protection is provided in **Appendix C**. **Worksheet 2** (**Appendix C**) is used to summarize groundwater-related feasibility criteria as supporting information for **Worksheet 1**. Methods for determining the measured infiltration rate and using the appropriate factor of safety on infiltration rates is provided in **Appendix D**; the results of this evaluation can be summarized in **Worksheet 3**.

4.2.2.2. Physical Capacity of BMP Location for Infiltration

Site-specific evaluation of infiltration capacity shall be conducted to determine the ability to reliably infiltrate stormwater at the identified BMP locations. The potential uncertainty in infiltration rates of full-scale facilities following construction activities must be considered in this assessment. Note that physical capacity for infiltration is only one factor in infiltration feasibility and this factor alone does not necessarily support feasibility findings.

Full Infiltration

Where all of the following conditions exist, full infiltration BMPs shall be evaluated further:

- Depth to seasonally high mounded groundwater with full infiltration of the DCV is at least 5 feet (this threshold relates to physical infiltration capacity only; greater separation is required to protect groundwater quality in some conditions); AND
- The "feasibility screening infiltration rate" (K_{screen}) or "design infiltration rate" (K_{design}) computed using appropriate methods and factors of safety as described in **Appendix D**, is at least 0.3 inches per hour[16];
  - Where K_{screen} or K_{design} is between 0.3 and 2 inches per hour, the design should include a description of the contingency that will be activated if infiltration rates fall below this range as part of more detailed investigation or through the construction process; AND
  - Where K_{screen} or K_{design} are greater than 2 inches per hour, a contingency approach is not required, but may still be advisable.

Biotreatment with Partial Infiltration

Where any of the following conditions exist, biotreatment BMPs with partial infiltration shall be considered:

- K_{screen} is between 0.05 and 0.3 inches per hour (K_{obs} is between 0.1 to 0.6 inches per hour); OR
- K_{screen} is greater than 0.3 inches per hour (K_{obs} is greater than 0.6 inches per hour), but a site specific evaluation of groundwater mounding indicates that full infiltration would

[16] K_{screen} is computed using a factor of safety of 2.0, so a K_{screen} of 0.3 inches per hour is equivalent to an observed infiltration rate of 0.6 inches per hour. K_{design} uses a factor of safety based on a number of different factors described in **Appendix D**, but is always equal to or higher than 2.0, so a K_{design} of 0.3 inches per hour is equivalent to an observed infiltration rate of *at least* 0.6 inches per hour.

result in a mound such that the depth to mounded seasonal high groundwater is less than 5 feet; OR

- The project is located within a zone mapped as hydrologic soil group D and available information at the proposed BMP site supports this classification as soil types such as silt, clay, or bedrock that have no reasonable potential to support full infiltration; OR
- The only reasonable BMP locations and elevations are located in proposed fill soils such that the infiltration rate cannot be reasonably estimated with confidence prior to construction of the project.

Biotreatment without Infiltration

Where the following conditions are demonstrated to exist, the project applicant may demonstrate that a biotreatment BMP without any infiltration is appropriate:

- Reliable K_{screen} is demonstrated via testing at the specific BMP location to be less than 0.05 inches per hour (K_{obs} is less than 0.1 inches per hour).

Results of Design Phase and Construction Phase Testing

If full infiltration is proposed, then the site investigation approach and project implementation process must provide adequate assurance that the full-scale infiltration rate of the built facility will support full infiltration at or above the design infiltration rate. A contingency plan may be needed, which could be activated if the results of detailed design phase testing or construction phase testing yield design infiltration rates less than used in BMP design. See **Section 4.3.3.1** for additional guidance on developing a contingency plan. It is mandatory that BMP feasibility determinations and BMP selection be updated if new information is obtained that conflicts with the original determination.

Small Project Modifications

Where a small project is located in a zone mapped as hydrologic soil group D, the project must utilize available information to confirm this determination, if available, but is not required to collect additional observations or measurements if available information is not available to confirm the mapped soil determination (low permeability soils).

Examples of Reasonable Risk Mitigation Approaches

Examples of reasonable mitigation approaches to improve the physical capacity of infiltration on include

- Infiltration screening at the site scale and design of the site to locate BMPs within areas where infiltration appears most feasible, while also considering other overriding factors in site design, such as access points, topography, and approved development density.

- Minor depths of over-excavation and backfill with permeable soils at BMP locations to allow infiltrated water access more permeable strata or penetrate fill materials.

Guidelines for measuring or estimating infiltration rates and selecting appropriate factors of safety are provided in **Appendix D**.

4.2.2.3. Groundwater Protection Criteria

Assessment of potential risks to groundwater contamination shall first consider the findings related to potential infiltration rates described in **Section 4.2.2.2**. The actual amount of infiltration that may occur given physical constraints must be considered in determining whether additional limitations on infiltration are required.

Full Infiltration

The presence of ANY of the following conditions at the proposed BMP location shall prohibit full infiltration of the DCV:

- Seasonally high groundwater or mounded groundwater is less than 5 feet below the designed bottom of the infiltration facility. (See **Appendix C** for specific guidance.)
- Seasonally high groundwater or mounded groundwater is less than 10 feet below the designed bottom of the infiltration facility and the BMP type is considered to have elevated risk of groundwater contamination (e.g., infiltration basins, infiltration trenches, dry wells, subsurface vaults, and similar BMPs) and the receiving aquifer supports beneficial uses. (See **Appendix C** for specific guidance.)
- The infiltration facility is less than 100 feet horizontally from a water supply well, non-potable well, drain field, or spring. (See **Appendix C** for specific guidance.)
- The BMP tributary area contains high risk land use activities which would result in significant risks to drinking water quality and groundwater quality that cannot be reasonably and technically mitigated through methods such as isolation of sources and/or pretreatment of runoff to address pollutants of concern prior to infiltration. (See **Appendix C** for specific guidance.)
- For brownfield sites or adjacent sites, where stormwater infiltration of the full DCV would result in a significant risk of mobilizing or moving contamination that cannot be reasonably and technically avoided, as documented by a site-specific or available watershed study. The documenting study shall have sufficient resolution to positively identify areas of the property where unremediated contamination is located and where stormwater infiltration should be restricted to prevent pollutant mobilization. (See **Appendix C** for specific guidance.)
- Where a groundwater pollutant plume (man-made or natural) is under the site or in close proximity and there is substantial evidence that full infiltration of the DCV would cause or contribute to plume movement that cannot be reasonably and technically avoided, as documented by a site-specific study or available watershed study. The

documenting study shall have sufficient resolution to positively identify areas where stormwater infiltration should be restricted. (See **Appendix C** for specific guidance.)

Biotreatment with Partial Infiltration

The presence of ANY of the following conditions at the proposed BMP location shall further prohibit the use of biotreatment BMPs that are designed to achieve partial infiltration of the DCV:

- Seasonally high groundwater or mounded groundwater is less than 5 feet below the designed bottom of the infiltration facility. (See **Appendix C** for specific guidance.)
- The infiltration facility is less than 100 feet horizontally from a water supply well, non-potable well, drain field, or spring. (See **Appendix C** for specific guidance.)
- The BMP tributary area contains high risk land use activities which would result in significant risks to drinking water quality and groundwater quality that cannot be reasonably and technically mitigated through methods such as isolation of sources and/or pretreatment of runoff to address pollutants of concern prior to infiltration. (See **Appendix C** for specific guidance)
- For brownfield sites or adjacent sites, where stormwater infiltration of the any portion of the DCV would result in a significant risk of mobilizing or moving contamination that cannot be reasonably and technically avoided, as documented by a site-specific or available watershed study. The documenting study shall have sufficient resolution to positively identify areas of the property where unremediated contamination is located and where stormwater infiltration in any volume should be restricted to prevent pollutant mobilization. (See **Appendix C** for specific guidance.)
- Where a groundwater pollutant plume (man-made or natural) is under the site or in close proximity and there is substantial evidence that any level of stormwater infiltration would cause or contributing to plume movement that cannot be reasonably and technically avoided, as documented by a site-specific study or available watershed study. The documenting study shall have sufficient resolution to positively identify areas where stormwater infiltration should be restricted. (See **Appendix C** for specific guidance))

Biotreatment without Infiltration

If any of the conditions in the previous section apply, a biotreatment BMP without any infiltration should be selected. In critical areas related to stormwater contaminants, contaminated sites, or groundwater plumes, the investigations above should consider whether biotreatment BMPs need to be lined with an impermeable liner to avoid any level of infiltration.

Documentation prepared by the project applicant or findings from available local studies are acceptable to document the conditions above.

Small Project Modifications

Small projects defined in **Section 4.2.2.6** may document that the BMP location is within a known groundwater plume to document the basis for not considering infiltration in any quantity except where a published report provides the basis for allowing full infiltration or biotreatment with partial infiltration in these areas.

More specific guidance on determining infiltration infeasibility related to groundwater protection is provided in **Appendix C**.

Examples of Reasonable Risk Mitigation Approaches

Examples of reasonable mitigation measures to improve the feasibility of infiltration include:

- Remediation of minor areas of contaminated soil on a site;
- Designing stormwater BMPs with isolation and pretreatment systems;
- Hydrologically isolating areas of the site that have higher risk of stormwater contaminants so that infiltration can be more feasibly applied to lower risk area; and
- Using BMP types that have lower risk of groundwater contamination and/or are more compatible with available groundwater separation (for example, using bioretention rather than dry wells where there is moderate risk of stormwater quality issues or where groundwater is moderately shallow).

Major cleanup of soil or groundwater contamination is not a reasonable requirement for the purpose of allowing stormwater infiltration. Additionally, it is not reasonable to require a project to wait for proximate cleanup activities to be completed in order for infiltration to become feasible.

Additional Recommendations

Project proponents are encouraged to consult with the local groundwater agency as soon as possible in the WQMP development process whenever infiltration BMPs are proposed. The project proponent is especially encouraged to consult with the groundwater agency for any proposed full infiltration BMP if any of the following apply:

- The BMP uses a pipe or conveyance to direct flow to a subsurface system (dry well, vault, infiltration trench, etc.);
- The BMP is comprised of surface infiltration with a cumulative tributary area that exceeds 5,000 square feet; or
- The BMP is proposed to be located over known soil or groundwater contamination.

Appendix C contains guidance on consulting with the local groundwater agency and a template and cover letter for facilitating consultation.

4.2.2.4. *Geotechnical Criteria*

Assessment of potential geotechnical risks shall first consider the findings related to potential infiltration rates described in **Section 4.2.2.2**. The actual amount of infiltration that may occur given physical constraints must be considered in determining whether infiltration would pose appreciable geotechnical risks.

Full Infiltration

Full infiltration of the DCV shall be prohibited where there is substantial evidence that stormwater infiltration would result in significantly increased risks of geotechnical hazards, such as liquefaction or landslides, that cannot be reasonably and technically mitigated to an acceptable level, as documented in a geotechnical report prepared by the geotechnical professional for the project. As default values, full infiltration of the DCV in a given location is deemed to result in a significant risk to geotechnical hazards if any of the following conditions apply:

- The location is less than 50 feet away from slopes steeper than 15 percent
- The location is less than eight feet from building foundations or an alternative setback established by the geotechnical expert for the project.
- The depth of proposed fill is greater than 10 feet.
- A study prepared by a geotechnical professional or an available watershed study determines that stormwater infiltration would result in significantly increased risks of geotechnical hazards on or adjacent to the project site that cannot be reasonably and technical mitigated. The documenting study shall have sufficient resolution to positively identify locations on a project site where stormwater infiltration should be restricted.

The geotechnical report shall support or revise these values, as applicable.

Biotreatment with Partial Infiltration

Biotreatment with partial infiltration of the DCV shall be prohibited where the specific spatial extents and the technical basis for this prohibition is documented in geotechnical report prepared by the geotechnical professional for the project. There are no default setbacks for partial infiltration. Given that some infiltration of rainwater occurs in all sites regardless of stormwater management approach, it is presumed that incidental infiltration does not present an incremental geotechnical risks unless demonstrated otherwise. This shall not be interpreted to transfer any liability for geotechnical design and recommendations to the reviewing jurisdiction.

Small Project Modifications

The default setback values for full infiltration may be accepted as the basis for determining infeasibility of full infiltration without a geotechnical report. This approach may be used at the discretion of the project applicant and reviewer. However, if infiltration will be used this does not waive the responsibility of the project applicant to provide appropriate site-specific documentation of recommended setbacks.

Examples of Reasonable Mitigation Approaches

It may be appropriate to require reasonable mitigation approach such that the feasibility of infiltration can be improved. Examples of reasonable mitigation approaches include:

- Attempting to locate BMPs in areas where they are outside of applicable set-backs and in areas without fill or with lower depths of fill.
- Over-excavation and backfill with more permeable materials in cases where the depth of fill is relatively shallow (less than approximately 5 feet below the invert of the BMP).
- Using a somewhat more robust foundation or retaining wall design of the same type as otherwise proposed such that some infiltration can be allowed; it would be unreasonable to require a project to utilize a different type of foundation or retaining wall design solely to accommodate infiltration.

Consideration of reasonable mitigation approach should be documented in the investigation prepared by the project geotechnical professional.

4.2.2.5. Groundwater Balance and Associated Issues

Assessment of potential risks associated with ground water balance shall first consider the findings related to potential infiltration rates described in **Section 4.2.2.2**. The actual amount of infiltration that may occur given physical constraints must be considered in determining whether further limits on infiltration are appropriate.

Full Infiltration or Biotreatment with Partial Infiltration

Infiltration shall be limited or prohibited where any of the following issues are identified and appropriately documented. These issues are anticipated to be rare and specific thresholds cannot be provided.

- There is substantial evidence that an increase in infiltration over pre-developed conditions would cause impairments to downstream beneficial uses, such as change of seasonality of ephemeral washes or increased discharge of contaminated groundwater to surface waters. The level of allowable increase in infiltration must be documented in a site-specific study or watershed plan, and it must be demonstrated that stand-alone infiltration BMPs would exceed the allowable level of increase in infiltration or what level could be infiltrated as a partial consideration.
- There is substantial evidence that infiltration from the project would result in increase in inflow and infiltration (I&I) to the sanitary sewer that cannot be sufficiently mitigated, and it is beyond the reasonable scope of the project to rehabilitate the sanitary sewer to

mitigate for I&I. Infiltration activities that have the potential to contribute to a significant increase in I&I should be coordinated with the local sewer agency to ensure project drainage plans are protective of sewer hydraulic capacity. It is recommended that coordination be initiated as early as possible during the Preliminary/Conceptual WQMP development process as part of the CEQA process (preferred) or otherwise.

- Infiltration of runoff from the project would violate downstream water rights. While it is not anticipated that infiltration of runoff would violate water rights in Orange County, water law in California is complex, and this TGD does not exclude the possibility that a rightful water rights claim could restrict infiltration of stormwater.

Screening Criteria to Determine Need for Further Investigation

Water balance is generally only of concern where all of the following criteria are met:

- Observed infiltration rates exceed 0.6 inches per hour,
- An ephemeral stream is located within 250 feet of the potential infiltration location, and
- The estimated or mapped depth to seasonally high groundwater is less than 20 feet.

Small Project Modifications

Small projects may deem that full infiltration is infeasible if all of the following are met:

- Observed infiltration rates exceed 0.6 inches per hour,
- An ephemeral stream is located within 250 feet of the potential infiltration location, and
- The estimated or mapped depth to seasonally high groundwater is less than 20 feet.

If a small project seeks to demonstrate that partial infiltration is not feasible based on water balance or related factors, then a site-specific report is required. Partial infiltration does not typically have the potential to change the natural water balance of a site greatly.

Worksheet 1, below, provides a format for documenting infiltration feasibility findings.

Worksheet 1: Infiltration Feasibility Categorization

Categorization of Infiltration Feasibility Condition			***Page 1 of 5***
Part 1: Physical Limitations of Infiltration Based on the criteria for physical limitations of infiltration described in Section 4.2.2.2, what level of physical feasibility of infiltration is the maximum that the BMP location will support?			
1	**Physical Infiltration Feasibility Category**	**Mark applicable category**	**Next step**
	Full Infiltration of the DCV		Continue to Part 2
	Biotreatment with Partial Infiltration		Continue to Part 3
	Biotreatment with No Infiltration		Select and Utilize Biotreatment without Infiltration
Provide summary of basis: Summarize findings of studies, provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.			

<table>
<tr><th colspan="2">Categorization of Infiltration Feasibility Condition</th><th colspan="2">Page 2 of 5</th></tr>
<tr><td colspan="2">Part 2: Risks Limiting Full Infiltration of the DCV –Would infiltration of the full DCV introduce risks of undesirable consequences that cannot reasonably be mitigated?</td><td>Yes</td><td>No</td></tr>
<tr><td>2</td><td>Would infiltration of the DCV pose significant risk for groundwater related concerns? Use criteria described in Section 4.2.2.3 and results from Worksheet 2 (Appendix C) to describe groundwater-related infiltration feasibility criteria.</td><td></td><td></td></tr>
<tr><td colspan="4">Provide basis:

Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.</td></tr>
<tr><td>3</td><td>Would infiltration of the full DCV pose significant risk of increasing risk of geotechnical hazards that cannot be mitigated to an acceptable level? Use criteria described in Section 4.2.2.4.</td><td></td><td></td></tr>
<tr><td colspan="4">Provide basis:

Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.</td></tr>
<tr><td>4</td><td>Would infiltration of the DCV cause an increase in groundwater flow or decrease in surface runoff over predevelopment conditions that would cause impairment to downstream beneficial uses, such as change of seasonality of ephemeral washes or increased discharge of contaminated groundwater to surface waters? Use criteria in Section 4.2.2.5.</td><td></td><td></td></tr>
<tr><td colspan="4">Provide basis:

Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.</td></tr>
</table>

Categorization of Infiltration Feasibility Condition		***Page 3 of 5***	
Part 2 (continued): Risks Limiting Full Infiltration of the DCV –*Would infiltration of the full DCV introduce risks of undesirable consequences that cannot reasonably be mitigated?*		***Yes***	***No***
5	Is there substantial evidence that infiltration of the DCV would **result in a significant increase in I&I to the sanitary sewer** that cannot be sufficiently mitigated?		
Provide basis: Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.			
6	Would infiltration of the DCV **violate downstream water rights**?		
Provide basis: Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.			
Part 2 Result	If the answer to all questions 2-6 are "No", then the DMA is categorized as "Full Infiltration" for the purposes of LID BMP type selection. Describe finding. At the Preliminary/Conceptual WQMP phase, describe the additional design-phase testing required to confirm this determination and identify contingencies for final design. At the Final Project WQMP phase, identify any required construction-phase testing and identify the design contingencies that should result based on construction-phase testing. If the answer to any of questions 2-6 is "Yes" then the site cannot be categorized as "Full Infiltration". Continue to Part 3: Partial Infiltration Feasibility		

<table>
<tr><td colspan="2">Categorization of Infiltration Feasibility Condition</td><td colspan="2">Page 4 of 5</td></tr>
<tr><td colspan="2">Part 3: Partial Infiltration Feasibility Criteria –Would infiltration of any appreciable volume of stormwater result in risks of undesirable consequences that cannot reasonably be mitigated?</td><td>Yes</td><td>No</td></tr>
<tr><td>8</td><td>Would use of biotreatment BMPs with partial infiltration pose significant risk for groundwater related concerns? Refer to criteria in Section 4.2.2.3 and Worksheet 1 (Appendix C) for guidance on groundwater-related infiltration feasibility criteria.</td><td></td><td></td></tr>
<tr><td colspan="4">Provide basis:

Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.</td></tr>
<tr><td>9</td><td>Would the use of biotreatment BMPs with partial infiltration pose elevated risks of geotechnical hazards that cannot be mitigated to an acceptable level? Refer to Section 4.2.2.4.</td><td></td><td></td></tr>
<tr><td colspan="4">Provide basis:

Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.</td></tr>
<tr><td>10</td><td>Would the use of biotreatment BMPs with partial infiltration elevate risks or introduced conflicts related to groundwater balance, inflow and infiltration, or water rights? Refer to Section 4.2.2.5. Note: this is uncommon and must be supported by site-specific analysis if it is used as a basis to reject biotreatment with partial infiltration.</td><td></td><td></td></tr>
<tr><td colspan="4">Provide basis:

Summarize findings of studies provide reference to studies, calculations, maps, data sources, etc. Provide narrative discussion of study/data source applicability.</td></tr>
</table>

Categorization of Infiltration Feasibility Condition		***Page 5 of 5***
Part 3 Result	If the answer to all questions 8-10 are “No”, then the DMA is categorized as “Biotreatment with Partial Infiltration” for the purposes of LID BMP type selection. If the answer to any of questions 8-10 is “Yes” then the site is categorized as “Biotreatment with No Infiltration” for the purposes of LID BMP type selection.	

4.2.2.6. *Definition of Small vs. Large Projects for Infiltration Feasibility Screening Methods*

In certain cases, alternative investigation approaches may be acceptable for small projects as defined in other sections of this TGD. The definition of project size categories is provided in **Table 4-2**.

Table 4-2: Definition of Project Size Categories

	Residential	Commercial, Institutional	Industrial
Small Projects	Less than 10 acres and less than 30 DU	Less than 5 acres and less than 50,000 SF floor area	Less than 2 acre and less than 20,000 SF floor area
Large Projects	Greater than 10 acres or greater than 30 DU	Greater than 5 acres or greater than 50,000 SF floor area	Greater than 2 acre or greater than 20,000 SF floor area

4.2.3. Harvest and Use Feasibility Criteria

Harvest and use shall be considered for projects that have a demand adequate to satisfy the LID sizing criteria described in **Section 2.5.1**. Projects are required to consider harvest and use if the reliable wet season demand for harvest water is adequate to use the DCV within 48 hours. This is expected to be very rare. Guidance for calculating harvested water demand is provided in **Appendix F**.

If there is any reliable demand for harvested water, then it is acceptable, but not required, to utilize harvest and use as part of meeting LID performance criteria. This could involve the use of larger harvesting systems that can compensate for smaller demand and still capture 80 percent of average annual runoff and/or the use of harvesting systems in combination with other LID BMPs.

4.2.4. Demonstrated Space Constraints and Influence on LID BMP Selection

Deficiency in suitable space for LID BMPs may be a legitimate technical issue that appropriately influences BMP selection and design. Under certain conditions, a demonstrated space constraint may support deviations from the standard LID BMP hierarchy and BMP selection menu described in this section.

4.2.4.1. *Criteria for Demonstrating Limited Space and Modifying BMP Selection based on Space Constraint*

There are two demonstrations that need to be provided in order to utilize space constraints as a basis for deviating from the standard BMP selection hierarchy:

- Demonstration that the site design has been developed to allow LID BMPs to the MEP, and
- Demonstration that the modified LID BMP selection resulting from the space constraint is consistent with the intent of the goal of maximizing volume retention

Both of these demonstrations must be made based on substantial evidence is subject to the discretion of the reviewer. Guidance on these demonstrations is provided below.

Site Design to Allow LID BMPs to the MEP

The Project WQMP must include a site design narrative that explains how the project was configured to allow as much space as possible. This narrative must identify any overriding factors in site design, such as inflexibility in access points, inflexibility in other code requirements, high intensity land use goals/prior approvals and/or other factors. This narrative should conform to one of the following options:

Option 1: Default Space Allocation

- At least the recommended portion of the site specified in **Table 4-3** (or a more stringent table developed by local jurisdictions) shall be provided in the site plans for surface plus subsurface BMPs. Local jurisdictions may develop a more stringent table (i.e., greater area required to be provided) at their discretion. In the absence of such a table, **Table 4-3** shall be the default; and
- The site shall be configured such that runoff can be routed to BMPs located in the available area(s) of the site; and
- The site shall be laid out such that BMPs are located in areas that best support full infiltration or partial infiltration of the DCV, as practicable given the constraints of the site, and
- Satisfaction of these criteria shall be documented in exhibits and/or narrative descriptions.

Option 2: Project Specific Space Allocation

- A site specific study shall be prepared as part of the Project WQMP that documents that the site cannot be designed to allow more area for BMPs. The study may consider:
    - Site conditions/constraints (e.g., depth to groundwater, topography, existing utilities)

- Zoning/code requirements (e.g., target density, accessibility, traffic circulation, health and safety, setbacks, etc.)
- Economic feasibility

Adherence to Modified LID Hierarchy to Maximize Volume Reduction

The Project WQMP must illustrate a good faith and technically-based attempt to utilize LID BMPs based on the feasibility category identified for the site and make modifications to the selection in a manner consistent with the LID hierarchy goal of maximizing volume reduction:

- In conditions that would otherwise support full infiltration, rejection of full infiltration based on space constraints must be based on sizing calculations using the lowest reasonable factor of safety on design infiltration rate supported by a good faith investigation. Deficiency in site investigation shall not be the basis for an artificially-high factor of safety that leads to rejection of full infiltration.
- If full infiltration is rejected, the next option considered must be biotreatment with partial infiltration. Because biotreatment with partial infiltration does not require a certain minimum underlying infiltration rate, this should allow for a smaller factor of safety and more space efficient design that must be considered before considering biofiltration with no infiltration.
- In conditions that would otherwise support biotreatment with partial infiltration, preference should be given to using a biotreatment BMP with partial infiltration with a reduced sizing factor within an acceptable range of design standards (i.e., a semi-compact non-proprietary biotreatment BMP) before considering a more compact proprietary system that is not accompanied by partial infiltration design elements. In other words, the BMP could have a footprint that is smaller than the target footprint for volume reduction (**Section 4.4.3**). This would still be preferable rather than defaulting to a compact proprietary biofiltration BMP. However, if space is so deficient that the system risks premature clogging, then using a compact biofiltration BMPs (which has been tested at high loading rates) is more appropriate.

Table 4-3: Default Space Allocations for LID BMPs by Project Type in Absence of Project-Specific Findings

Project Type		Default Space Allocation for LID BMPs (% of impervious area in DMA)[1, 2]
New Development	SF/MF Residential < 7 du/ac	8
	SF/MF Residential 7 – 18 du/ac	6
	SF/MF Residential > 18 du/ac	4
	MF Residential > 30 du/ac	3
	Mixed Use, Commercial, Institutional/Industrial w/ FAR < 1.0	8
	Mixed Use, Commercial, Institutional/Industrial w/ FAR 1.0 – 2.0	6
	Mixed Use, Commercial, Institutional/Industrial w/ FAR > 2.0	4
	Mixed Use, Commercial, Institutional/Industrial w/ FAR > 4.0	3
	Podium (parking under > 75% of project)	3
	Projects with zoning allowing development to lot lines	2
	Surface Parking	4
	Structure Parking	2
Redevelopment	SF/MF Residential < 7 du/ac	5
	SF/MF Residential 7 – 18 du/ac	4
	SF/MF Residential > 18 du/ac	3
	MF Residential > 30 du/ac	2
	Mixed Use, Commercial, Institutional/Industrial w/ FAR < 1.0	5
	Mixed Use, Commercial, Institutional/Industrial w/ FAR 1.0 – 2.0	4
	Mixed Use, Commercial, Institutional/Industrial w/ FAR > 2.0	3
	Podium (parking under > 75% of project)	2
	Projects with zoning allowing development to lot lines	1
	Surface Parking	3
	Structure Parking	2

[1] Must be provided in an area that is 1) is suitable for a LID BMPs and 2) receives runoff from impervious areas.
[2]Criteria for site design are only required to be met if the Project WQMP seeks to modify the BMP selection process based on a demonstrated space constraint; full compliance with LID requirements may be feasible with smaller space allowances
Key: du/ac = dwelling units per acre, FAR = Floor Area Ratio = ratio of gross floor area of building to gross lot area; MF = Multi Family, SF = Single Family

4.2.4.2. *Examples of Influence of Space Constraints on BMP Selection*

Two examples of the influence of space constraints on BMP selection are presented below.

Space Constraint as a Basis to use Biotreatment with Partial Infiltration Instead of a Full Infiltration BMP

Based on available space and reliable infiltration rates, there are conditions and project types under which a site would be categorized as full infiltration but it would not be feasible to infiltrate the full DCV in 48 hours or otherwise achieve 80 percent capture of average annual runoff.

At a design infiltration rate of 0.3 inches per hour (the observed infiltration rate adjusted with a prudent factor of safety per **Appendix D**), infiltration of the DCV in 48 hours requires a maximum effective depth of 1.2 feet and results in a sizing factor of 4 to 6 percent of the impervious area of the site depending on location. This footprint is larger than the default space allowance for some project types, particularly in redevelopment cases.

Before dismissing full infiltration, actual space availability and requirements must be determined. The Project WQMP must demonstrate the site has been designed per the criteria in **Section 4.2.4.1** and must demonstrate using an appropriate sizing method that infiltration BMPs would require more space than is available. Consideration must be given to whether HSCs could be used to reduce the DCV. Approaches like permeable pavement could significantly reduce the DCV and may not interfere with site use. Finally, it must be confirmed that the design infiltration rate used in sizing calculations is based on a realistic factor of safety and is not inappropriately inflated to compensate for inadequate sight investigation or failure to address clogging risks with pretreatment.

If these demonstrations are made, then it would be most appropriate for BMPs to be selected from the biotreatment with partial infiltration category. This allows a higher and more certain filtration rate to be used in sizing calculations and likely allows a smaller footprint.

Space Constraint as a Basis to Use Compact Proprietary Biofiltration instead of Non-proprietary Biotreatment with Partial Infiltration

Compact proprietary biofiltration systems that meet the acceptance criteria in **Appendix J** are a type of biotreatment BMP that have been specifically designed and tested to operate within very compact footprints and have defined maintenance requirements associated with this design. If supplemental retention is provided with a proprietary biofiltration BMP (See fact sheet BIO-5), then there is no preference between non-proprietary over proprietary biotreatment BMPs. Both systems provide adequate treatment and maximize volume reduction.

If supplemental retention is not provided, these biofiltration systems achieve little to no volume reduction, so they are a lower priority option than non-proprietary biotreatment systems that achieve partial infiltration (See **Section 2.5**) in the case where both are feasible. However, when the available space for BMPs is smaller than the range that is suitable for non-proprietary systems (i.e., would require them to operate with a surface loading rate that is outside of their intended range), then the use of compact proprietary biofiltration BMPs without supplemental retention may be acceptable. The following steps should be used to show this:

- The Project WQMP must demonstrate the site has been designed per the criteria in **Section 4.2.4.1** (Criteria for Demonstrating Limited Space) and demonstrate, using an appropriate sizing method, that non-proprietary BMPs would require more space than is available. Consideration must be given to whether HSCs could be used to reduce the DCV and allow BMPs to fit.
- If the result is that the space is less than can support a non-proprietary BMPs within acceptable design assumptions (e.g., depths, media filtration rates, hydraulic loading), then it would be preferable to use a compact proprietary system, subject to the acceptance criteria in **Appendix J**, rather than implementing a non-proprietary design outside of its range of acceptable design parameters.

4.3. LID BMP Sizing and Design References

This section details the standard types of LID BMPs and the sizing and design references for these BMPs.

4.3.1. Hydrologic Source Controls

The first step in the LID BMP selection process is to consider HSCs, such as downspout disconnects and other controls based on opportunities in the project layout. HSCs can be considered to be a hybrid between site design practices and LID BMPs. They are distinguished from site design BMPs in that they do not reduce the tributary area or reduce the imperviousness of a drainage area; rather they reduce the runoff volume that would result from a drainage area with a given imperviousness compared to what would result if HSCs were not used. HSCs are differentiated from LID BMPs in that they tend to be more highly integrated with site designs and tend to have less defined design and operation. For example, it may not be possible to precisely describe the storage volume and drawdown rate of a pervious area receiving drainage from downspout disconnects; however these systems can be very effective at reducing runoff.

There are no numeric standards requiring the use of HSCs. Therefore, for projects that fully conform to LID sizing requirements and fully address HCOCs, the use of HSCs is optional (although the use of other LID site design BMPs is required). However, if a project cannot feasibly meet LID sizing requirements or cannot fully address HCOCs, all applicable HSCs must be implemented as part of demonstrating that the BMP system has been designed to retain the maximum feasible portion of the DCV. Under these cases, the Project WQMP must demonstrate conformance with the requirement to select and use all applicable HSCs. This conformance analysis generally must take the following form, or equivalent methods of documenting that the requirements of the Model WQMP are met:

- Conformance should be demonstrated for each DMA within the project.
- Using the checklist of HSCs contained in Section 4 of the WQMP Template, or equivalent, note all HSCs that have been provided for the drainage area.
- For HSCs that have not been provided, provide rationale for why they are not applicable or mutually exclusive with another more effective BMP.
- Using **Worksheet 4** in **Appendix E**, the effect of HSCs should be accounted in tabulating overall system performance. The use of HSCs results in smaller design volumes for downstream BMPs. **Appendix E** provides additional guidance in accounting for the benefits of HSCs.

HSCs can be a cost-effective part of meeting LID requirements. Some HSCs are also effective at removing pollutants. HSCs that effectively remove pollutants are allowed to have their captured storm water volume count towards the DCV, consequently reducing the size of downstream structural BMPs. Where claimed, the contribution of HSCs can be quantified in terms of inches of the design capture storm depth or a percentage of average annual runoff volume that is reduced, depending on the BMP type and sizing method being used. Each of these has the effect of reducing the sizing criteria for downstream structural BMPs as described in **Appendix E**.

If the volume of runoff retained by HSCs in a DMA is greater than or equal to the design capture storm depth for the DMA, the DMA is considered to be "self-retaining" and no additional BMPs are required to treat discharges from the drainage area to meet LID or treatment control requirements. Soil amendments and other techniques can be used to make areas become self-retaining. HSC-6 in the BMP fact sheets contains additional guidance on self-retaining areas.

Appendix G.1 provides fact sheets for the types of HSCs that are recognized by this TGD.

HSC-1: Localized On-Lot Infiltration
HSC-2: Impervious Area Dispersion
HSC-3: Street Trees
HSC-4: Residential Rain Barrels
HSC-5: Green Roof / Brown Roof
HSC-6: Self-Retaining Areas

Permeable pavement (INF-5) is considered to be a self-retaining HSC in cases where the permeable pavement is designed to manage only rainfall that falls directly on the pavement and a small adjacent tributary area no more than 50 percent of the size of the permeable pavement footprint.

4.3.2. Fact Sheets for Miscellaneous Design Elements

Appendix G.2 provides fact sheets for miscellaneous BMP design elements including soil amendments and engineered bioretention soil media. These are used as components of many other BMP types including some HSCs in order to improve their ability to retain stormwater and pollutants.

4.3.3. Full Infiltration BMPs

If the infiltration feasibility category for a DMA is determined to be "Full Infiltration" based on the method discussed in **Section 2.5** and **Section 4.2**, then full infiltration BMPs must be selected. Full infiltration BMPs are Infiltration LID BMPs that are engineered to capture, store, and infiltrate the DCV and have no design surface discharge (underdrain or outlet structure) until the DCV is exceeded. These types of BMPs may also have losses to ET, but are characterized by having their most dominant volume losses due to infiltration. Methods for sizing full infiltration BMPs to capture and retain the entire DCV are provided in **Appendix E**. **Appendix G.3** provides fact sheets for several types of full infiltration BMPs which include their siting, design, and maintenance criteria.

INF-1: Infiltration Basin
INF-2: Infiltration Trench
INF-3: Bioretention with no Underdrain
INF-4: Drywell
INF-5: Permeable Pavement (concrete, asphalt, and pavers)
INF-6: Underground Infiltration

4.3.3.1. Contingency Recommendations and Contingency Design Options

It is the project applicant's responsibility to select BMPs based on the LID hierarchy and feasibility criteria. It is also the project applicant's responsibility to assure that post-construction operations will conform to applicable sizing criteria and operate safely without creating nuisance conditions. A change in understanding of site conditions that occurs during the detailed design or construction phase shall not be a basis to proceed with a design that is non-compliant, inoperable or unsafe. If the design infiltration rate is not met in post-construction conditions, this may be a basis for the local jurisdiction to withhold acceptance of the BMPs and delay closure of applicable permits.

Project plans and WQMPs can address uncertainty through the inclusion of contingency design elements in BMPs. A contingency design element consists of an adaptation to the BMP design that can be made contingent on new information obtained from infiltration testing as part of detailed design or during construction. A contingency plan identifies the testing required and the thresholds at which a contingency design element would be activated. If the contingency plan potentially involves changing the type of facility, calculations must be presented describing that the system would still conform to applicable LID sizing criteria if the contingency is activated. This may require primary and contingency calculations to be included in the Project WQMP. Examples of contingency design elements are provided in **Table 4-4**.

Contingency planning is strongly recommended where:

- The "feasibility screening infiltration rate" or the "design infiltration rate" (**Appendix D**) is between 0.3 and 2 inches per hour,
- Where it has not been possible to conduct testing adequate to confirm infiltration rates as part of design, or
- Where there is significant potential for disturbance during the construction phase.

A contingency plan may not be needed for sites with relatively high infiltration rates, rigorous design-phase testing, and limited proposed construction-phase disturbance.

Table 4-4. Potential Contingency Design Elements for Infiltration BMPs in Marginal or Uncertain Conditions

Infiltration BMP Type	Potential Contingency Design Elements in Marginal or Uncertain Conditions (some or all)
INF-1: Infiltration Basin	• Include an optional biofiltration media layer and underdrain system that can allow conversion to a biofiltration BMP (BIO-1) within the same footprint. • Provide a contingency to construct a larger footprint. • Provide contingency for the use of dry wells if needed to improve infiltration rates.
INF-2: Infiltration Trench	• Provide a contingency to construct a larger footprint. • Provide contingency for the use of dry wells if needed to improve infiltration rates.
INF-3: Bioretention with no Underdrain	• Design with a capped underdrain and outlet riser such the underdrain can be opened if to convert to a BIO-1. • Provide contingency for the use of dry wells attached to underdrains.
INF-4: Drywell	• Provide a contingency to add additional dry wells.
INF-5: Permeable Pavement (concrete, asphalt, and pavers)	• Provide a contingency to construct a larger footprint. • Provide contingency for the use of dry wells if needed to improve infiltration rates.
INF-6: Underground Infiltration	• Pre-treat influent using a proprietary biofiltration BMP to reduce clogging potential and allow that any water not infiltrated will have already been bio treated. • Provide a contingency to construct a larger footprint. • Provide contingency for the use of dry wells if needed to improve infiltration rates.

4.3.4. Harvest and Use BMPs

Harvest and use (aka Rainwater Harvesting) BMPs are LID BMPs that capture and store stormwater runoff for later use. These BMPs are engineered to store a specified volume of water and have no design surface discharge until this volume is exceeded. The utilization of captured water used should comply with codes and regulations (discussed in **Appendix F**) and should not result in runoff to storm drains or receiving waters. The use of harvest and use BMPs shall be consistent with the BMP selection process described in **Section 2.5.1** and detailed in **Section 4.2**.

Sizing and design of harvest and use must be based on a reliable wet season harvested water demand (See **Appendix F** for guidance).

Appendix E contains methods for sizing harvest and use BMPs both as stand-alone LID BMPs and as a retention component in a treatment train with biotreatment BMPs. **Appendix G.4** provides a fact sheet for two types of harvest and use configurations which include their siting, design, and maintenance criteria.

HU-1: Rainwater Harvesting Cisterns and Tanks

If harvest and use BMPs are used, they shall comply with Orange County Sanitation District Wastewater Discharge Regulations as well as all relevant building and plumbing codes, where applicable. Guidance on building and plumbing codes relevant to stormwater harvest and reuse is located in **Appendix F**. The Orange County Health Care Agency should be involved in this process, as applicable, at the discretion of the project engineer and plan reviewer, to ensure that harvest and use systems do not pose a significant risk to human health and conform to applicable health codes.

4.3.5. Biotreatment BMPs with Partial Infiltration

If the infiltration feasibility category for a DMA is determined to be "Biotreatment with Partial Infiltration" as discussed in **Section 2.5** and **4.2**, then partial infiltration biotreatment BMPs must be implemented. Specific BMPs within this category must be selected to address pollutants of concern.

Biotreatment BMPs with partial infiltration are LID BMPs meeting the MS4 Permit definition of "biofiltration" that are specifically designed to provide some volume reduction through infiltration of a portion of the stormwater that is managed by these BMPs.

Treatment mechanisms include media filtration (through biologically-active media), vegetative filtration (straining, sedimentation, interception, and stabilization of particles resulting from shallow flow through vegetation), general sorption processes (i.e., absorption, adsorption, ion-exchange, precipitation, surface complexation), biologically-mediated transformations, and other processes to address both suspended and dissolved constituents.

Biotreatment BMPs with partial infiltration are identified in the list below and Fact Sheets are included in **Appendix G.5**:

BIO-1: Bioinfiltration (bioretention with raised underdrain)
BIO-2: Vegetated Swale
BIO-3: Vegetated Filter Strip
BIO-4: Dry Extended Detention Basin
BIO-5: Proprietary Biotreatment with Supplemental Retention

4.3.5.1. Biofiltration BMPs

Only biotreatment BMPs that fit the definition of biofiltration BMPs may be used as LID BMPs. Other types of biotreatment BMPs may only be used as treatment control or pretreatment BMPs. They are included in the list of biotreatment BMPs only because they may be available to fulfill LID requirements in NOC after the future adoption of the 5th Term NOC MS4 Permit. Until that time, they are essentially treatment control BMPs for the purposes of the MS4 permit. Biofiltration BMPs are vegetated treat-and-release BMPs that filter stormwater through amended soil media that is biologically active, support plant growth, and also promote infiltration and/or evaporation. Bioinfiltration (BIO-1) and some types of proprietary biotreatment with supplemental retention (BIO-5) are the only kinds of biotreatment BMPs that fit the criteria to be biofiltration. Therefore, only these biotreatment BMPs may be used as LID BMPs.

4.3.5.2. Design to Maximize Volume Reduction and Pollutant Removal

Biotreatment BMPs with partial infiltration must be designed to maximize volume reduction through infiltration and ET and to maximize pollutant removal through proper media selection and design. This affects design parameters and the sizing method used when sizing biotreatment BMPs, as discussed in **Appendix E**. **Appendix E** contains methods for sizing each type of partial infiltration biotreatment BMP both as a stand-alone BMP and including supplemental retention including downstream infiltration, upstream HSCs, and/or upstream harvest and use cisterns.

- Biotreatment BMPs with partial infiltration have specific sizing standards that require a larger volume to be treated. **Appendix E** contains methods for sizing partial infiltration biotreatment BMPs to meet this criterion.
- Biofiltration BMPs with partial infiltration are subject to a target footprint sizes to maximize incidental volume reduction and avoid premature clogging. **Appendix E** contains guidance on determining these target footprint sizes.
- Biotreatment BMPs with partial infiltration are required to include certain design features, including stone storage sumps and/or amended soil to specifically target incidental volume reduction. **Appendix G.5** describes the specific design features that apply to each BMP type.

4.3.5.3. Selecting Biotreatment BMPs to Address Pollutants of Concern

In addition to meeting the MS4 permit definition of "biofiltration BMP", biotreatment BMPs must be selected and designed to effectively treat the Primary and Other POCs for the DMA.

Table 4-5 contains the expected performance for each biotreatment BMP type for various POCs. Performance is rated High, Medium, or Low based on recent analyses of BMP performance monitoring data from the International BMP Database. The BMP ratings are based on the observed effluent quality, observed differences between influent and effluent quality (magnitude and significance), and assumed unit operations and processes (UOPs) provided by each BMP. **A biotreatment BMP must be selected that provides medium or high effectiveness for all POCs.** If a single BMP does not provide medium or high effectiveness for all POCs, select a BMP that provides medium or high effectiveness for the primary POCs. If a single BMP does not provide medium or high effectiveness for all primary POCs, select multiple BMPs for use in a treatment train that collectively provide medium or high effectiveness for all primary POCs. The performance of biotreatment BMPs that do not meet the definition of biofiltration is included in this table in case they are used as treatment control BMPs, which also must effectively treat Primary and Other POCs from the DMA (**Section 4.3.7**).

In order for a BMP to achieve the level of performance anticipated by **Table 4-5**, the BMP must:

- Be designed to contemporary design standards based on the criteria contained in the BMP Fact Sheets (**Appendix G**), the guidance manuals referenced from these fact sheets, and **Section 4.4**.

- Include the assumed UOPs listed in this table. BMPs not found on this list may be acceptable on the basis of the UOPs they provide if they are based on published design criteria. **Table 4-6** relates UOPs to the pollutant classes they address and was used as the basis for expected BMP performance when monitoring data were not available or inconclusive.

Media selection is an important component in biotreatment BMP design to maximize infiltration and ET and address pollutants of concern. Guidance on media selection for biotreatment BMPs is located in **Appendix G.2**. Media selection can affect the BMP performance for various POCs.

Table 4-5: Relative Treatment Performance Rates for Biotreatment BMPs (H=high, M=medium, L=low)

Biotreatment BMP	Assumed Principal Unit Operations and Processes Provided	Suspended solids / sediment/ turbidity	Phosphorus	Nitrogen compounds	Heavy metals	Microbial / viral pathogens	Oils and grease	Dissolved toxic organic compounds	Trash and debris
Bioretention system (BIO-6)	• Particulate Settling • Size Exclusion • Inert Media Filtration • Sorption/Ion Exchange • Microbial Competition/Predation • Biological Uptake • Volume loss (via infiltration, ET)	**H**	**L**	**L**	**H**	**M**	**H**	**M**	**H**
Bioretention system with internal water storage zone and nutrient sensitive media design (BIO-1)	Bioretention UOPs, plus: • Microbially Mediated Transformations (if designed with internal water storage zone)	**H**	**M**	**M**	**H**	**M**	**H**	**M**	**H**
Dry extended detention basin (BIO-4) (For treatment control only)	• Particulate Settling • Size Exclusion • Floatable Capture • Vegetative Filtration (with low-flow channel) • Volume loss (via infiltration, ET)	**M**	**M**	**L**	**M**	**L**	**M**	**L**	**H**
Dry extended detention basin with vegetated sand filter outlet structure (Modified BIO-4) (For treatment control only)	Dry extended detention basin UOPs, plus: • Inert Media Filtration	**M**	**M**	**L**	**M**	**L**	**M**	**L**	**H**
Vegetated Swale (BIO-2) (For treatment control only)	• Vegetative Filtration • Sorption/Ion Exchange • Volume loss (via infiltration, ET)	**M**	**L**	**L**	**M**	**L**	**M**	**M**	**M**

Biotreatment BMP	Assumed Principal Unit Operations and Processes Provided	Suspended solids / sediment/ turbidity	Phosphorus	Nitrogen compounds	Heavy metals	Microbial / viral pathogens	Oils and grease	Dissolved toxic organic compounds	Trash and debris
Vegetated Filter Strip (BIO-3) (For treatment control only)	• Vegetative Filtration • Sorption/Ion Exchange • Volume loss (via infiltration, ET)	**M**	**L**	**L**	**M**	**L**	**M**	**M**	**L**
Wet detention basins and constructed stormwater wetlands (BIO-8 and BIO-9) (For treatment control only except for subsurface-flow wetlands)	• Particulate Settling • Size Exclusion • Floatable Capture • Sorption/Ion Exchange • Microbially Mediated Transformations • Microbial Competition/Predation • Biological Uptake • Solar Irradiation • Volume loss (via infiltration, ET)	**H**	**M**	**M**	**M**	**M**	**H**	**M**	**H**
Proprietary Biotreatment and Treatment Control (BIO-5 and BIO-7)	• Varies by product.	Where proprietary BMPs satisfy the criteria described in **Appendix J**, it is appropriate to conclude that H or M performance for POCs is demonstrated.							

<u>Sources</u>

Strecker, E.W., W.C Huber, J.P. Heaney, D. Bodine, J.J. Sansalone, M.M. Quigley, D. Pankani, M. Leisenring, and P. Thayumanavan, "Critical Assessment of Stormwater Treatment and Control Selection Issues." Water Environment Research Federation, Report No. 02-SW-1. ISBN 1-84339-741-2. 290pp

International Stormwater Best Management Practices (BMP) Database 2014 Performance Summaries *http://www.bmpdatabase.org/Docs/2014%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_StatisticalSummaryReport_December2014.pdf*

Oil and grease, Organics, and Trash and Debris based on review of unit operations and processes; comprehensive dataset not generally available. BMP must include design elements to address pollutants of concern.

Table 4-6: Pollutants Addressed by Unit Operations and Processes

Unit Operations and Process	Suspended solids / sediment	Particulate-bound pollutants	Dissolved Fraction: Nitrogen compounds	Dissolved Fraction: Phosphorus	Dissolved Fraction: Heavy metals	Microbial / viral pathogens	Oils and grease	Toxic organic compounds	Trash and debris
Volume Loss (via Infiltration and ET)	X	X	X	X	X	X	X	X	
Particulate Settling (Density separation)	X	X							X
Size exclusion (trash racks, outlet structures. Media filtration)	X	X							X
Floatable Capture (Density separation -outlet structures designed to remove floatables)							X		X
Vegetative Filtration	X	X					X		X
Inert Media Filtration	X	X			X[1]	X	X		X
Sorption/Ion Exchange within media or soils				X	X		X	X	
Microbially Mediated Transformation (oxidation, reduction, or facultative processes)			X	X	X		X	X	
Microbial Competition/ Predation						X			
Biological Uptake			X	X	X	X	X	X	
Solar Irradiation						X		X	

1 – Inert media filters (i.e. sand) in fact have shown the ability to remove dissolved constituents either after they have been “seasoned” (i.e. organics have built up in the media) or they contain specialized inorganic media (e.g., iron coated sand) which can result in dissolved metals removals.

Principal Source

Strecker, E.W., W.C Huber, J.P. Heaney, D. Bodine, J.J. Sansalone, M.M. Quigley, D. Pankani, M. Leisenring, and P. Thayumanavan, “Critical Assessment of Stormwater Treatment and Control Selection Issues.” Water Environment Research Federation, Report No. 02-SW-1. ISBN 1-84339-741-2. 290pp

4.3.6. Biotreatment BMPs without Infiltration

If the infiltration feasibility category for a DMA is determined to be "Biotreatment with No Infiltration" as discussed in **Section 2.5** and **Section 4.2**, then biotreatment BMPs that do not provide appreciable infiltration are appropriate to implement. Biotreatment BMPs without infiltration are similar to biotreatment BMPs with partial infiltration except that they do not provide significant volume reduction. They provide the same characteristics and treatment mechanisms and are designed to the same general sizing standards, but they are not designed with specific features to promote volume reduction. They may be lined to prevent any amount of infiltration, especially in areas where infiltration would otherwise occur but is not desirable.

Biotreatment BMPs are identified in the list below and Fact Sheets are included in **Appendix G.6**:

BIO-6: Bioretention with Underdrain and Impervious Liner
BIO-7: Proprietary Biotreatment
BIO-8: Wet Detention Basin
BIO-9: Constructed Wetland (Subsurface Flow Configuration)
BIO-10: Other Biotreatment BMPs with an Impervious Liner

Biotreatment BMPs must also be selected to address pollutants of concern per the process described in **Section 4.3.5.3**.

Similar to biotreatment BMPs with partial infiltration, biotreatment BMPs without infiltration must meet the criteria to be called biofiltration BMPs in order to meet LID BMP requirements. The only biotreatment BMPs without infiltration meeting the criteria to be called biofiltration BMPs are bioretention with underdrain and impervious liner (BIO-6), some types of proprietary biotreatment (BIO-7), and subsurface flow wetlands (variation of BIO-9).

4.3.7. Treatment Control BMPs

In some cases, treatment control BMPs may be used as part of LID requirements in combination with other alternative compliance methods. These cases are not covered in this TGD as they are expected to be rare. See **Section 2.5** of the Model WQMP for criteria pertaining to the usage of treatment control BMPs.

Guidance on sizing and design of treatment control BMPs is included in this TGD for cases where a project applicant may use them according to the requirements in the Model WQMP and for cases where they may be selected as a pretreatment option for LID BMPs.

Appendix G.7 provides fact sheets containing siting, design, and maintenance criteria for several types of treatment control BMPs as well as references to other guidance documents.

TRT-1: Sand Filters
TRT-2: Cartridge Media Filter

Biotreatment BMPs that do not meet the definition of biofiltration BMPs are also considered treatment control BMPs.

Similar to biotreatment BMPs, treatment control BMPs must be selected to address the POC for the DMA for which they are proposed. **Table 4-7** contains the expected performance for each treatment control BMP type for various POCs. If biotreatment BMPs that do not meet the definition of biofiltration BMPs are used as treatment control BMPs, their expected performance for various POCs is included in **Table 4-5**.

Table 4-7: Relative Treatment Performance Ratings of Treatment Control BMPs

Unit Operations and Process	Assumed Principal Unit Operations and Processes Provided	Suspended solids / sediment/ turbidity	Phosphorus	Nitrogen compounds	Heavy metals	Microbial / viral pathogens	Oils and grease	Dissolved toxic organic compounds	Trash and debris
Sand Filter (inert)	• Size Exclusion • Floatable Capture • Inert Media Filtration	H	M	M	M	M	H	M	H
Sand Filter (specialized Media)	Sand Filter UOPs, plus: • Sorption/Ion Exchange	H	M	M	M/H	M	H	M	H
Cartridge Media Filter	See proprietary BMP acceptance criteria in Appendix J								
Membrane/bag filter									
Hydrodynamic Separator									

Sources

Strecker, E.W., W.C Huber, J.P. Heaney, D. Bodine, J.J. Sansalone, M.M. Quigley, D. Pankani, M. Leisenring, and P. Thayumanavan, "Critical Assessment of Stormwater Treatment and Control Selection Issues." Water Environment Research Federation, Report No. 02-SW-1. ISBN 1-84339-741-2. 290pp

International Stormwater Best Management Practices (BMP) Database 2014 Performance Summaries *http://www.bmpdatabase.org/Docs/2014%20Water%20Quality%20Analysis%20Addendum/BMP%20Database%20Categorical_StatisticalSummaryReport_December2014.pdf*

Oil and grease, Organics, and Trash and Debris based on review of unit operations and processes; comprehensive dataset not generally available. BMP must include design elements to address pollutants of concern.

4.4. Supplemental LID BMP Design Guidance

4.4.1. Clogging of Infiltration and Filtration Systems

As sediment accumulates in soil and media in LID BMPs and treatment control BMPs, the permeability of the soil or media tends to decline over time. This applies to infiltration surfaces as well as filtration surfaces. Clogging with sediment is typically a progressive process and it is most often the determining factor in required maintenance frequency and usable design life of infiltration and filtration BMPs. As a target, the design life of BMPs relative to major maintenance to alleviate clogging should be at least 10 years.

The lifespan of infiltration and filtration BMPs between major maintenance events is a function of the following factors:

- **Presence of Disturbed Soil:** Sediment loads from disturbed or erodible soils (e.g., dirt roads, dirt parking, erodible slopes) can exceed normal urban sediment loads by orders of magnitude if there is active erosion occurring. The actual load that may occur is challenging or impossible to estimate. Even a few percent of a watershed could erode enough sediment to immediately clog an infiltration or filtration system. Therefore these areas must be kept hydrologically isolated from infiltration or filtration BMPs under all conditions or must be adequately stabilized.
- **Sediment and Gross Solids Concentration in Contributing DMAs**: Land covers that are expected to generate elevated sediment or gross solids concentrations include open space, gravel travel lanes or parking, areas with a high intensity of industrial or commercial uses, and areas with significant steep landscaping. Areas such as rooftops, low traffic roads or paths, well-established, dense vegetation, and depressed landscaped areas do not generate as much sediment.
- **Unit Surface Loading Rate**: The unit surface loading rate is the mass of sediment per unit area of the infiltrating surface (i.e., pounds of sediment per square foot). This is a function of the runoff volume treated, the concentration of sediment in runoff treated, and the infiltrating surface area of the BMP. A higher loading rate (e.g. larger mass of sediment per unit area of the BMP) will cause clogging and degradation faster than a low loading rate. In vegetated systems, plant action can sometimes mitigate low levels of sediment load to provide stable operation, but can be overwhelmed if sediment accumulation occurs too quickly. Typically, BMPs designed with a higher design infiltration or filtration rate and/or a deeper ponding depth have a higher unit loading rate.
- **Vegetation and Weathering Processes (surface vs. subsurface facilities):** Processes associated with vegetation root growth and other biological and weathering processes can reverse or slow compactive and clogging processes in soils and extend the lifespan of these facilities before maintenance is needed. BMPs containing subsurface infiltration galleries or media filters do not contain the same biological activity as BMPs with media exposed to the surface. This lack of biological activity can lead to decreased rates of

pollutant breakdown and aeration, so they are especially vulnerable to clogging. Experience with these types of BMPs in Orange County has shown that they can become clogged within several years, in some cases.

- **Pretreatment Approach:** Pretreatment can be helpful in improving BMP performance and extending BMP usable life. There is a range of approaches that can be used for pretreatment (these approaches are discussed further in the following section):
  - Sacrificial mulch or sand layers.
  - Settling chambers.
  - Approved proprietary "pretreatment" devices.
  - Biofiltration or treatment control BMPs, including approved proprietary "treatment" devices.
- **Factor of safety on infiltration or filtration rate**: A simple way to build in more resiliency is to design with a higher factor of safety. This allows for more decline in infiltration or filtration rate before the BMP falls below its design level of service and needs to be maintained.
- **Outlet control on biofiltration/filtration systems**: An filtration rate outside of the generally accepted range of 5 to 10 inches may not allow treatment processes to occur in non-proprietary systems. However, designing filtration media for this relatively small range can be challenging and can allow a limited decline in infiltration rate before maintenance is required. Through the use of outlet control on the underdrains of the system, the media can be specified with higher permeability (20 to 40 inches per hour) providing a larger factor of safety on clogging and the actual filtration rate can be controlled to 5 to 10 inches per hour.

4.4.1.1. Design Approaches to Demonstrate Acceptable Clogging Risk

Projects can use **Table E-4** provided in **Appendix E.4.1** to demonstrate that the potential for premature clogging is adequately addressed when designing infiltration or filtration BMPs. Reference to this table is included in applicable sizing methods in **Appendix E.3**.

This approach involves all of the following:

- Utilize a prudent factor of safety based on the methodology presented in **Appendix D**, and
- Develop drainage plans to hydrologically isolate areas with exposed soil, gravel, dirt or otherwise high sediment load from entering the BMP under any reasonable condition, and
- Adhere to target minimum footprint sizing factors based on BMP type, DMA tributary area characteristics, and pretreatment approach per the table provided **Appendix E.4.1**.

4.4.2. Selection of Pretreatment BMPs

There is a large range of potential pretreatment approaches and BMPs. Pretreatment BMPs may be necessary or strongly encouraged to reduce clogging (See **Section 4.4.1**). Pretreatment BMPs may also be required to avoid potential impacts to groundwater quality (See **Appendix C**). These recommendations or requirements stem from other sections of this TGD. To support appropriate selection and design of pretreatment approaches, **Table 4-8** identifies pretreatment BMPs and identifies appropriate uses. Guidance on incorporating of these pretreatment BMPs into overall BMP systems is provided in **Appendix G.2**.

Table 4-8. Pretreatment Options and Descriptions

Pretreatment Approach or BMP Type	Description	Sediment Removal Performance	GW Protection Performance	Appropriate Uses
Settling chambers or sacrificial forebay	At least 10 percent (preferably 20 percent) additional volume beyond DCV set aside for pre-settling.	Moderate	Negligible	Where land use is low risk or in combination with other approaches.
Catch basin inserts	Systems intended to strain coarse solids from stormwater as it enters catch basins.	Negligible	Negligible	For trash control only; no significant benefit for clogging or GW quality.
Sacrificial mulch layer	Mulch layer provided on the surface of vegetated systems with commitments to yearly maintenance.	Moderate	Limited	Bioretention systems where clogging risk is low.
Sacrificial sand layer	A course sand layer above the infiltrating surface with a filtration rate 5 to 10 times higher than underlying soil; ability and commitment to replacement of layer.	Moderate	Negligible	Non-vegetated surface or subsurface systems where sand layer can be removed and replaced.
Amended media layers	An engineered bioretention soil media layer (Meeting specification for MISC-2) installed in the surface of a bioretention BMP or infiltration basin to pre-filter sediment and treat other pollutants.	Moderate to high	Medium to high	Bioretention or infiltration systems; Ensure that media layer K_{design} has an appropriate factors of safety over the underlying K_{design} to not become the limiting surface.
Approved "pretreatment" devices	A system with an approved General Use Level Designation for "pretreatment" by Washington State TAPE or equivalent.	Moderate	Limited	Underground or surface systems with adequate head for pretreatment device and low to moderate clogging risk.
Non-proprietary biotreatment or treatment control BMPs	A biotreatment or treatment control BMP with M or H performance for pollutants of concern.	High	Medium to high	Where clogging risk and/or groundwater risks are elevated.
Approved "treatment" devices	A system with an approved General Use Level Designation for "basic treatment" by Washington State TAPE or equivalent.	High	Medium to high	Where clogging risk and/or groundwater risks are elevated.

4.4.3. Design for Maximizing Incidental Volume Reduction in Biofiltration BMPs

Biofiltration BMPs must be designed to maximize volume reduction where feasible. This is primarily achieved by selecting biotreatment BMPs with partial infiltration (BIO-1 or BIO-5) wherever conditions allow for partial infiltration to be feasibly achieved. This is also achieved through providing the target biotreatment BMP footprints as described in **Appendix E.4**. If these two approaches are used, then no further calculations related to volume reduction are needed.

Where projects seek to deviate from standard approaches, the following criteria must be met to demonstrate that volume reduction has been maximized:

- All applicable HSCs must be provided except where they are mutually exclusive with other LID BMPs
- Biotreatment BMPs must use amended media to maximize ET and pollutant removal and maximize contact time of runoff with media
- For biotreatment BMPs with underdrains, retention shall be provided below the underdrain that meets the following criteria:
    - A gravel storage layer shall be installed below the invert elevation of the underdrains, as applicable.
    - Rock should be assumed to have a porosity of 0.4 unless otherwise supported, and
    - The depth of rock should be selected so that the underdrain layer empties in 48 hours. Where the infiltration rate of the underlying soil is not known, a rate of 0.15 in/hr shall be assumed, resulting in a gravel depth of 18 inches.
    - As a target, one-third of the DCV should be included below the elevation of the underdrains.
- Soils shall be amended to promote infiltration

4.4.4. Design for Trash Capture

Where trash is identified as a primary pollutant of concern, BMPs must be designed to remove trash. Additionally, operation of the BMP must not be compromised by trash accumulation.

Additional requirements for trash capture may result from implementation of the Statewide Trash Amendments within future terms of MS4 Permits. Implementing trash control into BMPs now may help avoid retrofits in later permit terms.

Trash control approaches may include:

- Inlet screens or trash racks.
- Trash racks and screens in in the stormwater conveyance system.

- Trash racks or screens within BMPs or on BMP overflows.
- Hydrodynamic separators or other approved pretreatment devices.

Systems must be designed to remove trash that is 5 millimeters and greater.

Selection of trash control approaches should include an assessment of the rate of trash generation that is expected (including consideration of source controls used), the capacity of systems to hold trash without causing nuisance conditions, and the frequency of maintenance that is expected.

4.4.5. Design to Accommodate Off-site Run-on

If off-site run-on occurs to an on-site BMP, the BMPs need only be sized to treat the run-off generated on-site. However, this creates additional design considerations.

- Routing additional area to the BMP may cause the BMP to treat more water relative to its size than if it were only receiving the design storm from on-site flows, so it may require more frequent maintenance. The maintenance frequencies for various maintenance activities in the BMP fact sheets should be increased to account for the increased load of pollutants, sediment, and runoff from the off-site areas relative to the size of the BMP.
- Pollutants of concern must account for off-site areas. This runoff will comingle with project site runoff and therefore all pollutants of concern in the comingled runoff needs to be addressed.
- Inlet and outlet structures must be designed to accommodate or appropriately bypass excess flows resulting from the additional area.
- A project proponent may choose to divert offsite flows around or through the project site without treating them or routing them to on-site BMPs provided that these flows do not comingle with water from the project site that requires treatment.

Where off-site run-on occurs, the project proponent may choose to size and design a LID BMPs to treat all or a portion of off-site flows in order to generate DCV credits which could be transferred to other development projects unable to treat the DCV. Such a system of transfer would need to be in place for this option to apply. The project proponent would need to consult the local jurisdiction for requirements for specific guidelines and requirements for using on-site BMPs to treat off-site flows and generate DCV credits. See Section 3 of the **Model WQMP** for specific criteria related to DCV credits.

4.4.6. Design to Facilitate BMP Design and Maintenance

All structural BMPs will require regular maintenance and inspection in order to properly capture and/or treat runoff. The BMP fact sheets contain BMP-specific maintenance activities and frequencies and design features that are intended to support inspection and maintenance. Ongoing maintenance should be considered when designing the BMP. The measures in this section are intended to aid the BMP designer in maintenance considerations to control costs and meet BMP requirements.

4.4.6.1. Controlling maintenance costs

The most effective way to reduce maintenance costs for structural BMPs is to design the BMP to reduce the required frequency of maintenance activities and extend the BMP usable life. The most effective way to do this is to prevent or reduce sediment and pollutants generated on-site from being delivered to the BMP using source controls, site design BMPs, and using an appropriate pretreatment approach.

Second, BMPs should be located and designed so that they can be readily maintained, including:

- Provide access roads, as applicable.
- Provide pretreatment systems or sacrificial areas that are intended to concentrate the spatial extent of pollutant accumulation and maintenance activities.
- Locate system in areas accessible for maintenance (i.e., not underneath a structure or other site feature)
- Locate system in areas that will not require permits and costly mitigation to perform maintenance activities.
- Establishing maintenance protocols that establish the system as a treatment system and limit the potential future interpretations as a jurisdictional area.

4.4.6.2. Minimize entrainment of captured pollutants

Structural BMPs are required to be designed to minimize the entrainment and bypass of captured pollutants in the course of routine maintenance, normal operation, or overflow. If not properly designed, pollutants and sediment which have been removed from stormwater by the BMP may become entrained in stormwater during maintenance or during large storm events and washed downstream. If maintenance access is not properly considered, then maintenance activities could cause compaction of soils, damage to BMPs, or release of pollutants downstream.

In addition to the maintenance considerations included in the BMP fact sheets, the following measures should be used to ensure that pollutants trapped in the BMP do not become entrained

- Use trash screens or containers that do not allow for trash to be washed downstream at high flow rates.
- Design systems as off-line systems where higher flows bypass the system.
- If systems cannot be off-line, provide an internal bypass that conveys higher flows around areas where sediment and debris is intended to accumulate (e.g., allow bypass of the forebay during higher flows).

- Maintain pretreatment, forebays, detention, or debris collection frequently, before they fill completely.
- Design the BMP and pretreatment to be readily accessible for maintenance including equipment needed for maintenance. Depending on the BMP type, this may require consideration of heavy, large equipment such as heavy trucks, forklifts, vactor trucks, etc. These vehicles can be bulky and difficult to maneuver. A level pad adjacent to the BMP, preferably with no vegetation or irrigation system should be provided, where appropriate, for large equipment access.
- Provide manhole and cleanout access for all underground infrastructure including perforated pipes, storm drains, detention, and infiltration galleries. All manholes should have a ladder or steps for access.

4.4.6.3. Design mechanisms to allow for inspection and verification

Structural BMPs will require regular inspection to verify that they are working properly. To facilitate this, BMPs must be constructed to allow for inspection and verification of capture of the DCV. This may require measurement of volumes, flow rates, sediment, or water quality parameters. To accommodate inspection and verification, the following measures should be considered when designing BMPs:

- Structural BMPs shall include inspection ports for observing all underground components that require inspection and maintenance; a diameter of at least 6 inches is recommended to accommodate a range of water level measurement equipment.
- Silt level posts or other marking shall be included in all BMP components that will trap and store sediment, trash, and/or debris, so that the inspector may determine how full the BMP is with sediment.
- Expectations for vegetation coverage, size, and type should be provided on the structural BMP and/or landscaping plans as appropriate to allow assessment of conditions and needs for maintenance.
- Signage indicating the location and boundary of the structural BMP is recommended

4.4.6.4. Conformance to product-specific maintenance requirements

Proprietary BMPs that are approved by Washington TAPE must have defined maintenance activities and frequencies. The O&M Plan for the site must require that these BMPs be operated according to the maintenance protocols approved by TAPE and require that any project- or climate-specific protocols be developed through adaptive operation over time.

4.4.7. BMP Design Considerations for Facilities Built at a Larger Scale

Regional BMPs meeting specific criteria can be used as a path for compliance with LID, treatment control, and hydromodification criteria for projects that participate in these projects. See Section 3 of the Model WQMP for specific criteria. Additionally, projects developed at a large scale may include the use of centralized LID BMPs at a larger scale, similar to designs that could result though regional BMP pathways.

For the purpose of developing BMP sizing and design for larger-scale facilities, the design guidance included in this TGD should be consulted to develop designs for regional facilities. Specific issues encountered in larger-scale facilities include:

- Larger, more concentrated inflows, possibly requiring more robust energy dissipation and scour protection.
- In the case of biofiltration systems, surface distribution systems may be needed to spread water over the filtration surface to prevent concentrated points of source or overloading the parts of the media bed closer to the inlet. This could be achieved through the use of turf-reinforcement matting in shallow distribution swales.
- Different zones of the system may experience inundation at different intervals, potentially requiring different zones for planting and maintenance.
- Outlet control of underdrain system in biofiltration- or filtration-type systems is likely to be strongly preferred to encourage water to pool over the entire facility and avoid short circuiting in areas that experience most frequent loading.
- Procurement of media and plants in large volume may require specific considerations.
- Excavation and/or media placement methods may require equipment in the floor of the system if the system is too large to reach from the perimeter. Any areas that are compacted must be restored and infiltration or filtration rates should be confirmed following bulk grading and/or media placement.
- The entity responsible for maintenance should have capability and financial resources to perform O&M activities and accommodate unforeseen costs at the larger scale of the facility.

Additionally, for projects constructed at a large scale, project-specific design judgement is likely to be needed.

4.4.8. Additional Design Guidance Materials

The BMP fact sheets contained in **Appendix G** should provide the recommended guidance for most applications. However, not all development/redevelopment projects and scenarios can be considered. When additional guidance is needed beyond the BMP fact sheets, the project proponent should use other BMP guidance manuals such as those listed in **Table 4-9**, below. Note that site-specific adaptation of guidance may be necessary based on differences in climate, pollutants, or permit requirements.

Table 4-9: BMP Reference Manuals for BMP Design Guidance

Manual Name	Description	Link
Minnesota Stormwater Manual	Comprehensive guidance on stormwater management including concepts, pollutant fate and transport, permitting, BMP modeling and credits, non-structural and structural practices, and construction and post-construction issues. Online wiki and easily accessible and navigable.	http://stormwater.pca.state.mn.us/index.php/Main_Page Links to other relevant stormwater manuals: http://stormwater.pca.state.mn.us/index.php/Links_to_other_manuals
Stormwater Management Manual for Western Washington (SWMMWW)	Provides guidance on the measures necessary to control the quantity and quality of stormwater produced by new development and redevelopment, such that they comply with water quality standards and contribute to the protection of receiving waters.	https://fortress.wa.gov/ecy/publications/SummaryPages/1410055.html
Stormwater Best Management Practice Design and Maintenance Manual	Provides design criteria and guidelines for developers, to assist the County in the review and approval of stormwater treatment BMP designs, and to provide guidance on BMP maintenance requirements for those devices that will be publicly maintained.	http://dpw.lacounty.gov/des/design_manuals/StormwaterBMPDesignandMaintenance.pdf
Low Impact Development Standards Manual	Comply with the requirements of the 2012 NPDES MS4 permit for stormwater and non-stormwater discharges from the MS4 within the coastal watersheds of Los Angeles County (CAS004001, Order No. R4-2012-0175).	http://ladpw.org/ldd/lib/fp/Hydrology/Low%20Impact%20Development%20Standards%20Manual.pdf
New Development and Redevelopment BMP Handbook	Provide general guidance for selecting and implementing Best Management Practices (BMPs) to reduce pollutants in runoff in newly developed areas and redeveloped areas to waters of the state. This handbook also provides guidance on developing project-specific stormwater management plans including selection and implementation of BMPs	https://www.casqa.org/sites/default/files/BMPHandbooks/BMP_NewDevRedev_Complete.pdf

Manual Name	Description	Link
	for a particular development or redevelopment project.	
Model BMP Design Manual San Diego Region	This Manual addresses updated onsite post-construction storm water requirements for Standard Projects and Priority Development Projects (PDPs), and provides updated procedures for planning, preliminary design, selection, and design of permanent storm water BMPs based on the performance standards presented in the MS4 Permit. This manual is intended to be used as the basis for jurisdiction-specific BMP Design Manuals.	**http://www.projectcleanwater.org/images/stories/Docs/LDW/BMPDM/SD%20Model%20BMP%20Design%20Manual%20Feb%202016.pdf**
Portland Stormwater Management Manual	Provides policy and design requirements for stormwater management throughout the City of Portland. The requirements in the manual apply to all development, redevelopment, and improvement projects within the City of Portland on private and public property and in the public right-of-way.	**http://www.portlandoregon.gov/bes/64040**
Design Standards Manual and Appendices	Provides guidance on water quality and quantity sizing, best management practice (BMP) selection and design, and provides focused checklists to ensure permit submittal completeness. The DSM was tailored to address specific Port issues and challenges including wildlife attractant restrictions and other Federal Aviation Administration (FAA) requirements, stormwater run-on from off-site areas, impairment pollutants for receiving waters (TMDL and 303(d) listed), low impact development (LID), green infrastructure, sustainability and climate change.	**https://www2.portofportland.com/Inside/MasterSpecsDesignStandards**
Georgia Stormwater Management Manual (GSMM)	Provides guidance on the latest and best post-construction stormwater management practices available to Georgia communities to minimize the negative impacts of increasing stormwater runoff and its associated pollutants.	**http://www.georgiastormwater.com/**

SECTION 5. HYDROMODIFICATION CONTROL SELECTION AND DESIGN

5.1. Introduction

This section describes approaches for designing systems to address HCOCs. HCOCs are defined in **Section 2.6.1**. The basic options for hydromodification control include:

- Demonstrating that the BMPs provided to conform with LID BMP requirements provide the hydrologic performance necessary to meet HCOC criteria
- Adapting or augmenting the design of LID BMPs such that the combined stormwater management systems conform to both LID and hydromodification criteria, or
- Providing separate systems that conform to hydromodification criteria and do not modify the LID BMPs provided as part of Step 5 (See **Section 2.5**).

Additionally, there are possible pathways for conducting in-stream rehabilitation and protection project in order to exempt the project from site-specific compliance or potentially reduce on-site standards as discussed in **Section 2.3.5**. The potential role of in-stream projects is discussed briefly in **Section 5.5.4**, however design approaches described in this section focus on on-site approaches likely to be used by the majority of projects.

This section provides general guidelines for hydromodification design (**Section 5.2**), followed by design approaches specific to complying with applicable criteria (**Section 5.4**) and discusses different types of hydromodification control BMPs and design considerations for them (**Section 5.5**). The SOC HMP describes the calculation methods used in SOC.

Street, road, and surface drainage projects are not addressed specifically in this section, but similar principles presented in this section are applicable for these projects. **Section 2.9** is intended to present the criteria and design process associated with street, road, and surface drainage projects.

5.2. General Guidelines for Hydromodification Design

This section provides brief guidelines and clarifications for incorporating hydromodification into the overall BMP plan. This is not intended to serve as a stepwise process, as there are many potential ways that a designer may prefer to approach hydromodification. Examples of hydromodification design approaches are provided in **Section 5.4** and **Appendix B**.

5.2.1. Defining Points of Compliance

The locations where HCOCs for a project are evaluated are called points of compliance. Points of compliance are the locations where the relevant parameters are compared between pre-development (natural condition) and post-development conditions to determine if an HCOC exists or not and whether they have been adequately mitigated. Points of compliance are not necessarily the same as outlets from DMAs delineated for the purposes of determining LID compliance. The following minimum criteria apply for each point of compliance:

- A point of compliance must be defined at the nearest point to the project where all of the project runoff to a given outfall is combined.
    - If a project has a single pipe/channel that discharges off-site or to a susceptible water body, then this pipe at the point where it crosses the project boundary or discharges to the susceptible water body is the point of compliance.
    - If there are multiple pipes/channels that leave the site, but combine before discharging to a susceptible receiving water, then the point of compliance should be the location where the pipes combine.
- Points of compliance must be defined so that they are at the same location in the pre-development (natural condition) and post-development condition to the extent possible.
- Where a project has multiple outfalls to a susceptible receiving water, the point of compliance must be defined at each point where runoff from the project discharges to the susceptible receiving water.
    - For example, if a project discharges to a susceptible stream at three separate points, a point of compliance should be defined at each point.
- Points of compliance may be defined at the outlet of each DMA. This is not required if other provisions are met, but if this is done, then compliance with criteria at the outlet of each DMA is acceptable to assure that the project complies on an overall basis.

5.2.2. Area to Include in Compliance Calculations

By default, analyses of points of compliance should only account for area within the project boundary. Therefore, if a point of compliance is defined off-site that includes runoff from both on-site and off-site areas, the off-site area tributary to this point of compliance should not be included in the analysis.

For example, the project is located on parcel that has two connection points to the storm sewer system and the point of compliance is at a location further downstream in the piped network where the two connections come back together. There is additional off-site area that enters the pipe before the point of compliance. In this case, the model should evaluate only the project area that is tributary to the point of compliance.

The primary exception is if upstream or downstream area will be managed as part of a BMP that is proposed for the project. In this case, the drainage to that BMP is fundamental to the design and full tributary area to the BMP should be included in the analysis. The pre-development condition in this case should also include the full tributary area to the BMP and must consider this area in its pre-development natural condition.

5.2.3. Similarities and Synergies with LID Design

There are a number of similarities and synergies that can be leveraged when developing integrated BMPs systems that meet both LID and hydromodification design requirements.

- Volume reduction, where feasible, is also an effective approach for hydromodification management. An infiltration compartment can help manage flows at the lower part of the flow duration curve and improve BMP sizing efficiency.
- HSCs and effective site design can improve the efficiency of both LID and hydromodification BMPs. This can involve reduction in flow volume and flow rate and increase in time of concentration. Additionally, isolating critical course sediment areas is beneficial for LID BMP maintenance requirements and is also required as part of compliance with hydromodification criteria.
- In many cases, the scale of analysis can be the same. It is acceptable for points of compliance for hydromodification to be defined at the outlet of DMAs used to determine LID compliance. Compliance with hydromodification requirements at each DMA is not required, but if compliance at each DMA is demonstrated, this assures compliance for the project as a whole. This generally makes for a simpler analysis, but may result in somewhat larger hydromodification BMP requirements if there is a relatively long travel time between the DMA outlets and the actual point of compliance because it ignores this portion of the total travel time and the associated routing.
- Because hydromodification BMPs are designed up to a 10-year flowrate, there are compartments that are only used infrequently and can be “stacked” over LID compartments without creating conditions that interfere with water quality operations frequently enough to be of concern.

5.2.4. Influence of Infiltration and Harvesting Feasibility on Design Integration

Infiltration and harvesting feasibility should have a significant influence on how designs are integrated. For example:

- Infiltration or harvest and use BMPs can be accounted for in hydromodification calculations.
- Incidental losses that occur in hydromodification systems (e.g., open-bottom vaults) can be credited against volume reduction targets; this could justify more compact LID BMPs in combination with losses in hydromodification BMPs.

Examples of design integration for sites with different infiltration feasibility conditions re provided in **Appendix B**.

5.2.5. Differences Between Hydromodification Design and LID Design

There are a number of key differences between hydromodification and LID design and compliance determinations:

- Hydromodification management pertains to hydrologic management at a point of compliance. Unlike LID design which is applied at each DMA separately, this does allow the possibility that within the area contributing to a point of compliance, some areas are over-controlled while others are under-controlled if the net effect at the point of compliance meets requirements.

- Hydromodification BMP design considers larger storm events than LID BMP design. Different tools and methods are required to analyze these storms compared to methods used for LID sizing.

- There is no preference for volume retention versus detention for hydromodification control. While infiltration or harvest and use could be advantageous in design, these processes do not need to be considered beyond what is required to satisfy LID requirements.

- Hydromodification design is most often iterative as it is based on demonstrating that a given hydrologic condition is met rather than meeting a design sizing basis.

5.2.6. Potential Design Conflicts when Incorporating Hydromodification into LID Designs

In any case where LID BMPs are modified in order to also serve a hydromodification purpose, difference in operating objectives need to be considered and potential conflicts resolved. Examples of potential conflicts and approaches for addressing these conflicts include:

Issue: Hydromodification design could result in addition of storage depth that exceeds recommended LID storage depth

Approaches:

- Locate additional storage below ground to help with this.

- Demonstrate that the additional storage depth above the recommended LID depth would only be filled rarely (a couple times per year).
- Provide fencing if ponding depth exceeds 18 inches.

Issue: Hydromodification design could result in higher flow-through rates for detention design than desirable to support settling or filtration.

Approach: Ensure that flow through rates for storage volumes up to LID standards are consistent with LID BMP design criteria. This may result in less optimal detention designs but is mandatory if these facilities are to also address LID criteria.

Issue: Hydromodification design could result in long drawdown times of surface storage

Approaches:

- Locate more storage below ground.
- Do not locate LID treatment systems downstream of detention, which can result in excessively long wetted periods.

Issue: Hydromodification design could result in greater sediment load per unit filter area and result in earlier clogging because the BMP captures a greater fraction of long term runoff, including large events that may mobilize more sediment

Approaches:

- Provide better pretreatment.
- Provide an outlet for detained water that allows this water to bypass treatment (for the portion of the facility volume than the LID sizing criteria).
- Increase footprint and reduce depth.
- Do not locate LID treatment systems downstream of detention, which can result in excessively high loading per unit area.
- Conduct project-specific calculations to demonstrate that clogging is addressed (See **Section 4.4.1** and **Appendix E.4**).

Issue: Hydromodification design could require larger peak flows to be routed into the facility

Approaches:

- Provide adequate energy dissipation and scour protection.
- See design guidance for minimizing entrainment of captured pollutants (**Section 4.4.5**).

Other conflicts may be identified and must be addressed as part of the design and review process.

5.3. Hydromodification Design Approaches in North Orange County

[Placeholder for future addition after adoption of the 5th Term NOC MS4 Permit]

Table 5-1. Guidelines for Selecting Hydromodification Design Approach in SOC

5.4. Hydromodification Design Approaches in South Orange County

In South Orange County, project proponents must develop hydromodification designs using the methods in the HMP and avoid impacts to critical coarse sediment yield areas. This section contains example design approaches to meet both of these requirements while integrating with LID designs.

Selection between approaches depends on the types of BMPs feasible for the site and designer preference based on site-specific condition. **Table 5-2** provides guidelines for selecting approaches and the following subsections provide guidelines for these approaches. Conceptual examples of design approaches and conformance calculations are provided in **Appendix B**.

In each of these cases, the analysis of pre-development (existing) and post-project flow durations must occur at each point of compliance for the project. If these criteria are met at the discharge point from each LID BMP, then they can be assumed to be met at each point of compliance.

If the site is an existing graded and developed site, the pre-development condition should be based on the slopes and soils currently present at the site, but with impervious cover removed and representative local vegetative cover used in the pre-development condition.

Table 5-2. Guidelines for Selecting Hydromodification Design Approach in SOC

Suggested Approach		Favorable Conditions for Suggested Approach
1	Demonstrate that LID BMPs Conform to Flow Duration Control Requirements (**Section 5.4.1**)	This case is very rarely applicable except in cases with D soils and low impervious cover. Most of the time, hydromodification control will require a larger BMP size than LID BMPs.
2	Provide Supplemental Infiltration or Flow Duration Control within Combined Facilities (**Section 5.4.2**)	Where the allowable release rates for flow duration control do not conflict with drawdown times of LID (i.e., water ponded for too long) or require orifice sizes that are too small to maintain. Where space allows for enlargement of combined LID/hydromodification facilities.
3	Provide Separate LID and Flow Duration Control Systems (**Section 5.4.3**)	Where it is not practicable or not preferable to design facilities with combined purposes. Where hydromodification storage needs to be below ground due to space constraints.

5.4.1. Approach 1: Demonstrate that LID BMPs Eliminate HCOCs

This option involves no changes to the design of LID BMPs. However, it involves conducting separate hydrologic analyses of these systems using SOHM to demonstrate that the system meet the criteria in **Section 2.6.1.2**.

This option could also involve minor changes to the outlet control of these systems, provided that LID sizing and design criteria are still demonstrated to be met after these modifications.

5.4.2. Approach 2: Provide Supplemental Infiltration or Flow Duration Control within Combined Facilities

This option could involve increasing the footprint of LID facilities, adding storage compartments above or below LID storage compartments, and/or incorporating multiple-stage outlet structures so that systems conform to both LID and hydromodification criteria.

It is critical that this integration does not interfere with LID biofiltration treatment processes. Typical conflicts may include:

- Ponding and media saturation occurs for longer than 24 hours on a typical basis. Biofiltration BMPs should drain to at least 12 inches below the media surface within 24 hours after a typical DCV event.
- Media filtration rates exceed what is appropriate for treatment (5 to 10 inches per hour).
- Orifices are so small for flow duration control that they may become clogged, which could greatly upset treatment processes due to plant die-off, requiring major rehabilitation.

Meeting flow duration and LID criteria is inherently an iterative process. A suggested design approach is to:

- First use SOHM to determine the overall sizing and flow control parameters needed to conform with flow duration control criteria. How large of a volume is needed? How fast can low flows be released? What is the drawdown time from various points in the facility?
- Determine if there is space to simply increase the LID footprint, maintaining a standard LID depth profile, to provide the required volume for flow duration control. Check that drawdown times do not violate biofiltration design standards.
- If not, determine if there is an opportunity to provide the overall required volume using an adapted profile. This could include:

- A detention storage volume over the LID biofiltration storage volume, such that the biofiltration volume drains in an acceptable time and the detention storage is not utilized more than about 2 times per year on average.
- Add a detention layer below the LID biofiltration storage volume, such that extended detention would occur without extended surface ponding.

- Conduct flow duration and LID sizing checks on the combined system to demonstrate that both standards are met.

5.4.3. Approach 3: Provide Separate LID and Flow Duration Control Systems

This option involves designing separate LID and flow duration control systems. These systems may be designed at the same scale (e.g., both for the same DMA, but not integrated), or at different scales (e.g., LID at the DMA scale and flow duration control at the point of compliance).

- LID BMP would be sized based on LID sizing methods
- Flow duration control would be designed using SOHM, which could also account for the effect of LID features.

In general, individual sizing and design methods would be used.

There is one case in which a separate design approach could still be synergistic: If a DMA is classified as biotreatment with partial infiltration, it would not typically be permissible to use a compact proprietary biofilter that does not maximize infiltration. However, if a flow duration control detention system could be designed with a permeable bottom and design features to promote infiltration (sump area; design approaches to minimize compaction under the system), then the footprint of the soft-bottomed detention system could be used as the basis for maximizing retention and compact biofiltration systems could be used to treat flow at a rate of 150 percent of the DCV before it enters the flow duration control system. The footprint of the flow duration control system should be similar or larger to the footprint of a traditional biofiltration BMP with partial infiltration (approximately 3 percent of impervious area).

5.4.4. Mitigate Impacts to Critical Coarse Sediment Yield Areas

In addition to meeting flow duration control criteria, the SOC MS4 Permit and the HMP also require that Priority Projects avoid critical sediment yield areas or implement measures to allow critical coarse sediment to be discharged to the receiving waters, such that there is no net impact to the receiving water. See the HMP for guidance on identifying critical course sediment areas and avoiding or mitigating these areas, if present on site. Additionally, exhibits showing preliminary mapping of potential coarse sediment areas are included in **Appendix N.8**.

5.5. Hydromodification Control BMP Types

The design approaches described in **Section 5.4** refer to various types of hydromodification control BMPs. This section provides an introduction to each type of hydromodification control BMP.

5.5.1. On-Site / Distributed Controls

This type of BMP refers to LID BMPs that have been specifically sized and designed to meet applicable hydromodification control criteria. The design criteria applicable to the LID of interest, as described in **Section 4** and **Appendix G**, still applies even if the LID BMP is also used for hydromodification control. Deviations within the ranges allowed for LID design are acceptable. For example, adding additional depth of gravel below a bioretention system with underdrains can typically be done without concerns about increased ponding time or reduction in treatment performance.

5.5.2. Combination Basins

Combination basins refers to detention basins that have LID BMPs incorporated into the floor of the basin. Under most typical conditions, the LID BMP (of whatever type) in the floor of the basin operates as if it were located in any other location. Under storm events that are more critical for meeting the applicable flow control criteria, the ponding depth in the basin would exceed the LID storage volume and fill or partly fill the detention storage volume. Where this occurs infrequently and appropriate design approaches are followed, these two functions can coexist within a single facility. Specific design approaches and considerations for combination basins are discussed in 5.4.2.

5.5.3. Flow Control Basins or Vaults

Flow control basins or vaults should follow standard design approaches for detention basins or underground vaults described in applicable BMP design manuals. These BMPs do not serve a water quality purpose and should be designed to:

- Meet hydraulic flow control objectives applicable to the project,
- Avoid nuisance conditions such as standing water,
- Avoid public safety issues, and
- Facilitate inspection and maintenance.

5.5.4. In-Stream Controls

In some cases, hydromodification management can also be achieved by in-stream controls, including drop structures, bed and bank reinforcement, grade control structures, floodplain reconnection, and other approaches. The requirements for selecting in-stream controls versus on-site controls must always be based on a project-specific analysis and appropriate permitting process. This TGD does not provide guidance on this process. The Water Quality Improvement Plan includes a Conceptual Geomorphically Referenced Basis of Design approach which may become applicable for certain land development projects seeking to pursue in-stream controls in the future.

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SECTION 6. SOURCE CONTROL MEASURES

6.1. Introduction

Source Control BMPs reduce the potential for stormwater runoff and pollutants from coming into contact with one another. Source Control BMPs are defined as any administrative action, design of a structural facility, usage of alternative materials, and operation, maintenance, inspection, and compliance of an area to eliminate or reduce stormwater pollution. Each Priority Project and non-Priority Project is required to implement all Source Control BMP(s) that are applicable to the project.

Applicable Source Control BMPs (which includes subcategories of routine non-structural BMPs, routine structural BMPs and BMPs for individual categories/project features) are required to be incorporated into all new development and significant redevelopment projects regardless of their priority, including those identified in an applicable regional or watershed program, unless they do not apply due to the project characteristics. California Stormwater Quality Association (CASQA) BMP Fact Sheet numbers are included in parentheses where applicable.

6.2. Non-Structural Measures

N1 Education for Property Owners, Tenants and Occupants

For developments with no Property Owners Association (POA) or with POAs of less than fifty (50) dwelling units, practical information materials will be provided to the first residents/occupants/tenants on general housekeeping practices that contribute to the protection of stormwater quality. These materials will be initially developed and provided to first residents/occupants/tenants by the developer. Thereafter, such materials will be available through the Permittees' education program. Different materials for residential, office commercial, retail commercial, vehicle-related commercial and industrial uses will be developed. The developer is free to draw on existing materials from the County of Orange and other sources in developing these educational materials, and existing materials may be adapted and tailored to the project, as needed.

For developments with POA and residential projects of more than fifty (50) dwelling units, project conditions of approval will require that the POA periodically provide environmental awareness education materials, made available by the municipalities, to all of its members. Among other things, these materials will describe the use of chemicals (including household type) that should be limited to the property, with no discharge of wastes via hosing or other direct discharge to gutters, catch basins and storm drains. Educational materials available from the County of Orange can be downloaded here:
http://www.ocwatersheds.com/publiced/residents/glltd

N2 Activity Restrictions

If a property owner association (POA) is formed, conditions, covenants and restrictions (CCRs) must be prepared by the developer for the purpose of surface water quality protection. An example would be not allowing car washing outside of established community car wash areas in multi-unit complexes. Alternatively, use restrictions may be developed by a building operator through lease terms, etc. These restrictions must be included in the Project WQMP.

N3 (SC-73) Landscape Management

Identify on-going landscape maintenance requirements that are consistent with those in the County Water Conservation Resolution (or city equivalent) that include fertilizer and/or pesticide usage consistent with Management Guidelines for Use of Fertilizers (**DAMP Section 5.5**). Statements regarding the specific applicable guidelines must be included in the Project WQMP.

N4 BMP Maintenance

The Project WQMP shall identify responsibility for implementation of each non-structural BMP and scheduled cleaning and/or maintenance of all structural BMP facilities.

N5 Title 22 CCR Compliance

Compliance with Title 22 of the California Code of Regulations (CCR) and relevant sections of the California Health & Safety Code regarding hazardous waste management is enforced by County Environmental Health on behalf of the State. The Project WQMP must describe how the development will comply with the applicable hazardous waste management section(s) of Title 22.

N6 Local Water Quality Permit Compliance

The Permittees, under the Water Quality Ordinance, may issue permits to ensure clean stormwater discharges from fuel dispensing areas and other areas of concern to public properties.

N7 (SC-11) Spill Contingency Plan

A Spill Contingency Plan is prepared by building operator or occupants for use by specified types of building or suite occupancies. The Spill Contingency Plan describes how the occupants will prepare for and respond to spills of hazardous materials. Plans typically describe stockpiling of cleanup materials, notification of responsible agencies, disposal of cleanup materials, documentation, etc.

N8 Underground Storage Tank Compliance

Compliance with State regulations dealing with underground storage tanks, enforced by County Environmental Health on behalf of State.

N9 Hazardous Materials Disclosure Compliance

Compliance with Permittee ordinances typically enforced by respective fire protection agencies for the management of hazardous materials. The Orange County, health care agencies, and/or other appropriate agencies (i.e., Department of Toxics Substances Control) are typically responsible for enforcing hazardous materials and hazardous waste handling and disposal regulations.

N10 Uniform Fire Code Implementation

Compliance with Article 80 of the Uniform Fire Code enforced by fire protection agency.

N11 (SC-60) Litter Control

For industrial/commercial developments and for developments with POAs, the owner/POA should be required to implement trash management and litter control procedures aimed at reducing pollution of drainage water. The owner/POA may contract with their landscape maintenance firms to provide this service during regularly scheduled maintenance, which should consist of litter patrol, emptying of trash receptacles, and noting trash disposal violations by tenants/homeowners or businesses and reporting the violations to the owner/POA for investigation.

N12 Employee Training

Education program (see N1) as it would apply to future employees of individual businesses. Developer either prepares manual(s) for initial purchasers of business site or for development that is constructed for an unspecified use makes commitment on behalf of POA or future business owner to prepare. An example would be training on the proper storage and use of fertilizers and pesticides, or training on the implementation of hazardous spill contingency plans.

N13 (SD-31) Housekeeping of Loading Docks

Loading docks typically found at large retail and warehouse-type commercial and industrial facilities should be kept in a clean and orderly condition through a regular program of sweeping and litter control and immediate cleanup of spills and broken containers. Cleanup procedures should minimize or eliminate the use of water if plumed to the storm sewer. If wash water is used, it must be disposed of in an approved manner and not discharged to the storm drain system. If there are no other alternatives, discharge of non-stormwater flow to the sanitary sewer must be at an acceptable discharge point such as a cleanout, oil/water separator, grease interceptor, or industrial sewer connection. All sewer discharges shall be in accordance with the Orange County Sanitation District's Wastewater Discharge Regulations and/or Washwater Disposal Guidelines.

N14 (SC-74) Catch Basin Inspection

For industrial/commercial developments and for developments with privately maintained drainage systems, the owner is required to have at least 80 percent of drainage facilities inspected, cleaned and maintained on an annual basis with 100 percent of the facilities included in a two-year period. Cleaning should take place in the late summer/early fall prior to the start of the rainy season. Drainage facilities include catch basins (storm drain inlets) detention basins, retention basins, sediment basins, open drainage channels and lift stations. Records should be kept to document the annual maintenance.

N15 (SC-43, SC-70) Street Sweeping Private Streets and Parking Lots

Streets and parking lots are required to be swept prior to the storm season, in late summer or early fall, prior to the start of the rainy season or equivalent as required by the governing jurisdiction.

N16 (SD-30, SC-20) Retail Gasoline Outlets

Retail gasoline outlets (RGOs) are required to follow the guidelines of this TGD and Model WQMP and non-structural source control operations and maintenance BMPs shown in the CASQA Structural Source Control Fact Sheet SD-30, and Non-structural Source Control Fact Sheet (SC-20).

Other Non-structural Measures for Public Agency Projects

As required by the Model WQMP other non-structural measures shall be implemented and included in the Project WQMP as applicable for new public agency Priority Projects as described in the Municipal Activity fact sheets **http://media.ocgov.com/gov/pw/watersheds/documents/bmp/municipalactivities.asp**. These include BMPs FF-1 through FF-13 for Fixed Facilities and DF-1 for Drainage Facilities. These are listed in **Section 6.4**, below.

6.3. Structural Measures

The following measures are applicable to all project types. CASQA BMP Fact Sheet numbers are included in parentheses where applicable; these fact sheets provide further detail on these BMPs.

6.3.1. S1 (SD-13) Provide Storm Drain System Stenciling and Signage

Storm drain stencils are highly visible source control messages, typically placed directly adjacent to storm drain inlets. The stencils contain a brief statement that prohibits the dumping of improper materials into the municipal storm drain system. Graphical icons, either illustrating anti-dumping symbols or images of receiving water fauna, are effective supplements to the anti-dumping message. Stencils and signs alert the public to the destination of pollutants discharged into stormwater. The following requirements should be included in the project design and shown on the project plans:

1. Provide stenciling or labeling of all storm drain inlets and catch basins, constructed or modified, within the project area with prohibitive language (such as: "NO DUMPING-DRAINS TO OCEAN") and/or graphical icons to discourage illegal dumping.
2. Post signs and prohibitive language and/or graphical icons, which prohibit illegal dumping at public access points along channels and creeks within the project area.
3. Maintain legibility of stencils and signs.

See CASQA Stormwater Handbook BMP Fact Sheet SD-13 for additional information.

6.3.2. S2 (SD-34) Design Outdoor Hazardous Material Storage Areas to Reduce Pollutant Introduction

Improper storage of materials outdoors may increase the potential for toxic compounds, oil and grease, fuels, solvents, coolants, wastes, heavy metals, nutrients, suspended solids, and other pollutants to enter the municipal storm drain system. Where the plan of development includes outdoor areas for storage of hazardous materials that may contribute pollutants to the municipal storm drain system, or include transfer areas where incidental spills often occur, the following stormwater BMPs are required:

1. Hazardous materials with the potential to contaminate urban runoff shall either be: (1) placed in an enclosure such as, but not limited to, a cabinet, shed, or similar structure that prevents contact with storm water or spillage to the municipal storm drain system; or (2) protected by secondary containment structures (not double wall containers) such as berms, dikes, or curbs.
2. The storage area shall be paved and sufficiently impervious to contain leaks and spills.
3. The storage area shall have a roof or awning to minimize direct precipitation and collection of stormwater within the secondary containment area.
4. Any stormwater retained within the containment structure must not be discharged to the street or storm drain system.
5. Location(s) of installations of where these preventative measures will be employed must be included on the map or plans identifying BMPs.

See **CASQA Stormwater Handbook Section 3.2.6 and BMP Fact Sheet SD-34** for additional information.

6.3.3. S3 (SD-32) Design Trash Enclosures to Reduce Pollutant Introduction

Design trash storage areas to reduce pollutant introduction. All trash container areas shall meet the following requirements (limited exclusion: detached residential homes):

1. Paved with an impervious surface, designed not to allow run-on from adjoining areas, designed to divert drainage from adjoining roofs and pavements diverted around the area, screened or walled to prevent off-site transport of trash; and
2. Provide solid roof or awning to prevent direct precipitation.

Connection of trash area drains to the municipal storm drain system is prohibited.

Potential conflicts with fire code and garbage hauling activities should be considered in implementing this source control.

See **CASQA Stormwater Handbook Section 3.2.9 and BMP Fact Sheet SD-32** for additional information.

6.3.4. S4 (SD-12) Use Efficient Irrigation Systems and Landscape Design

Projects shall design the timing and application methods of irrigation water to minimize the runoff of excess irrigation water into the municipal storm drain system. The following methods to reduce excessive irrigation runoff shall be considered, and incorporated on common areas of development and other areas where determined applicable and feasible by the Permittee:

1. Employing rain shutoff devices to prevent irrigation after precipitation.
2. Designing irrigation systems to each landscape area's specific water requirements.
3. Using flow reducers or shutoff valves triggered by a pressure drop to control water loss in the event of broken sprinkler heads or lines.
4. Implementing landscape and irrigation plan consistent with County Water Conservation Ordinance or city equivalent, which may include provision of water sensors, programmable irrigation times (for short cycles), etc.
5. The timing and application methods of irrigation water shall be designed to minimize the runoff of excess irrigation water into the municipal storm drain system.
6. Employing other comparable, equally effective, methods to reduce irrigation water runoff.
7. Group plants with similar water requirements in order to reduce excess irrigation runoff and promote surface filtration. Choose plants with low irrigation requirements (for example, native or drought tolerant species). Consider other design features, such as:

    - Use mulches (such as wood chips or shredded wood products) in planter areas without ground cover to minimize sediment in runoff.
    - Install appropriate plant materials for the location, in accordance with amount of sunlight and climate, and use native plant material where possible and/or as recommended by the landscape architect.
    - Leave a vegetative barrier along the property boundary and interior watercourses, to act as a pollutant filter, where appropriate and feasible.
    - Choose plants that minimize or eliminate the use of fertilizer or pesticides to sustain growth.

Irrigation practices shall comply with local and statewide ordinances related to irrigation efficiency.

This source control measure must be carefully implemented, inspected and maintained for all priority and non-Priority Projects as a required element to address the Highest Priority Water

Quality Condition associated with unnatural dry weather flow regime established in the Water Quality Improvement Plan.

6.3.5. Dry Weather Flow Source Prohibition for Areas Not Draining to LID BMPs

Activities that are a potential source of dry weather flows, including irrigation, routing of air conditioner condensate to storm drains, car washing discharges to MS4, street washing discharges to MS4 and other applicable activities that have the potential to produce non-stormwater discharges to the MS4 must be prohibited with the following exceptions:

- Areas of the project that drain to LID BMPs with full or partial infiltration capacity.
- Areas of the project that drain to harvesting systems.
- Areas permitted to drain to the sanitary sewer system.
- Areas of the project that drain to landscaped pervious areas capable of retaining the dry weather runoff.
- Use of advanced, low-water use irrigation systems with a commitment to routine monitoring of systems to ensure overspray or other over-irrigation runoff does not occur.
- Non-stormwater discharges exempted per Section E.1.b of the MS4 Permit.

This source control measure must be implemented, inspected and maintained for all Priority and Non-Priority Projects as a required element to address the Highest Priority Water Quality Condition associated with unnatural dry weather flow regime established in the Water Quality Improvement Plan.

6.3.6. S5 Protect Slopes and Channels

Projects shall protect slopes and channels as described in **Section 3.4** of this TGD.

6.3.7. S6 (SD-31) Loading Dock Areas

Loading /unloading dock areas shall include the following:

1. Cover loading dock areas, or design drainage to preclude run-on and runoff, unless the material loaded and unloaded at the docks does not have potential to contribute to stormwater pollution, and this use is ensured for the life of the facility.
2. Direct connections to the municipal storm drain system from below grade loading docks (truck wells) or similar structures are prohibited. Stormwater can be discharged through a permitted connection to the storm drain system with a treatment control BMP applicable to the use.
3. Other comparable and equally effective features that prevent unpermitted discharges to the municipal storm drain system.
4. Housekeeping of loading docks shall be consistent with N13.

See CASQA Stormwater Handbook Section 3.2.8 for additional information.

6.3.8. S7 (SD-31) Maintenance Bays

Maintenance bays shall include the following:

1. Repair/maintenance bays shall be indoors; or, designed to preclude urban run-on and runoff in an equally effective manner.
2. Design a repair/maintenance bay drainage system to capture all wash water, leaks and spills. Provide impermeable berms, drop inlets, trench catch basins, or overflow containment structures around repair bays to prevent spilled materials and wash-down waters from entering the storm drain system. Connect drains to a sump for collection and disposal. Direct connection of the repair/maintenance bays to the municipal storm drain system is prohibited. If there are no other alternatives, discharge of non-stormwater flow to the sanitary sewer may be considered only if allowed by the local sewerage agency through permitted connection.

Other features which are comparable and equally effective that prevent discharges to the municipal storm drain system without appropriate permits.

See CASQA Stormwater Handbook Fact Sheet SD-31 for additional information.

6.3.9. S8 (SD-33) Vehicle Wash Areas

Projects that include areas for washing /steam cleaning of vehicles shall use the following:

1. Self-contained or covered with a roof or overhang.
2. Equipped with a wash racks, and with the prior approval of the sewerage agency (Note: Discharge monitoring may be required by the sewerage agency).
3. Equipped with a clarifier or other pretreatment facility.
4. If there are no other alternatives, discharge of non-stormwater flow to the sanitary sewer may be considered only allowed by the local sewerage agency through permitted connection. Alternately, non-storm water discharges may require a separate NPDES permit in order to discharge to the MS4. Some local jurisdictions also have permitting systems in place for these situations.
5. Other features which are comparable and equally effective that prevent unpermitted discharges, to the municipal storm drain system.

This source control measure must be carefully implemented, inspected and maintained for all Priority and Non-Priority Projects as a required element to address the Highest Priority Water Quality Condition associated with unnatural dry weather flow regime established in the Water Quality Improvement Plan. Any separate MS4 permitting of these facilities administered by local jurisdiction must be consistent with the Water Quality Improvement Plan.

See CASQA Stormwater Handbook Sections 3.2.7 and 3.2.10 and Fact Sheet SD-33 for additional information.

6.3.10. S9 (SD-36) Outdoor Processing Areas

Outdoor process equipment operations, such as rock grinding or crushing, painting or coating, grinding or sanding, degreasing or parts cleaning, landfills, waste piles, and wastewater and solid waste handling, treatment, and disposal, and other operations determined to be a potential threat to water quality by the Permittee shall adhere to the following requirements.

1. Cover or enclose areas that would be the sources of pollutants; or, slope the area toward a sump that will provide infiltration or evaporation with no discharge; or, if there are no other alternatives, discharge of non-stormwater flow to the sanitary sewer may be considered only allowed by the local sewerage agency through permitted connection.
2. Grade or berm area to prevent run-on from surrounding areas.
3. Installation of storm drains in areas of equipment repair is prohibited.
4. Other features which are comparable or equally effective that prevent unpermitted discharges to the municipal storm drain system.
5. Where wet material processing occurs (e.g. Electroplating), secondary containment structures (not double wall containers) shall be provided to hold spills resulting from accidents, leaking tanks or equipment, or any other unplanned releases (Note: If these are plumbed to the sanitary sewer, the structures and plumbing shall be in accordance with Section 7.II - 8, Attachment D, and with the prior approval of the sewerage agency). Design of secondary containment structures shall be consistent with "Design of Outdoor Material Storage Areas to Reduce Pollutant Introduction".

Some of these land uses (e.g. landfills, waste piles, wastewater and solid waste handling, treatment and disposal) may be subject to other permits including Phase I Industrial Permits that may require additional BMPs.

See CASQA Stormwater Handbook Section 3.2.5 for additional information.

6.3.11. S10 Equipment Wash Areas

Outdoor equipment/accessory washing and steam cleaning activities shall use the following:

1. Be self-contained or covered with a roof or overhang.
2. Design an equipment wash area drainage system to capture all wash water. Provide impermeable berms, drop inlets, trench catch basins, or overflow containment structures around equipment wash areas to prevent wash -down waters from entering the storm drain system. Connect drains to a sump for collection and disposal. Discharge from equipment wash areas to the municipal storm drain system is prohibited. If there are no other alternatives, discharge of non-stormwater flow to the sanitary sewer may be considered, but only when allowed by the local sewerage agency through a permitted connection.
3. Other comparable or equally effective features that prevent unpermitted discharges to the municipal storm drain system.

6.3.12. S11 (SD-30) Fueling Areas

Fuel dispensing areas shall contain the following:

1. At a minimum, the fuel dispensing area must extend 6.5 feet (2.0 meters) from the corner of each fuel dispenser, or the length at which the hose and nozzle assembly may be operated plus 1 foot (0.3 meter), whichever is less.
2. The fuel dispensing area shall be paved with Portland cement concrete (or equivalent smooth impervious surface). The use of asphalt concrete shall be prohibited.
3. The fuel dispensing area shall have an appropriate slope (2% - 4%) to prevent ponding, and must be separated from the rest of the site by a grade break that prevents run-on of stormwater.
4. An overhanging roof structure or canopy shall be provided. The cover's minimum dimensions must be equal to or greater than the area of the fuel dispensing area in the first item above. The cover must not drain onto the fuel dispensing area and the downspouts must be routed to prevent drainage across the fueling area. The fueling area shall drain to the project's Treatment Control BMP(s) prior to discharging to the municipal storm drain system.

See CASQA Stormwater Handbook Section 3.2.11 and BMP Fact Sheet SD-30 for additional information.

6.3.13. S12 (SD-10) Site Design and Landscape Planning (Hillside Landscaping)

Hillside areas that are disturbed by project development shall be landscaped with deep-rooted, drought tolerant plant species selected for erosion control, satisfactory to the local permitting authority.

6.3.14. S13 Wash Water Controls for Food Preparation Areas

Food establishments (per State Health & Safety Code 27520) shall have either contained areas or sinks, each with sanitary sewer connections for disposal of wash waters containing kitchen and food wastes. If located outside, the contained areas or sinks shall also be structurally covered to prevent entry of stormwater. Adequate signs shall be provided and appropriately placed stating the prohibition of discharging washwater to the storm drain system.

6.3.15. S14 Community Car Wash Racks

In complexes larger than 100 dwelling units where car washing is allowed, a designated car wash area that does not drain to a storm drain system shall be provided for common usage. Wash waters from this area may be directed to the sanitary sewer (with the prior approval of the sewerage agency); to an engineered infiltration system; or to an equally effective alternative. Pretreatment may also be required.

This source control measure must be carefully implemented, inspected and maintained for all priority and non-Priority Projects as a required element to address the Highest Priority Water

Quality Condition associated with unnatural dry weather flow regime established in the Water Quality Improvement Plan. Elimination of flow is required; it is not adequate to remove pollutants from car washwater.

6.4. Municipal Non-Structural Source Control Measures

The following measures are applicable to fixed facility municipal projects such as maintenance yards, schools, and libraries. Generally, these controls are more applicable to municipal projects than the fact sheets contained in **Section 6.2**, however other structural and nonstructural controls described in **Section 6.2** and **6.3** shall be used where applicable. The links below contain the most recent versions of the Fixed Facility fact sheets, which can also be found at **http://media.ocgov.com/gov/pw/watersheds/documents/bmp/municipalactivities.asp**.

- **FF-1, Bay/Harbor Activities**
- **FF-2, Building Maintenance and Repair**
- **FF-3 Equipment Maintenance and Repair**
- **FF-4, Fueling**
- **FF-5, Landscape Maintenance**
- **FF-6, Material Loading and Unloading**
- **FF-7, Material Storage, Handling, and Disposal**
- **FF-8, Minor Construction**
- **FF-9, Parking Lot Maintenance**
- **FF-10, Spill Prevention and Control**
- **FF-11, Vehicle and Equipment Cleaning**
- **FF-12, Vehicle and Equipment Storage**
- **FF-13, Waste Handling and Disposal**

APPENDICES

SOUTH ORANGE COUNTY

TECHNICAL GUIDANCE DOCUMENT

September 28, 2017

Version Notes:

This release of the TGD is intended to be used to support project development in South Orange County. In combination with the Model WQMP, this document is intended to serve as the "Model BMP Design Manual" for South Orange County pursuant to the requirements of the San Diego Regional MS4 Permit (Order No. 2013-0001 as amended by Orders 2015-0001 and 2015-0100).

THIS DOCUMENT IS NOT FOR USE IN NORTH ORANGE COUNTY AT THIS TIME. A subsequent reissuance of this TGD is anticipated in the future to support project development in North Orange County upon adoption of the 5^{th} Term MS4 Permit in the North Orange County Region. To aid in the future incorporation of the North Orange County MS4 Permit into this TGD once the new permit is adopted, placeholders have been incorporated throughout the TGD for the subsections, figures, tables, and appendices specific to North Orange County.

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EXAMPLES

APPENDIX A. EXAMPLES OF BMP DESIGN INTEGRATION IN NORTH ORANGE COUNTY [PLACEHOLDER]

[This appendix does not apply to projects in the South Orange County Permit Region. This appendix is a placeholder for the addition of content specific to North Orange County after adoption of the 5th Term North Orange County MS4 Permit. This content would be added through a subsequent reissuance of this TGD.]

APPENDIX B. EXAMPLES OF BMP DESIGN INTEGRATION IN SOUTH ORANGE COUNTY

Introduction to Integrated Structural BMP Sizing Approach

Priority Projects must demonstrate compliance with LID and hydromodification control requirements separately. However, these provisions overlap significantly and some BMPs may fulfill or partially fulfill both requirements. Substantial guidance is provided in the body of this TGD (**Section 2.6**, **Section 5**) regarding design integration approaches in cases where hydromodification requirements apply. These sections also discuss the potential conflicts in design and the associated checks that must accompany design integration.

The purpose of this appendix is to provide examples of integrated BMP systems that can simultaneously meet the requirements for both LID and hydromodification for projects in SOC. This appendix is not intended to replace or establish different processes than described in **Section 2.6** or **Section 5**.

Example 1: Upsizing an LID BMP to Meet Hydromodification Requirements

Scenario

- A 2-acre project will be 90 percent impervious.
- Infiltration is partially feasible at the project site and the project proposes to use bioretention with elevated underdrains to meet LID standards.

Summary of LID Calculations and Results

- Based on LID sizing calculations in **Appendix E.3**, the required BMP footprint is 2,350 sq-ft. The BMP is designed with an 18-inch gravel storage layer below the underdrains of the system.
- The estimated infiltration rate is 0.15 inches per hour, which will drain the 18 inches of stone (7.2-inch effective water depth) in 48 hours
- This configuration would comply with LID requirements but is not large enough to comply with hydromodification requirements.

Integrated Design Approach

1) An SOHM model of the pre-development (naturally-occurring) and post-development condition of the site is developed.

2) A BMP with a profile matching the LID profile is modeled, and an orifice is added to the underdrains of the system to control outflow rates to 10% of the pre-development 2-year flowrate. Infiltration losses, if any, should be included in this model. The footprint of the BMP is increased incrementally to determine the required volume to meet flow duration control standards.
3) If this footprint fits the site, then proceed to the next step. If the footprint is too large for the site, return to step 2 and consider a modification of the LID design with a deeper gravel profile.
4) Check the drawdown time of the surface storage, such that the water surface drains to at least 12 inches below the media surface within 24 hours following precipitation. If this cannot be met, then a greater portion of storage may need to be provided below the underdrain.
5) Check that the sizing calculations for the LID BMP still conform, after accounting for the slower drawdown time.

Applicability and Limitations

- A similar process could be used for any type of LID BMP to retain or biofilter the required LID volume to meet hydromodification requirements.
- Adding an orifice to the underdrains to meet a low flow threshold could greatly increase drawdown time. If there are increases in drawdown time, these must be reflected in LID sizing calculations and design checks to ensure nuisance conditions will not result.
- The option of upsizing an LID BMP to serve hydromodification purposes may result in a higher peak flow into the system, which should be accounted for in the inlet energy dissipation and scour protection.

Example 2: LID and Hydromodification Control in a Combination Basin

Scenario

- A 2-acre project will be 90 percent impervious.

- Infiltration is partially feasible at the project site and the project proposes to use bioretention with elevated underdrains to meet LID standards.

- It is known that the site will not allow LID footprint to be expanded, and therefore LID will need to be combined with flow duration control to meet hydromodification standards.

Summary of LID Calculations and Results

- Based on LID sizing calculations in **Appendix E.3**, the required BMP footprint is 2,350 sq-ft. The BMP is designed with an 18-inch gravel storage layer below the underdrains of the system.
- The estimated infiltration rate is 0.15 inches per hour, which will drain the 18 inches of stone (7.2-inch effective water depth) in 48 hours
- This configuration would comply with LID requirements but is not large enough to comply with hydromodification requirements.

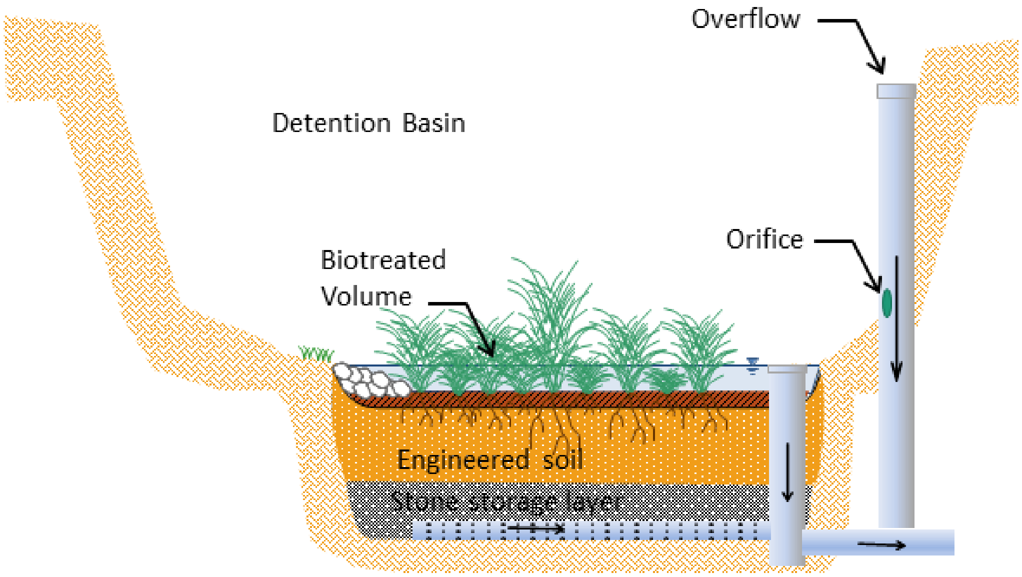
Integrated Design Approach

1) An SOHM model of the pre-development (naturally-occurring) and post-development condition of the site is developed.
2) A BMP is developed with the LID BMP in the bottom and a total BMP depth that can vary. An orifice for low flow is established from the LID BMP underdrains and a mid-height orifice is set above the LID storage volume.
3) The orifice sizes and total depth of the BMP are varied iteratively to arrive at a configuration that meets flow duration standards. The basin area could also be increased as part of these iterations to help limit the maximum depth.
4) Check the drawdown time of the LID surface storage, such that the water surface drains to at least 12 inches below the media surface within 24 hours following precipitation, assuming the LID compartment is full. If this cannot be met, then a greater portion of storage may need to be provided below the underdrain or this configuration may not be permissible.
5) Check that the sizing calculations for the LID BMP still conform, considering the slower drawdown time.

Applicability and Limitations

- A similar process could be used for any type of LID BMP to retain or biofilter the required LID volume to meet hydromodification requirements.
- Adding an orifice to the underdrains to meet a low flow threshold could greatly increase drawdown time. If there are increases in drawdown time, these must be reflected in LID sizing calculations and design checks to ensure nuisance conditions will not result.
- The option of upsizing an LID BMP to serve hydromodification purposes may result in a higher peak flow into the system, which should be accounted for in the inlet energy dissipation and scour protection.

Figure B-1: LID BMP with supplemental detention built into the BMP



Example 3: LID BMP Followed by Supplemental Detention/Retention in Series

Scenario (mostly the same as example 2)

- A 2-acre project will be 90 percent impervious.
- Infiltration is partially feasible at the project site and the project proposes to use bioretention with elevated underdrains to meet LID standards.
- It is known that the site will not allow LID footprint to be expanded or the use of a combination basin. Therefore, flow duration will need to be provided separately.

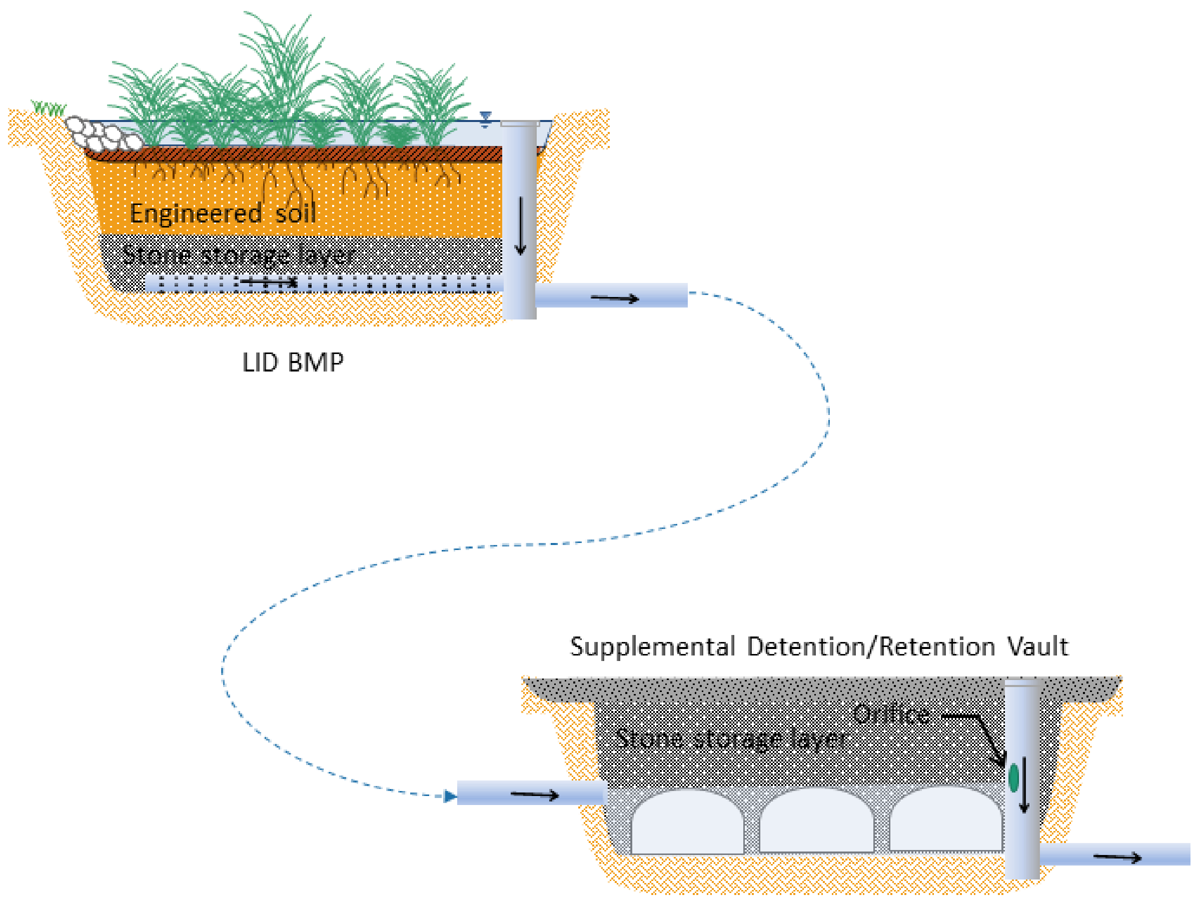
Summary of LID Calculations and Results (mostly the same as example 2)

- Based on LID sizing calculations in **Appendix E.3**, the required BMP footprint is 2,350 sq-ft. The BMP is designed with an 18-inch gravel storage layer below the underdrains of the system.
- The estimated infiltration rate is 0.15 inches per hour, which will drain the 18 inches of stone (7.2-inch effective water depth) in 48 hours.
- As a standalone system, this would comply with LID requirements

Integrated Design Approach

1) An SOHM model of the pre-development (naturally-occurring) and post-development condition of the site is developed.
2) The flow duration system (basin, tank, or chamber) is modeled in SOHM to determine the required volume to meet flow duration criteria on a standalone basis.
3) If location of the flow duration system is suitable for partial infiltration, the system should be soft-bottomed and infiltration should be accounted for.
4) If the system provides at least as much infiltration footprint as would have been provided in distributed LID BMPs (about 3% of impervious area of the site), then it is possible that more compact distributed LID BMPs could be used within the site, and goals to achieve incidental volume reduction could be satisfied via the losses in the flow duration system.
5) If flow-based biofiltration is used, then it must be sized for the flowrate required to provide 80 percent long term capture efficiency multiplied by a factor of 1.5.

Figure B-2: LID BMP followed by supplemental detention/retention in series



Applicability and Limitations

- This configuration could be tailored to fit most applications.
- There is no need to check for conflicts because the systems are largely separate.
- The operation of the flow duration control system requires that large storm flows enter the system, which are larger than the design of LID facilities. Therefore, even water that bypasses LID facilities should still flow to the flow duration control system.
- Both the LID BMP and hydromodification BMP should be selected based on infiltration feasibility to result in a combined system that maximized volume reduction.
- Upstream LID BMPs should generally provide adequate pretreatment for downstream infiltration/detention systems.
- This could be particularly useful if a centralized location has better feasibility for infiltration than the conditions below distributed LID BMPs.

APPENDIX C. GROUNDWATER-RELATED INFILTRATION FEASIBILITY CRITERIA

Infiltration BMPs shall not be used where they would adversely affect groundwater quality or where depth to groundwater would limit long term reliable infiltration rates. The purpose of this section is to provide guidelines for allowable use of infiltration BMPs to protect groundwater quality and ensure physical feasibility relative to groundwater and groundwater-related geotechnical considerations. This section considers:

- Depth to groundwater and mounding potential,
- Presence of groundwater plumes,
- Wellhead protection and septic systems,
- Contamination risks from land use activities in the area tributary to the BMP,
- Consultation with applicable groundwater agencies, and
- Technical requirements for conducting site specific studies.

C.1 Intended Use

The criteria contained in this appendix are intended to be used as part of the overall infiltration feasibility screening process. If one feasibility criterion renders infiltration infeasible, it is not necessary to also consider all the other criteria contained in this section. However, before infiltration BMPs are approved for use on a project, each of these groundwater quality-related criteria must be evaluated and documented. The contents of this section can be used together with Worksheet 1 (See TGD Chapter 4) to determine the overall infiltration feasibility category for a DMA. Worksheet 2 can be used to document the feasibility of infiltration from a groundwater perspective. Whenever a project proposes to utilize full infiltration BMPs, the project proponent should invite the local groundwater agency to consult. This is particularly recommended if:

- The BMP uses a pipe or conveyance to direct flow to a subsurface system (dry well, vault, infiltration trench, etc.).
- The BMP is comprised of surface infiltration with a cumulative tributary area that exceeds 5,000 square feet.
- The BMP is proposed to be located over known soil or groundwater contamination.

A template and cover letter for inviting the groundwater agency to consult are included in this appendix along with additional guidance.

C.2 Depth to Groundwater and Mounding Potential

Minimum separation between the infiltrating surface (bottom of infiltration facility) and seasonally high mounded groundwater shall be observed in the design of infiltration BMPs, depending on BMP type.

- If the depth to unmounded seasonally high groundwater is greater than 15 feet, the depth to groundwater does not constrain infiltration.
- If separation to unmounded seasonally high groundwater is greater than 10-feet and the infiltration area is less than 2,000 sq-ft, the depth to groundwater does not constrain infiltration.
- The separation between the infiltrating surface and the seasonally high mounded groundwater table shall not be less than 5 feet for all BMP types employing infiltration.
- The separation between the infiltrating surface and the seasonally high mounded groundwater table shall not be at less than 5 feet for the following BMP types:
    - Rain gardens and dispersion trenches (small, residential applications).
    - Bioretention and planters.
    - Permeable pavement.
    - Similar BMPs infiltrating over an extensive surface area and providing robust pretreatment or embedded treatment processes.
- Separation to mounded seasonally high groundwater shall be at least 10 feet for infiltration devices that inject water below the subsurface and surface infiltration BMPs with tributary area and land use activities that are considered to pose a more significant risk to groundwater quality. BMPs for which the 10-foot separation applies include:
    - Subsurface infiltration galleries or vaults.
    - Surface infiltration basins.
    - Infiltration trenches.
    - Dry wells.
    - Other functionally similar devices or BMPs.

C.2.1 Approved Methods for Determining the Depth to Seasonally High Groundwater

The seasonally high groundwater table is defined as the depth to the highest level of the saturated groundwater zone. It is quantified as the average of measured annual minima (i.e., the shallowest recorded measurements in each water year, defined as October 1 through September 30 are averaged) for all years on record.

C.2.1.1 Site Specific Determination of Seasonally High Groundwater Elevation

The depth to seasonally high groundwater is ideally determined from long-term groundwater level data near the project. If groundwater level data are not available or are inadequate, the seasonal high groundwater depth can be estimated by redoximorphic analytical methods combined with temporary groundwater monitoring for at least one month between November 1 and April 1 at the proposed Project site. In this approach, a professional geologist assesses soil-mottling characteristics of soil cores to determine the depth at which soil features display reductive conditions which indicate the seasonal height of groundwater. This is coupled with observed groundwater level and variability over one month during the wet season of to prepare a professional opinion about seasonally high groundwater table.

Unless criteria are met to use mapped groundwater elevations, each project should utilize site-specific methods to assess groundwater elevations.

C.2.1.2 Conditions for Use of Mapped Groundwater Elevations

There are two primary source of mapped groundwater elevation contours:

- **Appendix N** includes an exhibit of groundwater contours below ground surface. [Note: groundwater exhibits in **Appendix** N do extend to South OC. Other available maps could be used.]
- Seismic Hazard Evaluation Open-File Reports prepared by the California Geological Survey describe the highest recorded groundwater level. These files can be found at the following link: **http://www.conservation.ca.gov/cgs/shzp/pages/index.aspx**. Data are found under "Regulatory Maps" as an exhibit near the end of the "Seismic Hazard Zone Report" for the 7.5-minute quadrangle of interest.

Both sources are based on depth below existing ground surface, therefore changes in site grade and depth of the BMP invert below surrounding grade need to be considered in interpreting these maps.

For sites where the groundwater elevation based on the map in **Appendix N** is less than 5 feet below the proposed BMP invert, this may be used as a basis for not considering infiltration BMPs. However, the project proponent does have the discretion to conduct site-specific investigation to support the feasibility of infiltration, if desired. [Note: groundwater exhibits in **Appendix N** do extend to South OC. Other available maps could be used.]

For sites where the mapped groundwater elevation is greater than 15 feet below the proposed invert of stormwater infiltration BMP, the mapped groundwater elevation and may be used as part of demonstrating that infiltration is feasible. Corroboration with site-specific data is encouraged, but is not required.

C.2.2 Methods for Evaluation of Groundwater Mounding Potential

Stormwater infiltration and recharge to the underlying groundwater table will, in most cases, create a groundwater mound beneath the infiltration facility. The height and shape of the mound depends on the infiltration system design, the recharge rate, and the hydrogeologic conditions at the site, especially the horizontal hydraulic conductivity and the saturated thickness. Groundwater mounding beneath infiltration facilities also depends on the precipitation patterns, which affects the applied recharge rates and underlying soil moisture conditions. Maximum mounding potential is likely to occur in response to cumulative precipitation over relatively short periods, for example, a series of intense winter storms over a one to two-week period.

Methods for quantifying groundwater mounding potential range from detailed modeling studies to simple conservative estimation techniques. The methods employed by the project proponent will be subject to the acceptance of the reviewing agency.

Mounding Evaluation with Modeling Studies: A rigorous evaluation of mounding potential requires detailed site characterization and detailed modeling that accounts for the transient nature of stormwater infiltration and the site-specific hydrogeological conditions. For example, Carlton (2010)[1] used MODFLOW, an industry standard groundwater flow model, to evaluate groundwater mounding potential from infiltration facilities in hypothetical 1-acre and 10-acre developments. Modeling studies to evaluate groundwater mounding potential are applicable for design studies of large regional facilities. Detailed modeling analyses are typically not feasible for evaluation of on-site facilities in small development projects or dispersed small-scale facilities in larger projects.

Mounding Estimates Based on Simplified Groundwater Equations: Estimates of maximum mounding potential can be developed from analytical solutions to groundwater equations, called the Hantush equations. These equations incorporate several simplifying assumptions about the hydrogeology of the site including assumptions of uniform horizontal hydraulic conductivity and vertical infiltration rates. Solution of the Hantush equations can be accomplished with a simple Excel spreadsheet tool developed by the USGS (Carlton, 2010) available at online at **http://pubs.usgs.gov/sir/2010/5102/**.

This tool is simple to use but requires inputs about the saturated zone hydraulic conductivity, the thickness of the saturated zone, and estimates of the specific yield, which is related to the effective porosity. The tool also requires inputs about the infiltration conditions, including the dimensions of the infiltration facility, the uniform infiltration rate and the period application that will result in the maximum mounding height. Use of the USGS groundwater mounding tool is applicable and recommended for planning or design level analysis where there is the sufficient information of the surface conditions of the site and use of detailed modeling is not warranted.

[1] Carleton, G.B., 2010, Simulation of groundwater mounding beneath hypothetical stormwater infiltration basins: U.S. Geological Survey Scientific Investigations Report 2010–5102, 64 p. **http://pubs.usgs.gov/sir/2010/5102/**

Where information is not available, the following assumptions are recommended for using this tool to evaluating the potential for mounding under small-scale localized BMPs. Site-specific data and professional judgment should always be used in conducting groundwater mounding analyses.

- Recharge rate should be set to the design infiltration rate of the stormwater BMP, assuming that the BMP operates at its design infiltration rate throughout the critical period for groundwater mounding.
- The horizontal hydraulic conductivity should be set to 5 to 10 times the observed infiltration rate of the soil (**Appendix D**) to account for typical anisotropy of natural soils (ratio of horizontal to vertical hydraulic conductivity). Note the observed infiltration rate will generally be greater than or equal to 2 times the design infiltration rate (**Appendix D**).
- The period of simulation should be set to 10 days. Applying the design infiltration rate continuously over 10 days generally results in 3-5 times the DCV infiltrated over this period considering typical BMP drawdown times.
- The specific yield should be set to 0.2.
- The saturated zone thickness should be set to 20 feet.

An example using the USGS tool is included in **Example C.1** below.

Example C.1: Application of USGS Groundwater Mounding Tool Using a Hypothetical Range of Infiltration Scenarios

Given:

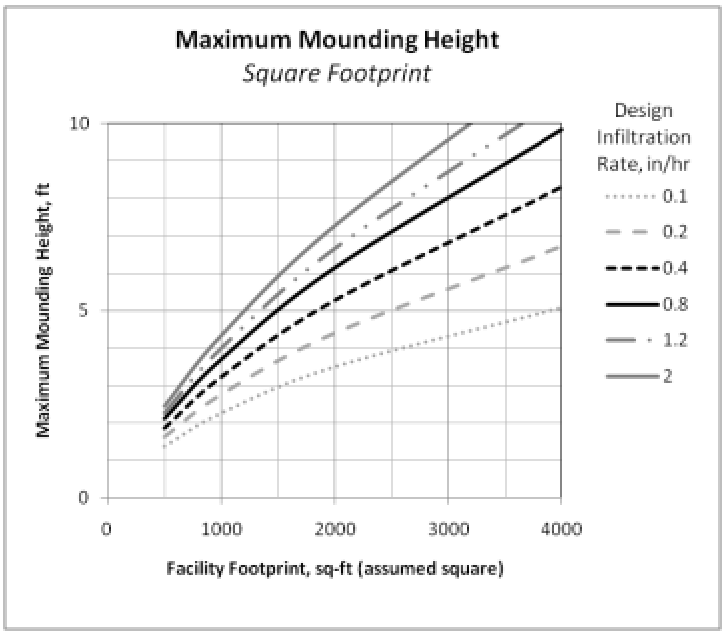
- Observed soil infiltration rate: 0.2 to 4 inches per hour
- Design infiltration rate: 0.1 to 2 inches per hour (Factor of Safety = 2.0)
- Horizontal Hydraulic Conductivity: 2 to 40 inches per hour (Anisotropy: 10:1 (H:V) applied to measured infiltration rate)
- Facility footprint: 500 to 4,000 sq-ft
- *System aspect ratio*: 1:1 (square) and 5:1
- Period of simulation: 10 days (total infiltrated depth =24 to 480 inches)
- Saturated zone thickness: 20 feet
- Specific yield: 0.2

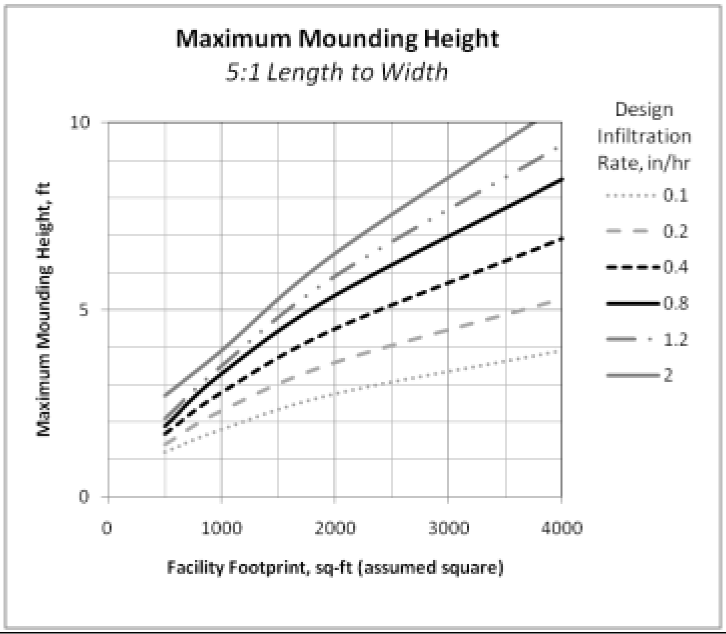
Required:
• Compute maximum mounding heights using USGS tool
Solution:

Maximum mounding heights calculated with the USGS tool are given in **Figure C-1**. While these results reflect a relatively conservative case, they indicate that system size and design infiltration rate both influence the potential for mounding. In addition, a linear geometry reduces the magnitude of mounding somewhat compared to a square geometry with the same footprint.

Figure C-1: Example Calculations of Maximum Mounding Height by Facility Configuration from USGS Calculator (Carlton, 2010)

(For illustration purposes only based on input assumptions above; inputs shall be based on professional judgment)





C.3 Groundwater Plumes

Infiltration shall not be allowed in the vicinity of mapped or potential groundwater plumes, except where infiltration would not adversely impact groundwater conditions as determined via a site-specific or watershed study applicable to the site. In the absence of a site-specific study, the following criteria apply:

- Infiltration is prohibited within *plume protection boundaries* identified by Orange County Water District (OCWD), or equivalent boundaries identified by applicable groundwater agencies, unless a site-specific study demonstrates that infiltration would not adversely impact groundwater conditions.
- Infiltration is prohibited in identified natural pollutant source areas (e.g., selenium), unless a site-specific study demonstrates that infiltration would not adversely impact groundwater conditions,
- Infiltration is prohibited within 250 feet of contaminated sites, such as sites found in the Geotracker or EnviroStor databases (http://geotracker.swrcb.ca.gov/, http://www.envirostor.dtsc.ca.gov/public/), unless a site specific study demonstrates that infiltration would not adversely impact groundwater conditions. The study must include a review of the magnitude and type of the original contaminants and byproducts shall be used to assess the level of risk posed by infiltration in the vicinity of closed sites. This criterion applies to active contaminated sites or closed sites that have significant remaining potential for pollutant mobilization resulting from stormwater infiltration.

- A site-specific investigation shall always be performed to assess the feasibility of stormwater infiltration when the project proposes to redevelop a previously-contaminated site (e.g., Brownfields or otherwise contaminated).

As locations, boundaries, and number of contamination sites is subject to change, it is the responsibility of applicants to use the most up-to-date maps available from the permittees and applicable groundwater management agencies. Requirements for conducting site-specific studies vary with project size and are identified in **Appendix C.7**.

Basis for 250-foot Setback

The 250-foot separation distance from contaminated sites is based on the following considerations:

- In general terms, the degree of subsurface contamination typically decreases in the horizontal direction away from a contaminated site (although there can be site-specific conditions where this is not the case);
- As the distance between a contaminated site and a potential engineered infiltration system increases, the risk decreases that the engineered infiltration system will infiltrate water into subsurface contamination or otherwise negatively affect contamination originating from the contaminated site;
- By precluding engineered infiltration systems within 250 feet of a contaminated site, the risk decreases that infiltration would be increased through an area of the subsurface containing non-aqueous phase liquid contamination or areas with groundwater containing very high levels of contamination;
- A survey of sites contaminated with petroleum-related products estimated horizontal benzene plume lengths (California Leaking Underground Fuel Tank (LUFT) Historical Case Analysis, UCRL-AR-122207, prepared by Lawrence Livermore National Laboratory, 1995). Based on a 10 part per billion concentration threshold, the survey estimated that 90 percent of the sites had benzene plume lengths of 261 feet or less. Some contaminants may have longer or shorter plume lengths than benzene and the amount of data on plume lengths is increasing as additional data are collected. Additional data and analysis may warrant reconsideration of this issue in the future.

C.4 Guidelines for BMP Selection by Tributary Land Use Activities

Table C-1 provides criteria for selection of BMPs to address the potential for contamination of groundwater from tributary land use activities. Infiltration BMPs shall be selected and applied as recommended by **Table C-1**.

To prevent contamination from materials used in the construction of the infiltration BMP itself, soil media, construction materials, and construction practices should be appropriately selected to ensure that hazardous chemicals or groundwater pollutants of concern are not inadvertently leached to the underlying groundwater.

Figure C-2: North Orange County Groundwater Basin Protection Boundary and Plume Protection Boundaries

[Placeholder for future addition after adoption of the 5th Term NOC MS4 Permit]

Table C-1: Recommendations/Requirements for BMP Selection to Minimize Groundwater Quality Impacts

Tributary Area Risk Category	Narrative Description of Category	Example Land Use Activities	BMP Selection Requirements
Low Runoff Contamination Potential	BMP receives runoff from a mix of land covers that are expected to have relatively clean runoff; significant spills in tributary area are unlikely.	• Rooftops with roofing material and downspouts free of copper and zinc • Patios, sidewalks, and other pedestrian areas • Mixed residential land uses with applicable source controls • Institutional land uses with applicable source controls • Driveways and minor streets	• Any infiltration BMP type may be used. • Pretreatment for sediment is strongly recommended, as applicable, to mitigate clogging.
Moderate Runoff Contamination Potential	BMP receives runoff from a mix of land covers, more than 10 percent of which have the potential to generate stormwater pollutants at levels that could potentially contaminate groundwater; there is potential for minor spills in the tributary area.	• Roadways greater than 5,000 ADT but less than 25,000 ADT • Commercial and institutional parking lots • Commercial land uses • Light industrial that does not include usage of chemicals that are mobile in stormwater and groundwater • Trash storage areas	• Any infiltration BMP type may be used. • Pretreatment shall be used. • The type of pretreatment shall be selected to address potential groundwater contaminants potentially found in stormwater runoff.
High Runoff Contamination Potential	BMP receives runoff from a mix of land covers, more than 10 percent of which have significant unavoidable potential to generate stormwater pollutants in quantities that could be detrimental to groundwater quality; and/or there is significant potential for major spills that could drain to BMPs.	• Roads greater than 25,000 ADT • Heavy and light industrial pollutant source areas, including areas with exposed industrial activity and high use industrial truck traffic, and any areas that cannot be isolated these areas. Does not include lower risk source sources areas within industrial zones (e.g., roofs, offices, and parking areas) that are hydrologically isolated from industrial pollutant source areas • Automotive repair shops • Car washes • Fleet storage areas • Nurseries, agriculture, and heavily managed landscape areas with extensive use of fertilizer • Fueling stations (infiltration prohibited under all conditions) • Motorized fleet vehicle storage	• Infiltration is prohibited unless advanced pretreatment and spill isolation can be feasibly used and enhanced monitoring and inspection are implemented. • Large projects[2] must evaluate feasibility of advanced pretreatment and spill isolation. • Small projects[2] may consider infiltration to be infeasible with narrative discussion.

[2] See **Table C-2** for definition of “Large” and “Small” projects.

C.5 Well Head Protection and Septic Systems

To ensure protection of groundwater quality, the following criteria shall be met:

- Stormwater shall not be infiltrated within 100 feet horizontally of a water supply well, non-potable well, or spring.
- Stormwater shall not be infiltrated within 100 feet horizontally of a septic tank drain field.

Because data regarding the location of supply wells, springs, and septic systems is not generally available to the public, the project proponent is strongly encouraged to consult with the local review agency early in the WQMP preparation process to determine whether these conditions apply to all or part of the project site.

C.6 Stormwater Runoff Pollutants

Stormwater BMPs shall be selected to minimize the introduction of contaminants into groundwater via infiltration of stormwater runoff. The potential for groundwater contamination from pollutants found in stormwater runoff is a function of the land use activities that are present in the tributary area to the BMP. **Table C-1** provides requirements for selection of BMPs and pretreatment devices based on the level of risk posed by land use activities.

C.7 Technical Requirements for Site Specific Study of Infiltration Impacts on Groundwater Quality

C.7.1 Project Size Applicability

Regardless of project size, any project proposing to use infiltration BMPs within a *plume protection boundary* or within 250 ft of a contaminated site shall conduct a site-specific study prior to using these BMPs to demonstrate that infiltration will not have adverse impacts on groundwater quality.

For small projects, a site-specific study is not required unless the project proponent chooses to use infiltration, in which case a site-specific study shall be prepared. If the proponent does not choose to use infiltration, the presence of one of the above-referenced conditions (including: shallow groundwater depth or mounding potential, presence of groundwater plumes, proximity to wellheads or septic systems, risks from land use activities, or other site-specific feasibility concerns) is sufficient to demonstrate infeasibility of infiltration BMPs.

For large projects, a site-specific study is required to determine if infiltration is feasible and would not adversely impact groundwater quality in the vicinity of plume(s) and/or contaminated sites, or adversely affect groundwater drinking supplies.

Large projects and small projects are defined in **Table C-2**.

Table C-2: Definition of Project Size Categories

	Residential	Commercial, Institutional	Industrial
Small Projects	Less than 10 acres and less than 30 DU	Less than 5 acres and less than 50,000 SF	Less than 2 acre and less than 20,000 SF
Large Projects	Greater than 10 acres or greater than 30 DU	Greater than 5 acres or greater than 50,000 SF	Greater than 2 acres or greater than 20,000 SF

C.7.2 Information and Documentation Required in Site-Specific Study

If a project proponent proposes to use infiltration BMPs within a *plume protection boundary* or within 250 ft of a contaminated site, the project proponent shall provide a written report to demonstrate that infiltration does not pose an adverse risk to groundwater. The written report should be prepared by a state-certified professional and provided to OCWD for review and comment. The report shall document that the following conditions are met:

1. Lateral and vertical extent of soil or groundwater contamination is defined at the site and is defined for off-site areas if contamination has migrated to the boundary of the site.
2. Groundwater conditions are defined based on site specific data (e.g., subsurface soil characteristics, depth to groundwater, groundwater flow direction, rate of groundwater movement).
3. Ongoing monitoring of soil or groundwater contamination is occurring and will continue to occur, as necessary.
4. A state-certified professional evaluates soil and groundwater data and evaluates whether proposed stormwater infiltration could cause adverse impacts to groundwater quality; an adverse impact to groundwater quality could include changing the movement of groundwater contamination, causing additional amounts of contamination in the unsaturated zone to migrate into the saturated zone, or negatively impacting an existing remediation system.
5. The applicable regulatory agency is identified and has continuing authority to require additional investigation or cleanup work if stormwater infiltration causes an adverse impact on groundwater quality.

In summary, infiltration shall not be allowed for sites where there is substantial evidence of an adverse risk to groundwater quality.

C.8 Groundwater-Related Feasibility Criteria Worksheet

Worksheet 2: Summary of Groundwater-related Feasibility Criteria

1	Is project large or small? (as defined by **Table C-2**) circle one	Large		Small
2	What is the tributary area to the BMP?	A		acres
3	What type of BMP is proposed?			
4	What is the infiltrating surface area of the proposed BMP?	A_{BMP}		sq-ft
5	What land use activities are present in the tributary area (list all)			
6	What land use-based risk category is applicable?	L	M	H
7	If M or H, what pretreatment and source isolation BMPs have been considered and are proposed (describe all):			
8	What minimum separation to mounded seasonally high groundwater applies to the proposed BMP? See **Appendix C.2** (circle one)	5 ft		10 ft
9	Provide rationale for selection of applicable minimum separation to seasonally high mounded groundwater:			
10	What is the separation from the infiltrating surface to seasonally high groundwater?			ft
11	What is the separation from the infiltrating surface to mounded seasonally high groundwater?			ft

Worksheet 2: Summary of Groundwater-related Feasibility Criteria

12	Describe assumptions and methods used for mounding analysis:	
13	Is the site within a plume protection boundary?	Y N N/A
14	Is the site within a selenium source area or other natural plume area?	Y N N/A
15	Is the site within 250 feet of a contaminated site?	Y N N/A
16	If site-specific study has been prepared, provide citation and briefly summarize relevant findings:	
17	Is the site within 100 feet of a water supply well, spring, or septic system?	Y N N/A
18	Is infiltration feasible on the site relative to groundwater-related criteria?	Y N
Provide rationale for feasibility determination:		

Note: if a single criterion or group of criteria would render infiltration infeasible, it is not necessary to evaluate every question in this worksheet.

C.9 Consultation with Applicable Groundwater Management Agencies

C.9.1 Consultation Recommendations

Consultation with the applicable groundwater management agency should be conducted early in the WQMP development process to the extent necessary to ensure that groundwater quality is protected. Consultation with the applicable groundwater management agency is especially encouraged if:

- The BMP uses a pipe or conveyance to direct flow to a subsurface system (dry well, vault, infiltration trench, etc.)
- The BMP is comprised of surface infiltration with a cumulative tributary area that exceeds 5,000 square feet
- The BMP is proposed to be located over known soil or groundwater contamination

This section presents a description of the consultation process, guidance for the process, and a template and cover letter that can be used by project proponents to facilitate consultation.

C.9.2 Applicable Groundwater Agencies

The primary groundwater management agency for South Orange County is the San Juan Basin Authority. Maps of their jurisdictions of groundwater management agencies can be obtained from the California Department of Water Resources website: **http://www.water.ca.gov/groundwater/boundaries.cfm**

C.9.3 Guidelines for Process and Timing of Groundwater Agency Consultation

As part of preparation and/or review of the Conceptual/Preliminary WQMP, the Permittee responsible for review should provide an opportunity for groundwater agency consultation. The project applicant should support this review by providing the necessary information about the project.

The consultation process is intended to be an opportunity for the applicable groundwater management agency to identify any project-specific issues that should be considered. It is not intended to replace the infiltration feasibility criteria contained in this TGD. Consultation should only be initiated if all feasibility factors described in this TGD have been evaluated and it is determined by the project applicant and Permittee reviewer that it is potentially feasible to use full infiltration BMPs.

To facilitate meaningful input from the groundwater management agency, the following information should be included, as applicable, with the invitation to consult and should be the responsibility of the project applicant to prepare:

- A brief description of the project including land uses and pollutants expected to be generated
- A vicinity map and neighborhood map identifying the project location and areas in which infiltration BMPs are being considered
- Conceptual Infiltration Feasibility Findings
    - Worksheet 1 (TGD **Section 4**) with attachments, as needed to provide additional details
    - Worksheet 2 with data sources, as needed to provide additional details
- Summary of the conceptual design of proposed infiltration BMPs including:
    - BMP type
    - BMP size (including depth, area, and volume)
    - Preliminary design info (media and gravel depths and infiltration rates, storage depths, overflow depths, footprint, etc.)
    - Pretreatment provided

The information needed for consultation is primarily prepared by the project applicant, but should be submitted by the Permittee with a cover letter. The cover letter should summarize the Permittee's tentative findings about infiltration feasibility and BMP selection. A template cover letter is included in **Appendix C.9.4**.

Timing for consultation is at the discretion of the project applicant and project reviewer. The goal should be to obtain input at a time when it can be meaningfully incorporated into conceptual BMP plans such that project plans avoid or mitigate potential groundwater quality issues. This process could be initiated prior to formal submittal of a Conceptual/Preliminary WQMP or in parallel with Permittee review of the Conceptual/Preliminary WQMP.

Groundwater management agencies may not desire to consult or have no comments. In this case, they may or may not respond. A period of two weeks should be provided for an expression of intent to consult, and a period of one month from date of the original invitation should be provided for receipt of comments.

C.9.4 Cover Letter and Template for Inviting Groundwater Management Agencies to Consult

The contents of this section can be used as a template for the invitation to the groundwater management agency to consult. Use of this language or format is not required, but is meant to provide consistency and streamline this process. Placeholders for project-specific inputs are included in square brackets. Guidance is included in parentheses.

[Jurisdiction Letterhead]

[Applicable Groundwater Management Agency, contact person, and address; email address if sent electronically]

Subject: Invitation to Consult on Stormwater Infiltration Proposal
[Project/Site Name]
Project/Site Street Address]
[Reviewing Jurisdiction Name]

To whom it may concern:

[Jurisdiction] is currently reviewing a preliminary project proposal for the subject site that includes stormwater infiltration. In the interest of protecting groundwater quality from potential impacts from stormwater infiltration, we are inviting you to consult on this proposal.

Instructions for Consultation

If [groundwater management agency] is interested in consulting on the proposed use of stormwater infiltration by this project, please reply in writing within 10 business days to indicate your intent to consult. If a letter of intent is received, then written input received within 30 calendar days of this letter will be considered in our review of the project. If responses are not received within the stated timeframes, we will assume that [groundwater management agency] finds the proposed use of stormwater infiltration to be acceptable or does not desire to consult on the project. [insert any specific instructions for communication].

Information to Support Consultation

The following information is attached to this letter to facilitate consultation on this project: (include any that apply; edit as appropriate)

A brief description of the project including land uses and pollutants expected to be generated

A vicinity map and neighborhood map identifying the project location and areas in which infiltration BMPs are being considered

Conceptual infiltration feasibility findings

- *Worksheet 1 with attachments, as needed to provide additional details*
- *Worksheet 2 with data sources, as needed to provide additional details*

Summary of the conceptual design of proposed infiltration BMPs including (to the extent known):

- *BMP type*
- *BMP size (including depth, area, and volume)*
- *Preliminary design info (media and gravel depths and infiltration rates, storage depths, overflow depths, footprint, etc.)*
- *Pretreatment provided]*

Preliminary Findings by [Jurisdiction]

[Jurisdiction] has reviewed the preliminary information described above. Our review has determined that the proposed use of stormwater infiltration is consistent with the criteria identified in the Orange County Technical Guidance Document and the applicable MS4 Permit. We have also determined that a good faith effort was made to investigate potential limits to stormwater infiltration.

[Insert any specific commentary or rationale that is deemed necessary to support this position]

[Jurisdiction] invites your input on this proposal, including identification of any additional data or factors that should be considered in our review.

[Insert any specific topics or questions that are of interest for groundwater agency input.]

Respectfully Submitted,

[Reviewing jurisdiction representative, title, and contact information]

APPENDIX D. GUIDELINES FOR INFILTRATION RATE EVALUATION

D.1 Introduction and General Guidelines

Estimation of reliable infiltration rates has an important role in various phases of project development. The purposes of this appendix are to:

- Explain the roles of infiltration testing at each project phase,
- Provide guidance for selection and application of different infiltration testing or estimation methods, and
- Provide guidance for calculation and selection of an appropriate factor of safety specific for infiltration rates.

D.1.1 Roles of Infiltration Testing

The role of soil characterization and infiltration testing differs with the size of the project, the soil types at the site, site groundwater and other characteristics, and the phase of project development. Some projects may not require any infiltration testing of any sort while others may require detailed testing in multiple phases. **Table D-1** summarizes the purpose of infiltration testing or estimation efforts at each phase of the project.

Table D-1. Role of Infiltration Testing

Project Phase	Key Questions/Burden of Proof	General Assessment Strategies
Site and BMP Planning Phase	• Where within the project area is infiltration potentially feasible? • What volume reduction approaches are potentially suitable for my project? • Is additional testing needed to support design? (needed for infiltration BMPs only)	• Use existing data and maps to the extent possible • Use less expensive testing methods, where needed, to allow a broader area to be investigated more rapidly • Reach tentative conclusions that are subject to confirmation/refinement at the design phase
BMP Design Phase	• What infiltration rates should be used to design infiltration facilities? • What factor of safety should be applied? • Do design infiltration rates support full infiltration? • If full infiltration will be used, is additional testing needed during construction?	• Use more rigorous testing methods at specific BMP locations • Support or modify preliminary feasibility findings • Estimate design infiltration rates with appropriate factors of safety

Project Phase	Key Questions/Burden of Proof	General Assessment Strategies
Construction Phase (if needed)	• What is the actual as-constructed infiltration rate? • Is this consistent with design assumptions? • Does a contingency option need to be activated to ensure reliable performance?	• Conduct drawdown testing of the full-scale facility, or infiltration testing at the final grade following heavy earthwork.

Several factors are important to note in planning and executing infiltration testing:

- Other feasibility criteria may limit infiltration feasibility, such as groundwater contamination and geotechnical considerations. If one of these factors controls feasibility, then infiltration testing may not be needed to support BMP selection. However, an understanding of how quickly water would move into and through soil often has underlying significance in addressing other questions of feasibility; therefore, some form of estimate of soil infiltration rate if often required to support general geotechnical evaluation.
- **Biotreatment BMPs with partial infiltration do not require design phase or construction phase testing.** These systems should take credit for a reasonable estimated infiltration rate, but their operation does not depend on a certain minimum infiltration rate.
- Testing for BMP planning and BMP design do not necessarily need to be separate. If testing conducted as part of BMP planning is adequately rigorous to support BMP design, then these phases can be combined.
- The BMP planning phase and design phase do not necessarily correspond to the Conceptual/Preliminary WQMP phase and Final Project WQMP phase, respectively. For some projects, it may be necessary or desirable to conduct planning and design phase testing prior to Conceptual/Preliminary WQMP submittal. In others cases, design phase testing could be deferred until the Final Project WQMP.
- Construction phase testing is strongly encouraged in cases where full infiltration will be used. It is especially important where it is not possible to conduct a rigorous test at the proposed elevation of infiltration during design, and/or where there will be significant earthwork and potential compaction that could impact infiltration rates. This is a key element in ensuring that infiltration BMPs are constructed as designed and should be strongly considered as part of the post-construction BMP verification process prior to permit closeout.
- While this appendix presents guidance on appropriate approaches at each phase, each project has specific considerations. It is ultimately at the discretion of the reviewing agency and project geotechnical professional to select and apply methods that are suitable to address the applicable questions based on site-specific factors.

- Finally, the need to fully consider infiltration as a first priority BMP must not be mistaken as an allowance to use infiltration without adequate justification and assurance. An initial indication of infiltration feasibility must be confirmed with appropriate design phase testing if full infiltration BMPs will be used. If this cannot be confirmed, then the BMP selection must be revised.

D.1.2 Project Size Categories for Determining Acceptable Methods

For the purpose of determining acceptable infiltration rate testing or estimation methods, **Table D-2** describes the criteria for defining a project as "Small" or "Large." These definitions are considered to be guidelines; they are not intended to reduce the requirement to conduct an evaluation of infiltration feasibility that is based on substantial evidence.

Table D-2: Definition of Project Size Categories

	Residential	Commercial, Institutional	Industrial
Small Projects	Less than 10 acres and less than 30 DU	Less than 5 acres and less than 50,000 SF	Less than 2 acre and less than 20,000 SF
Large Projects	Greater than 10 acres or greater than 30 DU	Greater than 5 acres or greater than 50,000 SF	Greater than 2 acres or greater than 20,000 SF

D.1.3 Selection of Methods for Infiltration Rate Testing or Estimation

In general, simpler and more efficient methods of infiltration rate investigation are appropriate for planning level evaluation of infiltration feasibility and identification of potential BMP sites. However, some of these methods do not provided adequate confidence and resolution to support design of full infiltration systems or confirmation of as-constructed condition. Factors that should be considered in selection of an infiltration testing or estimation method include:

- How uniform are soils with depth? Some tests can be biased when there is high variability at different depths in the soil strata.
- How uniform are soils with location? Where soils are variable, a greater number of simpler tests may be warranted at the planning phase to gain an understanding of potential feasible locations, followed by more rigorous tests once BMPs have been sited.
- What is the proposed grading plan relative to proposed BMP invert elevations? Will BMPs be located well below existing grade? Near existing grade? In some cases, a borehole-type method may be the only option until grading has occurred.
- What is the geometry of the proposed BMP? Some infiltration testing methods can be more reliably translated to specific BMP geometries than others. For example, results from borehole-type tests can translate directly to the design flowrate of dry wells and

infiltration trenches. It is unreliable to translate these results to vertical infiltration rates, which dominate in other types of BMPs.

Table D-3 provides guidance on methods appropriate for each purpose. This list is not intended to be exhaustive. A geotechnical engineer may use other methods that are appropriate for the application, subject to the approval of the reviewing agency.

In all cases the directionality and geometry of infiltration that the test is directly measuring should be clearly understood and should be compatible with the type of BMP being proposed. This has inherent limitations discussed further in **Section D.1.6**.

- Borehole methods primarily measure horizontal permeability and have limited reliability for BMPs that rely primarily on vertical infiltration. There is no reasonable way to convert horizontal permeability to vertical permeability.
- Open pit tests can be highly influenced by sidewall infiltration unless ponding depths are kept shallow.
- Infiltrometer and open pit tests only measure a relatively small portion of the soil profile immediately below the surface. Where soils change considerably within the top 10 to 15 feet, these tests may produce unreliable estimates of full-scale infiltration.

Clearly, case-by-case professional judgement must play a significant role in selecting and interpreting tests.

Table D-3: Suitability and Limitations of Infiltration Rate Investigation Methods for Different Phases of Project

Infiltration Rate Investigation Method	Used for Infiltration Feasibility Categorization and Site Identification	Used for Determination of Design Infiltration Rate for Full Infiltration BMPs	Key Limitations
Regional Maps and Available Data (**Appendix D.2.1**)	Yes, for small projects (defined above) that have mapped D soils; regional maps must be confirmed through use of available data	No	Maps are known to lack resolution to support definitive conclusions at a site scale. Therefore, maps are only used to identify Type D soils (indicating clear infeasibility) and must be confirmed with available site data. They have no reliable purpose for design-level investigation.
Simple Open Pit Test (**Appendix D.2.2**)	Yes	No. This test should be conducted as a design-level open pit test to estimate design infiltration rate (see below).	Measurement precision and small scale limit applicability for use in design development.
Borehole Methods {**Appendix D.2.3**) Well Permeameter Method Borehole Percolation Test Procedure Constant Head Well Permeameter, including commercial methods such as the Guelph Permeameter Method (multiple vendors) and Aardvark Permeameter	Yes, if conversion to infiltration rate is used	Yes, for dry wells and infiltration trenches. For other BMPs, these methods should be confirmed by a direct measurement at the finish grade following excavation using an acceptable method. In either cases, boring logs and soil layering over the testing interval and at least 15 feet below the proposed BMP should be carefully considered in interpreting tests.	Borehole-type tests can be strongly biased by horizontal flow into more permeable layers of soils within the testing interval. For example, a gravel lens within finer grained material. This type of test is most applicable for dry wells or infiltration trenches, as the majority of flow is horizontal in these BMPs. It may not be possible to reliably convert results of borehole tests to an estimate of vertical infiltration rate below a broader footprint BMP such as a bioretention area, infiltration basin, or infiltration gallery where the majority of flow is vertical. Confidence can be improved by measuring within each distinct layer of soil and inspecting boring logs to determine likely limiting layers. However, it is not possible to mitigate major uncertainty in actual full-scale infiltration rate.
Open Pit Methods (**Appendix D.2.4**) Open Pit Falling Head	Yes	Yes, if appropriate geometric corrections for infiltration into side walls is used. Proportions between floor area and side wall area in the	While these tests primarily measure vertical infiltration rate, some infiltration into side wall occurs during the test. Sidewall infiltration is typically a greater portion of total flow in tests than

Infiltration Rate Investigation Method	Used for Infiltration Feasibility Categorization and Site Identification	Used for Determination of Design Infiltration Rate for Full Infiltration BMPs	Key Limitations
Open Pit Constant Head		test should be reasonably similar to the proposed BMP. Should be done at the elevation of the proposed BMP. Interpretation should be accompanied by a boring log showing soil layering up to at least 15 feet below the proposed BMP.	in full-scale BMP geometry. Therefore, it is important to attempt to match ratios through the use of a shallow water depth in this test. Confidence improves with increasing size of test; however, this also requires more excavation and water. These tests primarily measure the near-surface infiltration rate. They do not account for the potential effect of a limiting horizons further below the BMP and potential mounding of water at this layer. Therefore, they should be accompanied by interpretation of boring logs to at least 15 feet below the BMP.
Infiltrometer Methods (**Appendix D.2.5**) Single Ring Infiltrometer Test Double Ring Infiltrometer Test Dual Head Infiltrometer (Decagon Devices)	Yes	Yes. Should be done at the elevation of the proposed BMP. Interpretation should be accompanied by a boring log showing soil layering up to at least 15 feet below the proposed BMP.	These tests provide a reliable estimate of the vertical infiltration rate into surficial soil layers at relatively low head (slightly conservative). These tests do not account for the potential effect of a limiting horizons further below the BMP and potential mounding of water at this layer. Therefore, they should be accompanied by interpretation of boring logs to at least 15 feet below the BMP.

D.1.4 Conversion of Field Measurements to Estimate Infiltration Rates for Feasibility or Design

In selecting and applying tests, it is important that it is understood what attribute of the soil the test is measuring and how this can be converted to a value that is meaningful for infiltration feasibility screening and design.

D.1.4.1 Infiltration Rate, Percolation Rate, and Hydraulic Conductivity

A common misunderstanding is that the "percolation rate" obtained from a percolation test is equivalent to the "infiltration rate" obtained from tests such as a single or double ring infiltrometer test which is equivalent to the "saturated hydraulic conductivity." These concepts are interrelated, but the terms have different meanings.

Saturated hydraulic conductivity (Ksat) is an intrinsic property of a specific soil sample under a given degree of compaction, with a given soil structure, in a given direction. It is a coefficient in Darcy's equation (Darcy 1856) that characterizes the flux of water that will occur through the soil under a given head (energy) gradient. Saturated hydraulic conductivity tested in a lab can be used as an indicator of infiltration rate, but it has limited direct value in determining the actual in situ infiltration rate of site soils. Tests that measure in-situ saturated hydraulic conductivity are primarily measuring infiltration or percolation rate and adjusting to a gradient of 1. This is reasonably similar to infiltration rate or percolation rate and is sometimes used interchangeably.

Infiltration rate is the rate of flux of water into the surface of the soil. Infiltration rate is a function of several factors including the soil grain size, layering of soil, density/compaction, macropores, depth of ponding on the soil surface, moisture content of the surface layer of the soil, and the rate at which water moves away from the surface once it is in the subsurface (i.e., the percolation rate). These factors control how quickly water can move into the soil. Infiltration rate tends to be higher at the start of an infiltration event as the soil wets, then declines to a steady state as the surface and near surface soils becomes saturated. Saturated infiltration rate is used for design of BMPs. There are two conceptual type of saturated infiltration rates:

- A **point infiltration rate** is the rate at which water will enter soil at a specific point and horizon, usually measured under saturated conditions. Most infiltration tests measure a point infiltration rate.
- The **full-scale infiltration rate** is the rate at which water will enter soil reliably from the actual proposed BMP under extended saturation conditions. The full-scale infiltration cannot typically be measured directly prior to construction. It must be estimated from point infiltration rates and accounting for whether

subsurface limitations could reduce the actual rate of infiltration at full scale and under sequential storm events.

Percolation rate is the rate at which water moves through soil under a given set of boundary conditions. Similar to infiltration rate, percolation rate measured in a test can be converted units of length per time (i.e., inches per hour). If the percolation rate is slower than the infiltration rate, then the percolation rate will tend to limit the infiltration rate after steady state conditions have been reached. In this case, it is reasonable to equate infiltration rate with percolation rate.

However, percolation rate can be much different than infiltration rate when the direction of percolation that is measured in a test is different than the direction of infiltration from the proposed BMP type. **Anisotropy** refers to preferential flow direction in soils. Most soils have a higher permeability in the horizontal direction than the vertical direction, commonly 5 to 10 times higher. Therefore, tests that primarily measure horizontal percolation rate (e.g., borehole tests) need to be carefully interpreted if they will be used to estimate the vertical hydraulic conductivity of soils.

D.1.4.2 Infiltration Rates Used in Infiltration Screening and Design

This TGD refers to three usages of infiltration rates. These infiltration rates are defined in **Table D-4** with guidance on what factors should be considered in establishing each rate.

Table D-4. Definition of Infiltration Rates Used in Screening and Design

Infiltration Rate	Appropriate Factors to Consider	Factor of Safety
Observed Infiltration Rate (K_{obs})	• This value should be the best estimate of saturated infiltration rate in the vertical direction at potential BMP locations based on field testing and information known about potential BMP types (except where dry wells are proposed, in which case horizontal infiltration rate is most applicable). • Include adjustment from test measurements to estimate vertical infiltration (such as conversion from water level fall in borehole to 1-D infiltration rate). • Select representative value from the range of observations; not necessarily worst case. • Adjustments for effects of water temperature on infiltration rate. • Effects of groundwater limiting horizon on full scale infiltration rate. However, in most cases, where groundwater separation distances are observed and limiting horizons are tested, there should be no need to convert account for the limiting effects of groundwater mounding in K_{obs}.	**None**

Infiltration Rate	Appropriate Factors to Consider	Factor of Safety
Feasibility Screening Infiltration Rate (K_{screen})	• K_{screen} is only intended to be used to determine if infiltration should be considered further. It is not to be used in design. • A minimum factor of safety 2.0 is applied to K_{obs} to account for a nominal level of unavoidable uncertainty and potential for long term clogging. • This factor of safety assumes a very rigorous investigation would be done to support full scale design of an infiltration BMP and a robust pretreatment approach would be used if infiltration BMPs are selected.	**2.0**
Design Infiltration Rate (K_{design})	• This is intended to be the infiltration rate that can be reliably assured over long-term operation of an infiltration BMP. • Consider additional factors in **Appendix D.4** to determine the appropriate factor of safety to apply to K_{obs} to determine the reliable long term K_{design}. • Consider results of any additional testing or exploration that is conducted to support design. • Consider specific BMP geometry in interpreting testing results. For example, if some amount of infiltration will occur through sidewalls, account for this in the infiltration rate used in design.	**Per Appendix D.4** **At least 2.0.**

D.1.5 Effects of Temperature on Infiltration Rates

The rate of infiltration of water through soil is strongly affected by the viscosity of the water, which is affected by the temperature of the water. Therefore, warmer water infiltrates much faster than colder water, all other things being equal.

If possible, testing should be conducted at a temperature that approximates the typical runoff temperatures for the site during the wet season (~60 degrees F). If this is not possible, then the results of infiltration tests must be adjusted to account for the difference between the temperature of the water used for testing and the typical temperature of runoff that the BMP will receive. **Table D-5** provides adjustment factors.

Table D-5. Correction Factors for Temperature of Test Water

Temperature of Test Water, F	Correction Factor (Multiply by Raw Observation)
60 or less	1.00
70	0.90
80	0.77
90	0.69
100	0.61

D.1.6 Inherent Limits of Infiltration Testing

There are a number of inherent limits in the degree to which infiltration testing can assure as-built and long-term design conditions. The investigation and reporting of infiltration rates should acknowledge these limitations to help provide realistic guidance to project designers about the level of confidence in findings and the need for additional testing and/or contingency plans.

D.1.6.1 Scaling from Point Measurements to Full-Scale and Long-Term Performance

There are several challenges in scaling short-term, point observations of infiltration rate to long-term, full scale performance.

1. Testing procedures are all approximations, with simplifications in the measurement geometry and scale compared to full scale BMPs. Correction factors are similarly simplified. Testing and interpretation methods often rely on assumptions about uniform soil properties, isotropic behavior (i.e., same in all directions), which are typically not entirely true.
2. Point measurements do not involve enough water or long enough testing periods to directly test the long-term infiltration capacity of the surface plus subsurface soil. These factors need to be estimated from soil and groundwater information.
3. Earthwork and associated compaction of the site can greatly change soil structure and associated infiltration rates. Compaction can reduce infiltration rates by an order of magnitude (10x), even in relatively sandy soils.
4. Over time, the surface of infiltration facilities can become plugged as sedimentary particles accumulate at the infiltration surface. Plant action can help avoid or reduce this. But the balance between these two factors is poorly characterized.

Prior to full scale construction and operation, it is appropriate to consider infiltration measurements to be "informed estimates" at best. But these measurements do not provide assurance of actual future conditions. For these reasons, it is expected that relatively large factors of safety are needed to support an infiltration design, unless the design also include a contingency plan for how the BMP will be modified if actual infiltration is less than planned. Additionally, construction phase testing is encouraged to confirm infiltration rate.

D.1.6.2 Infiltration in Future Fill Conditions

If the bottom of a BMP (infiltration surface) will be located in fill that has not yet been placed, it is not possible to test infiltration rates for the future compacted fill. There is no reliable basis for estimating the infiltration of future standard fill material. Where fill depths are not excessive below the invert of the BMP, the use of a granular permeable fill meeting project-specific requirements could allow infiltration in these conditions, provided that underlying soils also support infiltration. The design infiltration rate of the permeable fill materials should be at least two times higher than the underlying soils to ensure that this horizon does not limit infiltration. In any case, testing should be conducted following placement to ensure that specifications for permeable fill material were met.

D.1.7 Guidelines for Scoping and Reporting of Infiltration Investigations

D.1.7.1 Planning Phase Investigation

Tests should seek to characterize the infiltration rates at the likely elevation of the infiltration BMPs, but it is recognized that design-level BMP elevations may not be known at this time.

Spacing of tests should be determined based on the variability of conditions. This can be informed by other information about the soils and geology within the projects, such as previous geotechnical investigations. In sites with uniform conditions, a minimum of three tests per site is recommended, coupled with review of other information to interpolate or extrapolate from test results. For larger or more varied sites, additional tests may be needed. Testing locations should be focused where other soils and geologic data suggests that infiltration is most likely to be feasible. The density of testing does not need to be uniform throughout the site.

As described in **Section 2.3** of the TGD, the goal of this investigation should be to prepare a map of the site that overlays infiltration rate ranges with other constraints to identify potentially suitable areas for infiltration. The following ranges of K_{screen} ($K_{obs}/2$) are suggested to guide decision making:

- Areas K_{screen} of > 2 inch per hour (most favorable for infiltration).
- Areas with K_{screen} of 0.3 to 2 inches per hour (good possibility for infiltration, but a backup plan is likely needed).
- Areas with K_{screen} of 0.05 to 0.3 inches per hour (most suitable for biotreatment with partial infiltration designs).
- Areas with K_{screen} < 0.05 inches per hour (negligible infiltration potential).

A map is not necessarily applicable for small sites where conditions are reasonably consistent across the site.

As part of the planning/screening phase, review of NRCS soils maps and available information may be conducted by the project design professional. Simple open pit testing may also be conducted by the project design professional. These forms of testing do not require a report separate from the WQMP.

Other types of tests must be conducted by a licensed professional geotechnical engineer or registered geologist. These types of testing require reporting.

Reporting should include:

- Description of methods
- Identification of other data source uses
- Geologic setting
- Testing locations
- Testing results
- Interpretation of findings
- Graphical identification of ranges of infiltration rate (if applicable)

D.1.7.2 Design-Phase Investigation

Design phase testing must be conducted or overseen by a qualified professional, either a Professional Engineer (PE) or Registered Geologist (RG) licensed in the State of California.

Design phase testing should be conducted at the location of each infiltration BMP that is proposed.

The elevation of the tests should correspond to the facility elevation, plus 1 to 2 feet to account for soil amendments or decompacted zones under the infiltration system. If a confining layer, or soil with a greater percentage of fines, is observed during the subsurface investigation to be within 6 feet of the bottom of the planned infiltration system, the testing should be conducted within that confining layer.

The boring logs should continue to at least 15 feet below the invert of the proposed BMP. Borings should be conducted at each test location.

The recommended number of infiltration tests depends up on the footprint size and the soil variability. The following guidance is provided to estimate the number of tests per BMP.

- Three infiltration tests should be conducted for every Full Infiltration BMP, conducted within the proposed BMP footprint or within 20 feet of the perimeter in representative soil formations.
- For Full Infiltration BMPs with footprints larger than 10,000 square feet, conduct one additional test for every 10,000 square feet of BMP footprint area after the first 10,000 square feet

  For example, if a large BMP had an infiltration area of 30,000 square feet, 5 tests should be conducted (3 for the first 10,000 square feet, 1 for the next 10,000, and 1 for the next 10,000)
- One test for every 100 lineal feet of infiltration facility.
- In general, no more than five valid tests are required per BMP of any footprint, unless more tests would be valuable or necessary (at the discretion of the qualified professional assessing the site, as well as the reviewing jurisdiction).

These recommendations may need to be reduced or increased at the discretion of the project professional and reviewing jurisdiction depending on the complexity and variability of the site.

Reporting should include:

- Name and qualifications of preparer;
- Scope of investigation, including description of methods, identification of other data source uses;
- Geologic setting;
- Testing locations and depths;
- Testing results;
- Testing records and description of specific measurements;
- Interpretation of findings, including consideration of limiting horizons or groundwater conditions that could limit full scale infiltration;
- Confirmation or adjustment of preliminary infiltration screening – is it acceptable to utilize full infiltration BMPs?; and
- Recommended component of the overall factor of safety that is appropriate to account for variability or uncertainty in testing.

Reporting for planning phase and design phase testing does not need to be contained in separate reports, however the combined reporting must justify how the BMP locations were selected for detailed testing.

D.2 Guidance on Application and Interpretation of Methods

This section provides guidance on application and interpretation of selected infiltration testing or estimation methods. Methods should be selected based on the guidance provided in **Appendix D.1.3**.

D.2.1 Use of Regional Maps and "Available Data"

This section describes a method that satisfies the requirements for infiltration screening of small projects as defined by **Table D-2**. This method uses regionally mapped data coupled with all applicable data available through other site investigations to determine the infiltration rate for the purposes of infiltration feasibility screening and categorization.

Via this method, areas of a project identified as having Hydrologic Soil Group D soils (See **Appendix N**) are considered infeasible for Full Infiltration BMPs. This determination may be supported without testing if available data do not contradict this determination.

"Available data" is defined as data collected by the project or otherwise available that provides information about soil types or infiltration rates. Applicable data is expected to be available as part of nearly all projects subject to New Development and Significant Redevelopment stormwater management requirements in Orange County. Data sources may include:

- Geotechnical investigations,
- Due diligence site investigations,
- Other CEQA investigations, or
- Investigations performed on adjacent sites with applicability to the project site.

For projects permitted to utilize this method, additional infiltration testing data is not required to be obtained, however, infiltration testing data which is already available from previous studies must be used. If available data suggests that other soil types are present than the mapped soil types such that there is a reasonably chance that infiltration could be feasible, then a site-specific investigation with testing is needed.

The distinction between large and small projects is based on the lower spatial variability expected on smaller projects and the lower project value. In these cases, the expense associated with infiltration testing of HSG D soils to attempt to identify localized exceptions to this mapped and supported determination is considered to be an unreasonable economic burden.

D.2.2 Simple Open Pit Infiltration Test

The Simple Open Pit Infiltration Test is a simple, site-specific method which can be used to provide a preliminary estimate of infiltration rate for the planning level/screening level investigations. This approach is similar to the Open Pit Falling Head Test (D.3.1), but is less rigorous and does not need to be conducted by a licensed professional.

1. Excavate a test hole to the elevation of the likely bottom of proposed infiltration facilities or into the lowest permeability layer believed be present in the top 5 feet. The test hole can be excavated with small excavation equipment or by hand using a shovel, auger, or post hole digger. The hole should be a minimum of 2 feet in diameter or square and should be sufficient to allow for observation of the water surface level in the bottom of the hole. Remove loose material, as much as possible from the bottom of the hole but avoid compaction of the bottom surface. If a layer hard enough to prevent further excavation is encountered during excavation, or if noticeable moisture/water is encountered in the soil, stop and measure this depth. Proceed with the test at this depth.
2. Scarify the side walls and bottom with a rake or similar equipment to loosen soil and alleviate any "smearing" that is noted
3. Fill the hole with water to a height of about 18 inches from the bottom of the hole, and record the exact time. Check the water level at regular intervals (every minute for fast-draining soils to every 10 minutes for slower-draining soils) for a minimum of 3 hours or until at least 6 inches of water have infiltrated. Record the distance the water has dropped from a stable fixed reference point such as the top edge of the hole. A temporary staff gage driven in to the bottom of the hole is also recommended.
4. The infiltration rate is calculated by dividing the change in water elevation time (inches) by the duration of the test (hours).

5. Repeat this process two more times, for a total of three rounds of testing. These tests should be performed as close together as possible to accurately portray the soil's ability to infiltrate at different levels of saturation. The third test provides the best measure of the saturated infiltration rate.
6. For each test location, record all three testing results with the date, duration, drop in water height, and conversion into inches per hour.
7. Make adjustments for water temperature used in the test, if necessary.

Due to infiltration into sidewalls and lack of pre-saturation, this test is likely to produce results that are higher than other more rigorous tests.

Source: City of Portland, 2014, Stormwater Management Manual

D.2.3 Borehole Methods

Borehole permeameter methods are a class of methods used to estimate the subsurface hydraulic conductivity of soils by measuring the rate at which water discharges from a drilled borehole into surrounding soils. Various configurations of tests and interpretation methods exists.

D.2.3.1 General Usage and Limitations

Borehole permeameters primarily measure the lateral movement of water out of a borehole into surrounding soils. Therefore, these tests primarily yield an estimate of horizontal Ksat. In most soils, the horizontal Ksat is much larger than vertical Ksat due to soil layering and soil particle arrangement. The ratio between horizontal to vertical Ksat can be 10 to 100. This ratios is known as the soil "anisotropy." It is challenging to measure anisotropy directly, therefore borehole tests are typically not able to yield reliable information about vertical infiltration rates.

Depending on how the borehole is configured, the "interval" of the borehole can target measurement of certain zones of the soil. For example, the borehole can have a "screened interval" between 5 and 10 feet below ground surface to estimate the soil properties in this range. If there are different types of soil within this range, borehole tests can be biased. In general, it is recommended to test intervals within which soils are relatively uniform. Multiple tests can be conducted for different soil layers.

Primary usage of this test include:

- Preliminary screening-level testing where the finish grade of a BMP will be well below the current grade (i.e., a borehole test is the only realistic option). If an infiltration BMP is proposed, a direct measurement of vertical infiltration will typically be needed following grading to confirm infiltration rates.

- Design level investigations of BMPs that operate primarily via lateral infiltration, such as dry wells and infiltration trenches.

Due to the inability to reliably estimate vertical infiltration rate, a borehole permeameter method should typically not be used to determine design infiltration rate of BMPs besides dry wells or infiltration trenches.

Borehole tests may require a well drilling permit if the test will be operated for longer than 24 hours.

D.2.3.2 Well Permeameter Method (USBR Procedure 7300-89)

The United States Bureau of Reclamation Well Permeameter Method (USBR 7300-89) (see Figure D-2 and Figure D-3) is an in-hole hydraulic conductivity test performed by drilling test wells with an 8 inch diameter auger to the desired depth. See USBR procedure 7300-89 for further details. https://www.usbr.gov/tsc/techreferences/mands/mands-pdfs/earth2.pdf

Test Preparation

The test requires drilling a well, filling it with sand of a known density and high permeability to just below the water elevation, and using a float and a water reservoir to maintain a constant head in the well.

1. Prior to testing, the results of soil boring logs of the area should be reviewed to determine the approximate depth of groundwater and the presence of any lenses of soil with significantly different properties than the surrounding soil that are likely to have significantly different permeability which could affect test results.
2. A test well is drilled to the desired depth.
3. Fill the well with calibrated sand to a depth of about 150 mm below the water level that is to be maintained during the test. Measure the remaining sand to determine the mass of sand in the well. Measure the depth of the sand in the well and use the calibrated density of the sand to calculate the equivalent radius of the well (Figure D-14) using the equation below:

$$r = \sqrt{\frac{m_S}{\pi * h_S * \rho_S}} \qquad \text{Equation D.1}$$

Where:

r = equivalent radius of the well (ft)

m_s = mass of sand in the well (lb)
h_s = height of sand in well (ft)
ρ_s = density of sand (lb/ft^3)

4. Place the float guide, with the float inside, on top of the sand in the well and pour sand around it to keep it vertical. Set up the water reservoir and valve-float arrangement.

Test Procedure

1. Fill the well to the desired water level (typically the overflow elevation of the proposed BMP) and use the float and reservoir to maintain this level.
2. When the water level has stabilized, begin reading the volume gauge on the reservoir and the temperature of the water and record gauge readings at convenient time intervals using the form in Figure D-1, below or similar. The well must be kept continuously full until the test is completed. In general, dry soil at the start of the test absorbs water at a comparatively high rate. However, as the moisture content of the soil increases around the well, the rate generally decreases and usually stabilizes. It is this constant rate after stabilization that is used to compute permeability. Continue to maintain the water level taking flow readings at regular intervals until the rate of change of water usage is less than 10 percent over a 1 hour interval, or other stabilization criteria determined to be appropriate.

3. Plot the cumulative flow volume with time of until the slope of the plotted line has stabilized. Use the stabilized portion of the plotted line to compute the stable percolation rate.

Figure D-1: Form for Well Permeameter Test Data Recording and Calculations (County of Los Angeles, 2014)

WELL PERMEAMETER TEST
(reference USBR 7300-89)

Project: ____________________
Test Location: ____________________

____

____

BMP Invert: ____________________
Water Source: ____________________
Turbidity: ____________________
Tested By: ____________________

Boring/Test Number: [ ]

r, radius of boring: ____ ft

Date:

D, boring depth below ground surface: ____ ft

h, depth of water maintained from bottom of hole: ____ ft

W, water table, or impervious layer, depth below ground surface: ____ ft

T_u, depth to water table or impervious layer from surface of water maintained: ____ ft

Note: $T_u = W - D + h$

Condition I: $T_u \geq 3h$ [ ]

Condition II: $h \leq T_u \leq 3h$ [ ]

Water level determined by: [ ] Flow meter [ ] Float valve [ ] Calibrated tank

S, Anticipated Specific Yield: S = 0.1 for fine grained & 0.35 for course grained.

$$V_{min} = 2.09S\left[h - \frac{2}{\sqrt{\ln\left(\frac{h}{r} + \sqrt{\left(\frac{h}{r}\right)^2 + 1}\right) - 1}}\right]^3$$

Example: h = 3.5 ft, r = 0.5 ft, and S = 0.15, then the minimum water volume (V_{min}) needed for testing is 51 ft^3 or 381 gal.

$V_{max} = 2.05V_{min}$

Example: maximum water volume needed for testing, 381 gal(2.05) = 781 gal.

Trial No.	Date	Time (24hr format) hh:mm	Time Interval min	Accumulated Time min	Flow Meter / Tank Readings gallons	Flow Meter / Tank Readings Δ (gallons)	Accumulated Flow gallons	Water Temp. °F	Flow Rate, Q gpm	Flow Rate, Q ft^3/min	Remarks: weather conditions, etc.
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

Calculations

The flow rate obtained from the cumulative volume recordings must be converted into an infiltration rate. These calculations depend on the depth of groundwater relative to the depth of the well, as shown in Figure D-2.

There are three conditions relative to the depth of groundwater (Figure D-2). In Condition I, the depth to groundwater from the water surface, T_u is greater than three times higher than the height of water in the test well (h). In Condition II, the groundwater table is below the well, but the distance from the water surface to the groundwater table is less than three times greater than the height of the water. Condition III is irrelevant for the purposes of testing for infiltration BMPs because the groundwater table is within the well.

Under Condition I, the infiltration rate can be calculated using Equation D.2 below:

$$K_{obs} = \frac{360*Q}{\pi*h^2}\left[ln\left(\frac{h}{r}+\sqrt{\left(\frac{h}{r}\right)^2+1}\right)-\frac{\sqrt{1+\left(\frac{h}{r}\right)^2}}{\frac{h}{r}}+\frac{r}{h}\right]$$ Equation **D.2**

Where:

K_{obs} = observed horizontal infiltration rate (inches/hour)
Q = measured flow rate under stabilized conditions (cubic feet/minute)
h = height of water in well (feet) (see Figure D-2)
r = effective radius of well (feet) (see Equation D.1)

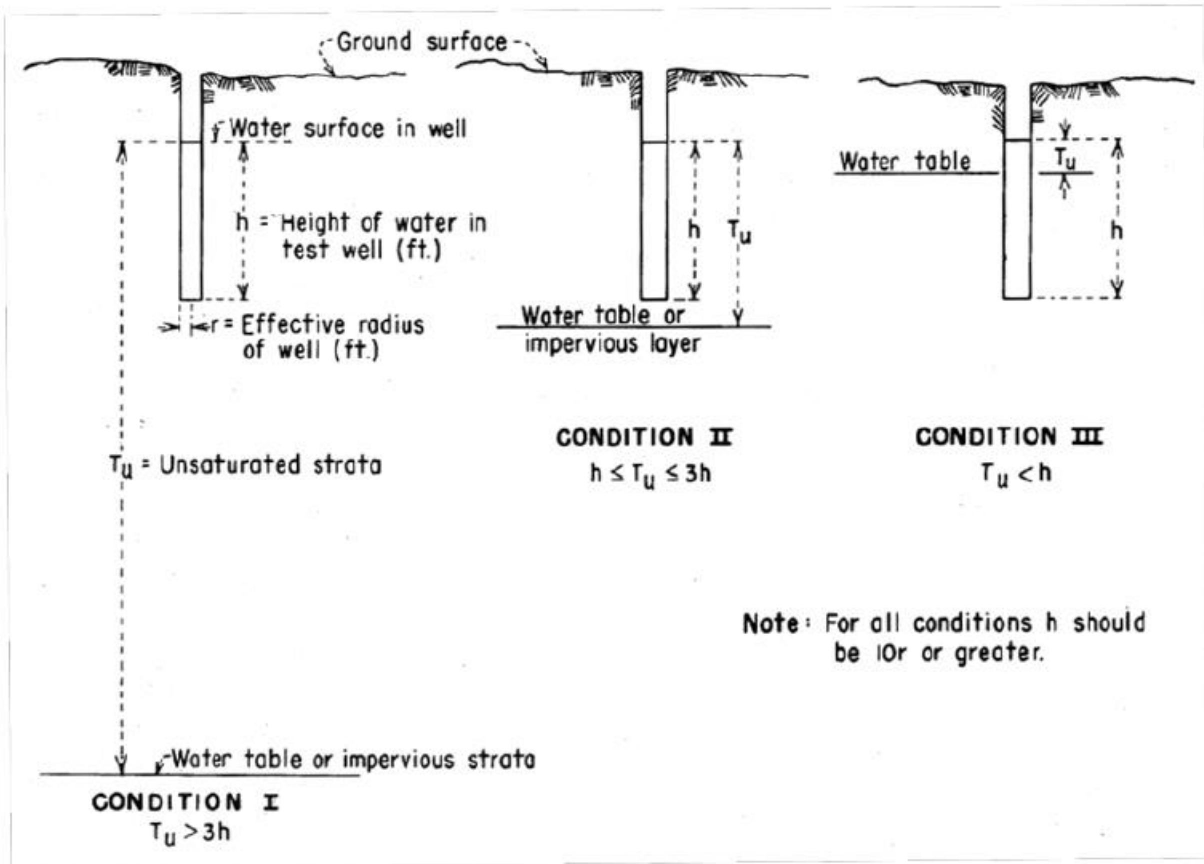
Under Condition II, the infiltration rate can be calculated using Equation D.3 below:

$$K_{obs} = \frac{360*Q}{\pi*h^2}\left[\frac{ln\left(\frac{h}{r}\right)}{\frac{1}{6}+\frac{1}{3}*\left(\frac{h}{T_u}\right)^{-1}}\right]$$ Equation **D.3**

Where:

K_{obs} = observed infiltration rate (inches/hour)
Q = measured flow rate (cubic feet/minute)
h = height of water in well (feet) (see Figure D-2)
r = effective radius of well (feet) (see Equation D.1)
T_u = unsaturated distance between the water surface and the water table or impervious strata

Figure D-2: Conditions used to Convert the Flow Rate Obtained from Data to an Infiltration Rate Using the Well Permeameter Test (USBR, 1990)



Example

The following example is adapted from County of Los Angeles, 2014.

Figure D-3 contains the filled-in measurement form for a well permeameter test along with the attributes of the well. The total volume infiltrated was 476.4 gallons. Using the data obtained from **Figure D-3**, the cumulative flow was plotted with time to ensure that the flow rate had stabilized, as shown in **Figure D-4**. The flow rate appears to have stabilized within the last several measurements. Therefore, the change in volume over the last three measurements over the change in time was used to compute the flow rate of 0.133 gallons/min (**Figure D-4**). This is converted to cubic feet per minute (0.018 cubic feet/in) for use in the infiltration rate calculation (**Figure D-3**). The average temperature of the water is found to be 62 degrees Fahrenheit (16.6 degrees Celsius). Which is close enough to an expected temperature of runoff for this area, so no adjustment for temperature is needed (See **Section D.1.5**). Based on the measurement to the groundwater table, the well is in Condition II. Therefore, using the information on the form (**Figure D-3**), the infiltration rate is 0.54 inches/hour.

Figure D-3: Example of Well Permeameter Measurement Form (Los Angeles County, 2014)

WELL PERMEAMETER TEST
(reference USBR 7300-89)

Project: Practice Infiltration Testing Test
Location: 123 Drive Road

BMP Invert: 5' below existing ground surface
Water Source: Potable Water
Turbidity:
Tested By: YH & CM

Boring/Test Number: [redacted]
r, radius of boring: 0.5ft Date: 5/4/2016
D, boring depth below ground surface: 6.0 ft
h, depth of water maintained from bottom of hole: 3.5 ft
W, water table, or impervious layer, depth below ground surface: 7.0 ft
Condition I: $T_u \geq 3h$ [ ]
Condition II: $h \leq T_u \leq 3h$ [X]
T_u, depth to water table or impervious layer from surface of water maintained: 4.5 ft Note: $T_u = W - D + h$
Water level determined by: [X] Flow meter [ ] Float valve [ ] Calibrated tank
S, Anticipated Specific Yield: 0.15 $S \approx 0.1$ for fine grained & 0.35 for course grained.

$$V_{min} = 2.09S\left\{h\frac{2}{\sqrt{\ln\left(\frac{h}{r}+\sqrt{\left(\frac{h}{r}\right)^2+1}\right)-1}}\right\}^3$$

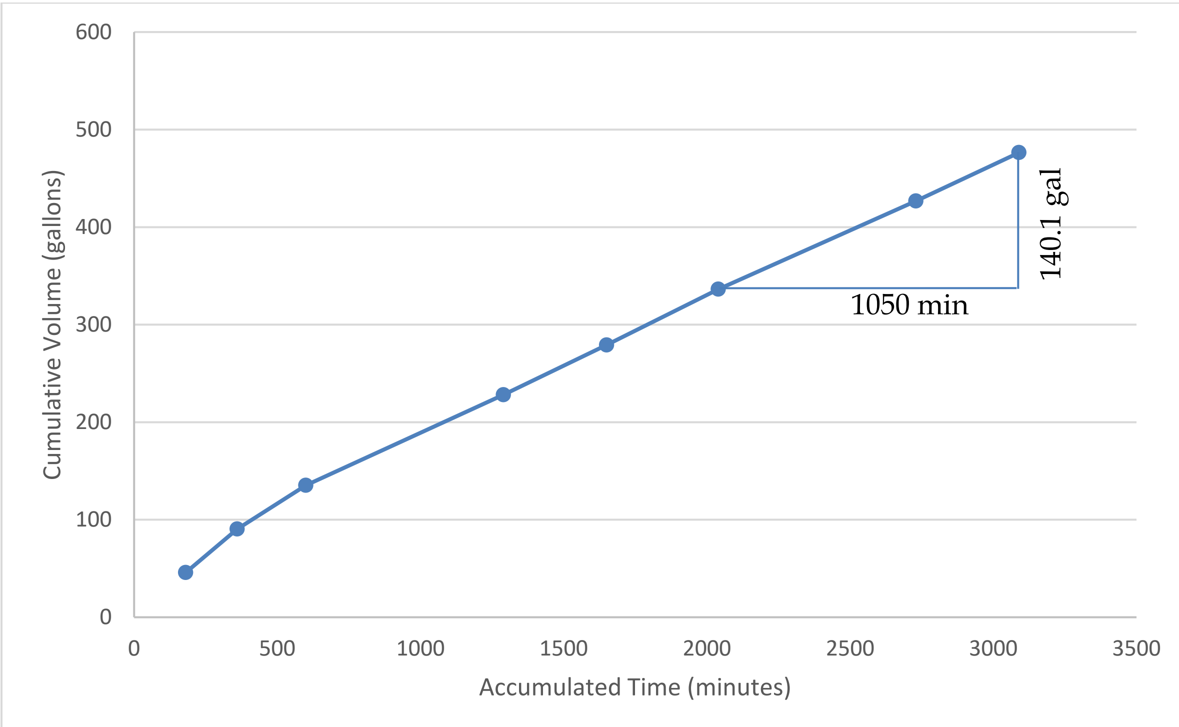
Example: h = 3.5 ft, r = 0.5 ft, and S = 0.15, then the minimum water volume (V_{min}) needed for testing is 51 ft³ or 381 gal.

$V_{max} = 2.05V_{min}$

Example: maximum water volume needed for testing, 381 gal(2.05) = 781 gal.

Trial No.	Date	Time (24hr format) hh:mm	Time Interval min	Accumulated Time min	Flow Meter / Tank Readings gallons	Δ (gallons)	Accumulated Flow gallons	Water Temp. °F	Flow Rate, Q gpm	Flow Rate, Q ft³/min	Remarks: weather conditions, etc.
1	10/8	08:00	180	180	0	45.8	45.8	61	0.254	0.034	70's slightly cloudy, used one 55-gal drum. Refilled before next test.
	" "	11:00			45.8						
2	" "	11:15	180	360	0	44.6	90.4	64	0.248	0.0331	
	" "	14:15			44.66						
3	" "	14:30	240	600	0	44.9	135.3	65	0.187	0.025	Connected 2 55-gal drums together for trial no. 4.
	" "	18:30			44.9						
4	" "	19:00	690	1290	0	92.8	228.1	63	0.134	0.018	
	10/9	06:30			92.8						
5	" "	06:40	360	1650	0	51.0	279.1	61	0.142	0.019	
	" "	12:40			51						
6	" "	12:55	390	2040	51	57.2	336.3	66	0.147	0.0196	disturbed some soil into hole when observing for turbidity
	" "	19:25			108.2						
7	" "	19:30	690	2730	0	90.5	426.8	55	0.131	0.0175	
	10/10	07:00			90.5						
8	" "	07:20	360	3090	0	49.6	476.4	60	0.138	0.0184	
	" "	13:20			49.6						

Figure D-4: Plotted Cumulative Flow Volumes with Cumulative Time for Well Permeameter Example (Los Angeles, 2014)



D.2.3.3 Falling Head Borehole Percolation Test Procedure

The percolation test procedure below (per Riverside County Department of Environmental Health) one procedure for conducting falling-head borehole percolation tests. The procedure for this test varies, depending on the depth of the hole to be used. Procedures for both scenarios (less than 10 feet or 10 - 40 feet deep) and diagrams (**Figure D-5** to **Figure D-7**) are included below.

Shallow Percolation Test (less than 10 feet)

Test Preparation

1) The test hole opening shall be between 8 and 12 inches in diameter or between 7 and 11 inches on each side if square. The size of the test hole is accounted for in the interpretation of the results. The interpretation of results assumes the how is not filled with rock or any other material.

2) The bottom elevation of the test hole should correspond to approximately 5 feet below the bottom elevation of the proposed basin (infiltration surface). A test interval that Keep in mind that this procedure will require the test hole to be filled with water to a depth of at least 5 times the hole's radius.

3) The bottom of the test hole shall be covered with 2 inches of gravel.

4) The sides of the hole shall remain undisturbed (not smeared) after drilling and any cobbles encountered left in place.

5) **Pre-soaking** shall be used with this procedure. Invert a full 5 gallon bottle (more if necessary) of clear water supported over the hole so that the water flow into the hole holds constant at a level at least 5 times the hole's radius above the gravel at the bottom of the hole. Testing may commence after all of the water has percolated through the test hole or after 15 hours has elapsed since initiating the pre-soak. Tests should be run immediately after pre-soaking..

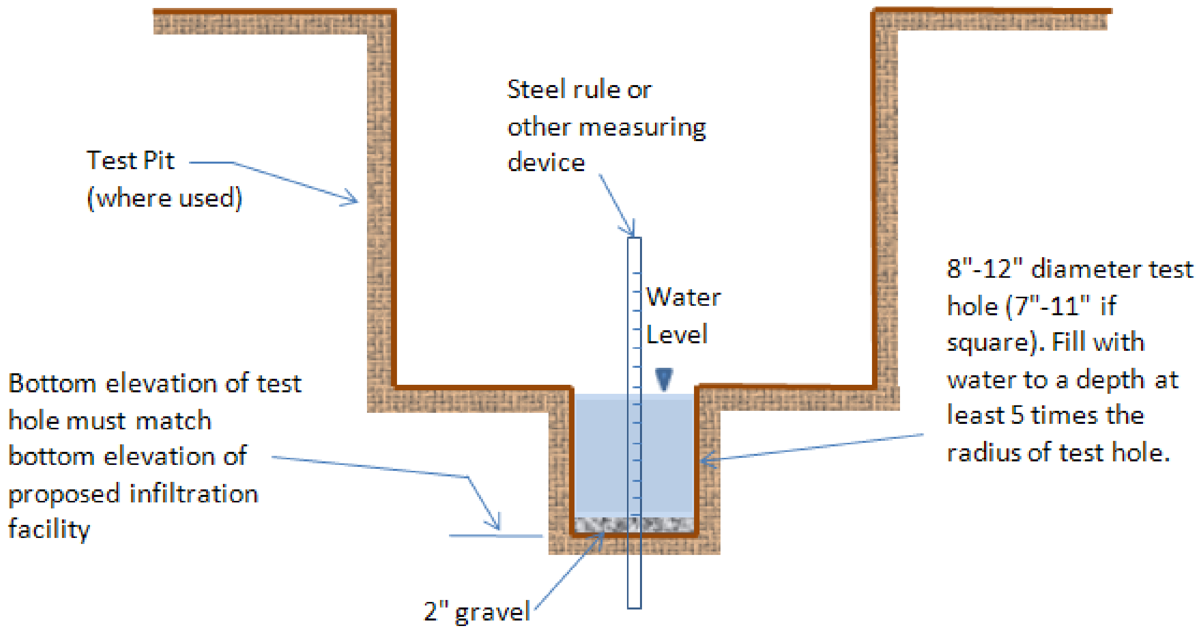
Test Procedure

Test hole shall be carefully filled with water to a depth equal to at least 5 times the hole's radius (H/r>5) above the gravel at the bottom of the test hole prior to each test interval.

- In **sandy soils**, when 2 consecutive measurements show that 6 inches of water seeps away in less than 25 minutes, the test shall be run for an additional hour after these initial, measurements with measurements taken every 10 minutes. Measurements shall be taken with a precision of 0.25 inches or better. The drop that occurs during the final 10 minutes is used to calculate the percolation rate. Field data must show the two 25 minute readings and the six 10 minute readings.

- In **non-sandy soils**, obtain at least twelve measurements per hole over at least six hours with a precision of 0.25 inches or better. From a fixed reference point, measure the drop in water level over a 30 minute period for at least 6 hours, refilling after every 30 minute reading. The total depth of the hole must be measured at every reading to verify that collapse of the borehole has not occurred. The drop that occurs during the final reading is used to calculate the percolation rate.

Figure D-5. Test Pit for Shallow Percolation Test



<u>**Deep Percolation Test (10 - 40 feet)**</u>

Test Preparation

1) Borehole diameter shall be either 6 inches or 8 inches. The size of the test hole is accounted for in the interpretation of the results. The interpretation of results assumes the how is not filled with rock or any other material.

2) The bottom elevation of the test hole shall correspond to approximately 5 feet below the bottom elevation of the proposed basin (infiltration surface). Keep in mind that this procedure will require the test hole to be filled with water to a depth of at least 5 times the hole's radius.

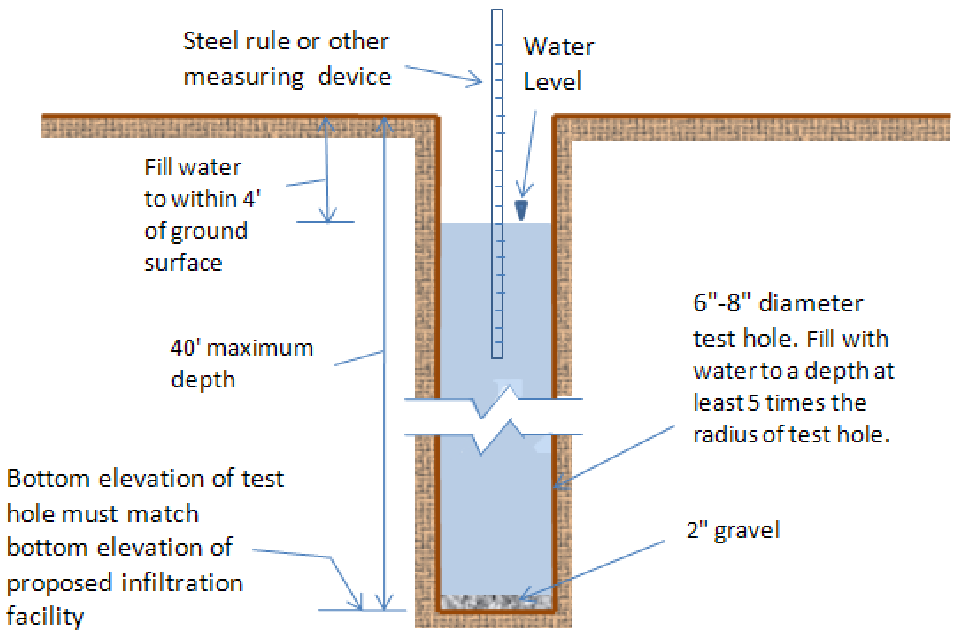
3) The bottom of the test hole shall be covered with 2 inches of gravel.

4) The sides of the hole shall remain undisturbed (not smeared) after drilling and any cobbles encountered left in place. Special care should be taken to avoid cave-in. If cave-in cannot

be avoided, a screen could be considered or an alternative test such as the USBR Well Permeameter Method should be used.

5) **Pre-soaking** shall be used with this procedure. Pre-soaking shall be performed for 24 hours over the entire test interval unless the site consists of sandy soils containing little or no clay. If sandy soils exist as described below, the tests may then be run after a 2 hour pre-soak. Tests should be run immediately after presoaking.

Figure D-6. Test Pit for Deep Percolation Test



Test Procedure

Carefully fill the hole with clear water to approximately 5 feet depth. At a minimum, the bore hole shall be filled with water to a depth equal to 5 times the hole's radius (H/r>5).

In **sandy soils**, when 2 consecutive measurements show that 6 inches of water seeps away in less than 25 minutes, the test shall be run for an additional hour with measurements taken every 10 minutes. Measurements shall be taken with a precision of 0.25 inches or better. The drop that occurs during the final 10 minutes is used to calculate the percolation rate. Field data must show the two 25 minute readings and the six 10 minute readings.

In **non-sandy soils**, from a fixed reference point, measure the drop in water level over a 30 minute period for at least 6 hours, refilling after every 30 minute reading. Measurements shall be taken with a precision of 0.25 inches or better. The total depth of hole must be measured at every reading to verify that collapse of the borehole has not occurred. The drop that occurs during the final reading is used to calculate the percolation rate.

Figure D-7. Sample Test Data Form for Falling Head Borehole Percolation Test

Percolation Test Data Sheet

Project:			Project No:			Date:	
Test Hole No:			Tested By:				
Depth of Test Hole, D_T:			USCS Soil Classification:				
Test Hole Dimensions (inches)					Length	Width	
Diameter (if round)=			Sides (if rectangular)=				

Sandy Soil Criteria Test*

Trial No.	Start Time	Stop Time	Time Interval, (min.)	Initial Depth to Water (in.)	Final Depth to Water (in.)	Change in Water Level (in.)	Greater than or Equal to 6"? (y/n)
1							
2							

*If two consecutive measurements show that six inches of water seeps away in less than 25 minutes, the test shall be run for an additional hour with measurements taken every 10 minutes. Other wise, pre-soak (fill) overnight. Obtain at least twelve measurements per hole over at least six hours (approximately 30 minute intervals) with a precision of at least 0.25".

Trial No.	Start Time	Stop Time	Δt Time Interval (min.)	D_o Initial Depth to Water (in.)	D_f Final Depth to Water (in.)	ΔD Change in Water Level (in.)	Percolation Rate (min./in.)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							

COMMENTS:

Example Calculation of Percolation Rate from Falling Head Borehole Data

The Percolation Test Data Sheet is prepared as the test is being performed. After the minimum required number of testing intervals, the test is complete. The data collected at the final interval is as follows:

Time interval, Δt = 10 minutes

Initial Depth to Water, D_0 = 12.25 inches

Final Depth to Water, D_f = 13.75 inches

Total Depth of Test Hole, D_T = 60 inches[3]

Test Hole Radius, r = 4 inches (diameter = 8 inches)

The conversion equation is used:

$$P = \frac{\Delta H(60r)}{\Delta t(r+2H_{avg})}$$ Equation D.4

"H_o" is the initial height of water at the selected time interval.

$H_o = D_T - D_0 = 60 - 12.25 = 47.75$ inches

"H_f" is the final height of water at the selected time interval.

Hf = DT - Df = 60 - 13.75 = 46.25 inches

"ΔH" is the change in height over the time interval.

$\Delta H = \Delta D$ = Ho - Hf = 47.75 – 46.25 = 1.5 inches

"H_{avg}" is the average head height over the time interval.

H_{avg} = (Ho + Hf)/2 = (47.75 + 46.25)/2 = 47.0 inches

"P" is the tested percolation rate:

$$I_t = \frac{\Delta H(60r)}{\Delta t(r + 2H_{avg})} = \frac{(1.5\ in)(\frac{60\ min}{hr})(4\ in)}{(10\ \text{min})((4\ in) + 2(47\ in))} = 0.37\ in/hr$$

[3] Where a rectangular test hole is used, an equivalent radius should be determined based on the actual area of the rectangular test hole (i.e., $r = (A/\pi)^{0.5}$).

This is a rudimentary measurement of the simple rate at which soil enters the wetted surface area of the borehole. It is a rough approximation of the horizontal rate at which water would discharge from the sides of a dry well or an infiltration trench. This estimate is not a reliable estimate of the rate at which water would infiltrate vertically from a BMP. However, it may be used as an approximate screening method to assess potential feasibility.

D.2.3.4 Other Borehole Methods

There are a range of other borehole permeability or percolation testing methods, including:

- Constant Head Well Permeameter Methods (such as Reynolds, 2008[4]) (note, there are also some commercial permeameters in this category, such as the Guelph permeameter and Aardvark Permeameter)
- California Test 749 or 750 (Caltrans, 1986),
- San Bernardino County Percolation Test (San Bernardino County, 1992),
- USEPA Falling Head Test (USEPA, 1980). Any standard method may be allowed subject to the approval of the geotechnical engineer and the reviewing agency.
- Guelph Permeameters, or equivalent

These methods may be acceptable at the discretion of the preparer and reviewer. The general limitations of borehole methods are generally applicable for these tests. Most importantly, it is challenging or unreliable to obtain an estimate of vertical soil infiltration rate using these methods.

D.2.4 Open Pit Methods

This section describes a specific open pit falling head procedure. Variations on this procedure may be acceptable.

D.2.4.1 General Usage and Limitations

Open pit falling head procedures are performed in an open excavation with permeable sidewalls and floor, therefore the total loss rate is a function of both vertical and lateral infiltration.

These tests are most appropriate where:

- The pit can be excavated to the proposed grade of the BMP
- Water supply is not constrained (these tests can require large volumes of water)

---

[4] Reynolds, W.D., 2008. Saturated hydraulic properties: well permeameter, in: Carter, M.R. and Gregorich, E.G. (Eds.), Soil Sampling and Methods of Analysis (2nd ed.). Canadian Society of Soil Science. CRC Press, Boca Raton, FL., USA, pp. 1025-1042.

- Proposed BMPs will allow infiltration into both bottom and side walls (e.g., bioretention areas without lateral barriers, infiltration basins, infiltration trenches)

Where the test is at the proposed BMP grade and approximates the relative vertical and horizontal infiltration of the BMP, then this test can be reasonably reliable. Pre-soaking is required. Maintaining relatively shallow water depths in the pit during the test is expected to provide the best approximation of the ratio from side wall to floor area in full scale BMPs. In a typical pit test, the size is much smaller than the full scale BMPs, which has the potential to have a high bias from sidewall infiltration unless depths are kept shallow.

D.2.4.2 Open Pit Falling Head Procedure

The Open Pit Falling Head Procedure that can be used to estimate design infiltration rates is similar to the Simple Open Pit Infiltration Test except that it includes more precise instructions, returns more precise measurements, and must be overseen by a geotechnical professional. The tester and excavator should conduct all testing in accordance with OSHA regulations regarding open pit excavations.

The procedure outlined below (adapted from the Portland, Oregon Stormwater Management Manual, City of Portland, 2010) is the recommended method to perform the open pit falling head procedure. However, any standard method may be used at the discretion of the geotechnical engineer subject to the approval of the reviewing agency.

A key requirement of this test is that the ratio of bottom area to sidewall area be reasonably similar to the proposed full scale BMP. For example a 2'x4' pit with 3 inches of ponding depth has approximately the same ratio of footprint to sidewall as a 30'x30' bioretention area with a 30 inch wetted depth. In general, setting the ponding depth in this test to 10 percent of the wetted depth of the full scale BMPs can help keep these ratios similar for typical-sized BMPs.

It is possible to correct for different ratios of side walls to floor in the test vs. full scale BMP, however this reduces the reliability of the test interpretation.

Procedure

1. Excavate a hole with bottom dimensions of at least 2 feet by 4 feet into the native soil to an elevation 1 to 2 feet below the proposed facility bottom to account for amendment of soils under infiltration areas. Larger pits are recommended, particularly if water supply for testing is not limited. If a smooth excavation bucket is used, scratch the sides and bottom of the hole with a sharp pointed instrument, and remove the loose material from the bottom of the test hole. The bottom of the hole should not be compacted and should be as level as possible.
2. Fill the hole with clean water a minimum of 1 foot above the soil to be tested, and maintain this depth of water for at least 4 hours (or overnight if clay soils are present) to

presoak the native material. In sandy soils with little or no clay or silt, soaking is not necessary. If after filling the hole twice with 12 inches of water, the water seeps completely away in less than 10 minutes, the test can proceed immediately.

3. Determine how the water level will be accurately measured. The measurements should be made with reference to a fixed point. A lath placed in the test pit prior to filling or a sturdy beam across the top of the pit are convenient reference points.
4. After the pre-saturation period, refill the hole with water to 3 inches above the soil and record the time. Alternative water depths may be used. The water depth used in infiltration testing should be about 10 percent of the wetted depth of the proposed BMP. For example, if a bioretention area will have 12 inches of ponding and 24 inches of media, the wetted depth would be 36 inches and the ponded water in the test could be about 4 inches.
5. Measure the water level to the nearest 0.01 foot (⅛ inch) at 10-minute intervals for a total period of 1 hour (or every 20-minute intervals for 2 hours in slower soils) or until all of the water has drained. In faster draining soils (sands and gravels), it may be necessary to shorten the measurement interval in order to obtain a well-defined infiltration rate curve.
6. Repeat the test. Successive trials should be run until the percent change in measured infiltration rate between two successive trials is minimal (<10 percent). At least three trials must be conducted. After each trial, the water level is refilled to the same starting level. Record results.
7. The average rate of water surface drop *(as cu-ft per hour)* over the last trial should be used to calculate the observed infiltration rate.

   $$Kobs = Q * (12 \text{ inches/ft}) / (A_{avg})$$

   Where:

   Q = average rate of discharge from the pit over the last trial (cu-ft/hr). This is calculated as the total volume of water infiltrated in a given time interval (as cu-ft) divided by the length of the time interval (in hours)
   A_{avg} = the average wetted area over the last trial, accounting for floor area and sidewalls (as sq-ft)

8. If the temperature of the water during the is significantly outside of the 50 to 60 degree range associated with stormwater runoff, then correct for temperature per D.2.5.
9. For very rapidly draining soils, it may not be possible to maintain a water head above the bottom of the test pit. If the infiltration rate meets or exceeds the flow of water into the test pit, conduct the test in the following manner:
   a) Approximate the area over which the water is infiltrating.
   b) Using a water meter, bucket, or other device, measure the rate of water discharging into the test pit.

c) Calculate the infiltration rate by dividing the rate of discharge (cubic inches per hour) by the area over which it is infiltrating (square inches) and correcting to units of inches per hour.

Constant head tests may be substituted for falling head tests at the discretion of the professional overseeing the infiltration testing. In this case, water is fed to the system at the flowrate needed to maintain a constant head of 3 inches (or alternative value). The rate of discharge of water is measured and divided by the footprint area. All other aspects of the procedure and interpretation apply.

D.2.5 Ring Infiltrometer Methods

Ring infiltrometers are a method to directly measure the vertical infiltration rate at the soil surface. Ring infiltrometers are large, metal cylinders driven several inches into the ground, filled with water, and either the volume or water level is measured with time to determine the infiltration rate.

D.2.5.1 Single Ring Infiltrometer Test

A single ring infiltrometer test using a single, large ring in diameter (40 inches or larger is optimal) has been shown reasonably approximate full-scale facility performance.

Usage

This test is most applicable for estimating design infiltration rate when:

- The BMP has primarily vertical infiltration (i.e., bottom area is much larger than side-wall area)
- There is not a limiting layer within 15 feet below the BMP
- The approximate elevation of the infiltration surface can be exposed during the testing phase
- The test is allows to run until the infiltration rate stabilizes (this is critical)

Other standard methods are allowable at the discretion of the geotechnical engineer and subject to the approval of the reviewing agency.

Guidance for Application and Interpretation

The following method is adapted from Riverside County Department of Environmental Health and follows the procedures outlined in ASTM D5126 (**Figure D-8** to **Figure D-10**). The cylindrical ring is driven approximately 12 inches into the soil. Water is ponded within the ring above the soil surface. The upper surface of the ring is often covered to prevent evaporation.

Care should be taken when driving the ring into the ground as there can be a poor connection between the ring wall and the soil. This poor connection can cause a leakage of water along the ring wall and an overestimation of the infiltration rate. This method should, therefore, not be used in gravelly soils where a good connection between the wall and the soil cannot be obtained.

Using the constant head method, the volumetric rate of water added to the ring sufficient to maintain a constant head within the ring is measured. The test is complete and the tested infiltration rate, I_t, is determined after the flow rate has stabilized (ASTM D5126). The initial infiltration rate is likely to be higher while the soil is still pre-soaking, so sufficient time must be given for the infiltration rate to fully stabilize in order to obtain an accurate infiltration rate. A test is considered to be stabilized when the estimated infiltration rate does not exceed 10 percent over a period of an hour.

To help maintain a constant head, a variety of devices may be used. A hook gage, steel tape or rule, length of steel, or plastic rod pointed on one end can be used for measuring and controlling the depth of liquid (head) in the infiltrometer ring. If available, a graduated Mariotte tube or automatic flow control system may also be used.

A falling-head method can also be used after the soil has been adequately pre-soaked. Sequential falling head tests should be conducted until the results of three sequential tests are within 10 percent. This can be reduced to 2 sequential tests if the time to conduct each test is more than 30 minutes.

<u>**Interpretation**</u>

Constant Head Tests. The volume of liquid used during each measured time interval may be converted into an incremental infiltration velocity (infiltration rate) using the following equation:

$$I_t = \frac{V}{A*t}$$ Equation D.5

where:

I_t = tested infiltration rate, in/hr
V = volume of liquid used during time interval to maintain constant head in the ring, in^3
A = internal area of ring, in^2
t = time interval, hr.

The average rate from the last hour of the test should be reported. Per above, less than 10 percent change in water infiltration rate over a one hour period is appropriate to determine that the test has stabilized.

Falling Head Test. The rate of fall of the water (inches per hour) within the ring can be used as the direct estimate of infiltration rate. A starting ponding depth between 6 and 12 inches is recommended. All other aspects of the test procedure described above apply.

Figure D-8. Photo of Single Ring Infiltrometer (UC Merced, 2017)

Figure D-9. Single Ring Infiltrometer Setup with Mariotte Tube (County of Riverside, 2011)

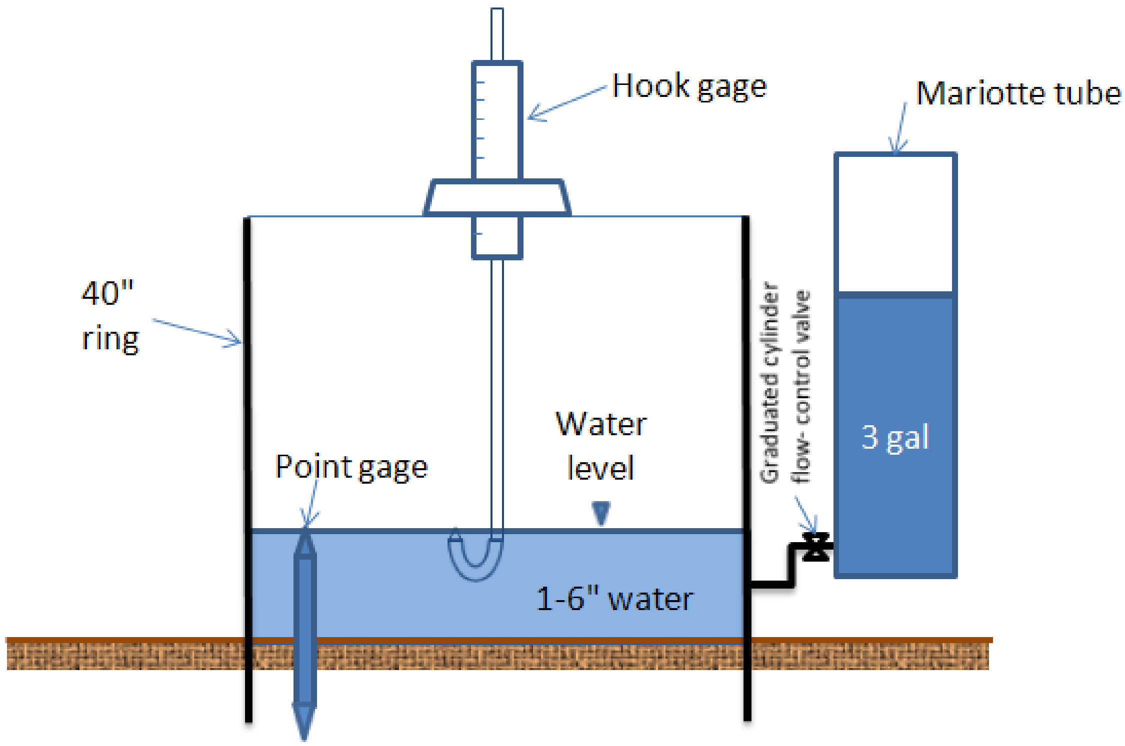


Figure D-10. Sample Test Data Form for Single Ring Infiltrometer Test (County of Riverside, 2011)

SINGLE RING INFILTROMETER TEST DATA				
Project Name and Test Location:	Constants-	Ring Data		Liquid Containers
		Ring Area, A_r (in²)	Depth of Liquid (in)	Reservoir Container Volume, V_r (in³/in)

Test By:		USCS Class:		Penetration of Ring into Soil (in.):			
Liquid Used:		pH:		Ground Temp (°F):		at Depth:	
Date of Test:		Depth to Water Table:					
Liquid Level Maintained by using:	( ) Flow Valve ( ) Float Valve ( ) Marriotte Tube ( ) Other:						
Additional Comments:							

Time interval	Time (hr:min)	Dt (min) & Total	Flow Readings Elev., H (In)	Flow Readings ΔH (in) & Q_f* (in³)	Liquid Temp (°F)	Infiltratn Rate, I**(in/hr)	Remarks
1 - Start							
End							
2 - Start							
End							
3 - Start							
End							
4 - Start							
End							
5 - Start							
End							
6 - Start							
End							
7 - Start							
End							
8 - Start							
End							
9 - Start							
End							
10 - Start							
End							
11 - Start							
End							
12 - Start							
End							
13 - Start							
End							
14 - Start							
End							
15 - Start							
End							

***Flow, $Q_f = \Delta H \times V_r$** **Infiltration Rate, $I = (Q_f/A_r)/$**

D.2.5.2 Double Ring Infiltrometer Test (ASTM D3385)

The double ring infiltrometer test (ASTM D3385) is a well-recognized and documented technique for directly measuring the soil infiltration rate of a site (see **Figure D-11** to **Figure D-16**). Double ring infiltrometers were developed in response to the fact that smaller (less than 40 inch diameter) single ring infiltrometers tend to overestimate vertical infiltration rates. This has been attributed to the fact that the flow of water beneath the cylinder is not purely vertical and diverges laterally. Double ring infiltrometers minimize the error associated with the single-ring method because the water level in the outer ring forces vertical infiltration of water in the inner ring.

Care should be taken when driving the rings into the ground as there can be a poor connection between the ring wall and the soil. This poor connection can cause a leakage of water along the ring wall and an overestimation of the infiltration rate. The double-ring infiltrometer test should be performed at an elevation 2 feet below the proposed elevation of the infiltration surface to account for the use of soil amendments below the infiltration system.

A typical double ring infiltrometer would consist of a 12 inch inner ring and a 24 inch outer ring. While there are two operational techniques used with the double-ring infiltrometer, the constant head method and the falling head method, ASTM D3385 mandates the use of the constant head method. With the constant head method, water is consistently added to both the outer and inner rings to maintain a constant level throughout the testing. The volume of water needed to maintain the fixed level of the inner ring is measured. To help maintain a constant head, a variety of devices may be used. A hook gage, steel tape or rule, or length of steel or plastic rod pointed on one end, can be used for measuring and controlling the depth of liquid (head) in the infiltrometer ring. If available, a graduated Mariotte tube or automatic flow control system may also be used.

The volume of liquid used during each measured time interval may be converted into an incremental infiltration velocity (infiltration rate) using the following equation:

$$I_t = \frac{V}{A*t}$$ Equation **D.6**

where:

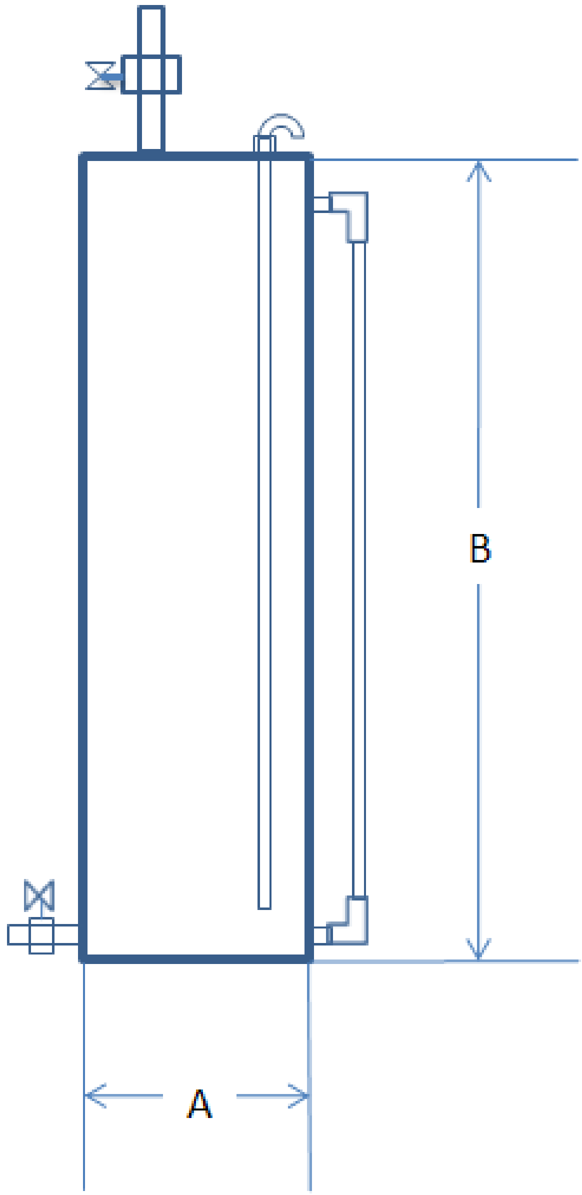
I_t = tested infiltration rate, in/hr
V = volume of liquid used during time interval to maintain constant head in the inner ring, in^3
A = area of inner ring, in^2
t = time interval, hr.

Figure D-11. Photo of Simple Double Ring Infiltrometer (County of Riverside, 2011)

Figure D-12. Photo of Pre-fabricated Double Ring Infiltrometer (County of Riverside, 2011)

(Photo courtesy of Turf-Tec International)

Figure D-13. Mariotte Tube (County of Riverside, 2011)



Mariotte Tube
Useful Capacity

	1 gal	3 gal
A =	3 in.	6 in.
B =	18 in.	24 in.

Figure D-14. Double Ring Setup with Mariotte Tubes (County of Riverside, 2011)

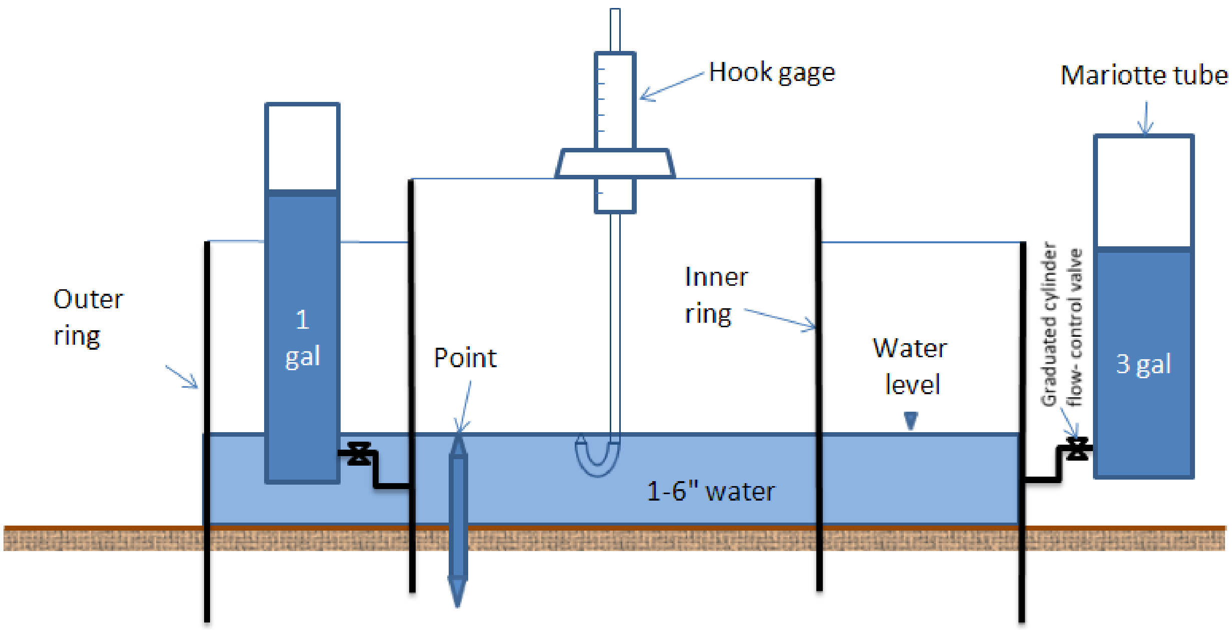


Figure D-15. Double Ring Infiltrometer Set-up with Mariotte Tubes (County of Riverside, 2011)

(Photo courtesy of Turf-Tec International)

Figure D-16. Double Ring Infiltrometer Set-up for Test at Basin Surface Elevation (County of Riverside, 2011)

(Photo courtesy of Turf-Tec International)

Figure D-17. Sample Test Data Form for Double Ring Infiltrometer Test (County of Riverside, 2011)

DOUBLE RING INFILTROMETER TEST DATA							
Project Name and Test Location:		Constants-		Ring Data		Liquid Containers	
				Area, A_r (in^2)	Depth of Liquid (in)	No.	Vol., V_r (in3/in)
			Inner Ring:				
Test By:	USCS Class:		Annular Space:				
Water Table Depth:		Penetration of Rings into Soil (in.):		Inner:		Outer:	
Date of Test:	Liquid Used:	pH:		Ground Temp (°F):		at Depth:	
Liquid Level Maintained by using:	( ) Flow Valve ( ) Float Valve ( ) Marriotte Tube ( ) Other:						
Additional Comments:							

Time interval	Time (hr:min)	Dt (min) & Total	Inner Ring Elev., H (In)	Inner Ring ΔH (in) &	Annular Ring Elev., H (In)	Annular Ring ΔH (in) &	Liquid Temp °F	Infiltration Rate, I** Inner in/hr	Infiltration Rate, I** Outer in/hr	Remarks
1 - Start										
End										
2 - Start										
End										
3 - Start										
End										
4 - Start										
End										
5 - Start										
End										
6 - Start										
End										
7 - Start										
End										
8 - Start										
End										
9 - Start										
End										
10 - Start										
End										
11 - Start										
End										
12 - Start										
End										
13 - Start										
End										
14 - Start										
End										
15 - Start										
End										

*Flow, $Qf = \Delta H \times Vr$ **Infiltration Rate, $I = (Qf/Ar)/\Delta t$

D.3 Computing the Design Factor of Safety for the Design Infiltration Rate

Given the known potential for infiltration BMPs to fail over time, an appropriate factor of safety applied to infiltration testing results must be mandatory. The infiltration rate will decline between maintenance cycles as the BMP surface becomes occluded and particulates accumulate in the infiltrative layer. Monitoring of actual facility performance has shown that the full-scale infiltration rate is often lower than the rate measured during design. It is important that adequate conservatism is incorporated in the selection of design infiltration rates to ensure LID goals are met and to avoid potential threats and costs associated with failing BMPs. The design infiltration rate discussed here is the infiltration rate of the underlying soil, below the elevation to which soil amendments would be provided. It is not the infiltration rate of the soil amendment.

The design factor of safety that should be applied to observed infiltration rates is a function of:

- Suitability of underlying soils for infiltration; and
- The infiltration system design, including how resilient the design is to uncertain conditions.

These factors are discussed in the following sections.

As discussed in **Appendix D.1.2**, the *feasibility screening infiltration rate* (K_{screen}) calculated to categorize infiltration feasibility shall be based on a feasibility factor of safety of 2.0 applied to the rates obtained from the infiltration test results. No adjustments from this value are permitted. The design factor of safety used to compute the *design infiltration rate* shall not be less than 2.0, but may be higher at the discretion of the design engineer and acceptance of the plan reviewer, per the considerations described in the following sections.

It is recognized that there are competing objectives in the selection of both the infiltration feasibility factor safety and the design factor of safety. A low feasibility factor of safety allows a broader range of systems to be considered "feasible" in marginal conditions. There is also an economic incentive to select a lower design factor of safety to yield smaller BMP designs. However, there are both economic and environmental incentives for the use of an appropriate factor of safety for both the feasibility factor of safety and the design factor of safety to prevent premature failure and substandard performance. The use of an artificially low factor of safety is shortsighted in that it does not consider the long-term operability and success of the system.

The best way to balance these competing factors is through a commitment to thorough site investigation, use of effective pretreatment controls, good construction practices, the commitment to restore the infiltration rates of soils that are damaged by prior uses or construction practices, including a contingency plan in BMP designs, and the commitment to effective maintenance practices. However, these commitments do not mitigate the need to apply a factor of safety to account for uncertainty and long term deterioration that cannot be technically mitigated. Therefore, a design factor of safety of no less than 2.0 shall be applied to the observed infiltration rate to compute the design infiltration rate for sizing BMPs; a typical design factor of safety should typically be higher. The remainder of this section discusses factors affecting the selection of a design factor of safety.

D.3.1 Site Suitability Considerations

Considerations related to the suitability of the site for infiltration include (**Table D-6**):

- Soil assessment methods – the site assessment extent (e.g., number of borings, test pits, etc.) and the measurement method used to estimate the infiltration rate (e.g. open pit falling head procedure with a pit much smaller than the proposed BMP).
- Predominant soil texture/percent fines – soil texture and the percent of fines can greatly influence the potential for clogging.
- Site soil variability – site with spatially heterogeneous soils (vertically or horizontally) as determined from site investigations are more difficult to estimate average properties for resulting in a higher level of uncertainty associated with initial estimates.
- Depth to seasonal high groundwater/impervious layer – groundwater mounding may become an issue during excessively wet conditions where shallow aquifers or shallow clay lenses are present.

Table D-6: Suitability Assessment Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Assessment methods (see explanation below)	Use of borehole methods to estimate vertical infiltration rate (not recommended, but may be necessary at a planning level) Less than 2 tests per BMP	At least 2 tests per BMP Use of borehole tests for dry wells or infiltration trenches Use of infiltrometer or small scale PIT methods for vertical infiltration BMPs	Extensive infiltration testing, such as: PIT testing or infiltrometer testing at 3+ locations per BMP, and/or Commitment to construction phase testing and design adaptation if necessary
Texture Class	Silty and clayey soils with significant fines	Finder sandy soils, with some loam content	Clean, granular soils (sands)
Site soil variability	Highly variable soils indicated from site assessment or limited soil borings collected during site assessment	Soil borings/test pits indicate moderately homogeneous soils	Multiple soil borings/test pits indicate relatively homogeneous soils
Depth to groundwater/ impervious layer	Groundwater conditions or movement not well understood	Seasonal high GW at least 10 ft below facility bottom	Seasonal high GW at least 15 ft below facility bottom

D.3.2 Design Related Considerations

Design related considerations include (**Table D-7**):

- Size of area tributary to facility – all things being equal, risk factors related to infiltration facilities increase with an increase in the tributary area served. Therefore, facilities serving larger tributary areas should use more restrictive adjustment factors.
- Level of pretreatment/expected influent sediment loads – credit should be given for good pretreatment by allowing less restrictive factors to account for the reduced probability of clogging from high sediment loading. Also, facilities designed to capture runoff from relatively clean surfaces such as rooftops are likely to see low sediment loads and therefore should be allowed to apply less restrictive safety factors.
- Redundancy – facilities that consist of multiple subsystems operating in parallel such that parts of the system remains functional when other parts fail and/or bypass should be rewarded for the built-in redundancy with less restrictive correction and safety

factors. For example, if a contingency plan is in place, such that a full infiltration BMP could be converted to a biofiltration BMP with partial infiltration, this could justify a lower factor of safety.

- Compaction during construction – proper construction oversight is needed during construction to ensure that the bottoms of infiltration facility are not overly compacted. Facilities that do not commit to proper construction practices and oversight should have to use more restrictive correction and safety factors.

Table D-7: Design Related Considerations for Infiltration Facility Safety Factors

Consideration	High Concern	Medium Concern	Low Concern
Tributary area size	Greater than 10 acres.	Greater than 2 acres but less than 10 acres.	2 acres or less.
Level of pretreatment/ expected influent sediment loads	Pretreatment from gross solids removal devices only, such as hydrodynamic separators, racks and screens AND tributary area includes landscaped areas, steep slopes, high traffic areas, or any other areas expected to produce high sediment, trash, or debris loads.	Good pretreatment with BMPs that mitigate coarse sediments such as vegetated swales AND influent sediment loads from the tributary area are expected to be relatively low (e.g., low traffic, mild slopes, disconnected impervious areas, etc.).	Excellent pretreatment with BMPs that mitigate fine sediments such as bioretention or media filtration or sedimentation OR Facility only treats runoff from relatively clean surfaces, such as rooftops.
Redundancy of treatment	No redundancy in BMP treatment train; no reasonable ability to adapt design if infiltration rates less than planned	There is a reasonable option for the BMP be converted to a biofiltration BMP with partial infiltration as a contingency plan, but this is not detailed in the WQMP. It would be a separate effort to fix this system if failure occurred.	A clear contingency plan is described in the WQMP, and adaptation to a biofiltration BMP with partial infiltration is relatively simple.
Compaction during construction	Construction of facility on a compacted site or elevated probability of unintended/ indirect compaction. (this scenario is strongly discouraged)	Low ground pressure equipment will be used for excavation and/or there is a medium probability of unintended/ indirect compaction.	Equipment is strictly prohibited from infiltration areas during construction and low probability of unintended/ indirect compaction.

D.3.3 Determining Design Factor of Safety

A design factor of safety shall be used. To assist in selecting the appropriate design infiltration rate, the measured short term infiltration rate should be adjusted using a weighted average of several safety factors using the worksheet shown in Worksheet 3 below. The design infiltration rate would be determined as follows:

1. For each consideration shown in **Table D-6** and **Table D-7** above, determine whether the consideration is a high, medium, or low concern.
2. For all high concerns, assign a factor value of 3, for medium concerns, assign a factor value of 2, and for low concerns assign a factor value of 1.
3. Multiply each of the factors by the corresponding weight to get a product.
4. Sum the products within each factor category to obtain a safety factor for each.
5. Multiply the two safety factors together to get the final combined safety factor. If the combined safety factor is less than 2, then 2 shall be used as the safety factor.
6. Divide the measured short term infiltration rate by the combined safety factor to obtain the adjusted design infiltration rate for use in sizing the infiltration facility.

The design infiltration rate shall be used to size BMPs and to evaluate their expected long term performance. This rate shall not be less than 2, but may be higher at the discretion of the design engineer.

Worksheet 3: Factor of Safety and Design Infiltration Rate and Worksheet

Factor Category		Factor Description	Assigned Weight (w)	Factor Value (v)	Product (p) $p = w \times v$
A	Suitability Assessment	Soil assessment methods	0.25		
		Predominant soil texture	0.25		
		Site soil variability	0.25		
		Depth to groundwater / impervious layer	0.25		
		Suitability Assessment Safety Factor, $S_A = \Sigma p$			
B	Design	Tributary area size	0.25		
		Level of pretreatment/ expected sediment loads	0.25		
		Redundancy/contingency plan	0.25		
		Compaction during construction	0.25		
		Design Safety Factor, $S_B = \Sigma p$			
Combined Safety Factor, $S_{Total} = S_A \times S_B$					
Observed Infiltration Rate, inch/hr, K_{obs} (corrected for test-specific bias)					
Design Infiltration Rate, in/hr, $K_{design} = K_{obs} / S_{Total}$					
Supporting Data					
Briefly describe infiltration test and provide reference to test forms:					

Note: The minimum combined adjustment factor shall not be less than 2.0 and the maximum combined adjustment factor shall not exceed 9.0.

D.4 Additional Considerations for Infiltration Rates

D.4.1 Waiver of Infiltration Testing Requirements

In addition to the conditions described in **Appendix D.1.1** where DMAs would not require infiltration testing (DMAs with obstacles to infiltration or DMAs in small projects with confirmed D-type soils), infiltration testing would also not be required for the following BMP types and site conditions:

- **Hydrologic source controls** (See HSC-1 through HSC-6 in **Appendix G**): Testing requirements are waived for most soil types, and most HSCs can be accommodated with all soil types. Soil amendments are required to use HSC-1 through HSC-3 where site soils are hydrologic soil group C or D. If soils cannot be amended and are type D soils, then some practices, such as Localized On-Lot Infiltration (HSC-1) or Self-Retaining Areas (HSC-6) should not be used unless infiltration testing is conducted to verify performance.
- **Porous pavement designed to be self-retaining** (See INF-5 in **Appendix G**): Testing requirements for this BMP are waived for A, B, and C soil types if soil type and general drainage conditions are confirmed with site-specific information. This waiver does not apply to porous pavement that accepts run-on from a tributary area larger than 50 percent of its area.

D.4.2 Maximum Infiltration Rates

In some cases, an infiltration test may show that an area has very high infiltration rates, such as 20 to 100 inches/hour or more in very coarse, sandy soils. While these may be excellent areas for infiltration, if stormwater moves too rapidly through the subsurface, it may not have time to be treated by the soil prior to reaching groundwater and could contaminate groundwater aquifers. In order to account for this, the project should utilize pretreatment and amended media which is selected based on the POCs where very high infiltration rates may threaten local groundwater supplies. This will help to ensure that the runoff is treated prior to contact with groundwater aquifers. Note that it is contact time with the soil that is required for treatment of the water, so using an orifice or other control to meter flows onto the rapidly draining soil is not an appropriate way to slow the infiltration rate. Groundwater contamination is of elevated concern if:

- Observed infiltration rates are greater than 20 inches per hour, or
- Organic content is less than 1 percent.

Acceptable options include:

- Provide enhanced pretreatment with a biofiltration or treatment control BMP, and/or

- Amend at least 1 foot of the underlying soil with a certified compost meeting the criteria in the MISC-1 or MISC-2 fact sheets.

The sizing methods for Full Infiltration BMPs are based largely on drawdown time, so with very high infiltration rates, very short drawdown times may be used, leading to very small footprints for Full Infiltration BMPs. While the calculation may show that a very small footprint may infiltrate a large volume due to the high infiltration rate, there is still a potential for the media to clog, especially with a small footprint relative to the tributary area. Therefore, as part of the sizing methods, a check on the footprint size relative to the clogging risk is required (See **Appendix E.3**). In general, the design infiltration rate should be limited to no more than 5 inches per hour.

D.5 References

ASTM D 3385-94, 2003. "Standard Test Method for Infiltration Rate of Soils Field Using Double-Ring Infiltrometer." American Society for Testing Materials, Conshohocken, PA. 10 Jun, 2003.

Caltrans, 2003. "Infiltration Basin Site Selection". Study Volume I. California Department of Transportation. Report No. CTSW-RT-03-025.

City of Portland, 2010. *Appendix F.2: Infiltration Testing.* Portland Stormwater Management Manual, Revised 2014

County of Los Angeles, 2014, Guidelines for Design, Investigation, and Reporting Low Impact Development Stormwater Infiltration. GS200-1.

County of Riverside, 2011, Low Impact Development BMP Design Handbook, Appendix A: Infiltration Testing.

United States Department of the Interior, Bureau of Reclamation (USBR), 1990, "Procedure for Performing Field Permeability Testing by the Well Permeameter Method (USBR 7300-89)," in Earth Manual, Part 2, A Water Resources Technical Publication, 3rd ed., Bureau of Reclamation, Denver, Colo.

APPENDIX E. HYDROLOGIC CALCULATIONS AND SIZING METHODS FOR LID AND TREATMENT CONTROL BMPS

E.1 Introduction

The purpose of this appendix is to provide detailed methodologies for sizing BMPs to meet LID and/or treatment control criteria. Each methodology is made up of a series of calculations. This appendix is divided into:

- **Section E.2**: Calculations in support of sizing methods. Calculations are not standalone sizing methods, and they may be common to multiple sizing methods.
- **Section E.3**: Sizing methodologies made up of several calculations. Methodologies are specific to BMP types.
- **Section E.4**: Other sizing resources and guidelines.

The project proponent should refer to this appendix according to the general framework for development of a Project WQMP (**Section 2** of the TGD). While this appendix discusses feasibility, it is not the basis for BMP selection. This appendix assumes that the initial site and watershed assessments (TGD **Section 2.3**), the site design and drainage plan incorporating site design and source control BMPs (TGD **Section 2.4**), determination of the infiltration feasibility category for each DMA (TGD **Section 2.5.1**), and selection of the appropriate LID BMP type (TGD **Section 2.5.2**) have all been previously completed, including Worksheets 1, 2, and 3 (Groundwater infeasibility, infiltration feasibility categorization, and design infiltration rate).

Based on the BMP type proposed, the project proponent should use the summary table in **Appendix E.3** to determine the applicable sizing method.

E.2 Calculations

This section contains individual calculations that are used as part of the BMP sizing methodologies in Section **E.3**. **The calculations in this section are only components of the sizing methodologies and are not intended to be used as standalone methods to size BMPs.** **Table E-1** contains a summary of calculations included in this section along with the subsection they are discussed in.

Table E-1: Calculations used in BMP Sizing Methodologies

Calculation	Typical Uses in the Methodologies in Section E.3	Subsection
Calculating the Effective Storage Depth and Capture Efficiency of HSCs	Used to adjust the design storm size or percent capture when sizing structural BMPs	E.2.1
Converting Between Storm Depth (d) and Runoff Volume (V)	Used in several volume-based BMP sizing methods.	E.2.2
Calculating Time of Concentration	Used in sizing flow-based BMPs	E.2.3
Converting Between Storm Intensity (i) and Flow Rate (Q)	Used in several flow-based BMP sizing methods	E.2.4
Calculating drawdown time of infiltration BMPs	Used in sizing methods for volume-based infiltration BMPs	E.2.5
Calculating provided storage volume in BMPs	Used as part of determining that BMP designs provide the required volume	E.2.6

E.2.1 Calculating the Effective Retention Depth and/or Capture Efficiency of HSCs

The effect of HSCs is accounted for in hydrologic calculations for sizing downstream structural BMPs as either an adjustment to the design storm depth or as a percentage of the long-term capture rate. The adjustment used is specific to the BMP sizing methodology. Adjustments are dependent on the type and magnitude of HSCs employed for the DMA. The process for accounting for HSCs includes:

1. Calculating the effective storm retention depth for each HSC in a DMA and the area to which each applies.
2. Calculating the area-weighted effective storm retention depth over a whole DMA using all of the HSCs (including the area not affected by any HSCs) and applying this to the design storm depth.
3. If the method used for sizing a structural BMP uses a long-term capture efficiency instead of a design storm depth, then the effective depth of the HSCs must be converted to an equivalent long term capture efficiency to calculate the effect on the size of the downstream structural BMP.

Different HSCs affect the capture depth in different ways. See the HSC Fact Sheets in **Appendix G** for guidance on calculating the effective capture depth of each HSC type. HSC-6: self-retaining areas do not apply to impervious area, so they are not used to adjust the design storm depth. They are instead used to subtract pervious areas from the total area of a DMA which decreases the total area, raises the imperviousness, and typically decreases runoff volumes and minimum required footprints.

This section provides the steps for calculating the overall effect of HSCs over a whole DMA (**E.2.1.1**) based on HSC-specific effective depths and effective areas (See **Appendix G.1**), and a method for calculating the equivalent long term average capture efficiency achieved by the HSCs (**E.2.1.2**).

E.2.1.1 Calculating the area-weighted effective storm retention depth for a DMA and applying to the design storm depth

A DMA may have multiple HSCs implemented within it, all applied to different areas. There are also likely to be portions of the impervious area within a DMA to which no HSCs are available to be applied. To determine the overall effect of any number of HSCs applied over any number of portions of a DMA, it is necessary to compute an area-weighted average of the individual effects of the HSCs on a DMA. This is done using the equation below:

$$d_{HSC\ total} = (\sum(d_{HSCi} \times IA_i)) / IA_{total}$$ Equation **E.1**

Where:

$d_{HSC\ total}$ = combined effective storm retention depth of HSCs in DMA (inches)
d_{HSCi} = effect of individual HSC_i per criteria in the relevant fact sheet (**Appendix G.1**) (inches)
IA_i = impervious area tributary to individual HSC_i as explained in the relevant fact sheet (**Appendix G.1**); areas cannot be counted twice if more than one HSC captures runoff from the same impervious area (e.g., street trees covering a roof top that is disconnected).
IA_{total} = total impervious area in drainage area

Worksheet 4 is provided below to aid in this calculation. An example calculation using Worksheet 4 is also provided below in Example E.1. The combined effective storm retention depth for the HSCs in the DMA ($d_{HSC\ total}$) is used to adjust the design storm depth for a DMA. So, for example, if the design storm depth for the site is 1.05 inches, and the combined effective storm retention depth for the HSCs provided on a DMA is 0.14 inches, then the adjusted design storm depth used to size the structural BMPs would be (1.05-0.14=0.91 inches). This leads to reduced required volumes in the structural LID BMPs for the DMA.

Worksheet 4: Hydrologic Source Control Calculation Form

Drainage area ID	________
Total drainage area	________ acres
Total drainage area Impervious Area (IA_{total})	________ acres

HSC ID	HSC Type/ Description/ Reference BMP Fact Sheet	Effect of individual HSC$_i$ per criteria in **relevant fact sheet (Appendix G.1)** (d_{HSCi})[1]	Impervious Area Tributary to HSC$_i$ (IA_i)	$d_i \times IA_i$
Box 1:		$\sum d_i \times IA_i =$		
Box 2:		$IA_{total} =$		
[Box 1]/[Box 2]:		$d_{HSC\ total} =$		
		Percent Capture Provided by HSCs (Table E-2)		

1 – None of the values in this column may be larger than the design storm depth for the project

Example E.1: Hydrologic Source Control Calculation Form (Worksheet 4)

Drainage area ID: A

Total drainage area: 2.1 acres

Total drainage area Impervious Area (IA_{total}): 1.3 acres

HSC Type/ Description/ Reference Section	Effect of individual HSC_i per criteria in **Section E.2.1.1**) (d_{HSCi})	Impervious Area Tributary to HSC_i (IA_i)	$d_i \times IA_i$
Downspout Dispersion, 1:2 ratio (0.5) of rooftop to pervious area for 0.38 acres	0.25”	0.38	0.095
Street Trees, perennial canopy over 0.25 acres of impervious area	0.05”	0.25	0.0125
Downspout Infiltration, 10-15 cu-ft storage per 1000 sf of roof for 0.21 acres	0.15”	0.21	0.032
Residential Rain Barrels, four 55 gallon barrels per 1000 sf of roof (4*55*50%=110 gal/1000 sf) for 0.2 acres	0.18”	0.2	0.036
Box 1:	$\sum d_i \times IA_i =$		0.175
Box 2:	$IA_{total} =$		1.3
[Box 1]/[Box 2]:	$d_{HSC\ total} =$		0.135
	*Percent Capture Provided by HSCs (**Table E-2**)*		26%

E.2.1.2 Calculation of the Long-Term Average Capture Efficiency for HSCs

For sizing methodologies based on a long-term capture efficiency of 80%, it is necessary to convert the effective storm retention depth of HSCs calculated in **Section E.2.1.1** to a long-term capture efficiency. **Table E-2** provides the conversions from the combined effective storm retention depth (d_{HSC}) to a long-term capture efficiency in both lowland and mountainous areas of Orange County.

Table E-2: Fraction of Average Long Term Runoff Reduced (Capture Efficiency) by HSCs

Combined HSC Adjustment to Design Capture Storm Depth (d_{hsc})	Capture Efficiency Achieved Lowland Regions (<1,000 ft)	Capture Efficiency Achieved Mountainous Regions (>1,000 ft)
<0.05	0	0%
0.05”	8%	7%
0.1”	20%	16%
0.2”	37%	31%
0.3”	48%	42%
0.4”	57%	50%
0.5”	64%	57%
0.6”	70%	63%
0.7”	75%	68%
0.8”	80%	72%
0.9”	80%	76%
1.0”	80%	80%

E.2.2 Converting Between Capture Depth and Capture Volume

Volume-based BMP sizes are often represented in one of two ways:

- **Design storm depth**: the depth of precipitation falling on the area contributing to a BMP that the BMP is designed to capture without overflowing, or
- **Design Capture Volume (DCV):** the volume of runoff that the BMP can retain without overflowing.

In several of the BMP sizing methodologies in **Section E.3**, it is necessary to convert one of these quantities to the other. The volume of runoff produced from a storm event of a given depth is primarily a function of the total tributary area receiving precipitation, and the imperviousness of that area. The equation to convert the storm depth into the runoff volume is:

$$V = C \times d \times A \times 43560\ sf/ac \times 1/12\ in/ft \qquad \text{Equation E.2}$$

Where:

V = runoff volume during the design storm event, cu-ft

C = runoff coefficient = $(0.75 \times imp + 0.15)$

imp = impervious fraction of drainage area (ranges from 0 to 1)

d = storm depth (inches)

A = tributary area (acres)

Note that this example is a calculation to be used as referenced from the methods in Section E.3 and is not a stand-alone method for sizing LID BMPs.

The tributary area includes all of the area that drains to the BMP (including any run-on from off-site areas), except for any pervious areas that are self-retaining (See BMP Fact sheet for HSC-6: Self-Retaining Areas). Self-retaining areas do not receive runoff from impervious areas, so they are not accounted for in HSC adjustments to the design storm depth. However, they are pervious areas that are graded and/or amended so that they do not produce any runoff during the design storm event. They are accounted for by removing the self-retaining pervious area from the total contributing area of the DMA.

An example of this calculation is provided in Example E.2. **Note that this example is a calculation to be used as referenced from the methods in Section E.3 and is not a stand-alone method for sizing LID BMPs.**

Example E.2: Convert storm depth into a runoff volume accounting for self-retaining areas

Given:

- A DMA consists of a 1 acre building roof with 2 acres or pervious landscaping and 0.5 acres of connected impervious road/driveway area. 0.75 acre of the landscaping has received soil amendments so that it is fully self-retaining and receives no run-on from impervious areas. The whole drainage area is to drain to a single BMP.
- The storm depth is 0.85 inches (see map in **Appendix N**)

Required:

- Calculate the runoff volume resulting from the storm depth

Result:

1) Calculate the total area contributing to the BMP: A = 1 acre impervious rooftop + 2 acres pervious landscaping +0.5 acre impervious area - 0.75 acres self-retaining area = 2.75 acres
2) Calculate the imperviousness = impervious area/total area: IA= (1 acre rooftop + 0.5 acre impervious area) / 2.75 total acres = 0.545
3) Calculate the runoff coefficient (c): C = (0.75 * 0.545 +0.15) = 0.559
4) From Equation E.2: V = C × d × A × 43560 sf/ac × 1/12 in/ft
5) d = 0.85 inches
6) V = 0.559 × 0.85 in × 2.75 ac × 43560 sf/ac × 1/12 in/ft = **4,740 cu-ft**

In some BMP sizing methodologies, it may be necessary to "back-calculate" the storm depth based on the runoff volume and a description of the DMA. The design storm depth can be calculated by rearranging Equation E.2, above:

$$d = V \times 12\ in/ft/[C \times A \times 43560\ sf/ac] \qquad \text{Equation E.3}$$

Example E.3 illustrates how a given volume of stormwater would be translated to an equivalent storm depth.

Example E.3: Back-computing storm depth from runoff volume

Given:
• A DMA consists of a 1 acre building roof surrounded by 0.25 acres of landscaping (80 percent composite imperviousness)
• An LID BMP with 1,200 cu-ft of storage is provided
Required:
• What is the equivalent storm depth corresponding to this BMP volume?
Result:
1) From Equation E.3: d = V × 12 in/ft/[C × A × 43560 sf/ac]
2) V = 1,200 cu-ft (given)
3) C = (0.75×0.8 + 0.15) = 0.75
4) A = 1.25 ac
5) d = 1,200 cu-ft × 12 in/ft / [0.75 × 1.25 ac × 43560 sf/ac] = 0.35 **inches**

E.2.3 Calculating the Time of Concentration

The time of concentration is used in flow-based LID BMP sizing methodologies. The time of concentration for sizing flow-based LID BMPs is calculated individually for each DMA.

The time of concentration is the time required for the entire DMA to begin contributing runoff to the BMP. It is, therefore, the travel time of the longest flow path on the DMA to the BMP. Whether computed by hand or by a modeling tool, the time of concentration should be calculated using one of the following methods:

- Method from Section D of the Orange County Hydrology Manual, or
- Method from Chapter 3 of the TR-55 Manual.

These methods are summarized below. In most cases, a modeling tool will be used to calculate the time of concentration. The WinTR-55 model provides an acceptable model-calculated method of calculated Tc through its Time of Concentration Details window.

The time of concentration for use in other models, such as WMS-Orange County and HEC-HMS, should be supported by hand calculations of the time of concentration per the criteria below.

The inputs provided to the models to compute Tc should be per guidance contained in the Orange County Hydrology Manual or the TR-55 Manual and should be submitted with the Project WQMP documentation.

E.2.3.1 Orange County Hydrology Manual Methods

The Orange County Hydrology Manual method entails computing the initial time of concentration of a subarea of a limited length, based on a nomograph, and summing it with the travel time(s) to the outlet of the DMA through downstream conveyances.

The time of concentration is a function of the length of the flow, the slope, the surface roughness, and the geometry of the flow path. An adaptation of the Orange County Hydrology Manual method for computing the time of concentration is outlined in the steps below:

1. Using CAD, GIS, a grading plan, or similar design drawings of the proposed development, locate the point in the DMA that is farthest from the outlet and calculate the length of overland flow that would occur until it entered some kind of stormwater

collection system (curb and gutter, swale, storm drain, channel, etc.). The maximum length of this path is 330 feet[5].

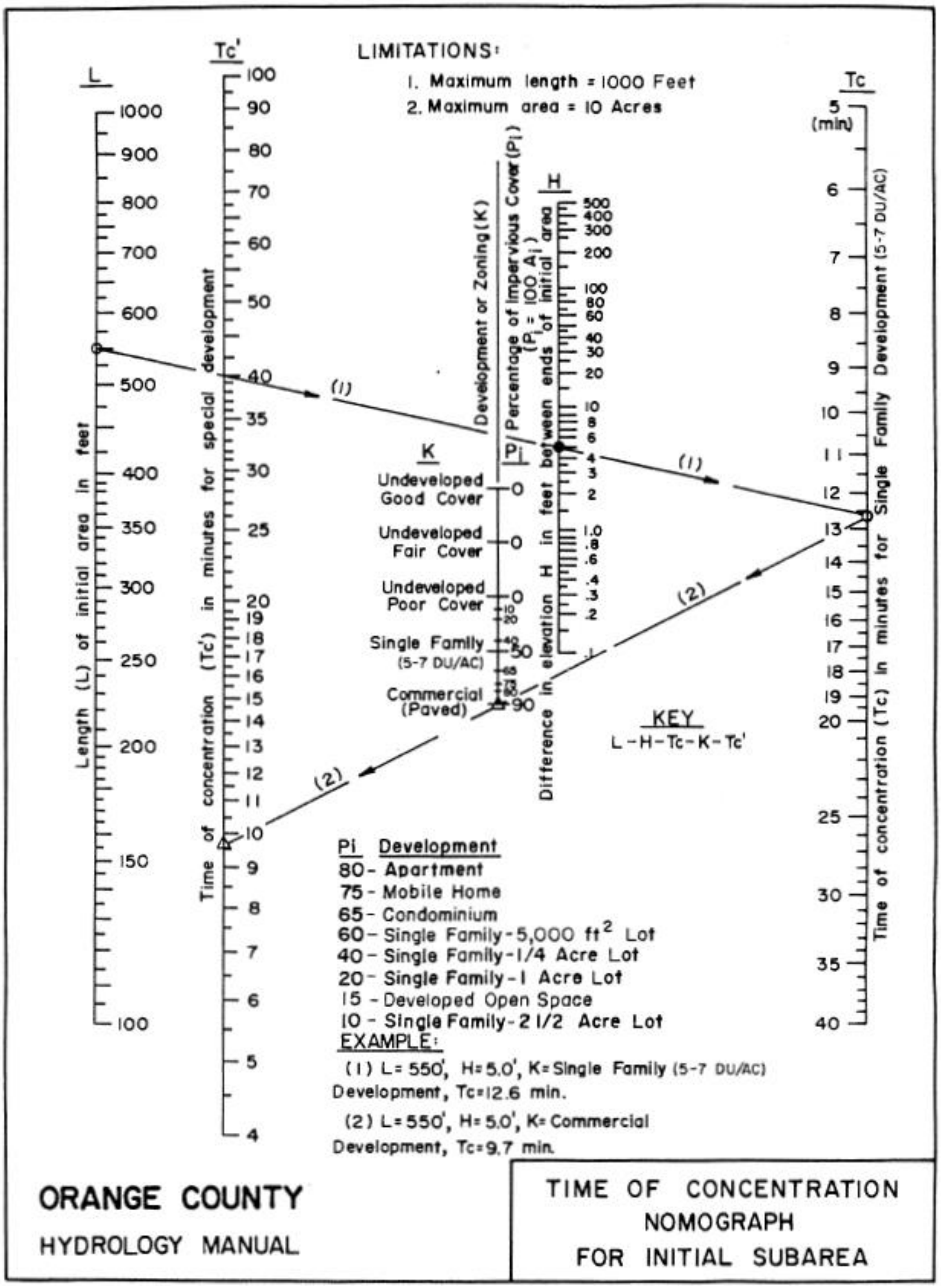
   a. Several potential points in the DMA may need to be tested to obtain the longest time of concentration due to the combination of length of flow, slope, roughness, and subsequent travel time. Typically, the farthest location from the outlet of the DMA (the proposed BMP) will be a reasonable estimate for the longest travel time.

2. Determine the change in elevation between the beginning and end of the overland flow path.
3. Record the dominant land use type for the subarea contributing flow to the overland flow path
4. Use the nomograph in **Figure E-1** to compute the initial time of concentration.
5. Use the design drawings of the stormwater conveyance system, or each portion of the conveyance system for long flow paths, to determine the length, slope, cross section geometry, and Manning's roughness factor for each portion of the collection system between the overland flow portion and the outlet of the DMA (into the proposed BMP)
6. Use the information from Step 5 to estimate the velocity in each portion of the stormwater conveyance(s), or use Manning's formula to compute the velocity using an estimate of the hydraulic radius
7. Divide the length of each portion of the conveyance by the velocity to obtain the travel time
8. Sum the initial time of concentration obtained from Step (4) with the travel time(s) obtained in Step (8) to compute the time of concentration for the DMA.

In most situations, the initial time of concentration of the overland flow is much larger than the time of travel in the conveyance system to the BMP and is the most sensitive factor. BMPs can typically be sized based on the overland flow time of travel only.

[5] While **Figure E-1** states that 1000 feet is allowable, a 1996 addendum to the hydrology manual limits this length to 330 feet.

Figure E-1: Nomograph for computing initial time of concentration (Orange County Hydrology Manual, 1986)



E.2.3.2 TR-55 Manual Methods

The TR-55 method for computing the time of concentration involves computing travel times for sheet flow, shallow concentrated flow, and channel flow for a given flow path and summing them to obtain the time of concentration. Sheet flow is flow over plane surfaces, typically occurring at the most remote parts of the DMA. The length of sheet flow is typically less than 100 feet. Shallow concentrated flow is more concentrated than sheet flow, but not as concentrated as channelized flow. Channelized flow is flow in conveyance systems such as curb and gutter, storm drain networks, etc.

A method for computing the time of concentration for a DMA adapted from the TR-55 Manual is included below. This method is most simple to implement within the WinTR-55 software. Hand calculation steps are also provided below.

1. Using CAD, GIS, a grading plan, or similar design drawings of the proposed development, locate the point in the DMA that is farthest from the outlet and calculate the length of overland flow that would occur until it entered some kind of stormwater collection system (curb and gutter, swale, storm drain, channel, etc.).
    a. Several potential points in the DMA may need to be tested to obtain the longest time of concentration due to the combination of length of flow, slope, roughness, and subsequent travel time. Typically, the farthest location from the outlet of the DMA (the proposed BMP) will be a reasonable estimate for the longest travel time.
2. If the length computed in Step (1) is greater than 100 feet, the first 100 feet can be considered sheet flow and the remaining length can be considered shallow concentrated flow.
3. Using the grading plan, drainage plans, or similar, compute the slope of the sheet flow and shallow concentrated flow portions of the flow path.
4. Determine the 2-year, 24-hour storm event depth in inches. This is 2.05 inches for locations below an elevation of 2000 feet and 3.81 inches for locations above an elevation of 2000 feet.
5. Use Table 3-1 of the TR-55 manual (included as **Figure E-2** below) to estimate the Manning's roughness coefficient for the sheet flow portion of the flow path.
6. Calculate (or allow the TR-55 model to calculate) the travel time for the sheet flow portion of the flow path using the equation below:

$$T_t = \frac{0.007(nL)^{0.8}}{P^{0.5}S^{0.4}}$$ Equation **E.4**

Where:

T_t = travel time of the sheet flow portion of the flow path (hours)

n = Manning's roughness coefficient

L = flow length of the sheet flow portion of the flow path (ft)

P = 2-year, 24-hour rainfall (inches)

s = slope of hydraulic grade line (land slope ft/ft)

7. Calculate (or allow the TR-55 model to calculate) the travel time of the shallow concentrated flow portion of the flow path by dividing the length of the shallow concentrated flow path by the average velocity obtained from **Figure E-3** below.
8. Use the design drawings of the collection system, or each portion of the collection system for long flow paths, to determine the length, slope, cross section geometry, and Manning's roughness factor for each portion of the collection system between the overland flow portion and the outlet of the DMA (into the proposed BMP). Note that the Manning's roughness coefficient for the conveyance system should not be estimated using **Figure E-2** because those are tailored for sheet flow, only.
9. Use the information from Step 8 to estimate the velocity in each portion of the stormwater conveyance(s), or use Manning's formula to compute the velocity using an estimate of the hydraulic radius.
10. Divide the length of each portion of the conveyance by the velocity to obtain the travel time for the conveyance.
11. Sum the travel time for the sheet flow, shallow concentrated flow, and channelized flow for each portion of the flow path to obtain the time of concentration for the DMA.

In most situations, the sheet flow and shallow concentrated flow dominates the time of concentration and is the most sensitive factor. BMPs can typically be sized based on the overland flow time of travel only.

Figure E-2: Roughness coefficients (Manning's n) for sheet flow (TR-55 Manual)

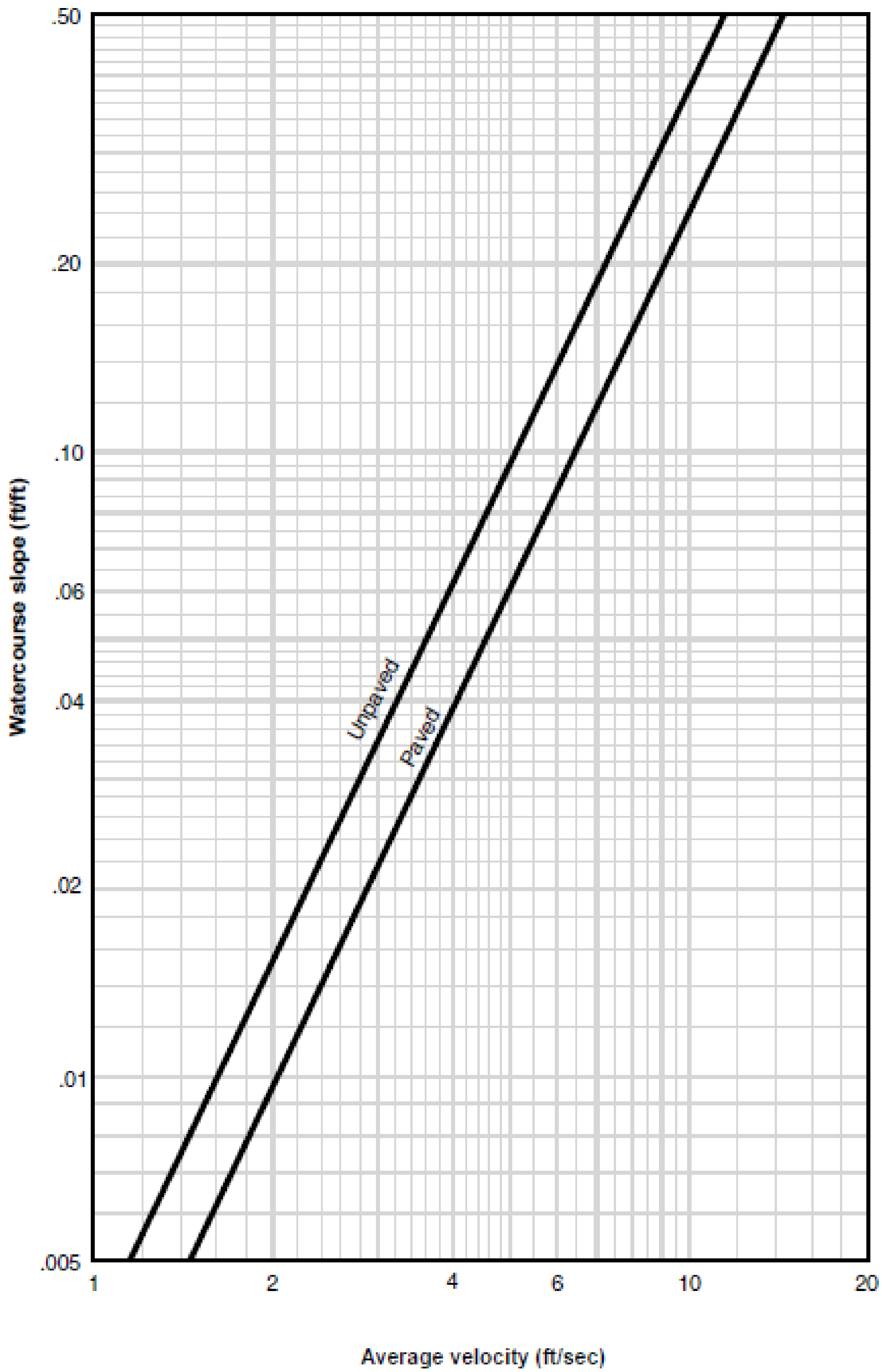
Surface description	n [1/]
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤20%	0.06
Residue cover >20%	0.17
Grass:	
Short grass prairie	0.15
Dense grasses [2/]	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:[3/]	
Light underbrush	0.40
Dense underbrush	0.80

1 The n values are a composite of information compiled by Engman (1986).

2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Figure E-3: Average Velocities for Estimating Travel Time for Shallow Concentrated Flow (TR-55 Manual)



E.2.4 Converting Between Storm Intensity and Runoff Flow Rate

Flow-based BMP sizes can be represented in one of two ways:

- **Design storm intensity**: the rainfall rate (inches/hour) falling on the area contributing to a BMP that the BMP is designed to capture without overflowing, or
- **Design Flow Rate:** the flow rate (cubic feet per second) of runoff that the BMP can capture without overflowing.

In the flow-based BMP sizing methodologies in **Section E.3**, it is necessary to convert one of these quantities to the other. Under uniform rainfall intensity, the flow rate of runoff produced from a given rainfall intensity is primarily a function of the total tributary area receiving precipitation, and the imperviousness of that area. The equation to convert the rainfall intensity to the runoff flow rate is:

$$Q = c \times i \times A$$ Equation **E.5**

Where:

Q = runoff flowrate, cfs
c = runoff coefficient = $(0.75 \times imp + 0.15)$
imp = impervious fraction of drainage area (ranges from 0 to 1)
i = rainfall intensity (inches/hour)
A = tributary area (acres)

This is a calculation method. It is not a standalone sizing method. Flow-based BMP sizing methods must be used to determine the appropriate intensity (*i*) to use in this calculation to meet sizing criteria.

Note that, as long as the units shown in the definitions above are used, no unit conversion is necessary. This is because the conversion from square feet to acres (43,560 sq ft/acre) is approximately equal to the conversion to inches to feet and seconds to hours (43,200 in*seconds/ft*hour).

The tributary area includes all the area that drains to the BMP (including any run-on from off-site areas), except for any pervious areas that are self-retaining (See BMP Fact sheet for HSC-6: Self-Retaining Areas). Self-retaining areas are accounted for by removing the area from the contributing area.

An example of this calculation is provided in Example E.4.

Example E.4: Convert storm intensity into a runoff flow rate accounting for self-retaining areas

Given:

- A DMA consists of a 1 acre building roof with 2 acres or pervious landscaping and 0.5 acres of connected impervious road/driveway area. 0.75 acre of the landscaping has received soil amendments so that it is fully self-retaining and receives no run-on from impervious areas. The whole drainage area is to drain to a single BMP.
- The rainfall intensity is 0.23 inches/hour (this is a hypothetical example; it would be determined via one of the sizing methods).

Required:

- Calculate the runoff flow rate resulting from the storm intensity.

Result:

1) Calculate the total area contributing to the BMP: A = 1 acre impervious rooftop + 2 acres pervious landscaping +0.5 acre impervious area - 0.75 acres self-retaining area = 2.75 acres
2) Calculate the imperviousness = impervious area/total area: IA= (1 acre rooftop + 0.5 acre impervious area) / 2.75 total acres = 0.545
3) Calculate the runoff coefficient (c): C = (0.75 * 0.545 +0.15) = 0.559
4) From Equation E.5: Q = C × i × A
5) i = 0.23 inches/hour
6) Q = 0.559 × 0.23 × 2.75 ac= **0.35 cfs**

In some instances, it may be necessary to "back-calculate" the storm intensity from a runoff volume and a description of the DMA. This could be the case where a BMP exists with a known treatment flow rate, but it is not known what fraction of the design intensity it fulfills. The rainfall intensity of a given flow rate can be calculated by rearranging Equation E.5 above:

$$i = Q/(c \times A) \qquad \text{Equation E.6}$$

E.2.5 Calculating Drawdown Time of Infiltration BMPs

Drawdown time is the time it takes to drain a BMP from brim full after inflow to when the BMP has stopped. The drawdown time of infiltration BMPs or storage compartments within BMPs is a common calculation needed to support BMP sizing methods. There are two primary ways of calculating drawdown time.

Method 1: Simple Vertical Infiltration

For simple BMPs that have primarily vertical infiltration (i.e., the plan view footprint is much larger than side walls), the drawdown time can be estimated as the effective depth of the BMP divided by the design infiltration rate. The effective depth is the storage depth expressed as the effective water depth. The depth of porous layers is converted to an effective depth by multiplying by the freely drained porosity. Freely drained porosity of 0.2 for amended media and 0.4 for washed drain rock gravel are reasonable assumption.

$$\text{Drawdown time} = D_{effective}/K_{design} \qquad \text{Equation E.7}$$

Where,

$$D_{effective} = D_{ponding} + D_{media} * 0.2 + D_{gravel} * 0.4 \qquad \text{Equation E.8}$$

Where $D_{ponding}$, D_{media}, and D_{gravel} refer to the total depth of these layers before converting for porosity. Alternative porosity values can be used, with supporting documentation.

Method 2: Vertical plus Sidewall Infiltration

This method accounts for the specific geometry of the BMP including the sidewall area and plan view area. The average infiltration discharge rate (as cu-ft/hr) is calculated based on the wetted infiltration area when the BMP is half full multiplied by the design infiltration rate. The full BMP volume is then divided by the infiltration discharge rate to determine the drawdown time.

$$\text{Drawdown time (hours)} = V_{design}/Q_{infiltration} \qquad \text{Equation E.9}$$

Where,

V_{design} is the total water quality design volume of the BMP (cu-ft)

$Q_{infiltration}$ (cu-ft/hr) = K_{design} (in/hr) * wetted surface area when BMP is half full (sq-ft) * 1 ft/12 inches

E.2.6 Calculating Provided Volume in BMPs

Determining the volume provided in a BMP is a typical calculation needed as part of showing that BMPs are in compliance. There are two primary methods that are acceptable.

Method 1: Effective area/effective depth method. This method involves determining the effective depth of water stored in the BMP (see calculations in **Appendix E.2.5**) and multiplying it by the effective area. For systems with vertical walls, the effective area is simply the plan view area. For systems with side slopes, the effective area can be approximated as the plan view area inundated when the ponded depth is half full. This is the area of the contour at an elevation half way between the surface of the BMP and the overflow elevation. This method is generally acceptable for most BMPs.

Method 2: Area takeoff/trapezoidal method. For more complex BMP geometries, it may be necessary to perform area takeoffs at regular contour intervals within the BMP and apply trapezoidal geometry calculations. The effectively breaks the BMP into horizontal slices. Each horizontal "slice" would have a vertical thickness, an average surface area, and an effective porosity. The product of these values is the storage volume in the slice. The sum of all slices is the total storage volume.

In both methods, volume should only be tabulated below the overflow or bypass elevation of the BMP. Surcharge or freeboard storage should not be included in calculations

E.3 BMP Sizing Methodologies

This section contains the methodologies to be used to size structural LID BMPs and treatment control BMPs. The project proponent should determine the applicable infiltration feasibility category and BMP type based on guidance in TGD Chapter 2 and 4, then use **Table E-3** below to select an appropriate sizing methodology. Alternative methods, including continuous simulation, may also be acceptable provided the LID criteria are shown to be met.

Table E-3: BMP Sizing Methodologies

Infiltration Feasibility Category	BMP Application	Included BMPs	BMP Sizing Method Option Descriptions
Full Infiltration	Infiltration BMPs	• Infiltration Basin • Infiltration Trench • Bioretention with no Underdrain • Drywell • Permeable Pavement • Underground Infiltration	Simple DCV Method: **Section E.3.1** **OR** Capture Efficiency via Nomograph Method: **Section E.3.2**
Biotreatment with Partial Infiltration / No Infiltration[6]	Volume-based Biofiltration BMPs	• Bioretention with Raised Underdrain	Biofiltration Routing Method: **Section E.3.3**, **OR** Biofiltration Static Volume Method: **Section E.3.4**
	Compact Biofiltration BMP	• Proprietary Biofiltration with Supplemental Retention	Flow Based Biofiltration + Volume Reduction (if applicable): **Section E.3.5**
Any	Harvest and Use BMPs	• Above-Ground Cisterns • Underground Detention	Capture Efficiency via Nomograph Method: **Section E.3.6**
Any	Flow-based Treatment Control BMPs	• Media Filters • Cartridge Media Filters • Vegetated Swales • Vegetated Filter Strips	Flow-based Capture Efficiency via Nomograph Method: **Section E.3.7**
	Volume-based Treatment Control BMPs	• Dry Detention Basins • Wet Detention Basins	Simple DCV Method: **Section E.3.1**

[6] The methods in this category can be applied to Biotreatment with Partial Infiltration condition or the Biotreatment with No Infiltration condition. The latter is supported in these methods by ignoring the infiltration and volume reduction components described in each method.

E.3.1 Simple DCV Method for Sizing of Infiltration BMPs and Volume-based Treatment Control BMPs

This method is used to determine the required volume of infiltration BMPs when a DMA is in the Full Infiltration Category. It can also be used to size volume-based treatment control BMPs. This is the simplest method, and may result in a BMP that achieves greater than 80 percent capture of long term runoff, and may, therefore, be somewhat oversized to meet minimum performance criteria. This would result where the DCV can draw down in less than 48 hours. If the size of the BMP that results from this method is impracticable because it is oversized, the capture efficiency via nomograph method for sizing infiltration BMPs is recommended (**Section E.3.2**).

E.3.1.1 Simple DCV Method Stepwise Instructions for Sizing Infiltration BMPs

The method includes the following calculations:

1. Determine the 85th percentile, 24-hour design storm event depth (see map in **Appendix N**).
2. Reduce the design storm depth based on upstream HSCs in the DMA (See **Section E.2.1**). Also, include the volume retained by any other upstream LID BMPs (e.g., a cistern). The volume that is drawn down within 48 hours after the end of rainfall can be counted as retained for these BMPs. The retained volume can be converted to a storm depth using the method in **Section E.2.2**. This storm depth can be subtracted from the design storm depth (in addition to the volume retained by HSCs).
3. Convert the remaining design storm depth to a runoff volume to compute the DCV for the BMP of interest (See **Section E.2.2**).
4. Design the BMP vertical profile (i.e., ponding, media, and gravel elements) and determine the effective depth of storage in the BMP. The effective depth of storage is the ponding depth plus the depth stored in gravel and soil pores. Typical void ratios are 0.4 for gravel and 0.2 for soil media.
5. Determine the BMP area needed to provide storage for the design volume. If the BMP has sloped sides, this needs to be accounted for in calculations. For simplicity, the BMP area can be measured at the mid-ponding depth of the BMP. This can then be multiplied by the effective storage depth in the vertical profile to estimate the volume. For more complex geometries, the storage volume should be determined using area and volume take-offs from the proposed topography.
6. Ensure the BMP will fully draw down within 48 hours.
    a. For systems that rely primarily on vertical infiltration, divide the effective storage depth (inches) by the infiltration rate (K_{design}) of the underlying soil (inches per hour) to calculate the drawdown time (hours).
    b. Where systems have both lateral and vertical infiltration (such as infiltration trenches), first calculate the total infiltration discharge rate (cu-ft per hour) based

on the wetted infiltration surface area when the system is half full. This can be calculated as the wetted infiltration surface area when the system is half full multiplied by the design infiltration rate, with appropriate unit conversions. Calculate the drawdown time by dividing the total storage volume (cu-ft) by the total estimated infiltration discharge rate when the system is half full (cu-ft/hr).

c. If drawdown time exceeds 48 hours, then reduce the effective depth of the BMP and expand the footprint to compensate until the drawdown time is less than 48 hours.

7. Check that the infiltrating surface area of the BMP meets the minimum surface area guidelines to avoid premature clogging (See **Section E.4.1**). If it does not, increase the infiltrating surface area or provide more robust pretreatment to support a smaller infiltrating surface area.

E.3.1.2 Example Using the Simple DCV Method for Sizing Infiltration BMPs

Example E.5: Using the Simple DCV Method to Size a Full Infiltration BMP

Given:

- Redevelopment project, 85th percentile, 24-hr storm depth = 0.85 inches
- Drainage Area = 1.5 acres
- Imperviousness = 80%
- Effective retention depth of HSCs (d_{HSC}) = 0.2 inches (from Worksheet 4)
- No upstream cisterns or other retention BMPs
- Design infiltration rate of underlying soil = 0.5 in/hr (from Worksheet 3)
- ***Required:***
- Determine LID DCV by the Simple Method and check that this volume can be drawn down in less than or equal to 48 hours

Solution:

1. Design capture storm depth = 0.85 inches
2. Design capture storm depth, less HSCs = 0.85 inches – 0.2 inches = 0.65 inches
3. DCV = 1.5 ac × (0.75*0.8 + 0.15) × (0.65 inches) * 43,560 sf/ac × 1/12 in/ft = 2,650 cu-ft
4. Design a bioretention BMP profile based on fact sheet in **Appendix G.1**, select 12 inches of ponding and 24 inches of media, therefore the effective storage depth is 12 inches + 24 inches * 0.2 in/in = 16.8 inches = 1.4 ft.
5. Design the BMP with a footprint adequate to store the runoff volume: 2,650 cu-ft/1.4 ft = 1,890 sq-ft. This is the needed effective area. This should be measured at the mid-ponding depth of the BMP.

6. Calculate the drawdown time: For a simple BMP such as this, the drawdown can be calculated as the effective storage depth divided by the design infiltration rate: 16.8 inches/0.5 in/hr = 34 hours. This is less than 48 hours and is acceptable.

7) Check for potential clogging risk. For an urban mixed land use without open space, and a bioretention area without pretreatment, the target infiltrating surface area to avoid premature clogging is 2.8 percent of the total impervious area of the DMA (See table in **Section E.4.1**). As designed, the infiltrating surface area of the system at half ponding depth is 1,890 sq-ft / (1.5 ac * 80% imp * 43560 ft/ft) = 3.6% of the impervious tributary area. This exceeds the 2.8 percent target and is acceptable. No further calculations are needed.

E.3.1.3 Worksheet for Using the Simple Method to Size Full Infiltration BMPs

Worksheet 5: Simple Design Capture Volume Sizing Method for Full Infiltration BMPs

Part 1: Calculate the DCV				
1	Enter design capture storm depth, *d* (inches)	d=		inches
2a	Enter the combined effect of provided HSCs, d_{HSC} (inches) (based on Worksheet 4) including any other upstream BMPs	d_{HSC}=		inches
2b	Calculate the remainder of the design capture storm depth, $d_{remainder} = d - d_{HSC}$	$d_{remainder}$=		inches
3a	Enter DMA area tributary to BMP(s), *A* (acres) excluding any self-retaining areas	A=		acres
3b	Enter DMA Imperviousness, imp (unitless) after removal of self-retaining areas	imp=		
3c	Calculate runoff coefficient, *C= (0.75 x imp) + 0.15*	C=		
3d	Calculate runoff volume, *DCV = (C x $d_{remainder}$ x A x 43560 x (1/12)) (See* ***Section E.2.2****)*	DCV=		cu-ft
Part 2: Design BMP and Calculate Effective Storage Depth and Footprint				
4	Enter total effective storage depth (sum of values below)	$D_{total\_effective}$		inches
4a	Ponding storage depth	D_{pond}		inches
4b	Media effective storage depth (depth * 0.2)	$D_{media\_effective}$		inches
4c	Gravel effective storage (depth * 0.4)	$D_{gravel\_effective}$		inches
5	Determine required effective footprint: A_{BMP} = DCV /(D_{Total} *12 inches/ft) If sides are sloped, measure A_{BMP} at the mid-ponding depth of the BMP.	A_{BMP}=		sq-ft
Part 3: Check Drawdown Time				
6a	Calculate design infiltration rate, $K_{design} = K_{observed} / S_{total}$ (See Worksheet 3 and **Appendix D**)	K_{design}=		in/hr
6b	Calculate drawdown time ($D_{total\_effective} / K_{design}$) (must be less than or equal to 48 hours).	$T_{drawdown}$=		hours
6c	If using Method 2 for drawdown (**Section E.2.5**) which accounts for sidewall infiltration, insert result and attach relevant calculations below.	$T_{drawdown}$=		hours
Part 4: ***Check Minimum Infiltrating Surface Area for Premature Clogging***				
7a	Calculate BMP infiltrating surface area as percent of tributary impervious area ($A_{infiltrating}$/(A * imp * 43560 sq-ft/ac)			%
7b	Calculate minimum infiltrating surface area required for BMP to avoid premature clogging (**Section E.4.1**)			%

E.3.2 Capture Efficiency via Nomograph Method for Sizing Infiltration BMPs

This method is used to determine the required volume of infiltration BMPs when a DMA is in the Full Infiltration Category. The method has the ability to account for upstream HSCs and other types of upstream retention. The target using this method is to achieve 80 percent long-term average capture of runoff. This method is more complicated than the Simple Method (**Section E.3.1**) and is iterative by its nature, but it implicitly accounts for infiltration that occurs during a storm event in computing the retained volume. When the drawdown time is approximately 48 hours, both the Simple Method and the Capture Efficiency via Nomograph Method yield a similar required BMP volume. However, when the drawdown time is less than 48 hours, the Capture Efficiency via Nomograph Method can yield smaller required BMP sizes than the Simple Method. Additionally, when a drawdown time of 48 hours cannot be achieved, the Capture Efficiency via Nomograph Method can compute the capture efficiency corresponding to a longer drawdown time which can still meet LID criteria, whereas the Simple Method requires the drawdown time to be 48 hours or less.

This method is only suitable for Full Infiltration BMPs that have a drawdown rate that can be approximated as constant throughout the year or over the wet season. A BMP that relies in whole or part on irrigation to draw down the BMP should not use this method as irrigation demand varies throughout the year.

E.3.2.1 Capture Efficiency via Nomograph Method Stepwise Instructions for Sizing Full Infiltration BMPs

The method includes the following calculations:

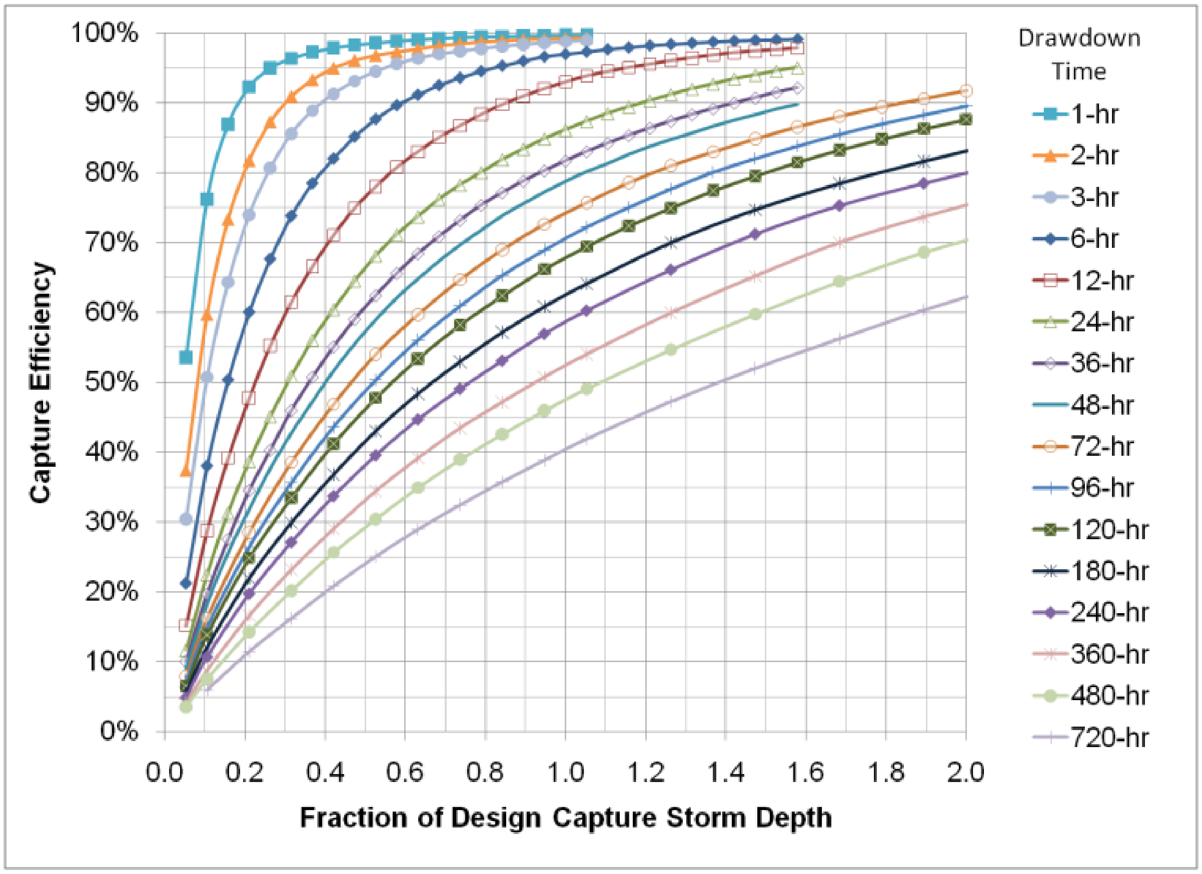
1. Design the BMP vertical profile (i.e., ponding, soil media, gravel depths) and determine the effective depth of storage in the BMP. The effective depth of storage is the ponding depth plus the depth stored in soil and gravel pores. Typical void ratios are 0.4 for gravel and 0.2 for soil media.
2. Calculate the drawdown time of the BMP (See **Section E.2.5**).
    a. For systems that rely primarily on vertical infiltration, divide the effective storage depth (inches) by the infiltration rate (K_{design}) of the underlying soil (inches per hour) to calculate the drawdown time (hours).
    b. Where systems have both lateral and vertical infiltration (such as infiltration trenches), first calculate the infiltration discharge rate (cu-ft per hour) based on the wetted infiltration surface area when the system is half full. Calculate the drawdown time by dividing the total storage volume (cu-ft) by the total estimated infiltration discharge rate when the system is half full (cu-ft/hr).
3. Locate the line corresponding to the estimated drawdown time in **Figure E-4**. Locate the point on the line that corresponds to 80% capture (y-axis) and record the corresponding value from the x-axis. This is the total fraction of the 85th percentile, 24-hour storm that

needs to be captured in order to achieve 80% capture at the selected drawdown time. This is referred to as X_1.

4. Determine the capture efficiency achieved by any upstream retention including HSCs (**Section E.2.1**) or Harvest and Use BMPs (**Section E.3.6**) and trace a horizontal line on **Figure E-4** corresponding to the computed capture efficiency. Trace this line horizontally. This is referred to as Y_2.
5. Find where the line traced in step (4) intersects the line corresponding to the drawdown time of the BMP selected in step (2). Pivot down and read the value on the x-axis correspond to this location. This is the fraction of the equivalent design storm already captured by upstream HSCs or harvest and use BMPs. This is referred to as X_2. Note that if no upstream retention is provided in HSCs or harvest and use BMPs, X_2 will be 0.
6. Subtract X_2 from X_1 to determine the fraction of the design storm depth that must be provided in the Full Infiltration BMP to achieve 80% capture.
7. Determine the 85th percentile, 24-hour design storm event depth (see map in **Appendix N**).
8. Multiply the results of step (6) by the 85th percentile design storm depth from step (7) to obtain the design storm depth for the BMP.
9. Convert the design storm depth from step (8) to the DCV (**Section E.2.2**). This is the required BMP retention volume.
10. Maintaining the same vertical design profile as determined in Step 1, size the footprint of the BMP to retain the required volume from Step 9.
11. Calculate the infiltrating surface area of the BMP, including bottom and walls, where applicable, and check that the wetted infiltrating surface area meets the minimum area requirements to avoid premature clogging (See **Section E.4.1**). If it does not, increase the BMP size so that the infiltrating surface area is at least this minimum, or provide more robust pretreatment to address clogging risk. The infiltrating surface should be based on the wetted area when the BMP is half full.

This method may require some iteration to determine a BMP profile and footprint that provide an optimal and compliant combination of storage volume and drawdown time. Iteration parameters could include BMP footprint and BMP depth.

Figure E-4. Capture Efficiency Nomograph for Constant Drawdown BMPs in Orange County



E.3.2.2 *Example Using the Capture Efficiency via Nomograph Method to Size a Full Infiltration BMP*

Example E.6: Computing Design Criteria to Achieve Target Capture Efficiency, Full Infiltration BMP

Given:

- 85th percentile, 24-hr storm depth = 0.85 inches
- Drainage Area = 1.5 acres
- Imperviousness = 80%
- Effect of provided HSCs (d_{HSC}) = 0.2 inches
- Initially assume BMP is an infiltration chamber, 30-inch total effective depth
- Design infiltration rate = 0.31 in/hr

Required:

- Determine volume required to achieve 80 percent capture

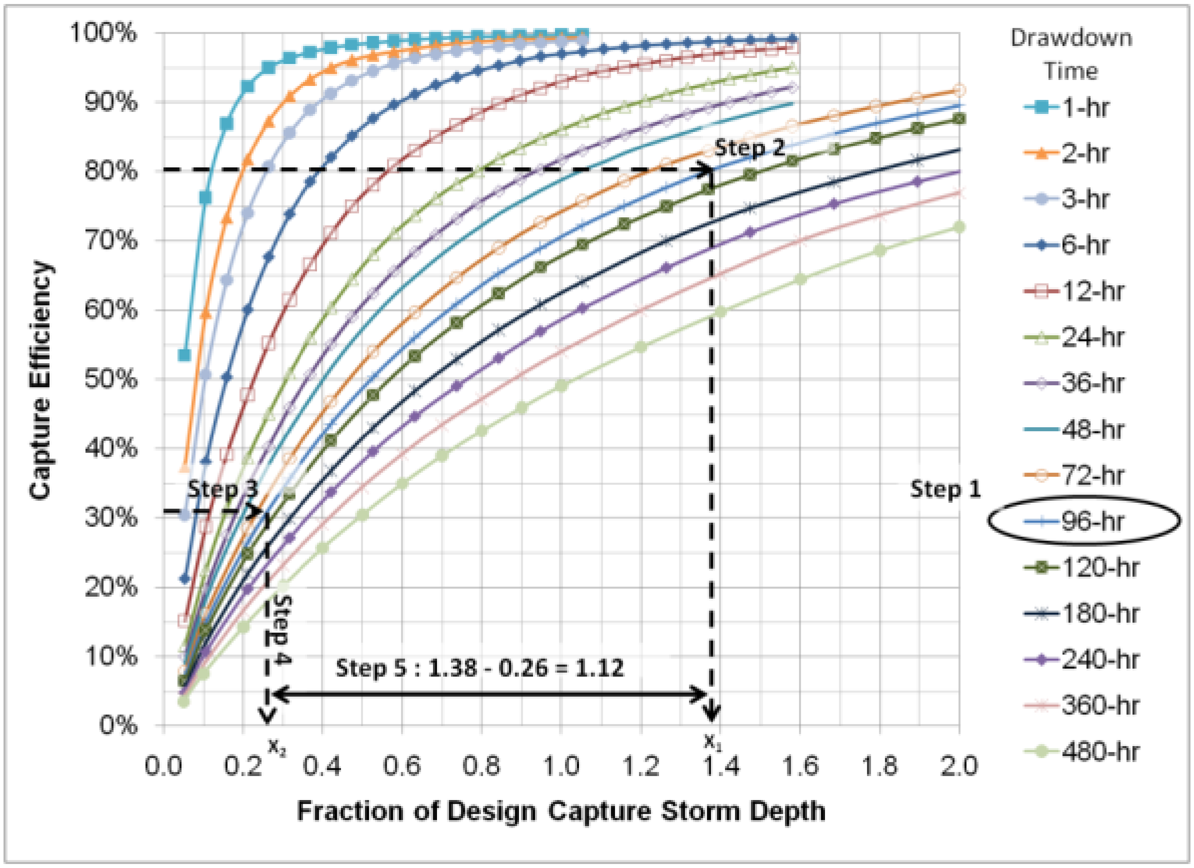
Solution:

1. BMP has total effective depth of 30 inches
2. The drawdown time can be calculated via a simple approach by dividing the effective storage depth by the design infiltration rate
   →30 in / 0.31 in/hr = 96-hour total drawdown
3. From **Figure E-4**: X_1 = 1.38 (point where 80% capture intersects with 96-hour drawdown)
4. Capture efficiency achieved by 0.2 inches of HSCs = 31% (From **Section E.2.1**)
5. From **Figure E-4**: X_2 = 0.26 (point where 31% capture intersects with 96-hour drawdown)
6. Fraction of 85th percentile, 24-hour storm depth required (X1 – X2) = (1.38 – 0.26) = 1.12
7. The 85th percentile, 24-hour storm event is 0.85 inches
8. Required design storm depth = 0.85 inches * (1.12) = 0.95 inches
9. Required storage volume = 1.5 ac × 0.95 inches × (0.8×0.75 + 0.15) × 43560 sf/ac × 1/12 in/ft = 3,880 cu-ft
10. Assuming the original retention depth of 30 inches (2.5 feet), the required footprint to capture the DCV = 3,880 cu-ft/2.5 ft = 1,550 sq-ft.
11. Using the method in **Section E.4.1**, the default footprint to avoid premature clogging is 3% of the total impervious area of the. The wetted infiltrating surface area is 1,550 sq-ft (3.0 % of tributary impervious area). So, the footprint provided just meets the minimum requirement for clogging to avoid premature clogging and no adjustment is necessary.

(see graphical operations on following page)

Graphical operations supporting solution:

Graphical Operations Supporting **Example E.6**



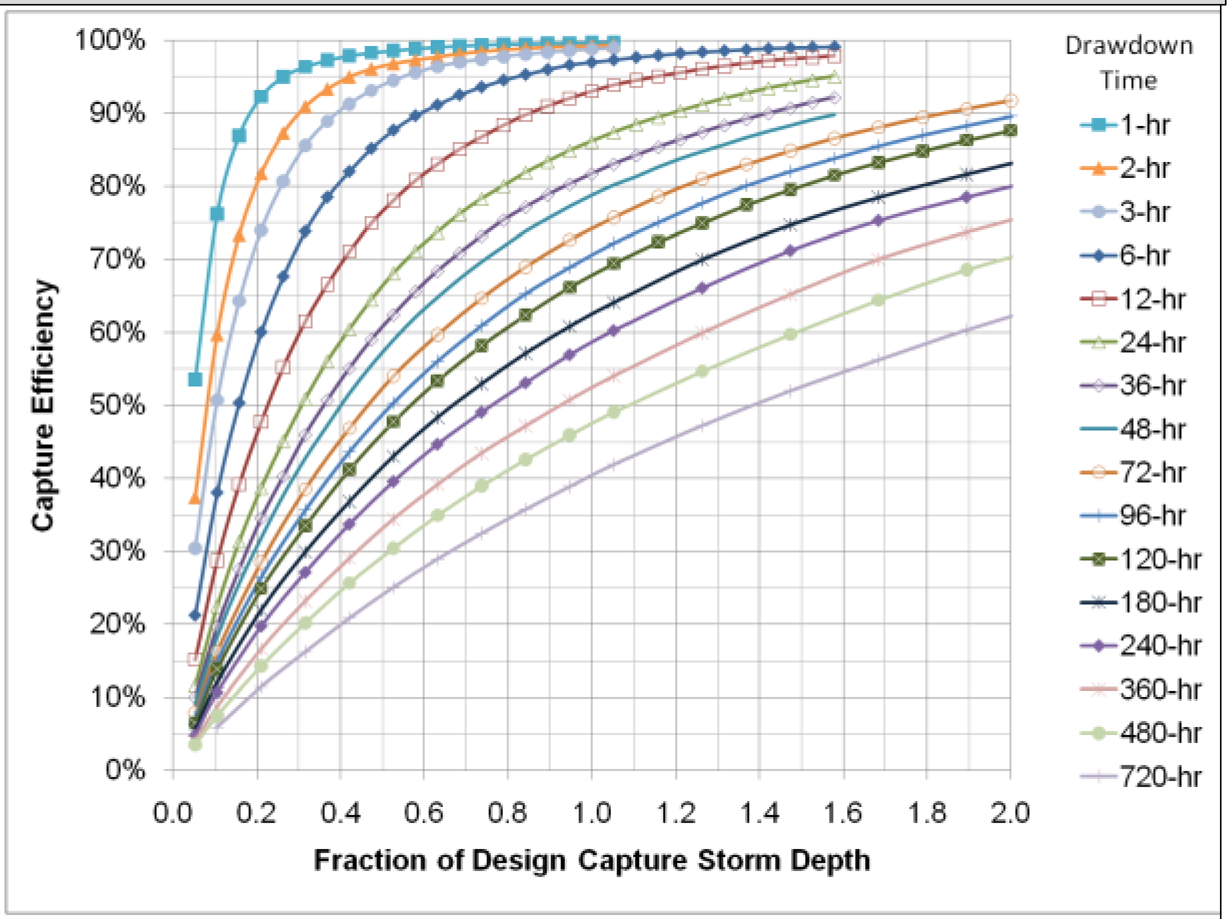
E.3.2.3 *Worksheet for Using the Capture Efficiency via Nomograph Method to Size a Full Infiltration BMPs*

Worksheet 6: Capture Efficiency Method for Full Infiltration, Constant Drawdown BMPs

Part 1: Calculate the design depth and drawdown time				
1	Enter total effective storage depth (sum of values below)	$D_{total\_effective}$		inches
1a	Ponding storage depth	D_{pond}		inches
1b	Media effective storage depth (depth * 0.2)	$D_{media\_effective}$		inches
1c	Gravel effective storage (depth * 0.4)	$D_{gravel\_effective}$		inches
2a	Calculate design infiltration rate, $K_{design} = K_{observed} / S_{total}$ (See Worksheet 3 and **Appendix D**)	K_{design}=		in/hr
2b	Calculate drawdown time ($D_{total\_effective} / K_{design}$)	$T_{drawdown}$=		hours
2c	If using Method 2 for drawdown (**Section E.2.5**) which accounts for sidewall infiltration, insert result and attach relevant calculations below.	$T_{drawdown}$=		hours
Part 2: Determine the portion of the design storm for the BMP				
3	Using **Figure E-4** or the figure within the worksheet below, determine the "fraction of design capture storm depth" at which the BMP drawdown time line intersects with 80% capture efficiency. Trace down to determine X_1	X_1=		
4	Enter capture efficiency corresponding to upstream HSCs and/or upstream Harvest and Use BMPs, Y_2.	Y_2 =		%
5	Using **Figure E-4** or the figure within the worksheet below, determine the fraction of "design capture storm depth" at which the drawdown time of the BMP intersects with the equivalent of the upstream capture efficiency (Y_2). Trace down to determine X_2	X_2=		
6	Calculate the fraction of design capture storm depth that must be provided by the BMP, fraction = $X_1 – X_2$	fraction=		
7	Enter design capture storm depth from N-1, d (inches)	d=		inches
8	Calculate the storm depth to use in sizing calculations, $d_{fraction}$= fraction × d	$d_{fraction}$=		inches
Part 3 Calculate the DCV (Section E.2.2)				
9a	Enter DMA area tributary to BMP (s), *A* (acres) (not including any self-retaining areas)	A=		acres
9b	Enter DMA Imperviousness, *imp*	imp=		unitless
9c	Calculate runoff coefficient, *C= (0.75 x imp) + 0.15*	C=		unitless

Worksheet 6: Capture Efficiency Method for Full Infiltration, Constant Drawdown BMPs

9d	Calculate the DCV= *(C x $d_{fraction}$ x A x 43560 x (1/12))*	DCV=		cu-ft
Part 3: Check footprint and drawdown times				
10	Footprint required to retain the DCV, DCV/$D_{effective}$ (A_{BMP} is measured at the mid ponding depth for systems with side slopes)	A_{BMP}		sq ft
11a	Infiltrating surface area required to avoid premature clogging (from **Section E.4.1**), as percent of tributary impervious area	$\%A_{min,clog}$		%
11b	Provided infiltrating surface area as a fraction of the tributary impervious surface (included wetted infiltrating area when BMP is half full)	$\%A_{infiltration\_surface}$		%
Supporting Calculations				



Provide supporting graphical operations.

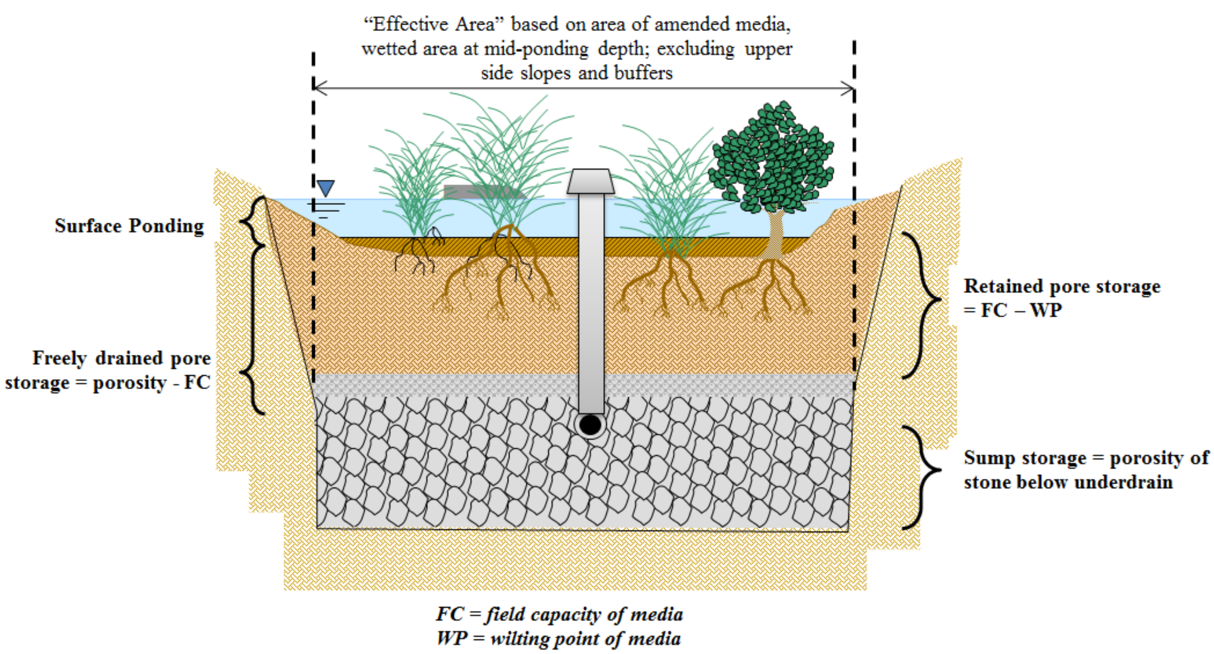
E.3.3 Biofiltration Routing Method for Sizing Volume-Based Biofiltration BMPs

This method can be used to design biofiltration BMPs. Sizing criteria (listed in TGD **Section 4.2.4**) include:

- Biofilter at least 150% of the portion of the DCV not reliably retained,
- Maximize volume reduction (except in the No Infiltration Condition), and
- Avoid premature clogging.

This sizing method has been specifically tailored to a Bioretention BMP with underdrains (See BMP fact sheets in **Appendix G** and **Figure E-5** below). In the Partial Infiltration condition, the retention volume must be maximized, and the discharge point of the underdrain is typically elevated such that water is first stored in a gravel layer for retention (**Figure E-5**) before biofiltered water begins to discharge. In the No Infiltration Condition, the internal water storage may still be desirable for pollutant control (water held below underdrain discharge elevation), but is not counted in sizing methods. This method assumes that the Bioretention BMP is in the Partial Infiltration condition and includes a retention sump. This method can be used to size a Bioretention BMP in the No Infiltration Condition by ignoring the volume provided in the infiltration sump.

Figure E-5: Bioretention volume compartments for sizing purposes



Either this method or the Biofiltration Static Volume Method (**Section E.3.4**) may be used for sizing biofiltration BMPs.

E.3.3.1 Biofiltration Routing Method Stepwise Instructions for Sizing Biofiltration BMPs

The method includes the following calculations:

1. Determine the 85th percentile, 24-hour design storm event depth (see map in **Appendix N**).
2. Reduce the design storm depth based on upstream HSCs in the DMA (See **Section E.2.1**) and the equivalent storm depth corresponding to water captured in any other upstream retention BMP.
3. Convert the remaining design storm depth to a runoff volume (See **Section E.2.2**).
4. Select a BMP effective footprint area by reviewing the limiting factors for biofiltration footprint:
    a. Minimum footprint to avoid premature clogging (**Section E.4.1**) (applies in all conditions).
    b. Footprint to achieve target incidental volume reduction (**Section E.4.2**) (partial infiltration conditions only).
    c. Prior iterations of this method may show that the actual footprint needs to exceed the footprints above to satisfy sizing calculations, in which case the higher footprint should be used.
    d. In absence of other information, start with a footprint equivalent to 3 percent of the tributary impervious area.
5. (Partial Infiltration category only) Determine the target effective depth of the gravel sump storage by dividing the design infiltration rate, K_{design}, of the underlying soil obtained using the factor of safety from Worksheet 3 (**Appendix D**) by 48 hours. If Kdesign is not known, assume 0.15 in/hr. A porosity of 0.4 can be used for washed drain rock. The depth of drain rock below the underdrain discharge elevation does not need to exceed 18 inches, but may be as large as the depth that would infiltrate in 48 hours based on a reliable design infiltration rate.
6. (Partial Infiltration category only) Calculate the volume retained in the gravel sump below the underdrain by multiplying the effective depth of the gravel from step (5) by the footprint from step (4).
7. Select an initial media depth (typically 24") using the BMP fact sheets and multiply by 0.1 to calculate the effective retention depth of the media. Multiply this depth by the footprint from step (4) to obtain the volume retained in the media (retention of runoff on the media grains and in pores that does not drain freely, but is instead evapotranspired).
8. Calculate the remaining portion of the DCV by subtracting the volume retained by the gravel sump from step (7) and the volume retained on the media from step (8) from the initial design volume from step (3).
9. Multiply the remaining DCV by 1.5 to obtain the volume that must be biofiltered (not retained) by the Bioretention BMP.

10. Select an initial profile above the underdrain including the soil media thickness selected in step (8), and surface ponding (typically 6"-12") based on guidance in the BMP fact sheet for Bioretention (**Appendix G**). Calculate the total effective biofiltration storage depth of the media and ponding assuming a void ratio of 0.2 for the media.

$$D_{biofilter\_effective} = \text{ponding depth} + 0.2 * \text{media depth}$$

11. Calculate the volume biofiltered by the BMP during an allowable routing period accounting for the actual duration of real storms. Use a routing period, T_{rout}, of 5 hours[7] and an infiltration rate, K_{media} of 2.5 inches/hour for the media or justify other values.

$$V_{treated} = (D_{biofilter\_effective} + K_{media} * T_{rout}) * A_{BMP\_EFF} * (1ft/12\ inches)$$ Equation **E.10**

Where:

$V_{treated}$ = the volume of runoff biofiltered, including stored plus routed volume (cubic feet)
$D_{biofilter\_effective}$ = the effective depth of biofiltration storage in the media and ponding area above the underdrain (inches) calculated in step (10)
K_{media} = the infiltration rate of the soil media (in/hr) (2.5 in/hr, unless otherwise justified)
T_{rout} = the routing period (5 hours, unless otherwise justified)
A_{BMP_EFF} = the effective footprint of the BMP (sq ft) calculated in step (4)

12. Ensure the volume biofiltered in step (12) is greater than or equal to the required biofiltered volume calculated in step (9). If the volume from step (12) is less than the required from step (9) iteratively adjust footprint and/or profile and repeat steps (6) through (12) until the provided biofiltered volume ($V_{treated}$) equals or exceeds the required biofiltered volume ($V_{treat\_required}$). Do not decrease the footprint below the minimum required for volume reduction and avoiding premature clogging calculated in step (4), and do not increase the gravel sump depth above the depth calculated in step (5) that will drain in 48 hours.

---

[7] Routing period of 5 hours is based on the 15th percentile storm duration for storms similar (within 10%) to the 85th percentile rainfall depth. Estimated based on inspection of continuous rainfall data from the Fullerton Dam, Santiago Dam, and Laguna Beach 2 rain gages between 1948 and 2008.

E.3.3.2 Example Using Biofiltration Routing Method for Sizing Biofiltration BMPs

Example E.7: Using Biofiltration Routing Method for Sizing Bioretention BMPs with Underdrains

Given:

- Redevelopment project, 85th percentile, 24-hr storm depth = 0.85 inches
- Drainage Area = 1.5 acres
- Imperviousness = 80%
- Effective retention depth of HSCs (d_{HSC}) = 0.1 inches (from Worksheet 4)
- Design infiltration rate not measured, assume 0.15 in/hr
- Biofiltration BMP with raised underdrain discharge elevation in the Partial Infiltration category
- ***Required:***
- Size the Biofiltration BMP to meet LID sizing criteria

Solution:

1. Design capture storm depth = 0.85 inches
2. Design capture storm depth, less HSCs = 0.85 inches – 0.1 inches = 0.75 inches
3. Runoff volume = 1.5 ac × (0.75*0.8 + 0.15) × (0.75 inches) * 43,560 sf/ac × 1/12 in/ft = 3,060 cu-ft
4. Select the minimum footprint using guidance from **Sections E.4.1** and **E.4.2**.
   Minimum footprint to avoid premature clogging: **2.1%** of impervious area (**Section E.4.1** Urban mixed land use, no significant open space, vegetated surface BMP with forebay)

   Target footprint for volume reduction: **1.8%** of impervious area (**Section E.4.2**.)

   Select 2.5% : Effective footprint = 0.025 * 1.5 acres * (0.8) * (43,560 sq ft/acre) = 1,310 square feet (this selection was based on iterative approach, indicating that a size larger than the minimums is needed)
5. Target effective depth of storage in gravel = 0.15 in/hr * 48-hour drawdown time = 7.2 inches. (Actual gravel depth will be 7.2 inches/0.4 porosity =18 inches).
6. Calculate the volume retained in the gravel sump = effective gravel sump depth * footprint = 7.2 inches * 1,310 sq ft * (1 ft/12 inches) = 780 cubic feet retained in infiltration sump
7. Select 24 inches of media. Calculate the volume retained in the soil media = 0.1* 24 inches * (1 ft/12 inches) * 1,310 sq ft = 260 cubic feet
8. Remaining DCV = 3,060 cubic feet (from step 3) – 780 cubic feet (from step 6) - 260 cubic feet (from step 7) = 2,020 cubic feet
9. Volume to be biofiltered equals 1.5 x the remaining DCV = 1.5 * 2,010 = 3,030 cubic feet
10. Select profile of 12 inches surface storage plus the 24 inches of media previous selected.

$D_{biofilter\_effective}$ = 0.2 (24 inches) + 12 inches = 16.8 inches

11. $V_{treated}$ = (16.8 inch + 2.5 in/hr * 5 hour)* 1,310 square feet * (1 ft/12 inches) = 3,200 cubic feet
12. 3,200 cubic feet treated (from step 11) > 3,030 cubic feet (from step 10). This BMP is adequate sized and could be downsized slightly, if desired.

E.3.3.3 Worksheet for Using Biofiltration Routing Method for Sizing Biofiltration BMPs

Worksheet 7: Biofiltration Routing Method for Sizing Bioretention BMPs with Underdrains

Part 1: Calculate Design Storm Volume				
1	Enter design capture storm depth, *d* (inches)	d=		inches
2a	Enter the combined effect of provided HSCs, d_{HSC} (inches) (based on Worksheet 4)	d_{HSC}=		inches
2b	Calculate the remainder of the design capture storm depth, $d_{remainder}$ = d - d_{HSC}	$d_{remainder}$=		inches
3a	Enter DMA area tributary to BMP(s), *A* (acres) excluding any self-retaining areas	A=		acres
3b	Enter DMA Imperviousness, imp (unitless) after removal of self-retaining areas	imp=		
3c	Calculate runoff coefficient, *C= (0.75 x imp) + 0.15*	C=		
3d	Calculate runoff volume, *DCV = (C x $d_{remainder}$ x A x 43560 x (1/12)) (See **Section E.2.2**)*	DCV=		cu-ft
Part 2: Select Initial BMP Effective Footprint Area (can be iterative)				
4a	Calculate minimum area required for BMP to avoid premature clogging from **Section E.4.1**.(as percent of impervious tributary area)	$\%A_{min,clog}$=		%
4b	Calculate minimum area required for BMP to meet volume reduction requirements (Partial Infiltration category only) using **Section E.4.2**.	$\%A_{min,vol}$=		%
4c	Effective footprint of BMP as percent of tributary impervious area, must be equal to or greater than both $\%A_{min,clos}$ and $\%A_{min,vol}$ (as applicable)	$\%A_{BMP\_EFF}$		%
4d	Effective footprint of BMP ($\%A_{BMP\_EFF}$ * A * imp)	A_{BMP_EFF}		sq-ft
Part 3: Calculate Retention Volume in BMP				
5a	Determine gravel layer depth (18 inches or an alternative depth that will infiltrate within 48 hours)	D_{gravel}		inches
5b	Calculate effective retention storage depth of gravel layer D_{eff_gravel} = 0.4 porosity * D_{gravel} (Partial Infiltration Category only)	$D_{eff,gravel}$		inches
6	Calculate volume retained in gravel layer (Partial Infiltration Category only) Vgravel = $D_{eff,gravel}$ * A_{BMP_EFF} * (1 ft/12 inches)	V_{gravel_retain}		cu-ft

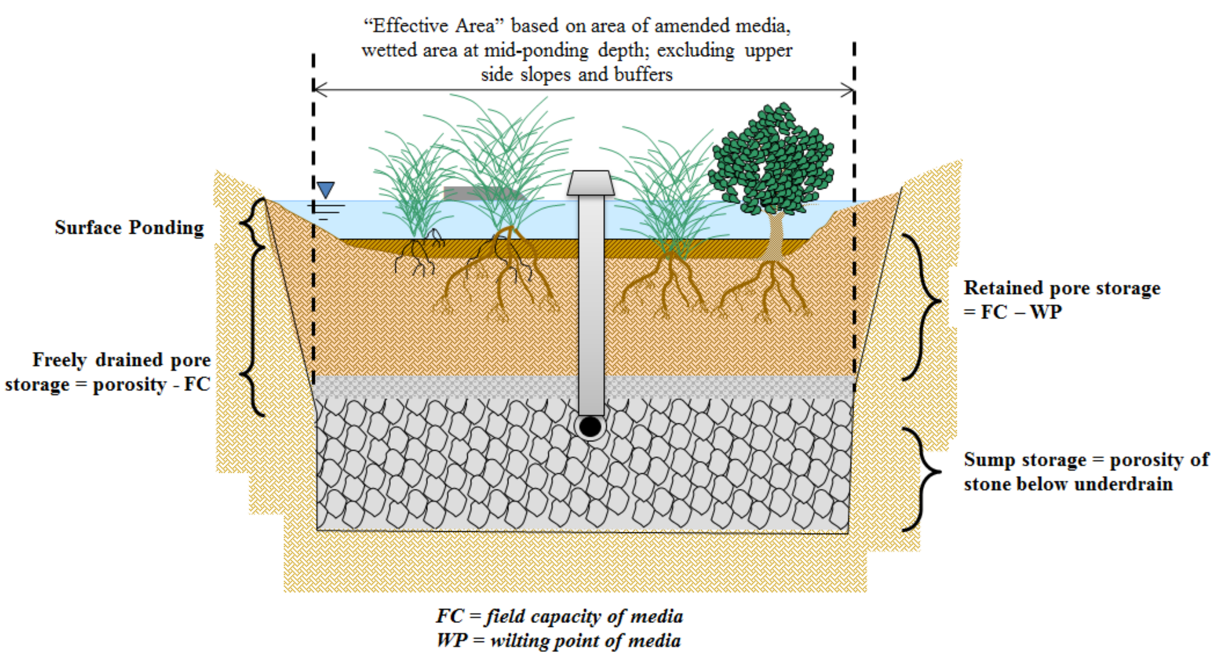
7a	Media depth D_{media} (24 inches typical) See BMP fact sheet (**Appendix G**)	D_{media}		inches
8b	Calculate volume retained in soil media layer, $V_{media} = 0.1 * D_{media} * A_{BMP\_EFF} * (1 \text{ ft}/12 \text{ inches})$	V_{media_retain}		cu-ft
Part 4: Calculate Required and Provided Biofiltered Volume				
9	Calculate the remaining DCV by subtracting the retained volume in the gravel layer and media layer from the initial design volume, $DCV_{remain} = DCV - V_{gravel\_retain} - V_{media\_retain}$	DCV_{remain}		cu-ft
10	Calculate the required volume to be biofiltered by multiplying the remaining DCV by 1.5, $V_{treat\_req} = 1.5 * DCV_{remain}$	V_{treat_req}		cu-ft
11a	Surface storage ponding depth (6-12 inches typical) See BMP fact sheet (**Appendix G**)	$D_{ponding}$		inches
11b	Calculate effective depth of the biofiltration storage above the underdrain, $D_{biofilter\_effective} = D_{ponding} + 0.2 * D_{media}$	$D_{biofilter\_effective}$		in
12a	Routing period (5 hours is default, proponent must justify any other value), T_{rout}	T_{rout}		hours
12b	Media infiltration rate (2.5 inches/hour default, proponent must justify any other value)	K_{media}		in/hr
12c	Calculate biofiltered volume, $V_{treated} = (D_{biofilter\_effective} + K_{media} * T_{rout}) * A_{BMP\_EFF} * (1 \text{ ft}/12 \text{ in})$	$V_{treated}$		cu-ft
13	Verify that $V_{treated} > V_{treat\_req}$. If it is not, must revise profile or footprint while conforming to criteria			

E.3.4 Biofiltration Static Volume Method for Sizing Volume-Based Biofiltration BMPs

This method is very similar to the Biofiltration Routing Method (**Section E.3.3**) with a few minor changes. This method can be used lieu of the method in **Section E.3.3** to design biofiltration BMPs to meet the required sizing criteria.

This sizing method has been specifically tailored to a Bioretention BMP with underdrains (See BMP fact sheets in **Appendix G** and **Figure E-6** below). In the Partial Infiltration condition, the retention volume must be maximized, and the discharge point of the underdrain is typically elevated such that water is first stored in a gravel layer for retention (**Figure E-5**) before biofiltered water begins to discharge. In the No Infiltration Condition, the internal water storage may still be desirable for pollutant control (water held below underdrain discharge elevation), but is not counted in sizing methods. This method assumes that the Bioretention BMP is in the Partial Infiltration condition and includes an infiltration sump. This method can be used to size a Bioretention BMP in the No Infiltration Condition by ignoring the volume provided in the infiltration sump.

Figure E-6: Bioretention with raised underdrain volume compartments for sizing purposes



E.3.4.1 Biofiltration Static Volume Method Stepwise Instructions for Sizing Biofiltration BMPs (For use in SOC only)

The method includes the following calculations:

1. Determine the 85th percentile, 24-hour design storm event depth (See **Appendix N**)
2. Reduce the design storm depth based on upstream HSCs in the DMA (See **Section E.2.1**) and the equivalent storm depth corresponding to water captured in any other upstream retention BMP.
3. Convert the remaining design storm depth to a runoff volume (See **Section E.2.2**)
4. Select a BMP effective footprint area by reviewing the limiting factors for biofiltration footprint:
    a. Minimum footprint to avoid premature clogging (**Section E.4.1**) (applies in all conditions).
    b. Footprint to achieve target incidental volume reduction (**Section E.4.2**) (partial infiltration conditions only).
    c. Prior iterations of this method may show that the actual footprint needs to exceed applicable minimums to satisfy sizing calculations, in which case the higher footprint should be used.
    d. In absence of other information, start with an effective BMP footprint equal to 3 percent of tributary impervious area.
5. (Partial Infiltration category only) Determine the target effective depth of the gravel sump storage by dividing the design infiltration rate, K_{design}, of the underlying soil obtained using the factor of safety from Worksheet 3 (**Appendix D**) by 48 hours. If Kdesign is not known, assume 0.15 in/hr. A porosity of 0.4 can be used for washed drain rock. The depth of drain rock below the underdrain discharge elevation does not need to exceed 18 inches, but may be as large as the depth that would infiltrate in 48 hours based on a reliable design infiltration rate.
6. (Partial Infiltration category only) Calculate the volume retained in the gravel sump below the underdrain by multiplying the effective depth of the gravel from step (5) by the footprint from step (4).
7. Select an initial media depth (typically 24") using the BMP fact sheets and multiply by 0.1 to calculate the effective retention depth of the media. Multiply this depth by the footprint from step (4) to obtain the volume retained in the media (retention of runoff on the media grains and in pores that does not freely drain, but is instead evapotranspired).
8. Calculate the remaining portion of the DCV by subtracting the volume retained by the gravel sump from step (7) and the volume retained on the media from step (8) from the initial design volume from step (3).
9. Multiply the remaining DCV by 0.75 to obtain the volume that must be held in static biofiltration storage by the Bioretention BMP ($V_{biofilter\_storage\_req}$).

10. Select an initial profile above the underdrain including the soil media thickness selected in step (8), and surface ponding (typically 6"-12") based on guidance in the BMP fact sheet for Bioretention (**Appendix G**). Calculate the total effective biofiltration storage depth of the media and ponding assuming a void ratio of 0.2 for the media.

$$D_{effective\_biofilter} = 0.2 * \text{media depth} + \text{ponding depth}$$

11. Calculate the volume of the pores in the gravel, media, and surface storage above the underdrain.

$$V_{biofilter\_storage} = D_{effective\_biofilter} * A_{BMP\_EFF} * (1ft/12\ inches)$$ Equation **E.11**

Where:

$V_{biofilter\_storage}$ = the biofilter volume of storage provided in the pores of the media and surface storage above the underdrain (cubic feet)
$D_{effective\_biofilter}$ = the effective depth of biofiltration storage in the media and ponding area (inches) calculate in step (11)
A_{BMP_EFF} = the footprint of the BMP (sq ft) calculated in step (6)

12. Ensure the static biofiltration volume provided in step (11) is greater than or equal to the required static biofiltration volume calculated in step (9). If the volume from step (11) is less than the required from step (9) iteratively adjust footprint and/or profile and repeat steps (6) through (11) until it reaches this volume. Do not decrease the footprint below the minimum required for volume reduction and avoiding premature clogging calculated in step (4), and do not increase the gravel sump depth above depth that will drain in 48 hours as calculated in step (5).

E.3.4.2 Example Using Static Volume Method for Sizing Biofiltration BMPs

Example E.8: **Static Volume Method for Sizing Biofiltration BMPs in SOC**

Given:
• Redevelopment project, 85th percentile, 24-hr storm depth = 0.85 inches
• Drainage Area = 1.5 acres
• Imperviousness = 80%
• Effective retention depth of HSCs (d_{HSC}) = 0.1 inches (from Worksheet 4)
• Design infiltration rate not measured, assume 0.15 in/hr
• Biofiltration BMP with raised underdrain discharge elevation in the Partial Infiltration category
• ***Required:***
• Size the Biofiltration BMP to meet LID sizing criteria

Solution:

1. Design capture storm depth = 0.85 inches
2. Design capture storm depth, less HSCs = 0.85 inches – 0.1 inches = 0.75 inches
3. Runoff volume = 1.5 ac × (0.75*0.8 + 0.15) × (0.75 inches) * 43,560 sf/ac × 1/12 in/ft = 3,060 cu-ft
4. Select the minimum footprint using either site-specific methods from **Section E.4.1** and **E.4.2**. Minimum footprint to avoid premature clogging: **2.1%** of impervious area **(Section E.4.1** Urban mixed land use, no significant open space, vegetated surface BMP with forebay)

   Target footprint for volume reduction: **1.8%** of impervious area (**Section E.4.2**)

   Select 2.5% : Effective footprint = 0.025 * 1.5 acres * (0.8) * (43,560 sq ft/acre) = 1,310 square feet (this selection was based on iterative approach, indicating that a size larger than the minimums is needed)
5. Target effective depth of gravel = 0.15 in/hr * 48-hour drawdown time = 7.2 inches. (Actual gravel depth will be 7.2 inches/0.4 porosity =18 inches).
6. Calculate the volume retained in the gravel sump = effective gravel sump depth * footprint = 7.2 inches * 1,310 sq ft * (1 ft/12 inches) = 780 cubic feet retained in infiltration sump
7. Select 24 inches of media. Calculate the volume retained in the soil media = 0.1* 24 inches * (1 ft/12 inches) * 1,310 sq ft = 260 cubic feet
8. Remaining DCV = 3,060 cubic feet (from step 3) – 780 cubic feet (from step 6) - 260 cubic feet (from step 7) = 2,020 cubic feet
9. Biofilter volume required to be provided in pores of media and surface ponding storage above the underdrain equals 0.75 x the DCV = 0.75 * 2,020 = 1,520 cubic feet = $V_{biofilter\_storage\_req}$
10. Select profile of 12 inches surface storage plus the 24 inches of media previous selected.

    $D_{effective\_biofilter}$ = 0.2 (24 inches) + 12 inches = 16.8 inches
11. $V_{biofilter\_storage}$ = 16.8 inches* 1,310 square feet * (1 ft/12 inches) = 1,830 cubic feet
12. 1,830 cubic feet > 1,520 cubic feet (size is acceptable; BMP footprint area or surface storage ponding depth could be reduced slightly to optimize design)

E.3.4.3 Worksheet for Using Static Volume Method for Sizing Biofiltration BMPs

Worksheet 8: Static Volume Method for Sizing Bioretention BMPs with Underdrains in SOC

Part 1: Calculate Design Storm Volume				
1	Enter design capture storm depth, *d* (inches)	d=		inches
2a	Enter the combined effect of provided HSCs, d_{HSC} (inches) (based on ***Worksheet 4***)	d_{HSC}=		inches
2b	Calculate the remainder of the design capture storm depth, $d_{remainder}$ = d - d_{HSC}	$d_{remainder}$=		inches
3a	Enter DMA area tributary to BMP(s), *A* (acres) excluding any self-retaining areas	A=		acres
3b	Enter DMA Imperviousness, imp (unitless) after removal of self-retaining areas	imp=		
3c	Calculate runoff coefficient, *C= (0.75 x imp) + 0.15*	C=		
3d	Calculate runoff volume, *DCV = (C x $d_{remainder}$ x A x 43560 x (1/12)) (See **Section E.2.2**)*	DCV=		cu-ft
Part 2: Select Initial BMP Effective Footprint Area (can be iterative)				
4a	Calculate minimum area required for BMP to avoid premature clogging from **Section E.4.1**.(as percent of impervious tributary area)	$\%A_{min,clog}$=		%
4b	Calculate minimum area required for BMP to meet volume reduction requirements (Partial Infiltration category only) using **Section E.4.2**	$\%A_{min,vol}$=		%
4c	Effective footprint of BMP as percent of tributary impervious area, must be equal to or greater than both $\%A_{min,clos}$ and $\%A_{min,vol}$ (as applicable)	$\%A_{BMP\_EFF}$		%
4d	Effective footprint of BMP ($\%A_{BMP\_EFF}$ * A * imp)	A_{BMP_EFF}		sq-ft
Part 3: Calculate Retention Volume in BMP				
5a	Determine gravel layer depth (18 inches or an alternative depth that will infiltrate within 48 hours)	D_{gravel}		inches
5b	Calculate effective retention storage depth of gravel layer $D_{eff,gravel}$ = 0.4 porosity * D_{gravel} (Partial Infiltration Category only)	$D_{eff,gravel}$		inches
6	Calculate volume retained in gravel layer (Partial Infiltration Category only) V_{gravel} = $D_{eff,gravel}$ * A_{BMP_EFF} * (1 ft/12 inches)	V_{gravel_retain}		cu-ft
7a	Media depth D_{media} (24 inches typical) See BMP fact sheet (**Appendix G**)	D_{media}		inches
8b	Calculate volume retained in soil media layer, V_{media} =0.1*D_{media}*A_{BMP_EFF} * (1 ft/12 inches)	V_{media_retain}		cu-ft
Part 4: Calculate Required and Provided Biofiltered Volume				
9	Calculate the remaining DCV by subtracting the retained volume in the gravel layer and media layer from the initial design volume, DCV_{remain}= DCV-V_{gravel}-V_{media}	DCV_{remain}		cu-ft

9	Calculate the required static biofiltration volume to be provided in the pores of the media and surface ponded storage above the underdrain, $V_{biofilter\_storage\_req}$ = 0.75 * DCV_{remain}	$V_{biofilter\_storage\_req}$		cu-ft
10a	Surface storage ponding depth (6-12 inches typical) See BMP fact sheet (**Appendix G**)	$D_{ponding}$		inches
10b	Calculate effective depth of the biofiltration storage above the underdrain, $D_{effective\_biotreat}$ = 0.2 * D_{media} + $D_{ponding}$	$D_{effective\_biotreat}$		in
11	Calculate static biofiltration storage volume provided in pores of media, and surface ponded storage above the underdrain $V_{biofilter\_storage}$ = ($D_{effective\_biotreat}$) * A_{BMP_EFF} * (1 ft/12 in)	$V_{biofilter\_storage}$		cu-ft
12	Verify that $V_{biofilter\_storage}$ > $V_{biofilter\_storage\_req}$. If it is not, must revise profile or footprint.			

E.3.5 Flow-Based Compact Biofiltration Sizing Method

This sizing method is used to size compact, flow-based biofiltration BMPs. At this time, this method applies only to proprietary BMPs deemed acceptable per **Appendix J**.

In DMAs that are categorized as "Biotreatment with Partial Infiltration" the use of a compact BMP may need to be supplemented with volume reduction features. This method includes steps to account for supplemental volume reduction features. In DMAs that are categorized as "Biotreatment with No Infiltration" supplemental volume reduction features are not needed and those elements of the sizing method are not relevant.

E.3.5.1 Stepwise Instructions for Sizing Compact Biofiltration BMPs

The method includes the following calculations:

1. Calculate the time of concentration for the DMA (See **Section E.2.3**).
2. Locate the line corresponding to the time of concentration (T_c) in **Figure E-7**. Locate the point on the line that corresponds to 80% capture (y-axis) and record the corresponding value from the x-axis. This is the design intensity required in order to achieve 80% capture (I_1).
3. Determine the capture efficiency achieved by any upstream HSCs (**Section E.2.1**) or harvest and use BMPs (**Section E.3.6**). Trace a horizontal line **Figure E-7** corresponding to the capture efficiency achieved by the upstream HSC or harvest and use BMPs.
4. Find where the line traced in step (3) intersects the line corresponding to the time of concentration of the BMP selected in step (1) and read down to the x-axis. This is the equivalent flow rate captured by upstream HSCs or harvest and use BMPs. This is referred to as I_2. Note that if no upstream retention is provided in HSCs or harvest and use BMPs, I_2 will be 0.
5. Subtract I_2 from I_1 to determine the design intensity for flow-based BMPs that would achieve 80 percent long term capture.
6. Convert this intensity to a flow rate (See **Section E.2.4**).
7. Multiply the flow rate from Step (6) by 150% to obtain the required design flow rate of the compact flow-based biofiltration BMP.

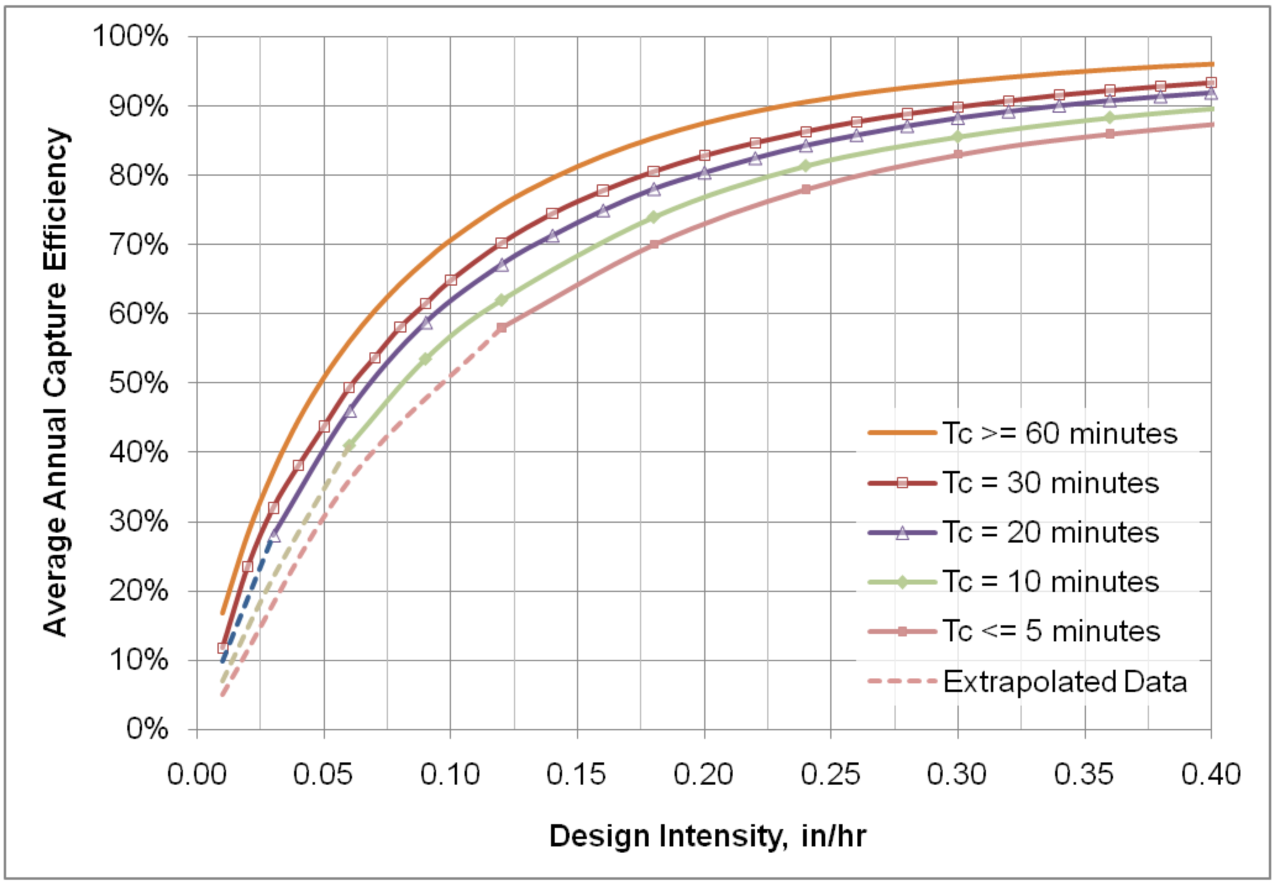
For BMPs in a DMA categorized a "biotreatment with no infiltration" stop here. For BMPs in a DMA categorized as "biotreatment with partial infiltration" proceed.

8. Select and describe HSCs, upstream BMPs, and/or downstream BMPs that are provided to result in volume reduction. This could include any HSC from **Appendix G**, cisterns or permeable pavement upstream of the BMP, or shallow infiltration galleries or trenches downstream of the BMP.
9. Demonstrate that one of the following options is met:

Option 1 for Supplemental Retention: Demonstrate that HSCs, upstream BMPs, and downstream BMPs collectively achieve at least 40 percent average annual runoff volume for the DMA. This can be demonstrated using the nomograph capture efficiency method in **Section E.3.2**, but setting the target for 40 percent rather than 80 percent.

Option 2 for Supplemental Retention: Demonstrate that the effective footprint for infiltration provided by HSCs, upstream BMPs, and downstream BMPs, as applicable, is equivalent to a conventional biofiltration BMP. The footprint to achieve partial volume reduction goals is determined via **Section E.4.2**.

Figure E-7. Capture Efficiency Nomograph for Flow-based Biotreatment BMPs in Orange County



E.3.5.2 Guidance on Sizing Compact Biofiltration with Upstream Detention

There are some design scenarios where an upstream cistern or tank could be used to detain and slow the flow entering a compact biofiltration BMP. This design approach can be used to extend the time of concentration of the catchment up to a maximum of 60 minutes. It cannot be used to significantly extend the duration of flow through the compact biofilter. The following guidance applies to this configuration:

- Detention outlet should be sized such that the maximum discharge rate is equal to or less than the design capacity of the biofilter when the detention storage is full

- An adjustment to the time of concentration used in biofilter sizing can be calculated as:

  Tc increase = Volume of detention (cu-ft) / [Design flowrate of biofilter (cfs) * 3600 sec/hr]

  In no case can the total Tc used in sizing calculations exceed 60 minutes.

- The tank should be demonstrated to drain within 6 hours following the end of precipitation. It is unacceptable to use compact biofilters downstream of extended detention or flow duration control basins that drain over a longer time period due to potential issues with extended saturation and elevated loading per footprint area of the biofilter.

Proprietary compact biofiltration BMPs have not typically be tested for certification purposes under extended drawdown and heavier loading as would result from additional credits for detention. This adjustment to a maximum of a 60-minute time of concentration is the limit to which detention effects can be considered at this time.

E.3.5.3 Example Using the Method for Sizing Compact Biofiltration BMPs

Example E.9: Sizing to Achieve Target Average Annual Capture Efficiency, Flow-based Biotreatment BMPs

Given:

- Partial Infiltration condition
- Drainage Area = 1 acre
- Imperviousness = 90%
- The BMP is located in an area with an 85th percentile, 24-hour storm of 0.8 inches.
- HSCs upstream provide 15% volume reduction (See **Section E.2.1**)
- A compact biofiltration BMP is used that meets the acceptance criteria in **Appendix J**
- A shallow infiltration gallery will be provided downstream of the BMP to provide supplemental volume reduction
- The assumed infiltration rate is 0.15 inches per hour based on initial feasibility screening efforts; detailed design-level analyses are not required

Required:

- Determine compact biofiltration design flowrate and size supplemental infiltration gallery

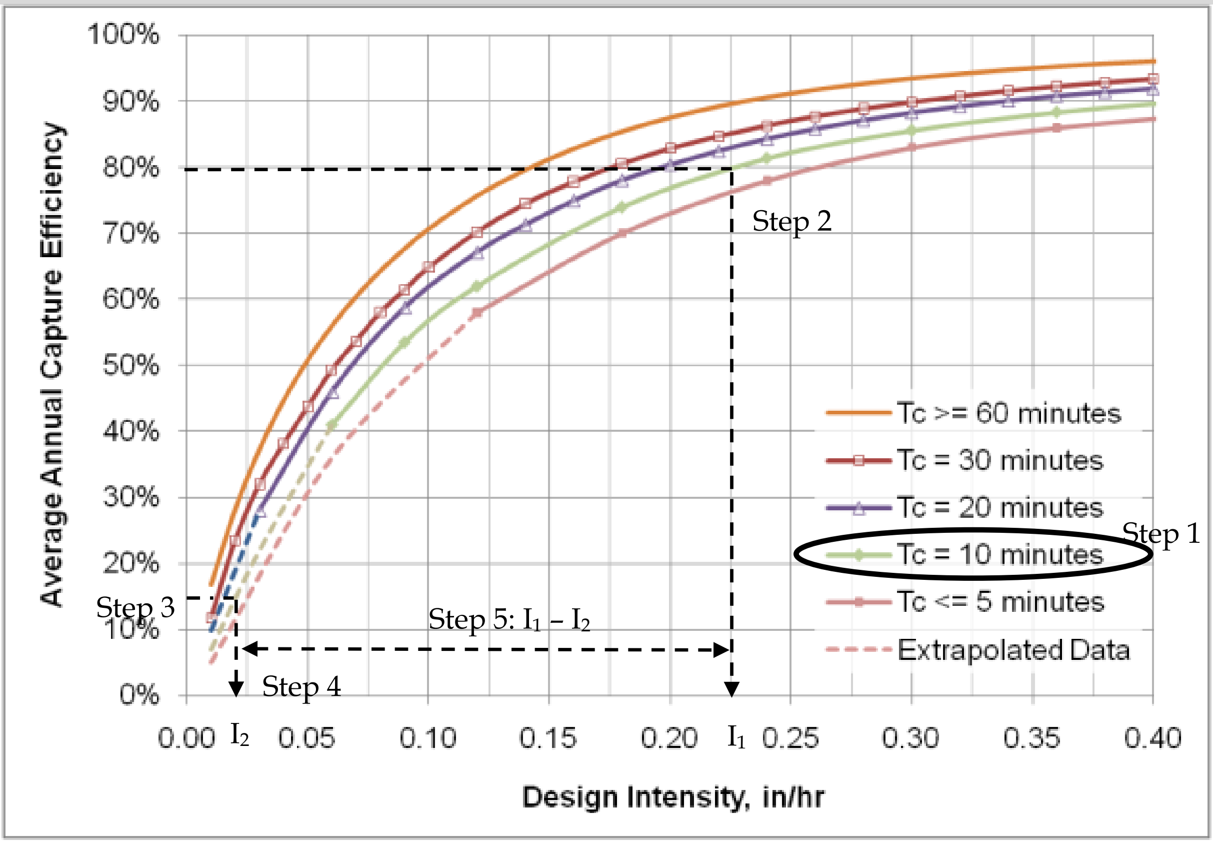
Solution:

1. Computed time of concentration, T_c = 10 minutes (This would be calculated per methods in **Section E.2.3**)
2. From **Figure E-7**: I_1 = 0.23 in/hr
3. Capture efficiency achieved in upstream HSCs is 15% (This would be calculated per methods in **Section E.2.1**)
4. From **Figure E-7**: I_2 = 0.02 in/hr
5. $I_1 – I_2$ = design intensity = 0.21 in/hr
6. Q = [(0.90 ×0.75+0.15) × 0.21 in/hr × 1 ac] = 0.17 cfs
7. Q_{design} = 0.17cfs x 150% = **0.26 cfs**
8. Upstream HSCs achieve 15% volume reduction (<40%), so additional supplemental infiltration is needed if determined to be feasible. A shallow infiltration gallery with a depth of 18 inches of stone will be used. Water from underdrains of the compact biofilter will be routed to this gallery to infiltrate. The degree of infiltration is comparable to a biofiltration BMP with elevated underdrains.
9. The demonstration of adequacy will be made based on providing an equivalent footprint for infiltration compared to a conventional biofiltration BMP. See The footprint to achieve partial volume reduction goals is determined via **E.4.2**. Per this section the combined footprint of upstream and downstream BMPs needs to be 1.7 percent of the tributary impervious area.

   90% * 1 ac * 1.7% * 43560 sq-ft/ac = 670 sq-ft infiltration area required.

   Provide a shallow infiltration gallery with a footprint of at least 670 sq-ft. Provide an overflow pipe at 18 inches above the bottom of the gallery. Alternatively, more aggressive use of upstream BMPs, such as permeable pavement, could provide the needed footprint for infiltration without a downstream infiltration gallery, and could also reduce the required size of the compact biofilter.

Graphical operations supporting solution:



E.3.5.4 Worksheet for Using the Flow-Based Compact Biofiltration with Supplemental Retention Method for Sizing Compact Biofiltration BMPs

Worksheet 9: Flow-Based Compact Biofiltration with Supplemental Retention Method

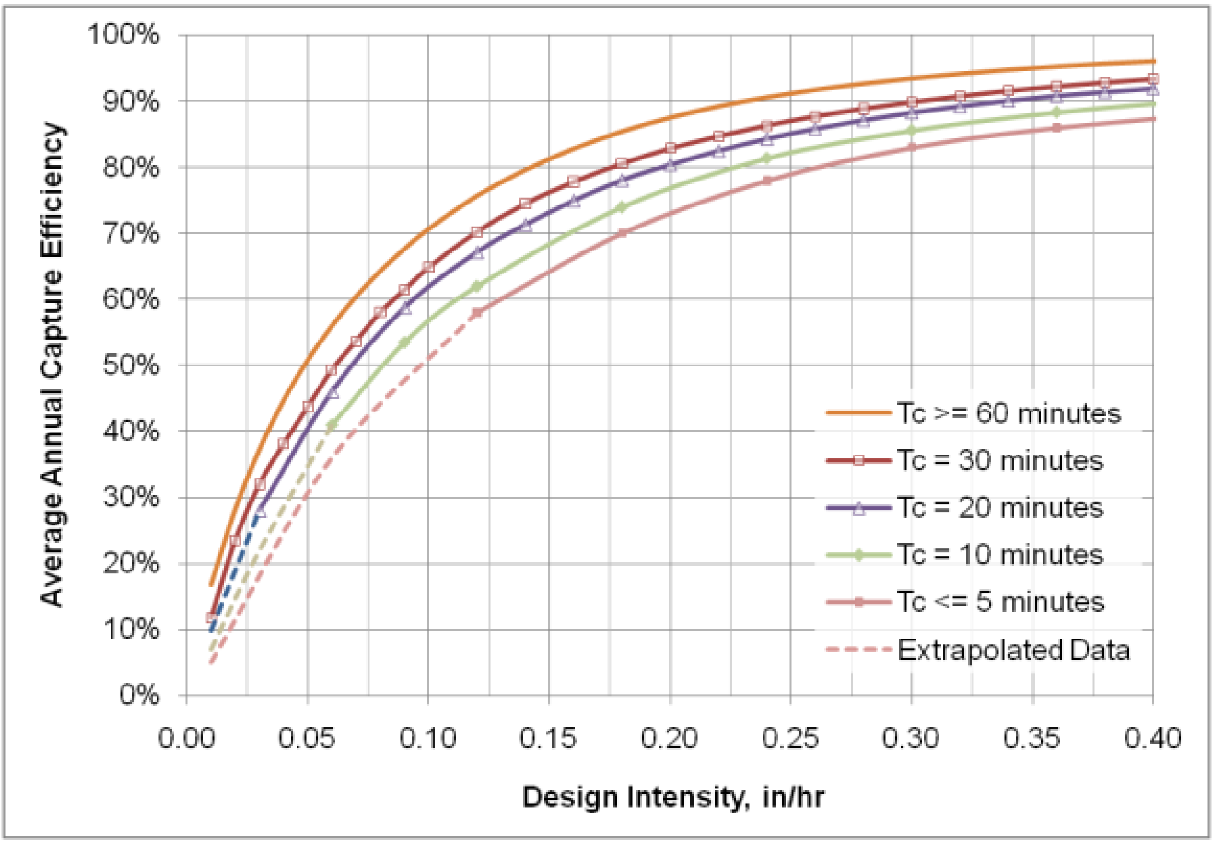
Part 1: Determine the design storm intensity of the compact biofiltration BMP				
1	Enter the time of concentration, T_c (min) (See **E.2.3**) (account for upstream detention by increasing Tc to a maximum 60 minutes per **Section E.3.5.2** if detention is provided)	T_c=		min
2	Using **Figure E-7** or the figure included in the worksheet, determine the design intensity at which the estimated time of concentration (T_c) achieves 80% capture efficiency, I_1	I_1=		in/hr
3	Enter capture efficiency corresponding to upstream HSCs and/or upstream BMPs, Y_2. Attach associated calculations.	Y_2 =		%
4	Using **Figure E-7**, determine the design intensity at which the time of concentration (T_c) achieves the upstream capture efficiency(Y_2), I_2	I_2=		in/hr
5	Determine the design intensity that must be provided by BMP to achieve 80 percent capture, $I_{design}= I_1 - I_2$	$I_{design\_80\%}$ =		in/hr
Part 2: Calculate the design flowrate of the compact biofiltration BMP (Section E.2.6)				
6a	Enter DMA area tributary to BMP (s), *A* (acres)	A=		acres
6b	Enter DMA Imperviousness, imp (unitless)	imp=		
6c	Calculate runoff coefficient, $c = (0.75 \times imp) + 0.15$	c=		
6d	Calculate flowrate to achieve 80 percent capture, $Q_{80\%} = (c \times I_{design} \times A)$	$Q_{80\%}$=		cfs
7	Calculate design flowrate, $Q_{design} = Q_{80\%} \times 150\%$	Q_{design}=		cfs
Part 3: Demonstrate that Supplemental Retention BMPs Conform to Volume Reduction Targets (Only DMAs Categorized as "Biotreatment with Partial Infiltration")				
8	Describe system, including features to maximize volume reduction (if applicable):			
9	Summarize calculations to demonstrate that volume reduction targets are met, where feasible and applicable.			

Worksheet 9: Flow-Based Compact Biofiltration with Supplemental Retention Method

Supporting Calculations

Provide time of concentration assumptions:

Graphical Operations



Provide supporting graphical operations in figure above.

E.3.6 Capture Efficiency via Nomograph Method for Harvest and Use BMPs

Harvest and Use BMPs capture and store rainwater for later use as irrigation, toilet flushing, and other demands. Because these BMPs rely on demand for the harvested water rather than infiltration, their drawdown is typically much slower. The drawdown time is calculated based on the size of the cistern and the magnitude of the indoor and outdoor demands. **Appendix F** contains methods for computing both indoor and outdoor harvested water demand. Outdoor demands are typically seasonal while indoor demands are more constant. Because outdoor demand is more common for harvested rainwater in Orange County, this method focuses only on determining the capture efficiency of a Harvest and Use BMP configuration with a seasonally varying use rate (irrigation demand). The capture efficiency of a Harvest and Use BMP configuration used for constant indoor demand can be calculated using a similar method, except that a constant drawdown nomograph (**Figure E-4**) is used instead of the EIATA-based nomograph (**Figure E-8**), with the drawdown time based on the indoor demand rather than outdoor demand. For Harvest and Use BMP systems with both seasonally varying outdoor demand and constant indoor demand, continuous simulation modeling will be required to determine the capture efficiency.

Harvest and Use BMPs cannot typically achieve 80% capture of long term runoff in Orange County because their drawdown time is typically much longer than other LID BMPs. Typically, this method will be used as a component of other LID BMP sizing methodologies to calculate the capture efficiency of upstream Harvest and Use BMPs, so that the required size of downstream LID BMPs is reduced.

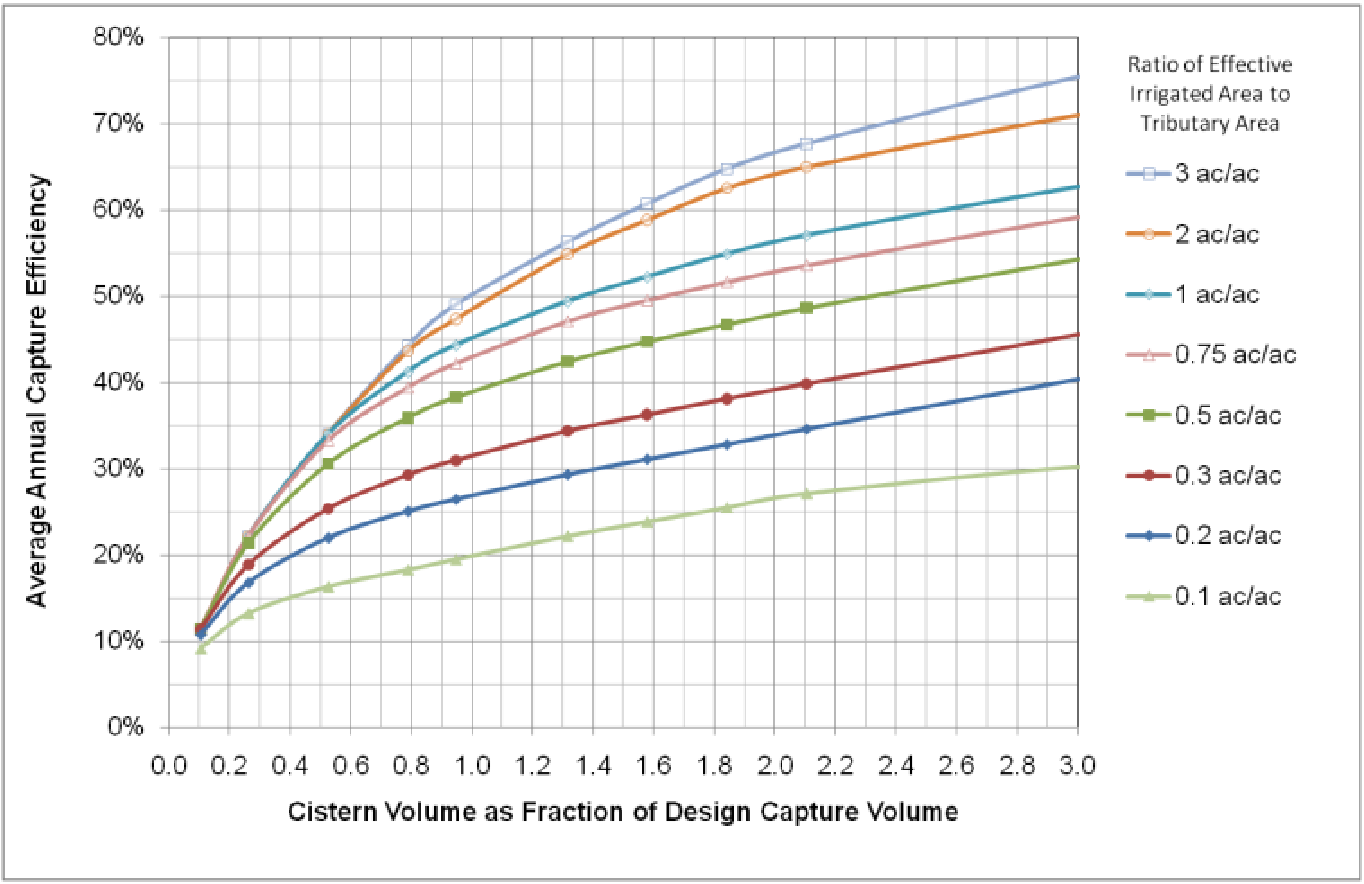
E.3.6.1 Stepwise Instructions for Capture Efficiency via Nomograph Method for Harvest and Use BMPs

The method includes the following calculations:

1. Estimate the effective irrigation area ratio of the system (EIATA) (See **Appendix F**). This is calculated as the amount of irrigated area divided by the amount of impervious area tributary to the cistern.
2. Determine the capture efficiency achieved by any upstream HSCs (**Section E.2.1**). Trace a horizontal line corresponding to this capture efficiency on **Figure E-8**. Locate where this line intersects the line corresponding to the EIATA computed in Step (1).
3. Pivot and read down to the horizontal axis. This is X_1. Note that if no HSCs are provided, X_1 will be 0.
4. Determine the 85th percentile, 24-hour design storm event depth (See map in **Appendix N**).
5. Convert the design storm depth from Step (4) into a design capture volume (**Section E.2.2**).
6. Calculate the storage volume of the BMP (the volume of the cistern, tank, vault, etc.)

7. Divide the storage volume from Step (6) by the DCV from Step (5) to obtain the storage volume as a fraction of the DCV.
8. Add the result of Step (7) to X_1 from Step (3). This is X_2.
9. Draw a vertical line from X_2 to intersect with the line corresponding to the EIATA. Pivot and read to the vertical axis. This is the cumulative capture efficiency achieved by the Harvest and Use BMP and any upstream HSCs.

Figure E-8: Capture Efficiency Nomograph for Harvest and Use Systems with Irrigation Demand in Orange County



E.3.6.2 *Example Using the Capture Efficiency via Nomograph Method for Sizing Harvest and Use BMPs*

Example E.10: Computing the Capture Efficiency of a Harvest and Use BMP

Given:

- 85th percentile, 24-hr storm depth = 0.85 inches
- Drainage Area = 3 acres
- Imperviousness = 70%
- Captured runoff will be used to irrigate 2 acres of turf
- Effect of provided HSCs (d_{HSC}) = 0.1 inches
- 30,000 gallon stormwater vault

Required:

- Determine the capture efficiency provided by the Harvest and Use BMP (and upstream HSCs)

Solution:

1. Compute EIATA from **Appendix F**.

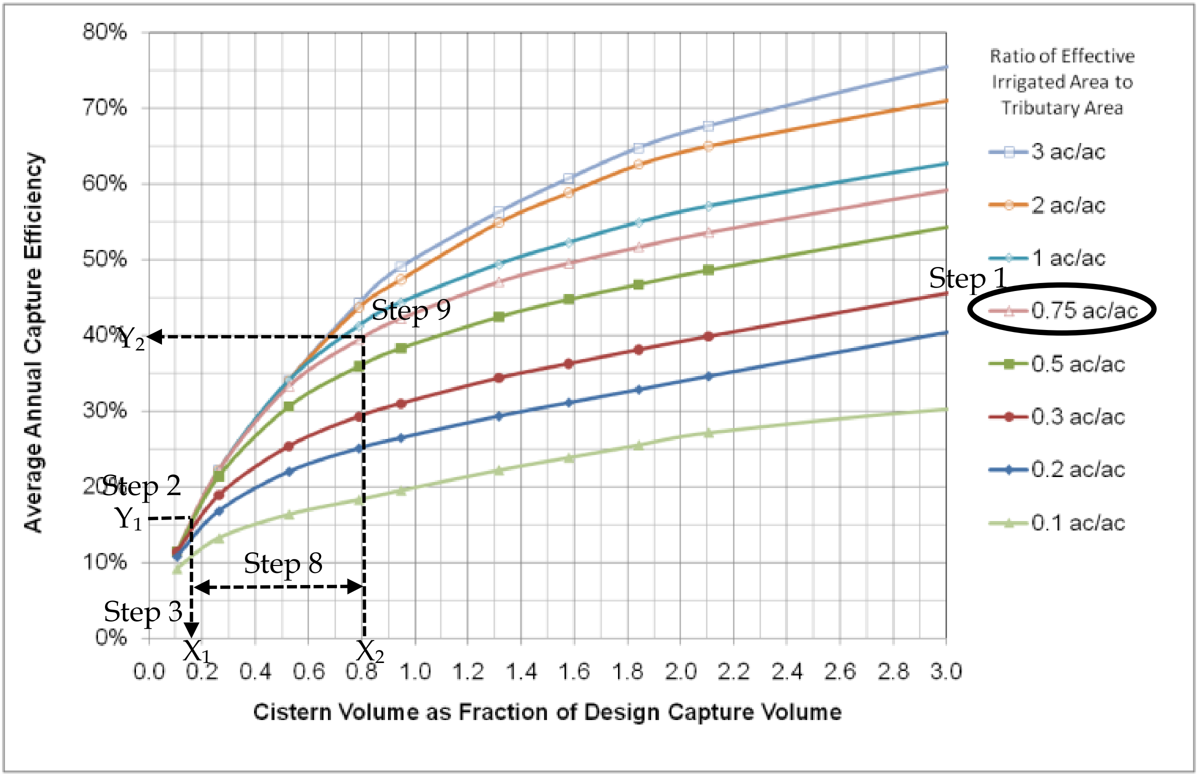
   LA = 2 acres

   K_L = 0.7

   EIATA = LA * K_L / 0.9 * Imp Area) = (2 *0.7) / (0.9 * 0.7 * 3) = 0.74 effective irrigated acre per impervious tributary acre

2. Capture efficiency achieved by 0.1 inches of HSCs = 16% (From **Section E.2.1**).
3. From **Figure E-8**, X_1 = 0.17
4. 85th percentile, 24-hour storm event is 0.85 inches
5. DCV = 3 ac × 0.85 inches × (0.7×0.75 + 0.15) × 43560 sf/ac × 1/12 in/ft = 6,248 cu-ft
6. V = 30,000 gallons/7.48 = 4,011 cu-ft
7. V/DCV = 4,011/6,248 = 0.64
8. $X_2 = X_1$ + V/DCV = 0.17 + 0.64 = 0.81
9. From **Figure E-8**: Long term capture efficiency of the harvest and use BMP with upstream HSCs = 40%. This value can be used as the amount of upstream retention as part of other BMP sizing methods.

Graphical operations supporting solution:

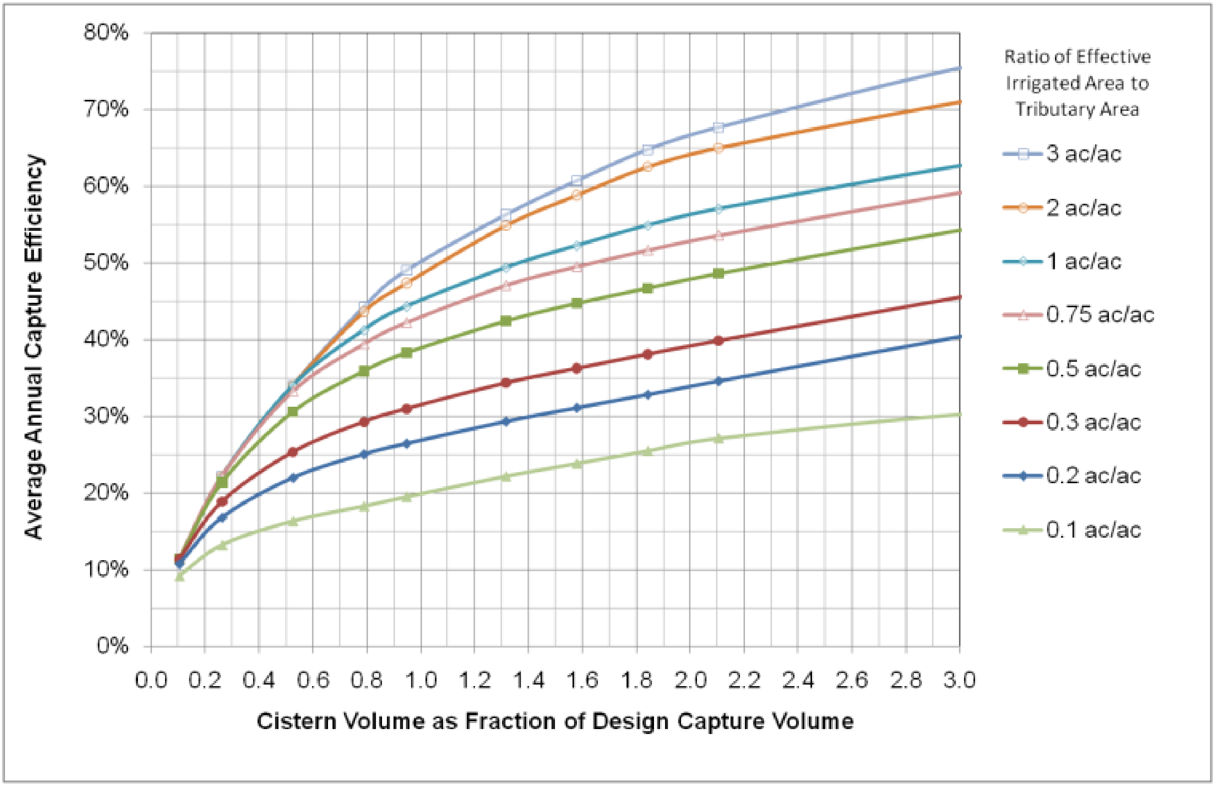


E.3.6.3 Worksheet for Using the Capture Efficiency via Nomograph Method for Sizing Harvest and Use BMPs

Worksheet 10: Nomograph Method for Determining Capture Efficiency of Harvest and Use BMPs

Part 1: Calculate the EIATA and the effect of upstream HSCs				
1a	Landscape area irrigated with harvested water	LA=		acres
1b	Area-weighted landscape coefficient (typically 0.7 for active turf, 0.35 for conservation landscape design)	K_L=		
1c	Irrigation efficiency (typically 0.90)	IE		
1d	Enter DMA area tributary to BMP (s), *A* (acres) (not including any self-retaining areas)	A=		acres
1e	Enter DMA Imperviousness, *imp* (unitless)	imp=		
1f	Effective Irrigated Area to Tributary Area ratio, EIATA = LA * K_L / (IE * imp * A)	EIATA		ac/ac
2	Enter capture efficiency corresponding to upstream HSCs (Worksheet 4) and locate on **Figure E-8** or the figure within the worksheet below	Y_1=		%
3	Using **Figure E-8** or the figure within the worksheet below, determine the cistern volume as a fraction of the DCV corresponding to the capture efficiency of the HSCs	X_1=		
Part 2: Calculate the DCV				
4	85^{th} percentile, 24-hour design storm	d =		inches
5a	Calculate runoff coefficient, *C= (0.75 x imp) + 0.15*	C=		
5b	Calculate the DCV= *(C x d x A x 43560 sf/ac x (1 ft/12 in))*	DCV=		cu-ft
Part 3: Calculate capture efficiency				
6	Storage Volume of BMP (cistern, vault, etc.)	V		cu ft
7	Storage Volume as a fraction of DCV, V_{frac} = V/CDV	V_{frac}		
8	Final equivalent volume as a fraction of DCV from combination of HSCs and harvest and use BMPs, $X_2 = X_1 + V_{frac}$	X_2		
9	Using **Figure E-8** or the figure within the worksheet below, determine the capture efficiency of the harvest and use BMPs and any upstream HSCs	Y_2		%

Worksheet 10: Nomograph Method for Determining Capture Efficiency of Harvest and Use BMPs

Supporting Calculations
Describe system:
Graphical Operations
 Provide supporting graphical operations.

E.3.7 Flow-Based Capture Efficiency via Nomograph Method for Sizing Treatment Control BMPs

This method is used to size treatment control BMPs. Treatment control BMPs are only used to treat on-site runoff from the site when LID BMPs cannot feasibly meet LID requirements or when alternative off-site BMPs are used to meet LID requirements that do not treat runoff from the site. This method does not account for any upstream BMPs or HSCs because in those rare cases where LID BMPs are infeasible or where off-site BMPs are implemented.

The project proponent has the option of simply selecting 0.2 inches/hour as the design storm intensity or computing a design storm intensity based on an 80% capture efficiency. When the time of concentration is equal to 20 minutes, these will be the same. When the time of concentration is greater than 20 minutes, using the capture efficiency method will yield a smaller design intensity than 0.2 inches/hour.

E.3.7.1 Flow-Based Capture Efficiency via Nomograph Method Stepwise Instructions for Sizing Treatment Control BMPs

The method includes the following calculations:

1. Calculate the time of concentration for the DMA (See **Section E.2.3**).
2. If the time of concentration is less than 20 minutes, select 0.2 inches/hour as the design storm intensity. If the time of concentration is greater than 20 minutes, locate the line corresponding to the time of concentration (T_c) in using **Figure E-7**. Locate the point on the line that corresponds to 80% capture (y-axis) and record the corresponding value from the x-axis. This is the design intensity required to achieve 80% capture (I_1).
3. Convert the design intensity from step (2) to a design flow rate (See **Section E.2.4**).

E.3.7.2 Example Using the Flow-Based Capture Efficiency via Nomograph Method for Sizing Treatment Control BMPs

Example E.11: Sizing to Achieve Target Average Annual Capture Efficiency, Flow-based Biotreatment BMPs

Given:

- Drainage Area = 3.5 acres
- Imperviousness = 95%

Required:

- Determine media filter design flowrate

Solution:

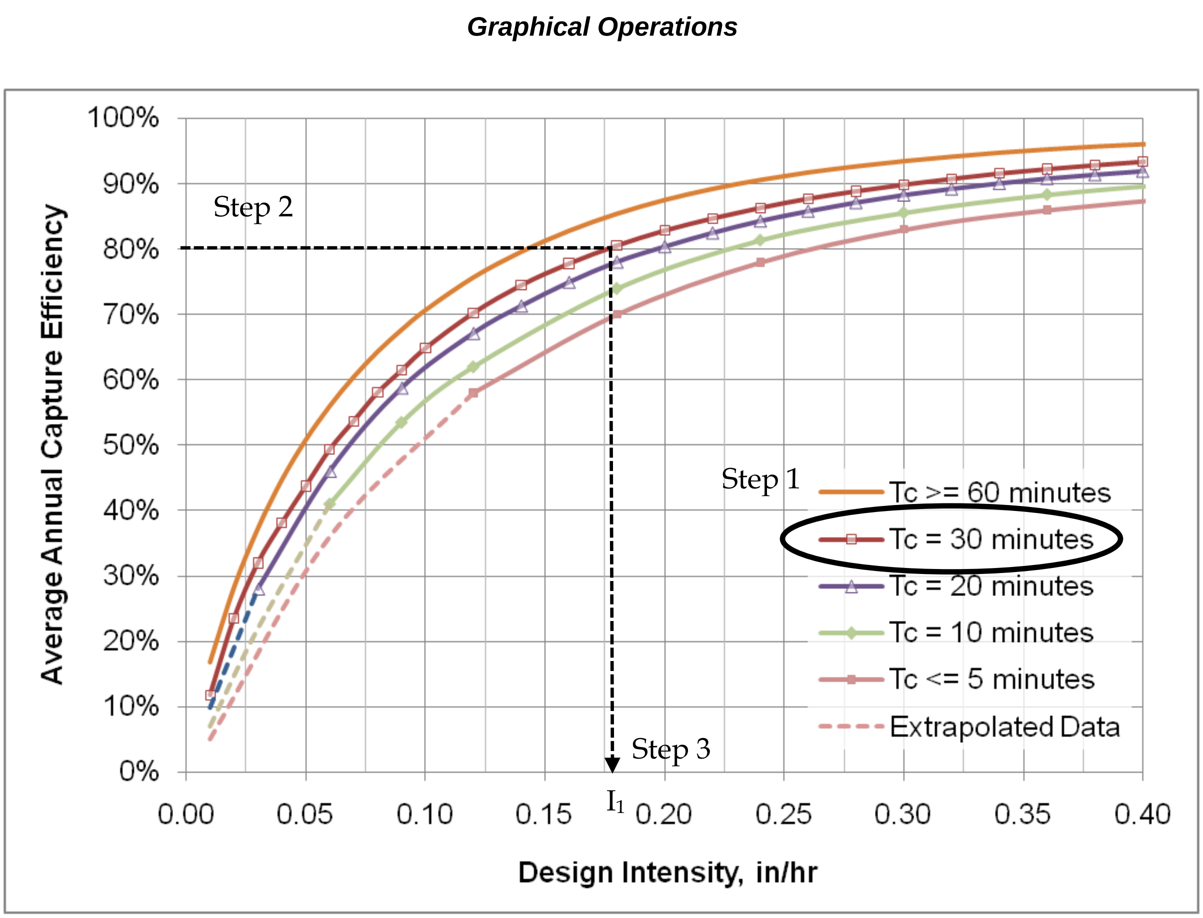
1. Computed time of concentration, T_c = 30 minutes (See **Section E.2.3**)

2. Because T_c is greater than 20 minutes, it will result in a more efficient size to compute the design intensity using 80% capture.

   From Using **Figure E-7**: I_1 = 0.18 in/hr

3. Q = [(0.95×0.75+0.15) × 0.18 in/hr × 3.5 ac] = 0.54 cfs

Graphical operations supporting solution:

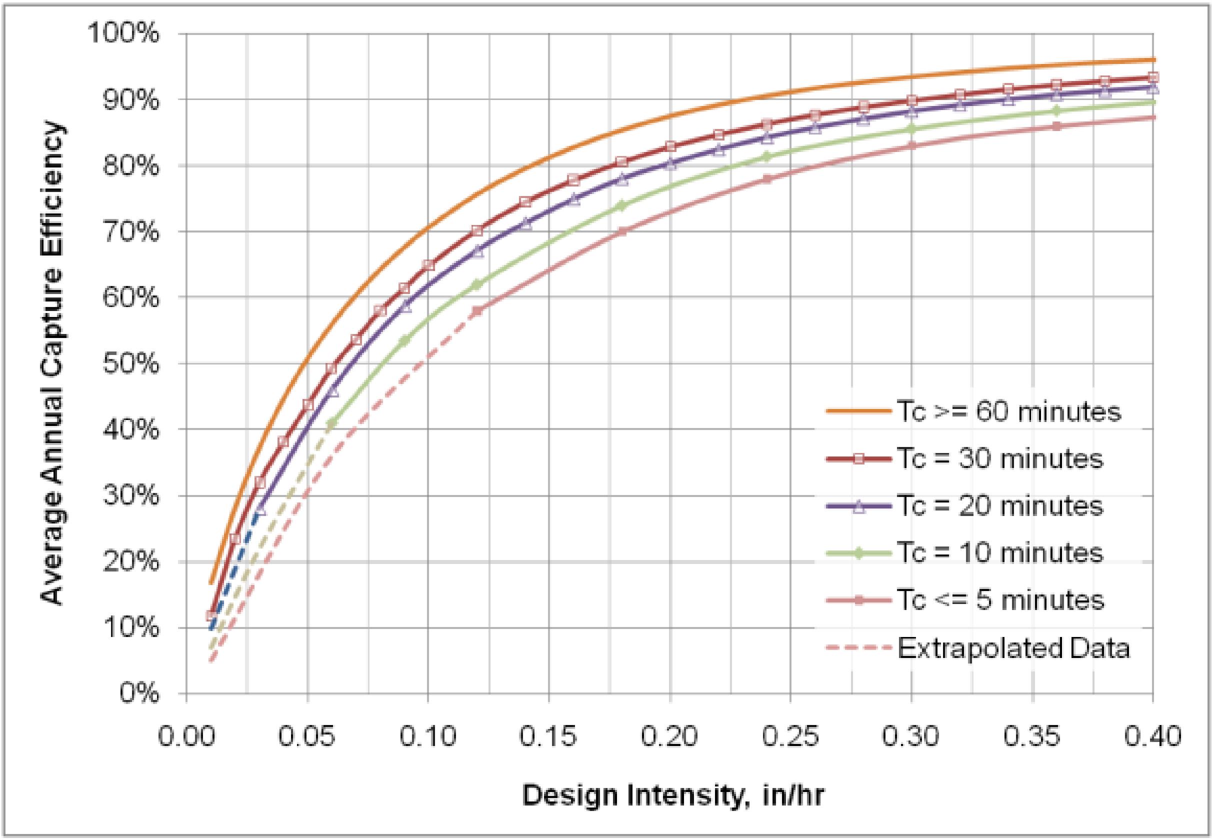


E.3.7.3 Worksheet for Using the Flow-Based Capture Efficiency via Nomograph Method for Sizing Treatment Control BMPs

Worksheet 11: Capture Efficiency and Multiplier Method for Flow-Based Biotreatment BMPs

Part 1: Determine the design storm intensity and flow rate				
1	Enter the time of concentration, Tc (min) (See **Section E.2.3**)	T_c=		min
2	If T_c is less than 20 minutes, then use I_1 = 0.2 in/hr. Otherwise, using **Figure E-7** or the figure included in the worksheet, determine the design intensity at which the estimated time of concentration (T_c) achieves 80% capture efficiency, I_1	I_1=		in/hr
3a	Enter DMA area tributary to BMP (s), *A* (acres)	A=		acres
3b	Enter DMA Imperviousness, imp (unitless)	imp=		
3c	Calculate runoff coefficient, *c= (0.75 x imp) + 0.15*	c=		
3d	Calculate design flowrate, *Q= (c x I_{design} x A)*	Q=		cfs
Supporting Calculations				
Describe system:				
Provide time of concentration assumptions:				

Worksheet 11: Capture Efficiency and Multiplier Method for Flow-Based Biotreatment BMPs

Graphical Operations
 Provide supporting graphical operations.

E.4 Other Sizing Resources and Considerations

E.4.1 Calculating the Infiltrating Surface Area to Avoid Premature Clogging

The clogging of soil and media in BMPs is an expected outcome of filtration and infiltration treatment processes. Clogging risk can be a controlling factor in the footprint of infiltration and biofiltration BMPs. The rate of clogging is a function of:

- Sediment load in stormwater,
- Effectiveness of pretreatment,
- Whether the BMP is vegetated and exposed to the surface or below ground and not exposed to weathering,
- Effective infiltrating surface area of the BMP.

Further discussion is provided in **Section 4.4.1** of the TGD. Rehabilitation of BMPs to alleviate sediment accumulation and associated clogging will be needed. This TGD establishes a minimum target of 10 years between rehabilitation events.

Table E-4 provides a lookup table of target minimum infiltration surface area, as a percent of the tributary impervious area, for a range of combinations of the factors listed above. This table should be consulted to select the target value that best represents the proposed BMPs design. This value is used as part of sizing methods as a check on minimum footprint sizing of the BMP. The minimum BMP surface area to avoid premature clogging should be measured against the BMP wetted surface area, including bottom and slopes or side walls, when the BMP is half full.

It may not be possible to exactly match site conditions to a value in **Table E-4**. The best match is acceptable. Alternatively, site-specific calculations can be performed. **Table E-5** documents acceptable inputs to these calculations.

This table only presents a check for premature clogging. Larger footprints may be required to meet DCV capture requirements and volume reduction targets. This is not intended to serve as a sizing chart that accounts for all sizing factors.

Proprietary BMPs are also subject to clogging. However, these BMPs have been tested and have defined maintenance regimes that allow them to operate at smaller footprints. This section is not intended to be applied to proprietary BMPs.

Table E-4. Infiltration Surface Area to Avoid Premature Clogging

DMA Dominant Land Cover Category	Pretreatment Approach	Subsurface BMP (load to clog = 1.0 lb/sq-ft)	Vegetated Surface BMP (load to clog = 2 lb/sq-ft)	Vegetated Surface BMP with High Permeability Media and Outlet Control (load to clog = 3 lb/sq-ft
		Target BMP Infiltrating or Filtering Surface Area as Percent of Tributary Impervious Area		
Urban Mix with Open Space 10 to 25% of Area	None	8.7%	4.3%	2.9%
	Forebay	6.5%	3.3%	2.2%
	Certified Pretreatment	4.3%	2.2%	1.4%
	Certified Treatment	2.2%	1.1%	0.72%
Urban Mix, no significant Open Space	None	5.6%	2.8%	1.9%
	Forebay	4.2%	2.1%	1.4%
	Certified Pretreatment	2.8%	1.4%	0.93%
	Certified Treatment	1.4%	0.7%	0.46%
High Vehicle Intensity (roads, commercial parking lots, light industrial)	None	6.6%	3.3%	2.2%
	Forebay	5.0%	2.5%	1.7%
	Certified Pretreatment	3.3%	1.7%	1.1%
	Certified Treatment	1.6%	0.83%	0.55%
Low Traffic Paths, Streets, Parking Lots (<20% landscaping/ slopes)	None	3.4%	1.7%	1.1%
	Forebay	2.7%	1.4%	0.90%
	Certified Pretreatment	2.0%	1.0%	0.68%
	Certified Treatment	1.4%	0.68%	0.45%
Rooftops and Paths (no landscaping)	None	0.91%	0.45%	0.30%
	Forebay	0.91%	0.45%	0.30%
	Certified Pretreatment	0.91%	0.45%	0.30%
	Certified Treatment	0.65%	0.32%	0.22%
DMA contains disturbed or erodible exposed soils; or open space > 25% of area	Isolate or stabilize sediment sources Route open space separately			

Note: This table only presents a check for premature clogging. Larger footprints may be required to meet DCV capture requirements and volume reduction targets.

E.4.1.1 Basis for BMP Surface Area Calculations to Avoid Premature Clogging

The basis for the values in **Table E-4** is explained in this section. The method is based on estimating the accumulation of sediment mass per unit area of BMP per year. At a certain degree of accumulation, the BMP is assumed to require maintenance. **Table E-5** documents the inputs to these calculations.

Table E-5: Inputs and Results of Clogging Calculations

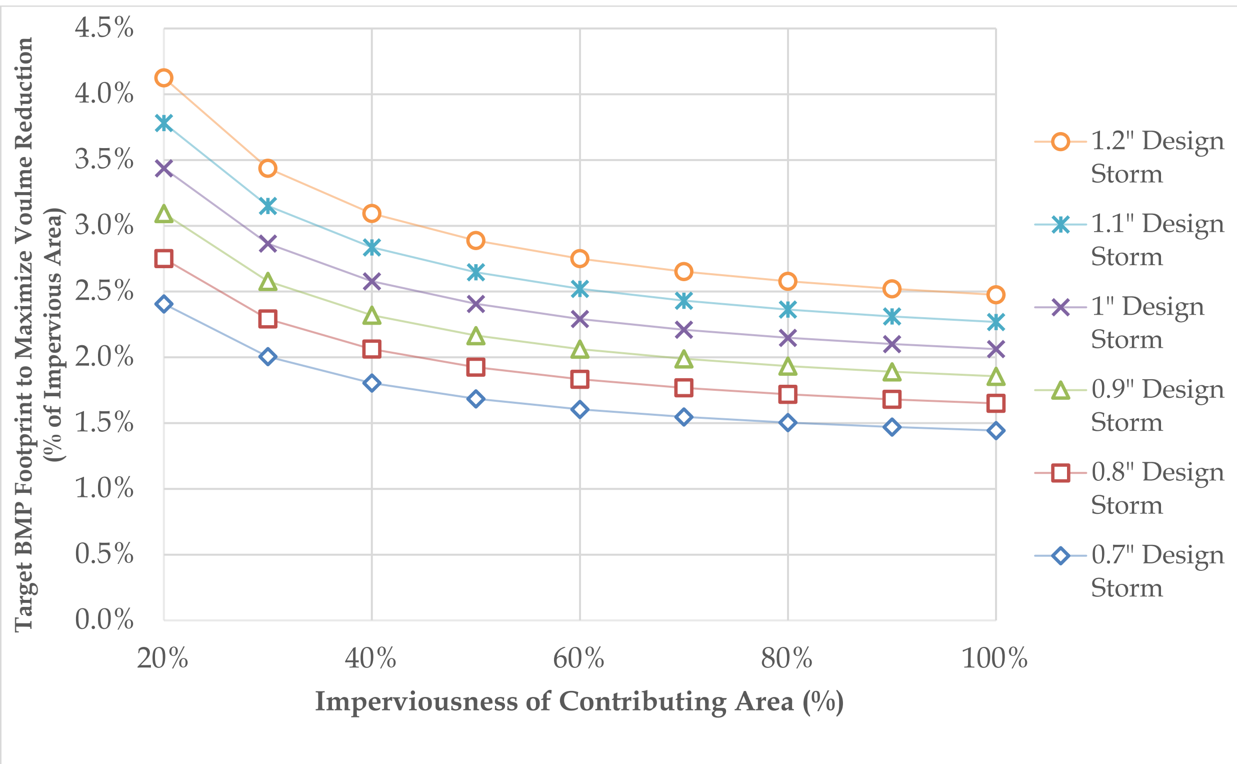
Parameter	Value	Reference
Representative TSS Event Mean Concentration (mg/L)	Urban mix: 120 Urban mix, no OS: 80 High vehicle intensity: 100 Low traffic paths, streets parking lots: 50 Rooftops: 14	Approximate average of EMCs based on Los Angeles County monitoring data (See Table 2-2 of the TGD)
Imperviousness	Based on land use	Based on land use type
Runoff coefficient of impervious surface	0.9	*C* = runoff coefficient = $(0.75 \times imp + 0.15)$
Average Annual Precipitation	11.4”-13.9”	Based on analysis of long term data from five rain gages in Orange County (http://www.ocalmanac.com/Weather/we02.htm)
Load to Initial Maintenance, lb/sq-ft	Subsurface BMP: 1 lb/sq-ft Vegetated Surface: 2 lb/sq-ft Vegetated Surface BMP with High Permeability Media and Outlet Control: 3 lb/sq-ft	Pitt, R. and S. Clark, 2010. Evaluation of Biofiltration Media for Engineered Natural Treatment Systems. Also based on various literature studies.
Allowable period to initial clogging, years	10	Policy-level assumption; more frequent maintenance may be acceptable in some cases
Adjustment to sediment load to account for pretreatment	Forebay: 25% Certified Pretreatment: 50% Certified Treatment: 75% (lower ratios when influent is lower)	Estimated based on International BMP Database and Washington State TAPE testing

E.4.2 Calculating the Target Biofiltration Footprint to Maximize Volume Reduction

This section applies to Biofiltration BMPs within DMAs categorized as "Biotreatment with Partial Infiltration," specifically BIO-1 (Bioretention with Elevated Underdrain Discharge) and BIO-5 (Compact Biofiltration with Supplemental Retention). The footprint of biofiltration BMPs is an important factor in the degree to which incidental volume reduction is expected to occur in these BMPs.

Figure E-9 provides a simple method to determine the target biofiltration BMP footprint to maximize volume reduction. This is expressed as a percent of the tributary impervious area. In some cases, this factor may control the sizing of biofiltration BMPs. It is used as a check in various sizing methods. Based on the design capture storm depth and the DMA imperviousness, the best match from this figure should be used. The presence of documented and supported space constraints (as discussed in **Section 4.2.4** of the TGD) can be considered in establishing a target footprint smaller than the target in **Figure E-9**.

Figure E-9. Target Biofiltration Footprint to Maximize Volume Reduction



E.4.2.1 Basis for Target Footprint for Incidental Volume Reduction

This TGD establishes the goal that BMPs should achieve incidental volume reduction of 40 percent of average annual volume reduction. This is intended to provide equivalent pollutant load reduction in biofiltration BMPs as would be achieved in full infiltration BMPs. This equivalence is based on page F-103 of the Regional MS4 Permit Fact Sheet. Further, this TGD acknowledges that it becomes increasingly challenging to achieve 40 percent volume reduction if soil permeability is lower. For sites at the threshold of feasibility (0.3 in/hr design infiltration rate) and no other infiltration feasibility limits, this value should be generally feasible. However, for sites with lower permeability, this may not be possible.

Figure E-9 was developed based on the capture efficiency nomographs using the following assumptions and methods:

- Assumes 18" gravel below underdrain discharge elevation and media depth of 24" which are the default standards for BIO-1 and BIO-7.
- Assumes an underlying infiltration rate of 0.3 in/hour, which is the threshold of feasibility for full infiltration BMPs.
- DMA imperviousness and the depth of the 85^{th} percentile, 24-hour storm were varied.
- For each combination of DMA imperviousness and the depth of the 85^{th} percentile, 24-hour storm, the BMP footprint required to achieve 40 percent long term volume reduction was determined.

The results of this analysis are plotted in **Figure E-9**. Interpolation from this figure is acceptable to match site and DMA conditions.

It is acceptable for a project proponent to present a project-specific calculation demonstrating that a proposed biofiltration BMP meets the target of 40 percent volume. The Capture Efficiency Method via Nomograph Method for Sizing Full Infiltration BMPs (**Section E.3.2**) can be used. The main differences are the '80% capture' is replaced with '40% capture'.

E.4.3 Capture Efficiency via Continuous Simulation Method for Sizing LID BMPs

For projects with complex hydrologic conditions or for evaluation of BMP designs that include both LID and hydromodification, the SOHM can be used to compute long term capture efficiency and volume reduction. The model should be run using a local precipitation record and project-specific information about soils, slopes, and BMP designs.

When using continuous simulation methods for sizing a Full Infiltration BMP, the target to demonstrate appropriate sizing is 80 percent long-term capture efficiency with all captured water being infiltrated. This can be done by using the model to calculate the long-term runoff volume into the BMP and the volume that discharges from the BMP. If the total volume that discharges from the BMP is 20% or less of the total runoff volume, then the BMP is achieving 80% long term capture efficiency.

For biofiltration BMPs, the continuous model should be used to determine the BMP size needed for 80 percent long term capture efficiency and treatment. This can be done by using the model to calculate the long-term runoff volume into the BMP and the total untreated volume that discharges from or bypasses the BMP. After the volume to achieve 80 percent long-term capture is determined, then the BMP should be increased in size by the required 150 percent multiplier. The SOHM can also be used to demonstrate that the target of 40 percent volume reduction is met for BIO-1 or BIO-5 BMPs.

Due to the variability of possible scenarios using continuous simulation modeling, no stepwise instructions, example, or worksheet is provided for continuous simulation methods.

E.4.4 Treatment Trains

The most common treatment trains involve LID BMPs downstream of HSCs and/or harvest and use BMPs, or supplemental volume reduction downstream of compact biofiltration BMPs. These cases have been incorporated into the BMP sizing methods in **Section E.3**.

However, it is allowable for project proponents to meet LID criteria using multiple BMPs in parallel or in series to meet applicable requirements. In those cases, any of the methods in **Section E.3** can be adapted. BMPs should be evaluated from upstream to downstream. The portion of the DCV or the long-term capture efficiently achieved in an upstream BMP can be used as an input to the sizing method for the downstream BMP.

Unconventional treatment trains should be modeled using continuous simulation models to demonstrate performance (See **Section E.4.3**).

E.4.5 Regional BMPs

Any of the sizing methods in **Section E.3** can be applied to on-site or regional BMPs. However, when sizing regional BMPs, it is often not necessary to size them to achieve 80% capture from the entire contributing area. This will depend on the other surrounding developments planning to use the regional BMP, what partnerships and agreements have been made, etc. In general, however, as long as a regional BMP is large enough to capture the DCV from the site and other projects that plan to utilize it, it does not necessarily need to achieve 80 percent capture for its entire tributary area. A smaller percent capture from a much larger area can be a larger amount of long term volume captured than would have been achieved by capturing 80 percent of runoff from a given project site. The key metric in analyzing regional BMPs should be the total long term volume captured. This should be demonstrated to exceed 80 percent of long term runoff volume from the project site. Sizing to treat a greater volume could be used to generate water quality credits, if mechanisms are in place.

E.5 Technical Basis for Equivalent Capture Efficiency Sizing Methods

This TGD equates capture of the DCV from a single storm event (and recovery of this storage within 48 hours) to 80 percent long term average capture of stormwater. The purpose of this section is to provide the technical basis for the capture efficiency-based expression of the DCV used throughout the TGD and the calculation methods described in the sections above.

E.5.1 Introduction

Stormwater BMPs can be conceptualized as having a storage volume and a treatment rate, in various proportions. Both are important in the long-term performance of the BMP under a range of actual storm patterns, depths, and inter-event times. Long-term performance is measured by the operation of a BMP over the course of multiple years, and provides a more complete metric than the performance of a BMP during a single event, which does not take into account antecedent conditions, including multiple storms arriving in short timeframes. A BMP that draws down more quickly would be expected to capture a greater fraction of overall runoff (i.e. long-term runoff) than an identically sized BMP that draws down more slowly. This is because storage is made available more quickly, so subsequent storms are more likely to be captured by the BMP. In contrast, a BMP with a long drawdown time would stay mostly full, after initial filling, during periods of sequential storms. The volume in the BMP that draws down more quickly is more "valuable" in terms of long term performance than the volume in the one that draws down more slowly. In the case of flow-based BMPs, the storage volume is typically not substantial, however it is recognized that flow-based BMPs can achieve high long term capture efficiencies by treating stormwater essentially as it arrives. A method is needed to relate the long-term performance of BMPs to their design attributes so that a common ground for comparison and "addition" of the benefit of different BMPs is possible.

The permit definition of the LID DCV does not specify a drawdown time, therefore the definition is not a complete indicator of a BMP's level of performance. An accompanying performance-based expression of the LID sizing standard is essential to ensure uniformity of performance across a broad range of BMPs and helps prevents LID BMP designs from being used that would not be effective.

E.5.2 Development of Capture Efficiency-based Performance Criterion

An evaluation of the relationships between BMP design parameters and expected long term capture efficiency has been conducted to address the needs identified above. Relationships have been developed through a simplified continuous simulation analysis of precipitation, runoff, and routing, that relate BMP design volume and storage recovery rate (i.e., drawdown time) to an estimated long term level of performance.

Based on these relationships, it has been demonstrated that a BMP sized for the runoff volume from the 85th percentile, 24-hour storm event (i.e., the DCV), which draws down in 48 hours is capable of managing approximately 80 percent of the average annual. There is precedent in California (e.g., prior MS4 permits, CASQA BMP Handbooks, other design manuals) for the assumption that BMPs should draw down in approximately 48 hour. There is also precedent (e.g., prior MS4 permits, CASQA BMP Handbooks, other design manuals, WEF/ASCE Manual of Practice 23/87) for 80 percent capture of average annual runoff as approximately the point at which larger BMPs provide decreasing capture efficiency benefit (also known as the "knee of the curve") for BMP sizing. The characteristic shape of the plot of capture efficiency versus storage volume (Figure E-4) illustrates this concept.

As such, this equivalency (between the DCV drawing down in 48 hours and 80 percent capture) has been utilized to fill three needed roles in this TGD: 1) provide a common currency between volume-based BMPs with a wide range of drawdown rates, 2) provide a means of unifying the sizing of volume-based and flow-based BMPs to allow different types of BMPs to be added as part of a treatment train, and 3) allow flexibility in the design of BMPs while ensuring consistent performance.

E.5.3 Modeling Methodology

The USEPA Stormwater Management Model Version 5.0 (SWMM5.0) was used to simulate the long term average capture efficiency for a range of general BMP design configurations over 22 years of historic hourly precipitation records at the CIMIS Irvine weather station (#75). SWMM was selected for this analysis as it is a relatively simple, open source, continuous simulation model that has well-demonstrated capability for simulation of rainfall-runoff processes in urban environments and simulating transient storage mechanisms in BMPs. A relatively simple representation of BMPs was used to develop the general relationships that conceptualized all BMPs with a simple storage volume and treatment rate. While this representation does not account for the nuances of BMP designs, it is appropriate to develop programmatic sizing factors. Assumed SWMM input parameters are provided in Table E.6. Sensitivity analyses demonstrated that the only inputs with significant sensitivity within typical input ranges were the precipitation and ET inputs and the BMP configurations. These were selected to be representative of Orange County, and results are interpreted to allow scaling across the rainfall zones of the County.

Table E.6: SWMM Simulation Input Parameters

SWMM Parameters	Units	Values
Period of Simulation	years	22 yrs (10/01/1987 to 10/01/2009)
Wet time step	seconds	600
Wet/dry time step	seconds	600
Dry time step	seconds	14,400
Precipitation	inches	Hourly precipitation data from CIMIS Irvine Gage (#75) 279 inches total in period of record
Impervious Manning's n		0.012
Hypothetical drainage area	acres	1
Shape		Rectangular, 250 ft flow path length
Impervious fraction modeled		100%
Slope	ft/ft	0.05
Evaporation	inches	Daily ET data from CIMIS Irvine Gage (#75) 1092 inches reference ETo total in period of record
Depression storage, impervious	inches	0.02, based on Table 5-14 in SWMM manual (James and James, 2000)
Runoff coefficient used to convert precipitation depth to design volume	unitless	0.90
Design capture storm depth (85^{th} percentile, 24-hour depth) calculated from Irvine Gage	inches	0.95
BMP Storage Volume	cu-ft	Varied over continuous range as discrete multipliers on design capture storm depth. Volume at 1.0 × DCV = 0.95 inches × 0.9 × 43,560 sq-ft × (1 ft/12 inches) = 3,100 cu-ft
Drawdown Rate	cfs	Varied over continuous range to represent discrete drawdown times. Q (cfs) = V(cu-ft) / Drawdown time (s) Drawdown rate @ 1.0 × DCV @ 48 hour drawdown time = 3,100 cu-ft / (48 hr × 3600 s/hr) = 0.018 cfs

E.5.4 Detailed Results and Findings

The resulting average annual capture efficiency (i.e., the fraction of average annual runoff that is captured and not immediately bypassed by the BMP) was extracted from model results for each model. The assumed impervious fraction of 100 percent is not important for this analysis because both runoff volume and modeled BMP volume have approximately linear dependency on impervious fraction.

Because this analysis was done at one location in the County, a method is needed to scale these results to different precipitation zones. Areas with larger design capture storm depths (85^{th} percentile, 24-hour depth) should theoretically require larger BMPs for an identical configuration of tributary area and drawdown time. An analysis of several gages in Southern

California has shown that normalizing input scenarios as a fraction of the design capture storm depth allows reliable extrapolation of results throughout the region. These relationships are represented by the nomograph shown as Figure E-4. Functionally, what these relationships show is that for drawdown times larger than 48 hours, a design volume greater than the DCV is needed to achieve 80 percent capture, while for drawdown times less than 48 hours, a design volume less than the DCV can be used to achieve 80 percent capture.

An analogous analysis was conducted for systems with irrigation demand by normalizing input scenarios to fractions of the design capture storm depth and the effective irrigation area to tributary area ratio (EIATA). This analysis considered irrigation demand to be controlled by the area irrigated, landscape demand of this area (i.e., fraction of ETo required for plant use) and the daily ETo timeseries. It was assumed that irrigation would not occur following rainfall until the ET had either summed to a depth equivalent to the rainfall depth or had exceeded 0.25 inches (smaller of these two).

E.5.5 Development of Flow-based BMP Capture Efficiency Nomographs

Flow-based BMPs do not have substantial storage volume; therefore function by treating runoff at the rate which it occurs. The concept of a uniform design intensity is commonly used for sizing criteria of flow-based BMPs. This design intensity is appropriately tied to the time of concentration (T_c) of the tributary area, where larger tributary areas should have a lower design intensity because greater attenuation of event peaks is provided in the watershed and the BMP sees lower peaks. While simplified, it can be conceptualized that the T_c of a watershed is the averaging period within which peaks should be averaged.

Because most urban watersheds have T_c much less than 1 hour, hourly precipitation data are not adequate to develop relationships between T_c and the required design intensity to manage a certain percentage of average annual runoff volume. Therefore, 10 years of 5-minute, 0.01" resolution precipitation data were obtained from the Automated Surface Observation System (ASOS) gage at Los Angeles International Airport and used for this analysis.

To represent different increments of T_c, different averaging periods were applied. The resulting intensities were then compared to a range of design intensities to determine the fraction of average annual runoff that intensity would be capable of addressing. It was assumed that if the measured intensity was less than the design intensity, that volume would be fully treated, and if the measured intensity was greater than the design intensity, the volume up to the design intensity would be treated. This implicitly assumes that BMPs are designed to be off-line and maintain their treatment processes even during peak flows.

Figure E-7 presents average annual capture efficiency results for a variety of design storm intensities and drainage area times of concentration.

E.5.6 Note on Using Nomographs to Combine BMPs in Series

The nomographs presented in Figure E-4, Figure E-7 each show declining response of capture efficiency with design volume and intensity. For example, from Figure E-4, approximately 25% of the DCV is required to achieve the first 40 percent capture of average annual runoff volume, while the remaining 75 percent of the DCV is required to achieve the remaining 40 percent. As such, when combining BMPs in series, capture efficiencies are not directly additive. In order to add the combined effects of BMPs in series, the nomographs should be used by starting at the point on the chart corresponding to the capture efficiency already achieved in upstream BMPs, and moving to the right on the chart along the line corresponding to the drawdown time of the current BMP of interest. This ensures that the appropriate portion of the volume-capture response curve is used.

E.5.7 Evaluation of Equivalent Sizing Approaches for Biofiltration BMPs

The 2009 MS4 Permit (Order R9-2009-0002) specified that biofiltration BMPs needed to be sized with a pre-filter storage volume (static basis) equivalent to 75 percent of the remaining portion of the DCV that had not been retained. Because biofiltration systems typically have a drawdown time much less than 48 hours (typically less than 6 hours), this minimum static storage volume resulted in a typical capture efficiency much greater than 80 percent. For example, per Figure E-4, the long term capture efficiency would be 93 percent for a BMP sized for 0.75 of the DCV with 6 hour drawdown time.

As part of the 2013 San Diego Regional MS4 Permit adoption process, an analysis was conducted to evaluate other options for sizing of biofiltration that could achieve similar long term capture efficiency and load reduction. A sizing approach was evaluated based on sizing BMPs to biofilter 150 percent of the DCV, without specifying a static storage volume. This could be achieved in a number of ways, including demonstrating that the BMP has routing plus storage capacity for 150 percent of the DCV, or sizing the BMP for 80 percent capture and then multiplying the resulting BMP size by 150 percent. The following pages describe scenarios that were evaluated to determine whether these sizing approaches would result in reasonably similar performance. These scenarios were presented and discussed with San Diego RWQCB staff via teleconference on April 17, 2013.

The results of this analysis show that the different options for biofiltration sizing generally result in similar capture efficiency among each other, typically greater than 90 percent capture. These scenarios show that when a BMP is sized to treat 50 percent greater capacity than the DCV, then it results in similar capture efficiency to a system designed with a static pre-filter volume of 75 percent of the DCV.

For reference, Figure E-6 (above) introduces terminology associated with biofiltration storage compartments.

Comparison of Alternative Biofiltration Sizing Standards

Scenario 1 - Typical Biofiltration - Median Routing Time; Typical Media Filtration Rate

Tributary Area Characteristics	Value	Explanation
85th Percentile, 24-hour Storm Depth, d, inches	0.85	Typical of SOC
Tributary Area, A, ac	1	For illustration purposes
Imperviousness	0.7	Typical mix of land uses
Runoff coefficient, RC	0.675	TGD runoff coefficient equation
Design Capture Volume, cu-ft	2083	A × d × RC × (43560 sf/ac) / (12 in/ft)

Baseline Biofiltration BMP Design Parameters	Value	Explanation
Ponding Depth, inches	12	Typical design; per TGD and other guidance
Media Thickness, inches	24	Typical design; per TGD and other guidance
Media Available Pore Space, in/in (porosity - FC)	0.25	Porosity, minus portion wetted by irrigation and/or previous event
Design Media Filtration Rate, in/hr	2.5	Default design; per TGD; LAMS4 guidance with 2.0 clogging facgtor

Assumptions and Baseline Calculations	Value	Explanation
Portion of DCV Reliably Retained, cu-ft	0	Assumption; theoretically yields largest difference between alternative biofiltration design approaches
Remaining DCV	2083	
Routing Period, hrs	7	Typical storm duration, storms similar to 85th pctl depth; sensitivity assumption
Depth filtered during routing period, inches	17.5	Media filtration rate × routing period
Depth of detention storage, inches	18	Ponding depth + pore space
Total Depth Treated, during and following event	35.5	Depth filtered + detention storage
Storage drawdown time, hours	7.2	Depth stored / media filtration rate

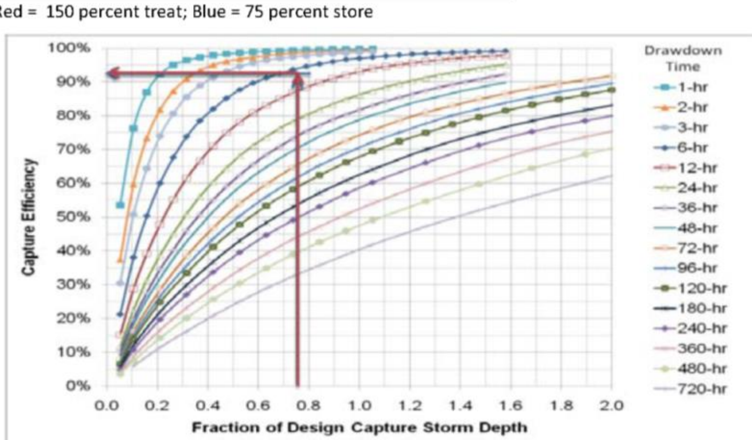
Results - Biofiltration Alternative 1 - Treat 150% of the remaining DCV.	Value	Explanation
Required Biofiltration Treated Volume, cu-ft	3124	1.5 × remaining DCV
Biofiltration Footprint Required, cu-ft	1056	Req'd Biofiltration Volume / Total Depth Treated + Stored
Storage Volume as fraction of remaining DCV	0.76	Storage volume / Remaining DCV
Average Annual Capture Efficiency	92%	From TGD nomograph; see below

Results - Biofiltration Alternative 2 - Store 0.75 of remaining DCV in pores and ponding.	Value	Explanation
Required Biofiltation Storage Volume, surface + pores	1562	0.75 × remaining DCV
Footprint Area, sq-ft	1041	required biofiltration storage volume / total storage depth (ponding + pores)
Effective storm volume filtered and stored during routing period, cu-ft	3081	Total stored plus filtered depth; multiplied by footprint area
Storage Volume as fraction of remaining DCV	0.75	
Average Annual Capture Efficiency	92%	From TGD nomograph; see below

Summary Comparison	Biofiltration Sizing Alternatives	
	Alt 1 - 150% treat	Alt 2 - 0.75 storage
Footprint	1,056	1,041
Effective Storm Volume Treated	3,124	3,081
Average Annual Capture Efficiency	92%	92%

Support for Percent Capture Calculations - Nomographs from TGD

Red = 150 percent treat; Blue = 75 percent store



Comparison of Alternative Biofiltration Sizing Standards

Scenario 2 - Typical Biofiltration - Longer Routing Time

Tributary Area Characteristics	Value	Explanation
85th Percentile, 24-hour Storm Depth, d, inches	0.85	Typical of SOC
Tributary Area, A, ac	1	For illustration purposes
Imperviousness	0.7	Typical mix of land uses
Runoff coefficient, RC	0.675	TGD runoff coefficient equation
Design Capture Volume, cu-ft	2083	A × d × RC × (43560 sf/ac) / (12 in/ft)

Baseline Biofiltration BMP Design Parameters	Value	Explanation
Ponding Depth, inches	12	Typical design; per TGD and other guidance
Media Thickness, inches	24	Typical design; per TGD and other guidance
Media Available Pore Space, in/in (porosity - FC)	0.25	Porosity, minus portion wetted by irrigation and/or previous event
Design Media Filtration Rate, in/hr	2.5	Default design; per TGD; LAMS4 guidance with 2.0 clogging facgtor

Assumptions and Baseline Calculations	Value	Explanation
Portion of DCV Reliably Retained, cu-ft	0	Assumption; theoretically yields largest difference between alternative biofiltration design approaches
Remaining DCV	2083	
Routing Period, hrs	12	Upper bound on potentially acceptable routing time
Depth filtered during routing period, inches	30	Media filtration rate × routing period
Depth of detention storage, inches	18	Ponding depth + pore space
Total Depth Treated, during and following event	48	Depth filtered + detention storage
Storage drawdown time, hours	7.2	Depth stored / media filtration rate

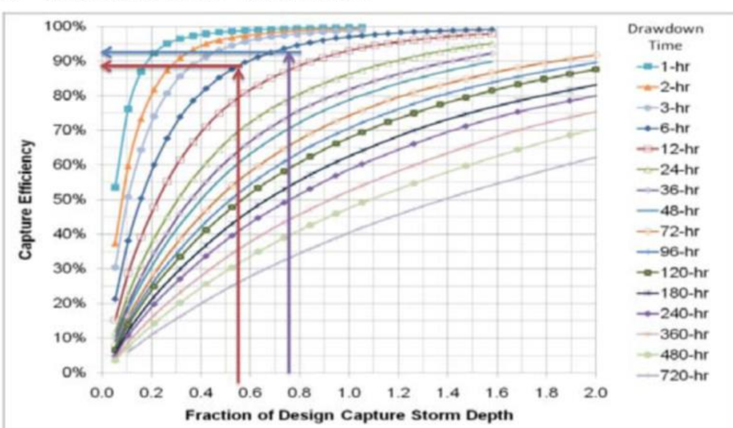
Results - Biofiltration Alternative 1 - Treat 150% of the remaining DCV.	Value	Explanation
Required Biofiltration Treated Volume, cu-ft	3124	1.5 × remaining DCV
Biofiltration Footprint Required, cu-ft	781	Req'd Biofiltration Volume / Total Depth Treated + Stored
Storage Volume as fraction of remaining DCV	0.56	Storage volume / Remaining DCV
Average Annual Capture Efficiency	87%	From TGD nomograph; see below

Results - Biofiltration Alternative 2 - Store 0.75 of remaining DCV in pores and ponding.	Value	Explanation
Required Biofiltation Storage Volume, surface + pores	1562	0.75 × remaining DCV
Footprint Area, sq-ft	1041	required biofiltration storage volume / total storage depth (ponding + pores)
Effective storm volume filtered and stored during routing period, cu-ft	4165	Total stored plus filtered depth; multiplied by footprint area
Storage Volume as fraction of remaining DCV	0.75	
Average Annual Capture Efficiency	92%	From TGD nomograph; see below

Summary Comparison	Biofiltration Sizing Alternatives	
	Alt 1 - 150% treat	Alt 2 - 0.75 storage
Footprint	781	1,041
Effective Storm Volume Treated	3,124	4,165
Average Annual Capture Efficiency	87%	92%

Support for Percent Capture Calculations - Nomographs from TGD

Red = 150 percent treat; Blue = 75 percent store



Comparison of Alternative Biofiltration Sizing Standards

Scenario 3 - Typical Biofiltration - Shorter Routing Time

Tributary Area Characteristics	Value	Explanation
85th Percentile, 24-hour Storm Depth, d, inches	0.85	Typical of SOC
Tributary Area, A, ac	1	For illustration purposes
Imperviousness	0.7	Typical mix of land uses
Runoff coefficient, RC	0.675	TGD runoff coefficient equation
Design Capture Volume, cu-ft	2083	A × d × RC × (43560 sf/ac) / (12 in/ft)

Baseline Biofiltration BMP Design Parameters	Value	Explanation
Ponding Depth, inches	12	Typical design; per TGD and other guidance
Media Thickness, inches	24	Typical design; per TGD and other guidance
Media Available Pore Space, in/in (porosity - FC)	0.25	Porosity, minus portion wetted by irrigation and/or previous event
Design Media Filtration Rate, in/hr	2.5	Default design; per TGD; LAMS4 guidance with 2.0 clogging facgtor

Assumptions and Baseline Calculations	Value	Explanation
Portion of DCV Reliably Retained, cu-ft	0	Assumption; theoretically yields largest difference between alternative biofiltration design approaches
Remaining DCV	2083	
Routing Period, hrs	4	Lower bound on acceptable routing time
Depth filtered during routing period, inches	10	Media filtration rate × routing period
Depth of detention storage, inches	18	Ponding depth + pore space
Total Depth Treated, during and following event	28	Depth filtered + detention storage
Storage drawdown time, hours	7.2	Depth stored / media filtration rate

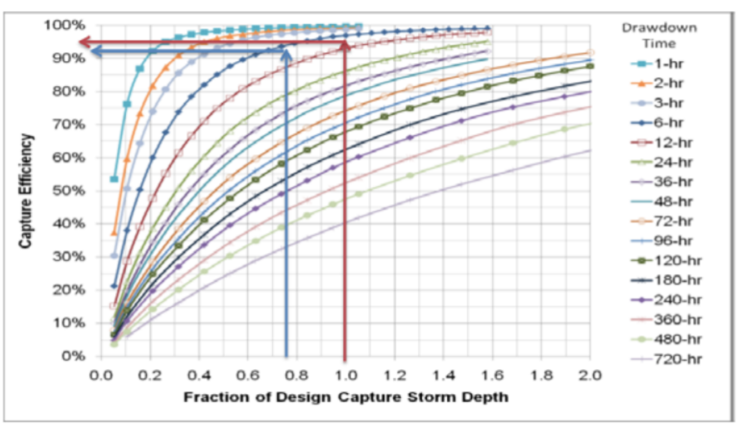
Results - Biofiltration Alternative 1 - Treat 150% of the remaining DCV.	Value	Explanation
Required Biofiltration Treated Volume, cu-ft	3124	1.5 × remaining DCV
Biofiltration Footprint Required, cu-ft	1339	Req'd Biofiltration Volume / Total Depth Treated + Stored
Storage Volume as fraction of remaining DCV	0.96	Storage volume / Remaining DCV
Average Annual Capture Efficiency	95%	From TGD nomograph; see below

Results - Biofiltration Alternative 2 - Store 0.75 of remaining DCV in pores and ponding.	Value	Explanation
Required Biofiltation Storage Volume, surface + pores	1562	0.75 × remaining DCV
Footprint Area, sq-ft	1041	required biofiltration storage volume / total storage depth (ponding + pores)
Effective storm volume filtered and stored during routing period, cu-ft	2430	Total stored plus filtered depth; multiplied by footprint area
Storage Volume as fraction of remaining DCV	0.75	
Average Annual Capture Efficiency	92%	From TGD nomograph; see below

Summary Comparison	Biofiltration Sizing Alternatives	
	Alt 1 - 150% treat	Alt 2 - 0.75 storage
Footprint	1,339	1,041
Effective Storm Volume Treated	3,124	2,430
Average Annual Capture Efficiency	95%	92%

Support for Percent Capture Calculations - Nomographs from TGD

Red = 150 percent treat; Blue = 75 percent store



Comparison of Alternative Biofiltration Sizing Standards

Scenario 4 - Typical Biofiltration - Higher Media Flowrate

Tributary Area Characteristics	Value	Explanation
85th Percentile, 24-hour Storm Depth, d, inches	0.85	Typical of SOC
Tributary Area, A, ac	1	For illustration purposes
Imperviousness	0.7	Typical mix of land uses
Runoff coefficient, RC	0.675	TGD runoff coefficient equation
Design Capture Volume, cu-ft	2083	A × d × RC × (43560 sf/ac) / (12 in/ft)

Baseline Biofiltration BMP Design Parameters	Value	Explanation
Ponding Depth, inches	12	Typical design; per TGD and other guidance
Media Thickness, inches	24	Typical design; per TGD and other guidance
Media Available Pore Space, in/in (porosity - FC)	0.25	Porosity, minus portion wetted by irrigation and/or previous event
Design Media Filtration Rate, in/hr	5	Default design; per TGD; LAMS4 guidance without clogging facgtor

Assumptions and Baseline Calculations	Value	Explanation
Portion of DCV Reliably Retained, cu-ft	0	Assumption; theoretically yields largest difference between alternative biofiltration design approaches
Remaining DCV	2083	
Routing Period, hrs	7	Typical storm duration, storms similar to 85th pctl depth; sensitivity assumption
Depth filtered during routing period, inches	35	Media filtration rate × routing period
Depth of detention storage, inches	18	Ponding depth + pore space
Total Depth Treated, during and following event	53	Depth filtered + detention storage
Storage drawdown time, hours	3.6	Depth stored / media filtration rate

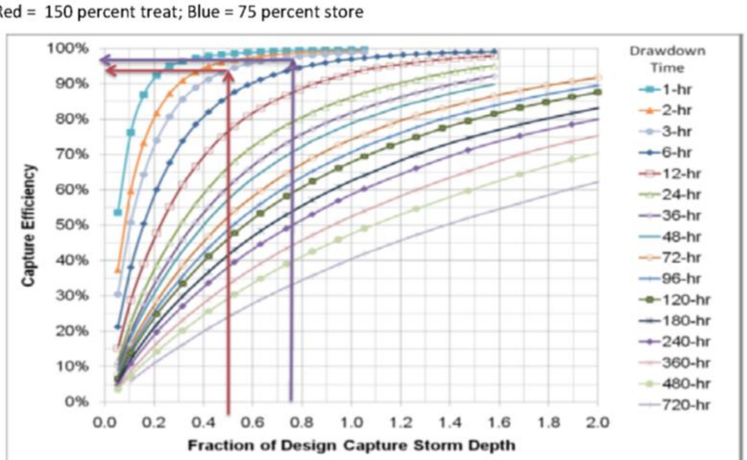
Results - Biofiltration Alternative 1 - Treat 150% of the remaining DCV.	Value	Explanation
Required Biofiltration Treated Volume, cu-ft	3124	1.5 × remaining DCV
Biofiltration Footprint Required, cu-ft	707	Req'd Biofiltration Volume / Total Depth Treated + Stored
Storage Volume as fraction of remaining DCV	0.51	Storage volume / Remaining DCV
Average Annual Capture Efficiency	93%	From TGD nomograph; see below

Results - Biofiltration Alternative 2 - Store 0.75 of remaining DCV in pores and ponding.	Value	Explanation
Required Biofiltation Storage Volume, surface + pores	1562	0.75 × remaining DCV
Footprint Area, sq-ft	1041	required biofiltration storage volume / total storage depth (ponding + pores)
Effective storm volume filtered and stored during routing period, cu-ft	4599	Total stored plus filtered depth; multiplied by footprint area
Storage Volume as fraction of remaining DCV	0.75	
Average Annual Capture Efficiency	96%	From TGD nomograph; see below

Summary Comparison	Biofiltration Sizing Alternatives	
	Alt 1 - 150% treat	Alt 2 - 0.75 storage
Footprint	707	1,041
Effective Storm Volume Treated	3,124	4,599
Average Annual Capture Efficiency	93%	96%

Support for Percent Capture Calculations - Nomographs from TGD

Red = 150 percent treat; Blue = 75 percent store



APPENDIX F. HARVEST AND USE DEMAND CALCULATIONS AND DESIGN CONSIDERATIONS

F.1 Introduction

The purpose of this appendix is to provide guidance for calculating harvested water demand, provide the conditions where harvest and use BMPs is required to be considered as an LID BMP, and provide guidance and considerations when designing harvest and use BMPs beyond what is in the fact sheets (**Appendix G**). This appendix contains the following:

- Harvested water demand calculation methods and guidance for preparing project-specific harvested water demand calculations (**Section F.2**).
- The method to determine if harvest and use BMPs are required to be considered versus when they are optional (**Section F.3**).
- Information and requirements from the California Plumbing Code and other sources regarding the use of harvested rain water for indoor and outdoor uses (**Section F.4**).

F.2 Harvested Water Demand Calculation

The following sections provide technical methods and guidance for estimating the harvested water demand of a project. These methods are intended to be used as part of evaluating the feasibility of harvest and use (planning phase) and to support sizing harvest and use systems if they are selected as an LID BMP.

While harvested water capture efficiency is evaluated at the scale of a single DMA (**Appendix E**), harvested water demand should be evaluated at the scale of the project, and not limited to single drainage areas. It is assumed that harvested water collected from one drainage area could be used within another.

F.2.1 Key Differences in Demand Calculations for Harvest and Use Feasibility versus Water Supply Planning

It is very important to note that harvested water demand calculations differ in purpose and methods from water demand calculations done for water supply planning. When designing harvest and use systems for stormwater management, a reliable method of relatively quickly regenerating storage capacity (i.e., using water) must exist to provide storage capacity for subsequent storms. Therefore, demand calculations for harvest and use BMPs should attempt to estimate the ***actual demand that is reliably present to drain stormwater cisterns during the wet season and especially within a short-term (week to a couple of weeks) series of typical storms***. This objective is fundamentally different from the objectives of water demand forecasting calculations done for water supply planning. Methods to estimate water demand may err toward higher estimates of demand to provide conservatism to account for uncertainty. In contrast, harvested water demand calculations used to determine the feasibility of harvest and use BMPs must be based on estimates of actual expected demand that are reliably present to drain the cistern during the wet season.

F.2.2 Types of Harvested Water Demand

Types of non-potable water demand anticipated to be applicable in the foreseeable future include:

- Toilet and urinal flushing,
- Irrigation,
- Vehicle washing,
- Evaporative cooling,
- Dilution water for recycled water systems,
- Industrial processes, and
- Other non-potable uses.

The following sections are divided between toilet flushing, outdoor irrigation demand, and other non-potable demands. The primary distinction between toilet/urinal flushing and irrigation demand is the level of treatment and disinfection that is required to use the water (See **Section F.4**) and the seasonal pattern of the demand. Other non-potable demands (e.g. industrial processes for example) are anticipated to be highly project specific and should be estimated using project-specific information.

F.2.3 Toilet and Urinal Flushing Demand Calculations

The following guidelines should be followed for computing harvested water demand from toilet and urinal flushing:

- If reclaimed water (e.g. greywater, recycled wastewater, or other non-stormwater sources) is planned for use for toilet and urinal flushing, then the demand for harvested stormwater is equivalent to the total demand minus the reclaimed water supplied, and should be reduced by the amount of reclaimed water that is available during the wet season. The basis for this priority is provided in **Section F.2.8**.
- Demand calculations for toilet and urinal flushing should be based on the average rate during the wet season for a typical year. In buildings with fairly consistent occupancy, a seasonal adjustment is not likely needed. However, if periods of lower occupancy align with the wet season (e.g., tourist hotels, recreational facilities), then an adjustment to account for wet season demand may be needed.
- Demand calculations should include changes in occupancy over weekends and around holidays and changes in attendance/enrollment over school vacation periods.
- For facilities with generally high demand but periodic shut downs (e.g., for vacations, maintenance, or other reasons), a project specific analysis should be conducted to

determine whether performance stormwater management can be maintained despite shut downs. Such an analysis should consider the statistical distributions of precipitation and demand, foremost the relationship of demand to the wet seasons of the year. It may be acceptable to have short periods of lower use if the overall average is adequate.

Table F-1 provides planning level estimated toilet and urinal flushing demand per resident or employee for a variety of project types. The per capita use per day is based on daily employee or resident usage. For non-residential types of development, the "visitor factor" and "student factor" (for schools) should be multiplied by the employee use to account for toilet and urinal usage for non-employees using facilities.

Table F-1: Toilet and Urinal Water Usage per Resident or Employee (gallons)

Land Use Type	Toilet User Unit of Normalization	Per Capita Use per Day		Visitor Factor[4]	Water Efficiency Factor[5]	Total Use
		Toilet Flushing [1,2]	Urinals[3]			
Residential	Resident	18.5	NA	NA	0.5	9.3
Office	Employee (non-visitor)	9.0	2.27	1.1	0.5	7 (avg)
Retail	Employee (non-visitor)	9.0	2.11	1.4	0.5	
Schools	Employee (non-student)	6.7	3.5	6.4	0.5	33
Various Industrial Uses (excludes process water)	Employee (non-visitor)	9.0	2	1	0.5	5.5

1- Based on American Waterworks Association Research Foundation, 1999. Residential End Uses of Water. Denver, CO: AWWARF

2 - Based on use of 3.45 gallons per flush and average number of per employee flushes per subsector, Table D-1 for MWD (Pacific Institute, 2003)

3 - Based on use of 1.6 gallons per flush, Table D-4 and average number of per employee flushes per subsector, (Pacific Institute, 2003)

4 - Multiplied by the demand for toilet and urinal flushing for the project to account for visitors. Based on proportion of annual use allocated to visitors and others (includes students for schools; about 5 students per employee) for each subsector in Table D-1 and D-4 (Pacific Institute, 2003)

5 – Accounts for requirements to use ultra-low flush toilets in new development projects; assumed that requirements will reduce toilet and urinal flushing demand by half on average compared to literature estimates. Ultra-low flush (ULF) toilets are required in all new construction in California as of January 1, 1992. ULF toilets must use no more than 1.6 gallons per flush (gpf) and ULF urinals must use no more than 1 gpf. (http://www.fypower.org/com/tools/products_results.html?id=100139) Note: If zero flush urinals are being used, adjust accordingly.

The demand for toilet and urinal flushing for the project is computed using the per capita demand from **Table F-1** ('Total Use' column) multiplied by the expected number of residents or employees for all buildings on the project which will use harvested water for toilet flushing during the wet season. Site-specific adjustments to the values in **Table F-1** are allowable if they are supported by sound evidence documented in the Project WQMP.

Toilet and urinal flushing demand can be used to evaluate the drawdown time of proposed harvest and use BMPs for the purpose of feasibility evaluation and BMP sizing.

F.2.4 General Requirements for Irrigation Demand Calculations

The following guidelines should be followed for computing harvested water demand from landscaping:

- If reclaimed water (greywater, recycled wastewater, or other non-stormwater) is planned for use for landscape irrigation, then the demand for harvested stormwater should be reduced by the amount of reclaimed water that is available during the wet season. The basis for this priority is provided in **Section F.2.8**.
- Irrigation rates should be based on the irrigation demand exerted by the types of landscaping that are proposed for the project, with consideration for water conservation requirements.
- Irrigation rates should be estimated to reflect the average wet season rates (defined as November through April) accounting for the effect of storm events in offsetting harvested water demand. In the absence of a detailed demand study, it should be assumed that irrigation demand is not present during days with greater than 0.1 inches of rain and the subsequent 3-day period. This irrigation shutdown period is consistent with standard practice in land application of wastewater and is applicable to stormwater to prevent irrigation from resulting in dry weather runoff. Based on a statistical analysis of Orange County rainfall patterns, approximately 30 percent of wet season days would not have a demand for irrigation.
- If land application of stormwater is proposed (i.e., irrigation in excess of agronomic demand), then this BMP must be considered to be an infiltration BMP and feasibility screening for infiltration must be conducted, including infiltration rates, geotechnical issues, water balance issues, and groundwater issues, as applicable. In addition, it must be demonstrated that land application would not result in greater quantities of runoff as a result of saturated soils at the beginning of storm events. Agronomic demand refers to the rate at which plants use water.

The following sections describe methods that should be used to calculate harvested water irrigation demand. While these methods are simplified, they provide a reasonable estimate of potential harvested water demand that is appropriate for feasibility analysis and project planning. These methods may be replaced by a more rigorous project-specific analysis that meets the intent of the criteria above.

F.2.5 OC Irrigation Code Demand Calculation Method

This method is based on the **County of Orange Landscape and Irrigation Code and Implementation Guidelines** Ordinance No. 09-010 (OC Irrigation Code). The OC Irrigation Code includes a formula for estimating a project's annual Estimated Applied Water Use (EAWU) based on the reference evaporation, landscape coefficient, and irrigation efficiency.

For the purpose of calculating harvested water irrigation demand applicable to the sizing of harvest and use systems, the EAWU has been modified to reflect typical wet-season irrigation demand. This method assumes that the wet season is defined as November through April. This method further assumes that no irrigation water will be applied during days with precipitation totals greater than 0.1 inches or within the 3 days following such an event. Based on these assumptions and an analysis of Orange County precipitation patterns, irrigation would not be applied during approximately 30 percent of days from November through April.

The following equation is used to calculate the Modified EAWU:

$$\text{Modified EAWU} = (ETo_{Wet} \times K_L \times LA \times 0.015) / IE$$

Where:

Modified EAWU = estimated daily average water usage during wet season
ETo_{Wet} = Average Reference ET from November through April (inches per month, See **Section F.2.5.1**)
K_L = Landscape Coefficient, $K_L = K_s \times K_d \times K_{mc}$ (See **Section F.2.5.2**)

- K_s = species factor
- K_d = density factor
- K_{mc} = microclimate factor

LA = Landscape Area (sq-ft)
IE = Irrigation Efficiency (assume 90 percent for demand calculations)

In this equation, the coefficient (0.015) accounts for unit conversions and shut down of irrigation during and for the three days following a significant precipitation event:

0.015 = (1 mo/30 days) ×(1 ft/12 in)×(7.48 gal/cu-ft)×(approximately 7 out of 10 days with irrigation demand from November through April)

When using this method, the worksheets contained within the OC Irrigation Code may be useful to determine the irrigation use for a project site, with the appropriate modifications to reflect the Modified EAWU calculations. These worksheets allow the user to area-weight the inputs for irrigation from different landscapes within the project.

Note: this is a method to compute average wet season demand. It is not a complete harvest and use sizing method.

F.2.5.1 Reference ET Data

Table F-2 contains data derived from CIMIS for the cities of Irvine, Santa Ana, and Laguna Beach. These values can be used to compute ETo_{Wet} in the Modified EAWU equation above. Other values may also be used as long as they are supported by sound evidence and documented in the Project WQMP.

Table F-2: Monthly Reference ET Rates for Orange County (Inches)

Station	J	F	M	A	M	J	J	A	S	O	N	D	Annual	Wet Season Average (in/mo) (Nov to Apr)
Irvine	2.2	2.5	3.7	4.7	5.2	5.9	6.3	6.2	4.6	3.7	2.6	2.3	49.9	3.00
Laguna Beach	2.2	2.7	3.4	3.8	4.6	4.6	4.9	4.9	4.4	3.4	2.4	2.0	43.3	2.75
Santa Ana	2.2	2.7	3.7	4.5	4.6	5.4	6.2	6.1	4.7	3.7	2.5	2.0	48.3	2.93

Source: County of Orange Landscape and Irrigation Code and Implementation Guidelines

F.2.5.2 Landscape Coefficient (K_L)

The Water Use Classifications of Landscape Species (WUCOLS, University of California and Department of Water Resources, 2000) should be used to determine the landscape coefficient that is applicable to each landscape irrigation zone. The landscape coefficient, K_L, is based on the product of the species factor (K_s), the density (K_d), and the microclimate (K_{mc}).

- The species factor is based on plant water needs derived from available data. At the time of the 2000 WUCOLs, 1,800 plant species had been evaluated for relative water needs. Specific species factors for these plant species are available in WUCOLs.
- The density factor is related to the vegetative or leaf cover for different plantings. Thinner or thicker than average density conditions are assigned density coefficients less than or greater than 1.0, respectively.
- The microclimate factor is related to features present in the urban landscape that influence temperature, wind, shading, and other climatic factors. An 'average' microclimate is equivalent to reference ET conditions (1.0), which is relatively uninfluenced by nearby buildings, structures, etc.

Table F-3 provides a general overview of these factors, ranging from low to high water use plant palettes.

Table F-3: Species, Density, and Microclimate Factors from WUCOLs for High, Moderate, Low and Very Low Water Use Plant Palettes

	High	Moderate	Low	Very Low
Species Factor* (k_s)	0.7-0.9	0.4-0.6	0.1-0.3	<0.1
Density (k_d)	1.1-1.3	1.0	0.5-0.9	
Microclimate (k_{mc})	1.1-1.4	1.0	0.5-0.9	

Source: Water Use Classifications of Landscape Species (WUCOLS, University of California and Department of Water Resources, 2000)

Table F-4 provides recommended composite landscape coefficients that are appropriate for planning purposes and feasibility screening.

Table F-4: Planning Level Recommendations for Landscape Coefficient (K_L)

General Landscape Type	Recommended Planning Level Landscape Coefficient (K_L)
Conservation Landscape Design (non-active turf)	K_L = 0.35
Active Turf Areas	K_L = 0.7

F.2.5.3 *Planning Level Irrigation Demands*

Using the inputs above, daily average wet season demands were developed for an acre of irrigated area based on location and landscape type (Table F-5).

Table F-5: Modified EAWU Daily Average Irrigation Demand by Location and Landscape Coefficient

General Landscape Type	Daily Average Modified EWUA (gpd per irrigated acre)		
	Irvine	Santa Ana	Laguna
Conservation Landscape Design (non-active turf): K_L = 0.35	740	720	680
Active Turf Areas: K_L = 0.7	1,480	1,450	1,360

These demand estimates can be used to calculate the average drawdown time of harvest and use systems for the purpose of LID BMP sizing calculations (Simple DCV Method (E.3.1), or Constant Drawdown Nomograph Method (E.3.2).

F.2.6 EIATA Demand Calculation and Sizing Method

The TGD also supports an alternative approach for quantifying harvested water demand that relies on the Effective Irrigated Area to Tributary Area (EIATA) ratio as a tool for sizing stormwater harvest and use systems. This ratio was developed to be a primary indicator of the ability of a harvest and use system to effectively capture and manage stormwater.

The EIATA ratio is calculated as follows:

$$EIATA = LA \times K_L / [IE \times \text{Tributary Impervious Area (acres)}]$$

Where:

EIATA = effective irrigated area to tributary area ratio (acre/acre)
LA = landscape area irrigated with harvested water, acres
K_L = Area-weighted landscape coefficient (per guidance in **Section F.2.5.2** above)
IE = irrigation efficiency (assume 0.90)

The calculated EIATA ratio can be used in the

Capture Efficiency via Nomograph Method for Harvest and Use BMPs in **Section E.3.6** to compute the capture efficiency of a given cistern size.

F.2.7 Calculating Other Harvested Water Demands

Calculations of other harvested water demands should be based on the knowledge of land uses, industrial processes, and other factors that are project-specific. Demand should be calculated based on the following guidelines:

- Demand calculations should represent actual demand that is anticipated during the wet season (November through April).
- Sources of demand should only be included if they are reliably and consistently present during the wet season.
- Where demands are substantial but irregular, a more detailed analysis should be conducted based on a statistical analysis of anticipated demand and precipitation patterns.
- Where the feasibility of harvest and use is contingent on a water demand that may not exist for the life of the project, this is a valid basis for rejecting the use of this BMP type. It may still be possible for this to be approved. However, should the demand cease to exist at a high enough level, the project would need to update the Project WQMP and provide a different BMP type to satisfy applicable LID BMP requirements.

F.2.8 Reclaimed Water Priority in Demand Calculations

If reclaimed water is available to meet or partially meet project non-potable water demands, the decision to use reclaimed water or harvested runoff water rests with the project proponent. If the project proponent elects to use reclaimed water or is required to use reclaimed water based on conditions placed on the project, then the demand for harvested water should be reduced by the amount of reclaimed water available. This criterion effectively allows the project proponent to consider harvest and use to be infeasible if sufficient reclaimed water supply is available to meet the project demand for harvested water.

This criterion intentionally prioritizes the use of reclaimed water over harvested water in cases where demand overlaps. The use of reclaimed water is being prioritized based upon the following considerations:

- In Order 2009-06, the State Water Board finds that "…recycled water is safe for approved uses, and strongly supports recycled water as a safe alternative to potable water for such approved uses". There are several other state mandates for reduction of potable water demand.
- A substantial investment has been made in the production and distribution of reclaimed water by local agencies to reduce potable water demand to meet state mandates.

- Utilizing reclaimed water where available inherently reduces the amount of treated municipal effluent discharged to the ocean. For those entities that rely primarily on use of reclaimed water for disposal of treated wastewaters, such as the Irvine Ranch Water District, prioritizing use of runoff over reclaimed water could increase wastewater discharges significantly during wet weather periods.
- Utilizing the capacity of the reclaimed water system, where available, has a significantly larger benefit for offsetting potable water supply than stormwater harvest and use systems. Reclaimed water is available year-round and therefore can effectively fulfill project non-potable water demands throughout the year. In contrast, a harvested water system designed for stormwater management would tend to make water available for a relatively minor fraction of the year (during storm events and for a relatively short period after), thereby meeting a substantially lower fraction of the project non-potable water demand.
- It is possible to engineer and deploy a combined reclaimed water/harvested stormwater non-potable use system. However, the costs of including both options would be much higher than employing one or the other. In addition, the most difficult time for reclaimed water disposal is during extended wet periods when irrigation demand is reduced and more wastewater from inflow and infiltration. This is the same time that stormwater harvested water is most plentiful.
- Potential impacts to groundwater quality related to use of reclaimed water, particularly salt and nutrient accumulation, must be evaluated and managed by providers of reclaimed water[8]. The priority for use of reclaimed water expressed in this TGD does not conflict or interfere with the obligation of reclaimed water providers to manage the application of reclaimed water. If, as a groundwater quality management action, a reclaimed water provider must limit the application of reclaimed water, it would be the responsibility of the reclaimed water provider to limit the amount of reclaimed water that is made available to a proposed project and/or limit its allowable uses on a project. This would limit the amount of project demand that can be offset by reclaimed water and would thereby require harvested water to be considered in applicable scenarios.
- Finally, it is noted that the State Board has evaluated, in general, the potential negative environmental consequences of reclaimed water on groundwater quality as part of developing its policy on reclaimed water, and the State Board supports the use of reclaimed water for landscape irrigation.

[8] In Water Quality Order No. 2000-07, the State Water Board determined that a Producer (i.e., reclaimed water purveyor) cannot shift responsibility for discharged salt to the User (i.e., project proponent).

F.3 Feasibility Evaluation and BMP Sizing

F.3.1 Planning Level Harvest and Use Feasibility Screening

Harvest and Use is required to be considered as an LID option if Full Infiltration BMPs cannot be used to capture the DCV. A simple test is used to determine whether harvest and use BMPs must be used:

- If the DCV for the project can be used within 48 hours of the end of precipitation and full infiltration is not feasible, then harvest and use is a mandatory BMP.
- If these conditions are not met, then harvest and use is an optional BMP. It may still be used as part of project compliance with LID requirements, but is not mandatory.

It is expected to be very rare that harvest and use will be mandatory. However, there are numerous cases where it may be a viable option for a portion of project LID BMP sizing requirements.

F.3.2 Options for Incorporating Harvest and Use into LID BMP Sizing

There are a few conceptual options for how harvest and use could be used as part of an overall LID BMP plan:

Partial capture: Size harvest and use based on available space and demand. Or size harvest and use for desired water supply benefits. Use the applicable calculation methods in **Appendix E** to estimate the long term stormwater capture efficiency of the proposed design. This is a function of the system size and use rate. Provide a biofiltration BMP for the overflow of the system to provide complementary treatment up to the full LID BMP sizing requirements. Because volume reduction is provided in the harvest and use system, it is not necessary to maximize volume reduction of biofiltration BMPs.

Full capture: Size harvest and use to capture 80 percent of long term runoff volume for all or a portion of the project. At typical demand rates, this may require a relatively large storage volume (several times larger than the DCV). However, no complementary BMPs are needed for the area captured by the harvest and use system.

Other configurations could be proposed that meet the underlying performance criteria for LID BMPs. If hydromodification control applies to the project, harvest and use can also be incorporated into hydromodification BMP designs.

F.4 Guidance and Considerations for Harvest and Use BMPs from California Plumbing Code and Other Sources

F.4.1 Introduction to Harvest and Use BMP Standards

When choosing to implement harvest and use BMPs in Orange County, systems must be implemented in accordance with plumbing code and any applicable local ordinances.

The 2013 California Plumbing Code is this current applicable code at the statewide level. The CPC is effectively the 2012 Uniform Plumbing Code, with some amendments. Chapters 16 and 17 of the California Plumbing Code (and the Uniform Pluming Code) contain regulations regarding alternate sources of water such as stormwater, rainwater, and gray water. This is currently the main standard which must be met in Orange County relative to harvest and use BMPs.

The Orange County Health Care Agency (OCHCA) Environmental Health Division conducts cross connection inspections in cases where recycled water is used. It should be assumed that this requirement applies to harvested stormwater unless otherwise notified in writing by OCHCA. Design of systems to adherence to the California Plumbing Code should avoid any issues with cross-connections between a harvested stormwater and a potable water system.

At the time of publication of this TGD, the permittees within Orange County utilize the 2013 CPC as part of project permitting. No additional policies are known to be in place. The requirements of the 2013 California Plumbing Code are explained below. This may be changed in the future, and the project proponent is responsible for following the most recent regulations when using harvest and use BMPs. For example, the Uniform Plumbing Code is typically updated every three years. The 2015 version of the Uniform Plumbing Code contains no significant changes regarding harvest and use BMPs, but that may change in the 2018 version, or in amendments made to the Uniform Plumbing Code in any future California Plumbing Code updates. In addition, local jurisdictions may develop their own standards and regulations relative to harvest and use BMPs. In general, the California Plumbing Code defers to any local jurisdiction when such regulations exist, as explained below. For example, the Los Angeles County Department of Public Health, developed Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses in 2016 which uses a tiered approach with several requirements above and beyond what is in the 2013 California Plumbing Code. It is possible that Orange County or local cities within Orange County will develop additional standards relative to harvest and use BMPs. The project proponent should therefore use the requirements from the 2013 California Plumbing Code below as guidance, but should always check to determine if local requirements exist.

F.4.2 Requirements in the 2013 California Plumbing Code

This section explains the requirements contained in the 2013 California Plumbing Code Chapters 16 and 17 relative to harvest and use BMPs. Several of the standards depend on the storage capacity, the application of the captured stormwater, and/or the surface the stormwater is collected from. This section is intended to help explain the California Plumbing Code for stormwater designers, but is not intended to modify it in any way. Where discrepancies are identified, the California Plumbing Code shall prevail.

F.4.2.1 General System Design

All harvest and use BMPs shall be designed by a person who demonstrates competency to design the system as required by the enforcing agency. The enforcing agency may also require plans and specifications to be prepared by a licensed design professional for complex systems.

In general, the harvest and use BMP is designated in the 2013 California Plumbing Code based on what surface it receives runoff from. Rainwater systems collect runoff only from rooftops or other impervious, man-made, above-ground surfaces that do not receive overflows or bleed-off discharges from roof-mounted equipment or appliances. Runoff from all other surfaces is termed on-site treated non-potable water and has some different requirements than rainwater, as outlined in the requirements below.

F.4.2.2 Permit Requirements and Local Authority Approval

Except the in the cases displayed in **Table F-6** below, the project proponent may not construct, install, alter, or cause to be constructed, installed, or altered a harvest and use BMP in a building or on a premise without first obtaining a permit to do such work from the authority having jurisdiction. The local jurisdiction will typically be the agency responsible for building permit review. No permit shall be issued until complete plumbing plans, with data satisfactory to the authority having jurisdiction have been submitted and approved.

Table F-6 identifies cases that require a permit and those that do not. Where a permit is required, this means that the local jurisdiction responsible for plumbing permits must consider the harvest and use system as part of the plumbing permit.

Table F-6: Determination of Need for Plumbing Permit for Harvest and Use BMP Scenarios

Cistern Capacity	Application	Runoff Collection Surface: Rooftops*	Runoff Collection Surface: All Other Surfaces
<5000 gallons <u>and</u> All equipment is outdoor, cistern is on-grade with <2:1 H:W ratio, no electrical connection, and no makeup water from potable	Subsurface irrigation	No permit required	Permit Required
	Surface non-spray irrigation		
	Surface spray irrigation	Permit Required	
	Car Wash		
	Indoor non-potable uses		
	Other Outdoor Uses (cooling water, ornamental fountain)		
>5000 gallons, or any of the other criteria above not met	Subsurface irrigation	Permit Required	
	Surface non-spray irrigation		
	Surface spray irrigation		
	Car Wash		
	Indoor non-potable uses		
	Other Outdoor Uses (cooling water, ornamental fountain)		

*Rooftops include any impervious, manmade, above-ground surface which receive no bleed valve discharge or overflow from mounted equipment

No changes or connections shall be made to either the rainwater catchments system or the potable water system on a site containing a harvest and use BMP requiring a permit without approval by the authority having jurisdiction.

If the development falls under the jurisdiction of the California Housing and Community Development, an additional exemption from permit requirement is given for cisterns with a capacity less than 360 gallons with all equipment outdoors used for spray irrigation.

F.4.2.3 Minimum Treatment Requirements

The harvest and use BMP must be equipped with the following minimum treatments according to **Table F-7** below. Rainwater tank openings shall be protected to prevent the entrance of insects, birds, or rodents into the tank and piping systems. Screens installed on vent pipes, inlets, and overflow pipes, shall have an aperture of not greater than 1/16 of an inch and shall be close fitting. The rainwater catchment conveyance system shall be equipped with means to prevent accumulation of leaves, needles, other debris, and sediment from entering the storage tank. Debris excluders shall be accessible and installed according to manufacturer's installation instructions. ***Note: Water quality requirements in Section F.4.2.4 also apply.***

Table F-7: Minimum Treatments Required for Various Harvest and Use BMP Applications

<table>
<tr><th rowspan="2">Application</th><th colspan="2">Runoff Collection Surface</th></tr>
<tr><th>Rooftops*</th><th>All Other Surfaces</th></tr>
<tr><td>Subsurface irrigation</td><td rowspan="2">• 100 micron filter
• Debris excluder</td><td rowspan="2">• 100 micron filter
• Debris excluder</td></tr>
<tr><td>Surface non-spray irrigation</td></tr>
<tr><td>Surface spray irrigation</td><td>• Debris excluder</td><td>• Disinfection
• Debris excluder</td></tr>
<tr><td>Car Wash</td><td rowspan="2">• 100 micron filter
• Debris excluder</td><td rowspan="3">• Disinfection
• 100 micron filter
• Debris excluder</td></tr>
<tr><td>Indoor non-potable uses</td></tr>
<tr><td>Other Outdoor Uses (cooling water, ornamental fountain)</td><td>• Debris excluder</td></tr>
</table>

*Rooftops include any impervious, manmade, above-ground surface which receive no bleed valve discharge or overflow from mounted equipment

F.4.2.4 Minimum Water Quality Requirements

The minimum water quality for harvested water shall meet the applicable water quality standards for the intended application as determined by the authority having jurisdiction for plumbing permit review. In the absence of water quality requirements from the authority having jurisdiction, the requirements in **Table F-8** below shall apply.

Whenever disinfection is required as a minimum water quality treatment or to meet minimum water quality standards, the treatment must ensure the required water quality at the point of use. Where chlorine is used for disinfection, water shall be tested for residual chlorine according to ASTM D 1253. The levels of residual chlorine shall not exceed the levels allowed for the intended use in accordance with the requirements of the local enforcing agency.

Table F-8: Minimum Water Quality Standards for Various Harvest and Use BMP Applications

<table>
<tr><th rowspan="2">Cistern Capacity</th><th rowspan="2">Application</th><th colspan="2">Runoff Collection Surface</th></tr>
<tr><th>Rooftops*</th><th>All Other Surfaces</th></tr>
<tr><td rowspan="6"><360 Gallons</td><td>Subsurface irrigation</td><td rowspan="4">None</td><td>None</td></tr>
<tr><td>Surface non-spray irrigation</td><td rowspan="5">NSF/ANSI 350 Certified Treatment System

Title 22 is acceptable for R-1 and R-2 occupancies</td></tr>
<tr><td>Surface spray irrigation</td></tr>
<tr><td>Car Wash</td></tr>
<tr><td>Indoor non-potable uses</td><td>• < 100 CFU/ 100mL E. Coli
• <10 NTU Turbidity</td></tr>
<tr><td>Other Outdoor Uses (cooling water, ornamental fountain)</td><td>• < 100 CFU/ 100mL E. Coli
<10 NTU Turbidity</td></tr>
<tr><td rowspan="6">>360 Gallons</td><td>Subsurface irrigation</td><td rowspan="2">None</td><td>None</td></tr>
<tr><td>Surface non-spray irrigation</td><td rowspan="5">NSF 350 Certified Treatment System

Title 22 is acceptable for R-1 and R-2 occupancies</td></tr>
<tr><td>Surface spray irrigation</td><td>• < 100 CFU/ 100mL E. Coli
• <10 NTU Turbidity</td></tr>
<tr><td>Car Wash</td><td>None</td></tr>
<tr><td>Indoor non-potable uses</td><td rowspan="2">• < 100 CFU/ 100mL E. Coli
• <10 NTU Turbidity</td></tr>
<tr><td>Other Outdoor Uses (cooling water, ornamental fountain)</td></tr>
</table>

*Rooftops include any impervious, manmade, above-ground surface which receive no bleed valve discharge or overflow from mounted equipment

More information on NSF/ANSI 350: https://www.nsf.org/newsroom_pdf/ww_nsf_ansi350_qa_insert.pdf

More information on Title 22 Treatment Standards:
http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/lawbook/RWregulations_20140618.pdf

F.4.2.5 Connections to Potable Water Supply or Other Alternate Water Sources

Harvest and Use BMPs shall have no unprotected connection to a potable water supply or alternate water source. Potable or alternate source water is permitted to be used as makeup water for a harvest and use BMP as long as the water supply connection is protected by an air gap or reduced-pressure principle backflow preventer in accordance with the 2013 California Plumbing Code.

Whenever a portion of a harvest and use BMP components are installed within a building, a cross-connection test is required before the building is occupied or the system is activated. The installer shall perform the cross-connection test in the presence of the authority having jurisdiction. The Orange County Health Care Agency also conducts regular inspections for cross-connections and backflow preventers.

F.4.2.6 Component Design, Sizing, and Materials

The following specific provisions apply to component design, sizing, and materials:

- Rainwater storage tanks shall be constructed of solid, durable materials not subject to excessive corrosion or decay and shall be watertight.
- Any materials that contain mercury shall not come in contact with the harvested water in any component of the systems.
- The materials used for components of the system used for supply and distribution must comply with the 2013 California Plumbing Code for potable supply and distribution systems.
- Materials used for drainage, including gutters, downspouts, conductors, and leaders shall comply with the 2013 California Plumbing Code for storm drainage.
- Any components of the harvest and use BMPs that are used indoor, as well as rainwater drains, gutter, conductors, and leaders shall all comply with all applicable parts of the 2013 California Plumbing Code including minimum slope requirements.
- Harvest and Use BMPs along with any indoor components shall be provided with the required appurtenances (e.g., valves, air or vacuum relief values, etc.) to allow for deactivation or drainage as required for maintenance and cross-connection tests.
- Rainwater storage tanks shall be provided with a means for draining and cleaning.
- The overflow outlet shall not be equipped with a shutoff valve and shall meet the 2013 California Plumbing Code requirements for overflow valves for stormwater systems.
- When overflow occurs to a storm drainage system, the overflow drain and tank shall be protected from backflows from the stormwater system.
- The overflow outlet shall be sized to accommodate the flow of rainwater entering the tank and shall not be less than the aggregate cross sectional area of all inflow pipes to the tank.
- Rainwater storage tanks must be equipped with at least one access opening for inspection and cleaning. Access openings and manholes shall be secured by either a lockable device or other approved method to prevent unauthorized access.
- Rainwater storage tanks must be equipped with a vent that is not connected to the sanitary system vents and is sized in accordance with the 2013 California Plumbing Code.
- Rainwater storage tanks shall be permitted above grade or below grade according to the requirements below:

- Above grade tanks shall be of an opaque material, approved for use in direct sunlight or shall be shielded from direct sunlight. Tanks shall be accessible to allow for inspection and cleaning. The tank shall be constructed on a foundation or platform constructed to accommodate loads in accordance with the building code.
- Below grade tanks shall be structurally designed to withstand anticipated earth or other loads. Tanks covers shall be capable of supporting an earth load of at least 300 psi where the tank is designed for underground installation. Underground tanks be constructed with manholes of at least a 24-inch diameter or square with 24 inch sides. The manhole covering shall not be less than 4 inches above, and the surrounding area must be sloped away from the manhole cover. Service ports in manhole covers shall be lea than 8-inch diameter. Underground tanks must also be ballasted, anchored, or otherwise secured to prevent the tank from floating out of the ground when empty. The combined weight of the tank and holding system must meet or exceed the buoyancy force of the tank.

Pumps serving harvest and use BMPs must be capable of delivering at least 15 psi of residual pressure to the highest and most remote outlet served. Where the water pressure within the building exceeds 80 psi, a pressure reducing value shall be installed to reduce the pressure to 80 psi in accordance with the 2013 California Plumbing Code.

F.4.2.7 Signage and Identification

Components of the harvest and use shall be labeled as follows:

- Interior components shall be labeled with a purple background with black, uppercase lettering with the words "CAUTION: NON-POTABLE RAINWATER WATER, DO NOT DRINK" for roof runoff[9] and "CAUTION: ON-SITE TREATED NON-POTABLE WATER, DO NOT DRINK" for runoff from any other surfaces. along with the direction of flow with lettering that meets the requirements in **Table F-9** below. This label shall be indicated every 20 feet, but not less than once per room, and shall be visible from floor level.

[9] Roof runoff includes include only any impervious, manmade, above-ground surface which receive no bleed valve discharge or overflow from mounted equipment. Runoff from roofs which do not meet this requirement shall be considered runoff from any other surface.

Table F-9: Text requirements for indoor components of harvest and use BMPs (Per Table 601.2.2 of the 2013 California Plumbing Code)

Outside Diameter of Pipe or Covering (inches)	Minimum Length of Color Field (inches)	Minimum Size of Letters (inches)
½ to 1¼	8	½
1½ to 2	8	¾
2½ to 6	12	1¼
8 to 10	24	2½
Over 10	32	3½

- Outside hose bibs shall be allowed on rainwater piping systems if marked with the words "CAUTION: NONPOTABLE WATER, DO NOT DRINK" and the figure below

Figure F-1: Figure Required on Hose Bibbs on rainwater piping systems (Per Figure 1702.9 of the 2013 California Plumbing Code

- Rainwater tanks shall be permanently marked with the capacity of the tank and the language "NONPOTABLE RAINWATER". Where openings are provided to allow a person to enter the tank, the opening shall be marked as "DANGER-CONFINED SPACE"

Components, piping, pumps, fittings, and equipment used to treat rainwater used in any harvest and use BMP system shall be listed or labeled by a listing agency and approved for the intended application.

Buildings using rainwater shall include the following signs in the designated locations:

- Commercial, Industrial, Institutional restrooms and residential common-use restrooms: A sign shall be installed in restrooms which states, "TO CONSERVE WATER, THIS BUILDING USES RAINWATER TO FLUSH TOILETS AND URINALS"
- Equipment rooms: Each equipment room containing non-potable rainwater equipment shall have a sign posted with the following wording in 1 inch letters: "CAUTION NONPOTABLE WATER, DO NOT DRINK. DO NOT CONNECT TO DRINKING WATER SYSTEM. NOTICE: CONTACT BUILDING MANAGEMNT BEFORE PERFORMING ANY WORK ON THIS WATER SYSTEM"

F.4.2.8 Operation, Maintenance and Inspection

An initial inspection and test shall be performed on the rainwater catchment system to ensure there is no cross-connectivity between the rainwater catchment system and the potable water system prior to occupancy of the building or activation of the system.

Rainwater catchment systems (runoff collected from rooftop systems) shall be inspected and tested in accordance with the applicable provisions of the 2013 California Plumbing Code for potable water and storm drainage systems. Alternative water source systems (runoff collected from non-rooftop surfaces) and components shall be inspected and maintained in accordance with the manufacturer's recommendations and/or as required by the enforcing agency. Where no manufacturer's recommendations or requirements from the enforcing agency exist, additional recommendations are listed in **Table F-10** below. The required maintenance and inspection of the systems is the responsibility of the property owner unless otherwise required by the authority having jurisdiction.

Table F-10: Recommended minimum alternative water source testing, inspection, and maintenance frequency where no manufacturer's recommendations exist (Per 2013 California Plumbing Code Table 1601.5)

Description	Minimum Frequency
Inspect and clean filters and screens, and replace as necessary	Every 3 months
Inspect and verify that disinfection, filters, and water quality treatment devices and systems are operational and maintaining minimum water quality requirements	No recommendation
Inspect pumps, valves, and pressure tanks and verify operation	After installation and every 12 months thereafter

Clear debris from and inspect storage tanks, locking devices and verify operation	After installation and every 12 months thereafter
Inspect caution labels and markings	After installation and every 12 months thereafter
Cross connection inspection and test	After installation and every 12 months thereafter

An operation and maintenance manual shall be supplied to the building owner by the system designer or installer for any rainwater or on-site treated water system required to have a permit. The operation and maintenance manual must include the following:

1. Diagram(s) of the entire system and location of system components;
2. Instructions on operating and maintaining the system;
3. Instructions on maintaining the required minimum water quality;
4. Details on startup, shutdown, and deactivating the system maintenance, repair, or other purposes;
5. Applicable testing, inspection, and maintenance frequencies;
6. A method of contacting the installer and/or manufacturer(s); and
7. Directions to the owner or occupant that the manual shall remain with the building throughout the life cycle of the structure.

F.4.3 OCHCA Cross Connection Inspection

Where a harvested water system will have any connection to a potable water system, a backflow prevention device and cross connection inspection by OCHCA should be assumed to be required. This applies unless otherwise notified in writing by OCHCA that this does not apply. See guidelines and contact information here: **http://www.ochealthinfo.com/eh/water/backflow**

APPENDIX G. BMP FACT SHEETS

This appendix contains BMP fact sheets for the BMP categories listed below. The BMP designs described in these fact sheets and in the referenced design manuals shall constitute what are intended as LID and Treatment Control BMPs for the purpose of meeting stormwater management requirements. Other BMP types and variations on these designs may be approved at the discretion of the reviewing agency if documentation is provided demonstrating similar functions and equivalent or better expected performance.

Hydrologic Source Control Fact Sheets (HSC)

Miscellaneous Design Elements Fact Sheets (MISC)

Full Infiltration BMP Fact Sheets (INF)

Note: ET plays an important role in the performance of HSC, INF, HU, and BIO BMPs. However, specific fact sheets for ET are not included.

** Indicates BMPs that can potentially meet the definition of "biofiltration BMPs". Biofiltration BMPs are vegetated treat-and-release BMPs that filter stormwater through amended soil media that is biologically active, support plant growth, and also promote infiltration and/or evapotranspiration. Biotreatment BMPs that do not meet this definition are not considered to be LID BMPs, but may be used as treatment control or Pretreatment BMPs.*

G.1 Hydrologic Source Control Fact Sheets (HSC)

HSC-1: LOCALIZED ON-LOT INFILTRATION

'Localized on-lot infiltration' refers to the practice of collecting on-site runoff from small distributed areas within a catchment and diverting it to a dedicated on-site infiltration area. This technique can include disconnecting downspouts and draining sidewalks and patios into french drains, trenches, small rain gardens, or other surface depressions. This HSC is limited to systems with very shallow depth of ponding, which provides improved resiliency to infiltration rate variability and and does not require BMP-specific testing.

For downspout disconnections and other impervious area disconnection involving dispersion over pervious surfaces, but without intentional ponding, see HSC 2: Impervious Area Dispersion.

Also known as:

- *Downspout infiltration*
- *Retention grading*
- *French drains*
- *On-lot rain gardens*

On-lot rain garden
Source: lowimpactdevelopment.org

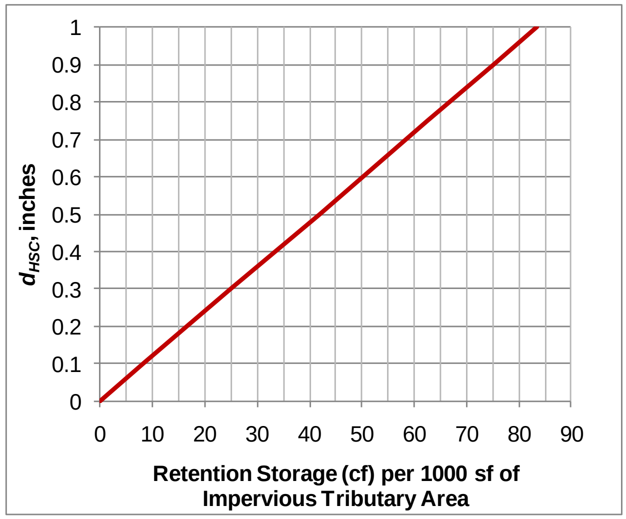
Recommended Selection and Siting Criteria

- A single application of this HSC should not be sized to retain runoff from impervious areas greater than 4,000 sq. ft (0.1 acres); if the drainage area exceeds this criteria, investigation and sizing should be based on guidelines for bioretention areas or infiltration trenches.
- 'Localized on-lot infiltration' should only be used in DMAs where full infiltration is feasible based on a reasonably-supported opinion.
- This HSC is appropriate in locations where runoff can be directed to and temporarily pond in pervious area depressions, rock trenches, or similar.
- Shallow utilities should not be present below infiltration areas.
- Setbacks from foundations or structures should be observed (minimum 8 feet or as recommended by project geotechncial professional).

Recommended Design Criteria and Considerations

- ☐ Maximum ponding depth should be should be no greater than 4 inches to reduce sensitivity to infiltration rate.
- ☐ Soil should be amended to a minimum depth of 12 inches based on the criteria in MISC-2.
- ☐ Side slopes of rain garden or depression storage should not be steeper than 3H:1V.
- ☐ Effective energy dissipation and uniform flow spreading methods should be employed to prevent erosion resulting from water entering infiltration areas.

☐ Overflow should be located such that it does not cause erosion is conveyed away from structures toward the downstream conveyance and treatment system.



Calculating HSC Retention Volume

- The retention volume provided by localized on-lot infiltration can be computed as the storage volume provided by surface ponding and the pore space within an amended soil layer or gravel trench.
- Estimate the average retention volume per 1000 square feet impervious tributary area provided by on-lot infiltration.
- Look up the storm retention depth, d_{HSC} from the chart to the right.
- The max d_{HSC} is equal to the design capture storm depth for the project site.

HSC-2: IMPERVIOUS AREA DISPERSION

Impervious area dispersion refers to the practice of routing runoff from impervious areas, such as rooftops, walkways, and patios onto the surface of adjacent pervious areas via sheet flow. Runoff is dispersed uniformly via splash block or dispersion trench and soaks into the ground as it moves slowly across the surface of pervious areas. Minor ponding may occur, but it is not the intent of this practice to actively promote localized on-lot storage (See **MISC-2** if localized ponding is intended).

In contrast to HSC-1, this practice can be used where infiltration is either fully feasible or partially feasible.

Also known as:

- *Downspout disconnection*
- *Impervious area disconnection*
- *Sheet flow dispersion*

Simple Downspout Dispersion
Source: toronto.ca/environment/water.htm

Recommended Selection and Siting Criteria

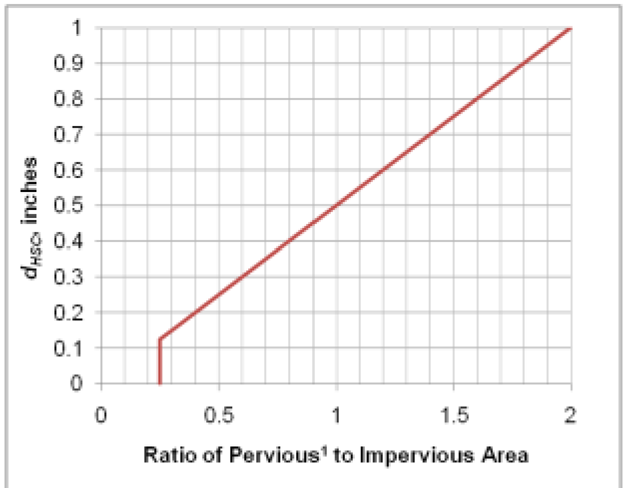
- Impervious area dispersion can be used in DMAs categorized as feasible for full infiltration or partial infiltration. It should be avoided if any level of infiltration would pose hazards.
- This HSC requires that there are significant pervious areas present in drainage area with shallow slopes that can receive runoff from adjacent impervious areas.
- The site plan should allow for verflow from pervious area to be appropriately managed.

Recommended Design Criteria and Considerations

- ☐ Soils should be preserved from their natural condition or restored via soil amendments to meet minimum criteria described in MISC-2.
- ☐ Lawn or landscaping should be well established
- ☐ A minimum of 1 part pervious area capable of receiving flow should be provided for every 2 parts of impervious area disconnected.
- ☐ The pervious area receiving flow should have a slope ≤ 2 percent and path lengths of ≥ 20 feet per 1000 sf of impervious area.
- ☐ For areas with sparse vegetation (e.g.. xeriscaped areas), appropriate contouring should be used to slow water, avoid preferential scour pathways and associated soil or mulch loss.
- ☐ Dispersion areas should be maintained to remove trash and debris, loose vegetation, and protect any areas of bare soil from erosion.
- ☐ Velocity of dispersed flow should not be greater than 0.5 ft per second to avoid scour.

Calculating HSC Retention Volume

- The retention volume provided by downspout dispersion is a function of the ratio of impervious to pervious area and the condition of soils in the pervious area.
- Determine flow patterns in pervious area and estimate footprint of pervious area receiving dispersed flow. Calculate the ratio of pervious to impervious area.
- Look up the storm retention depth, dHSC from the chart below.
- The max dHSC is equal to the design capture storm depth for the project site.



[1] Pervious area used in calculation should only include the pervious area receiving flow, not pervious area receiving only direct rainfall or upslope pervious drainage.

Chart extends to 0.25, but designs should not go below a minimum value of 0.5 (2 parts impervious to 1 part pervious).

HSC-3: STREET TREES

By intercepting rainfall, trees can provide several aesthetic and stormwater benefits including peak flow control, increased infiltration and ET, and runoff temperature reduction. The volume of precipitation intercepted by the canopy reduces the treatment volume required for downstream treatment BMPs. Shading reduces the heat island effect as well as the temperature of adjacent impervious surfaces, over which stormwater flows, and thus reduces the heat transferred to downstream receiving waters. Tree roots also strengthen the soil structure and provide infiltrative pathways, simultaneously reducing erosion potential and enhancing infiltration.

Also known as:

- *Canopy interception*

Street trees
Source: Geosyntec Consultants

Recommended Selection and Siting Criteria

- Street trees can be incorporated in green streets designs along sidewalks, streets, parking lots, or driveways.
- Street trees can be used in combination with bioretention systems along medians or in traffic calming bays.
- There must be sufficient space available to accommodate both the tree canopy and root system.

OC-Specific Design Criteria and Considerations

- ☐ Mature tree canopy, height, and root system should not interfere with subsurface utilities, suspended powerlines, buildings and foundations, or other existing or planned structures. Required setbacks should be adhered to.
- ☐ Depending on space constarints, a 20 to 30 foot diameter canopy (at maturity) is recommended for stormwater mitigation.
- ☐ Native, drought-tolerant species should be selected in order to minimize irrigation requirements and improve the long-term viability of trees.
- ☐ Trees should not impede pedstrian or vehicle sight lines.
- ☐ Planting locations should receive adequate sunlight and wind protection; other environmental factors should be considered prior to planting.
- ☐ Frequency and degree of vegetation management and maintenance should be considered with respect to owner capabilities (e.g., staffing, funding, etc.).
- ☐ A street tree selection guide, such as that specific to the City of Los Angeles, may need to be consulted to select species appropriate for the site design constraints (e.g., parkway size, tree height, canopy spread, etc.) (City of Los Angeles, Street Tree Division - Street Tree Selection Guide. http://bss.lacity.org/UrbanForestryDivision/StreetTreeSelectionGuide.htm
- ☐ Infiltration (if allowed into tree wells) should not cause geotechnical hazards related to adjacent structures (buildings, roadways, sidewalks, utilities, etc.)

Calculating HSC Retention Volume

- The retention volume provided by streets trees via canopy interception is dependent on the tree species, time of the year, and maturity.
- To compute the retention depth, the expected impervious area covered by the full tree canopy after 4 years of growth must be estimated using reasonable approaches. The maximum retention depth credit for canopy interception (dHSC) is 0.05 inches over the area covered by the canopy at 4 years of growth.

HSC-4: RESIDENTIAL RAIN BARRELS

Rain barrels are above ground storage vessels that capture runoff from roof downspouts during rain events and detain that runoff for later reuse for irrigating landscaped areas. The temporary storage of roof runoff reduces the runoff volume from a property and may reduce the peak runoff velocity for small, frequently occurring storms. In addition, by reducing the amount of storm water runoff that flows overland into a storm water conveyance system (storm drain inlets and drain pipes), less pollutants are transported through the conveyance system into local creeks and ocean. The reuse of the detained water for irrigation purposes leads to the conservation of potable water and the recharge of groundwater.

Also known as:

- *Small cistern*

Rain Barrel
Source: http://www.auburn.edu/projects/sustainability/website/newsletter/0910.php

Recommended Selection and Siting Criteria

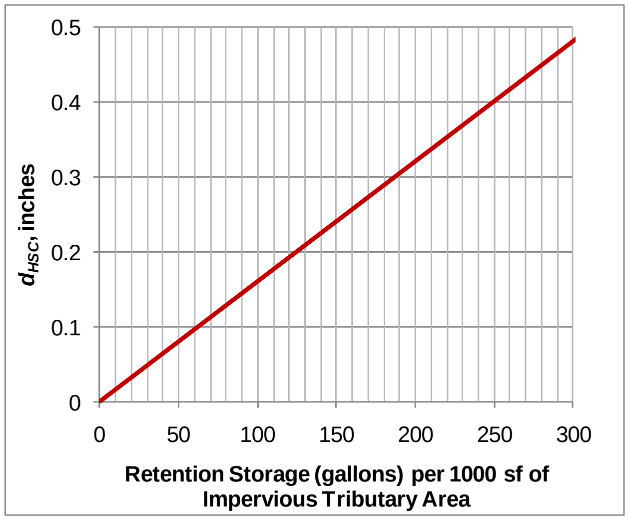
- Acceptable for rooftop downspouts or other suitable conveyances (e.g. rain chains).
- Sufficient vegetated areas must be present in drainage area to have a reasonable use for the water.
- An appropriate overflow pathway is needed.

Recommended Design Criteria and Considerations

- ☐ Screens on gutters and downspouts should be used to remove sediment and particles as the water enters the barrel or cistern. Removable child-resistant covers and mosquito screening should be used to prevent unwanted access.
- ☐ Above-ground barrels should be secured in place.
- ☐ Above-ground barrels should not be located on uneven or sloped surfaces; if installed on a sloped surface, the base where the cistern will be installed should be leveled prior to installation.
- ☐ Overflow dispersion should occur greater than 8 feet from building foundations.
- ☐ Dispersion should not cause geotechnical hazards related to slope stability.
- ☐ Dispersion should be only allowed to stable vegetated areas where erosion or suspension of sediment is minimized.
- ☐ Effective energy dissipation and uniform flow spreading methods should be employed to prevent erosion and facilitate dispersion.
- ☐ Aesthetics should be considered for placement of barrels and incorporation into surroundings. Placement should allow easy access for regular maintenance.
- ☐ To draw down a 55 gallon rain barrel within 4 days with plant watering, at least 800 square feet of conservation landscape or 400 square feet of active turf area is needed.

Calculating HSC Retention Volume

- At least 800 sq-ft of conservation landscape or 400 sq-ft of active turf landscape shall be provided for each rain barrel to claim an HSC credit volume
- The effective volume provided by rain barrels that are not actively managed can be computed as 50% of the total storage volume (e.g., 27.5 gallons for each 55 gallon barrel.)
- If the rain barrel is actively managed then it should be treated as a cistern as described in **Appendix E**.
- Estimate the average retention volume per 1000 square feet impervious tributary area provided by rain barrels. Example:
    - 1000 square feet of roof draining to two 55 gallon rain barrels
    - Credited retention volume = (110/2) = 55 gallons
    - Retention volume per 1000 sq feet = 55 gallons per 1000 sq-ft
    - Based on the retention storage estimated, look up the storm retention depth, d_{HSC} from the chart to the right = 0.09 inches
    - The max d_{HSC} is equal to the design storm depth for the project site.



HSC-5: GREEN ROOF / BROWN ROOF

Also known as:

- *Ecoroofs*
- *Roof Gardens*
- *Vegetated Roof Covers*
- *Brown Roofs*

Green Roof
Source: Milwaukee Department of Environmental Sustainability

Green roofs are also known as ecoroofs, roof gardens, or vegetated roof covers. Green roofs are roofing systems that layer a soil/vegetative cover over a waterproofing membrane. There are two types of green roofing systems: extensive, which is a light weight system; and intensive, which is a heavier system that allows for larger plants and requires additional maintenance. A green roof mimics pre-development conditions by limiting the impervious area created by development. Green roofs filter, absorb, and evapotranspire precipitation to help mitigate the effects of urbanization on water quality and delivery of excess runoff to the local storm water conveyance systems.

Brown roofs are essentially a type of green roof designed to maximize biodiversity. Brown roofs typically utilize natural soil and locally available substrates to create a protected biodiverse habitat for specific species of local flora and fauna. Rather than landscaping the roof during construction, plants are left to germinate and grow on their own in the native soils, thus the "brown" (i.e., initially unvegetated) designation. Seeding may be implemented where self-colonization via airborne seeds is unlikley.

Recommended Selection and Siting Criteria

- Green roofs should be selected with consideration for their impacts on irrigation during the dry season and during dry periods of the wet season.
- Green roofs can be applied to multi-family residential, commercial, or institutional land uses including rooftops and decks above building structures (e.g., parking structures, outdoor eating area roofs, or storage facilities.
- Roofs are ideally multi-story, such that the additional weight of the soil, retained water, and plants, can be be accomodated without significant changes to the structure, as confirmed by a licensed structural engineer.
- Roofs are ideally relatively flat.

Recommended Design Criteria

- ☐ A licensed structural engineer should be consulted to confirm that the roof has appropriate strength to support the green roof.
- ☐ Soil depth should be consistent with minimum depths provided in **Appendix H**.
- ☐ A drain pipe (gutter) is required to convey runoff safely from the roof.
- ☐ A drainage layer is recommended to move the excess runoff off of the roof. A proven proprietary drainage layer product should be used.
- ☐ Green roofs should be about 90% vegetated with a mix of erosion resistant plant species that effectively bind the soil and can withstand the extreme environment of rooftops (i.e., heat, cold, and high winds).
- ☐ A diverse selection of low growing plants that thrive under the specific site, climatic, and watering conditions should be specified. A mixture of drought tolerant, self-sustaining (perennial or self-sowing without need for fertilizers, herbicides, and or pesticides) is most effective. Native or adapted sedum/succulent plants are preferred because they generally require less fertilizer, limited maintenance, and are more drought resistant than exotic plants. When appropriate, green roofs may be planted with larger plants; however, this depends on structural support, soil depth, and irrigation requirements.
- ☐ Irrigation is required if the seed is planted in spring or summer. Use of a permanent smart (self-regulating) irrigation system, or other watering system, may help provide maximal water quality performance. Drought-tolerant plants should be specified to minimize irrigation requirements. For projects seeking "High Performance Building" recognition, ASHRAE Standard 189.1 states that potable water cannot be used for irrigating green roofs after they are established.
- ☐ Locate the green roof in an area without excessive shade to avoid poor vegetative growth. For moderately shaded areas, shade tolerant plants should be used.
- ☐ Project-specific planting recommendations should be provided by a landscape professional including recommendations on appropriate plants and irrigation requirements (if any) to ensure healthy vegetation growth.

Sizing

Appendix H provides minimum criteria for green roofs to be considered self-retaining and should be the governing sizing basis for green roofs.

HSC-6: SELF-RETAINING AREAS

Self-retaining areas are DMAs with the project site that do not generate runoff volumes or pollutant loads higher than natural conditions during a design capture storm event (85th percentile, 24-hour event). These DMAs can be excluded from sizing of downstream LID BMPs. There are two primary types of self-retaining DMAs:

- DMAs with impervious surface where the full effects of the impervious surface are mitigated by HSCs.
- DMAs without impervious surface where the condition of the pervious surface does not generate elevated runoff volumes or pollutant loads.

The following subsections provide criteria and examples for each type of DMA.

Criteria for DMAs with Impervious Surfaces

- HSC-1, HSC-2, HSC-5, if adequately sized, have the potential to fully mitigate the hydrologic effects of impervious surfaces and associated pollutant loading.
- In order to be self-retaining, these HSCs must be sized per the criteria in the respective fact sheet to provide a d_{HSC} that is equal to greater than the design capture storm depth for the project location. Sizing approaches differ by HSC.
- These HSCs must be clearly delineated in the WQMP and O&M Plan with appropriate covenents or similar mechanisms to ensure that they are maintained for the life of the project.

Criteria for DMAs without Impervious Surfaces

- If landscaped areas are designed as described in HSC-2 (impervious area dispersion), they are considered self-retaining.
- Other pervious areas may be considered self-retaining if it is reasonably demonstrated that they are not expected to produce runoff during the 85th percentile, 24-hour event. Examples of demonstration of self-retaining areas are provided below.

Examples of Methods of Demonstrating Self-Retaining Areas

In areas that can allow some infiltration and do not require underdrains, examples of demonstrating self-retaining criteria include:

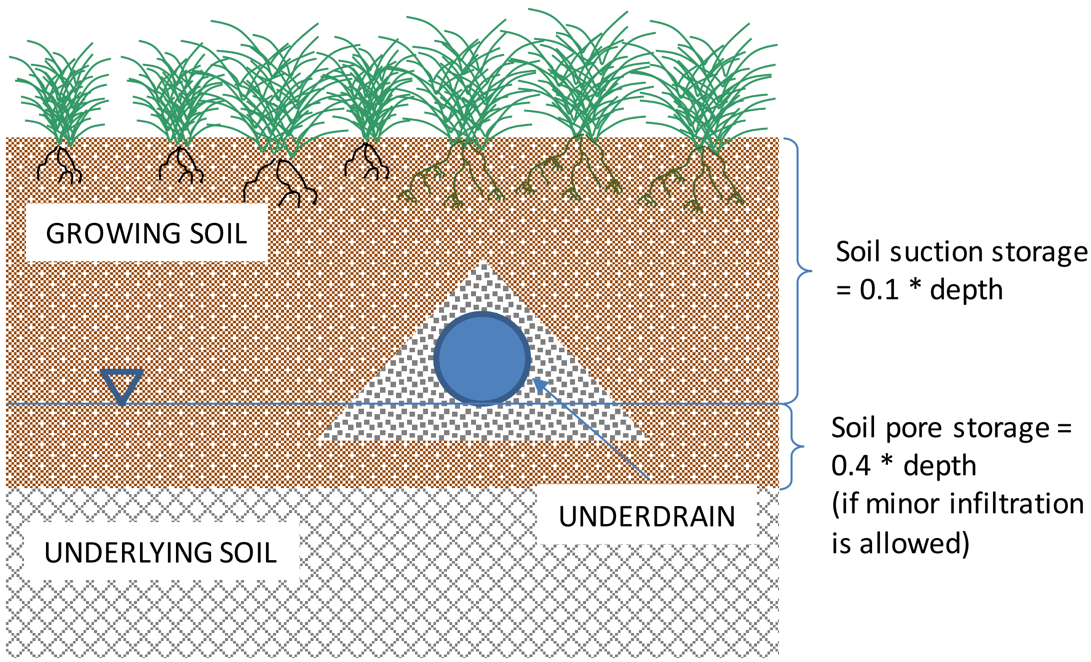
- Showing that soil infiltration rates reliably exceed 0.2 inches per hour.
- Showing that soil amendments provide freely drained pore spaces equal to at least the design capture storm depth.

In locations where partial infiltration is not feasible or pervious areas are designed with underdrain systems, this poses special considerations. Examples of how these areas could be considered self-retaining include:

- Do not allow excessive fertilizer or pesticides in the landscaped or turf areas that could wash through into underdrains, and

- Minimize nutrient content of growing soils consistent with MISC-1, and
- The soil above the underdrains should have suction (non-drained) storage capacity equal to the design capture storm depth. A reasonable estimate of 0.1 times the soil depth can be used to estimate the soil suction storage depth, or
- A water retention layer is provided below the elevation of the underdrains equal to the portion of the design capture storm depth that is not retained in the soil suction storage. This option requires that a small amount of infiltrated volume is feasible.
- Diagrams of these compartments are provided below. Note that this is not a preferred case; an underdrain below pervious area should only be used where needed for other reasons.

Diagrams of Water Retention Compartments in Pervious Areas with Underdrains



G.2 Miscellaneous Design Elements Fact Sheets (MISC)

MISC-1: BIORETENTION SOIL MEDIA

Bioretention soil media is a critical design element for bioretention BMPs, including INF-3, BIO-1, and BIO-6. It is also part of the design of some configurations of swales (BIO-2) and filter strips (BIO-3). Finally, it can be used as a filtering layer below infiltration systems to augment treatment and protect groundwater quality.

All bioretention soil media must provide appropriate properties for filtering stormwater and supporting vegetation.

In addition, for systems that filter water through BSM into an underdrain (BIO-1, BIO-6), additional criteria apply for media infiltration rate and chemical suitability to avoid pollutant leaching or premature clogging.

Also known as:

- *Bioretention media*
- *Biofiltration media*

Street-end biofiltration with planting/storage media
Source: City of Portland

Applicability of BSM Specification Elements

The model specifications described in this fact sheet include elements that do not apply to all BMP types. The following table identifies the elements of the model specifications that apply to the different types of BMPs.

BMP Type	Composition and Material Specifications	Basic Testing of Combined Mix	Infiltration Testing of Combined Mix	Chemical Suitability Testing of Combined Mix (leaching potential)
Bioretention with Underdrains (BIO-1, BIO-6)	X	X	X	X
BIO-1 or BIO-6 draining to nutrient-sensitive water bodies	X	X	X	X
Bioretention without Underdrains (INF-3)	X	X		
Amended Soils as Treatment Layer in Other Infiltration BMPs	X	X		
Swales (BIO-2) with Amended Soil Layer	X	X		
Filter Strips (BIO-3)	X	X		

General Criteria and Composition

- BSM should consist of 70 to 80% fine sand and 20 to 30% stable, well aged compost **by volume**, each meeting the quality standards described in the following sections. Alternative mix designs may be developed and tested to demonstrate suitability. Deviations from these ranges and material types may also be needed to achieve low nutrient leaching designs, where necessary. [*Note: The unit weight of compost is typically less than half of the unit weight of sand. Therefore, the percentage by mass is different.]*
- BSM should be designed to achieve the long term hydraulic design requirements associated with the design of the facility (i.e., design infiltration rate).
    - For BIO-1 and BIO-6 (systems with underdrains), the hydraulic conductivity should be evaluated via testing and conform to an acceptable range due to the importance of this value in sizing and performance of systems. Selection of an appropriate infiltration rate and evaluation of mix acceptability is described in “Infiltration Rate Evaluation” section of this Fact Sheet.
    - For other applications of BSM, infiltration rate of media is not as critical in design and can be assured via simpler checks on particle size information obtained as part of “Basic Whole Mix Testing Recommendations” part of this Fact Sheet.
- BSM should support the growth of hardy native plants suited to a well drained sandy soil. However BSM should not be excessively enriched, which can lead to excessive weeds and leaching of nutrients. Agronomic suitability and avoidance of excessive nutrient leaching is evaluated as part of “Basic Whole Mix Testing Recommendations” part of this Fact Sheet.
- BSM for use in BIO-1 or BIO-6 (systems with underdrains) should be more carefully evaluated for nutrient and other pollutant leaching potential as described in “Chemical Suitability Evaluation” part of this Fact Sheet.
- Blending should be conducted at a soil blending facility using an appropriate mechanical method to achieve complete and uniform mixing, such as a drum mixer. Moving piles of material around with a loader and/or transferring back and forth between bins to mix components is typically not adequate to achieve uniform mixing.
- Testing of the actual whole BSM mix to be delivered to the project is strongly recommended; prior testing conducted by the manufacturer may be used in place of project-specific testing provided that it is recent (within 6 months) and represents the actual mix proportions and compontents that are proposed for the project.
- Procurement, handling, and placement of BSM should adhere to guidelines in “Construction Guidelines” part of this Fact Sheet.

Sand for Bioretention Soil Media

- Sand should be free of wood, waste, coating such as clay, stone dust, carbonate, etc., or any other deleterious material.
- Sand should be washed.
- All aggregate passing the No. 200 sieve size should be non-plastic.
- Sand for bioretention should be analyzed by an accredited lab using #200, #100, #40, #30, #16, #8, #4, and 3/8 sieves (ASTM D 422 or as approved by the local permitting authority) and meet

the following gradation (Note: all sands complying with ASTM C33 for “fine aggregate concrete sand” comply with the gradation requirements below):

Sieve Size (ASTM D422)	Sieve Size (mm)	% Passing (by weight)	
		Minimum	Maximum
3/8 inch	9.5	100	100
#4	4.8	90	100
#8	2.4	70	100
#16	1.2	40	95
#30	0.60	15	70
#40	0.42	5	55
#100	0.15	0	15
#200	0.075	0	5

- Coefficient of Uniformity (Cu = D60/D10) should be equal to or equal to or greater than 4
- Note: the gradation of the sand component of the media an important major factor in the infiltration rate of the media mix. If the desired infiltration rate of the media cannot be achieved within the specified proportions of sand and compost), then it may be necessary to utilize sand at the coarser end of the range specified in the table above (“minimum” column) with more uniform particle size (i.e., poorly graded). Sand products such as “filter sand” and “top dressing sand” tend to meet the C33 specification and support higher infiltration rates.

Compost for Bioretention Soil Media

Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program). **It is expected that only select compost products will meet this specification.** Compost quality should be verified via a lab analysis to be:

- Feedstock materials shall be specified and include one or more of the following: landscape/yard trimmings, grass clippings, food scraps, and agricultural crop residues.
- Organic matter: 35-75% dry weight basis.
- Carbon and Nitrogen Ratio: 15:1 < C:N < 40:1; preferably above 20:1 to reduce the potential for nitrogen leaching/washout.
- Nitrogen between 0.6 and 3% by dry weight.
- Physical contaminants (manmade inert materials) not exceeding 1% by dry weight.
- Maturity/Stability (qualitative):Compost shall have dark brown color and a soil-like odor. Compost exhibiting a sour or putrid smell, containing recognizable grass or leaves, or is hot (120 F) upon delivery or rewetting is not acceptable.
- Maturity (seed emergence and seedling vigor): greater than 80% relative to positive control (Method TMECC 5.05-A, USDA and U.S. Composting Council)

- Stability (Carbon Dioxide evolution rate): less than 2.5 mg CO2-C per g compost organic matter (OM) per day or less than 5 mg CO2-C per g compost carbon per day, whichever unit is reported. (Method TMECC 5.08-B, USDA and U.S. Composting Council). Alternatively a Solvita rating of 6 or higher is acceptable.
- Toxicity: any one of the following measures is sufficient to indicate non-toxicity:
  - NH4:NH3 < 3
  - Ammonium < 500 ppm, dry weight basis
  - Seed Germination > 80% of control
  - Plant trials > 80% of control
  - Total Boron should be <80 ppm, soluble boron < 2.5 ppm
- Salinity: < 6.0 mmhos/cm or Soluble Salt Concentration less than 10 dS/m (Method TMECC 4.10-A, USDA and U.S. Composting Council).
- pH between 6.5 and 7.5 (may vary with plant palette)
- Compost for bioretention should be analyzed by an accredited lab using #200, ¼ inch, ½ inch, and 1 inch sieves (ASTM D 422 or as approved by the local permitting authority) and meet the following gradation:

Sieve Size (ASTM D422)	% Passing (by weight)	
	Minimum	Maximum
1 inch	99	100
½ inch	90	100
¼ inch	40	90
#200	0	10

- Tests should be sufficiently recent to represent the actual material that is anticipated to be delivered to the site. If processes or sources used by the supplier have changed significantly since the most recent testing, new tests should be requested. Compost quality can vary significanly by season and by batch.
- Note: the gradation of compost used in bioretention media can have an important influence on the saturated hydraulic conductivity of the media. To achieve a higher saturated hydraulic conductivity, it may be necessary to utilize compost at the coarser end of this range ("minimum" column). The percent passing the #200 sieve (fines) is believed to be the most important factor in hydraulic conductivity. In addition, a coarser compost mix provides more heterogeneity of the bioretention media, which is believed to be advantageous for more rapid development of soil structure needed to support health biological processes. This may be an advantage for plant establishment with lower nutrient and water input.

Mulch for Bioretention Soil Media

- The bioretention panting area should generally be covered with 2 to 4 inches (average 3 inches) of well aged, double or triple shredded mulch at the time of construction and an additional placement of 1 to 2 inches of mulch should be added annually. Mulch should be stockpiled and stored at least 12 months prior to application to the BMP and must be non-floating to avoid clogging of overflow structures.*The intention is to help sustain the nutrient levels, suppress weeds, retain moisture, and maintain infiltration capacity*.

- Inorganic mulch such as rock, may be used.

Basic Whole Mix Testing Recommendations

Basic whole mix testing should be done for any application of BSM in stormwater BMPs. The blended BSM should be submitted to an agronomic laboratory for a standard “Agronomic Soil Suitability Test” with texture class and organic matter analyses included (estimated $110 to $150).

- Organic Matter: between 2 and 5 percent by dry weight

  [Note: This range is not incompatible with the organic content requirements of compost. If compost is 20 percent of the mix by volume, this represents about 7.5 percent of the mix by dry weight. If compost has an organic fraction of 35 percent to 75 percent by dry weight, then the total mix organic content would be 2.5 to 5.5 percent]

- Total Nitrogen: 0.1 to 0.25% by dry weight (100 to 250 mg/kg)

  [Note: Similar to the explanation above, this is not incompatible with the compost nitrogen requirements]

- Plant Available Phosphorus (also known as “P Index”) (based on weak acid extraction: ammonium Bicarbonate/DTPA soil analysis or similar): 10 to 50 mg/kg (P Index 10 to 50)
- Percent Sand/Silt/Clay: Less than 2 percent clay; 5 to 20 percent silt or infiltration testing showing greater than 10 inches per hour
- pH range: 6.0-7.5
- Salinity less than 3.0 millimho/cm (as measured by electrical conductivity)
- Sodium adsorption ration (SAR) less than 3.0
- Chloride less than 150 ppm
- An assessment of agricultural suitability for hearty, well-suited plants based on test results should be conducted, including recommendations for adding amendments, chemical corrections, or both.

Testing reports should include:

- Date of Testing
- Project Name
- The Contractor’s Name
- Source of Materials and Supplier’s Name
- Adequate information to demonstration conformance with the criteria above.

Rationale: A BSM that aheres to the general guidelines for mix composition, sand properties, and compost properties should provide acceptable properties for most applications. However, due to ranges of physical and chemcial properties that exist in sand and compost specifications and variability in supply stocks, basic testing of the specific whole BSM proposed for the project is strongly recommended. The ranges of criteria are intended to avoid mixes that have clear material quality issues.

Infiltration Rate Evaluation

This section appiles to BIO-1 or BIO-6 where a specific range of media infiltration rates is established in design and is critical for sizing.

- The saturated hydraulic conductivity or infiltration rate of the whole BSM shall be measured by one of the following methods:
    - Measurement of hydraulic conductivity (USDA Handbook 60, method 34b) (commonly available as part of standard agronomic soil evaluation – estimated $30 to 50 per sample), or
    - ASTM D2434 Permeability of Granular Soils (at approximately 85 percent relative compaction Standard Proctor, ASTM D698)
- BSM should conform to hydraulic criteria associated with the BMP design configuration that best applies to the facility where the BSM will be installed (options describe below).
    - **Systems with hydraulic control on the outlet of the underdrain system** (i.e., outlet control). For systems in which the flowrate of water through the media is controlled via an outlet control device (e.g., orifice or valve) affixed to the outlet of the underdrain system, the infiltration rate or hydraulic conductivity of the media should be at least 20 inches per hour and not more than 40 inches per hour. The outlet control device should control the flowrate to between 5 and 12 inches per hour. This configuration reduces the sensitivity of system performance to the permeability of the material, reduces the likelihood of short circuiting through media, and allows more precise design and control of system flow rates. For these reasons, outlet control should be considered the preferred design option.
    - **Systems with free-flowing underdrain system** (i.e., flowrate is controlled by the permeability of the BSM). For systems with underdrains that are not restricted, the BSM should have minimum measured hydraulic conductivity of 8 inches per hour to ensure adequate flow rate through the BMP and longevity of the system. This results in a recommended design infiltration rate of 2 to 4 inches per hour to account for potential compaction and clogging. The BSM should have a maximum measured hydraulic conductivity of no more than 20 inches per hour to provide adequate contact time and treatment. Where this limit cannot be achieved, an outlet controlled configuration should be considered. In all cases, an upturned elbow system on the underdrain, measuring 6 to 12 inches above the invert of the underdrain, should be used to control velocities in the underdrain pipe and reduce potential for solid migration through the system.

Rationale: The media infiltration rate is a critical parameter in sizing and design of BIO-1 and BIO-6. It is necessary to confirm that the infiltration rate is reasonably consistent with what has been used in sizing and design and is capable of providing adequate treatment. Infiltration rates that are too slow may not provide long term capture performance adequate to meet sizing criteria. Infiltration rates that are too high may not provide adequate treatment or can be susceptible to short-circuiting unless used in an outlet controlled configuration.

Chemical Suitability Evaluation

This section appiles to BIO-1 or BIO-6 (systems with underdrains). In these systems, it is more critical to ensure that significant increases in pollutants will not occur as a result of filtration of water through the media (i.e., pollutant leaching). Nutrients are the most common form of leached pollutants. However, metals have also been observed.

The basic testing described above is adequate where nutrients or metals are not identified as impairments or TMDLs.

Where nutrients or metals are identified as impairments or TMDLs in any receiving water, the standard "Agronomic Soil Suitability Test" should be augmented with Saturated Media Extract Method (aka "saturation extract") testing that covers at least the following parameters.

- Nitrate as N: < 3 mg/L

- Plant Available Phosphorus (P Index): 10 to 30 mg/kg (this is a tighter range than specified for basic evaluation above)
- Zinc < 0.1 mg/L (100 ppb)
- Copper < 0.025 mg/L (25 ppb)
- Lead < 0.025 mg/L
- Arsenic < 0.02 mg/L
- Cadmium < 0.01 mg/L
- Mercury < 0.01 mg/L
- Selenium < 0.01 mg/L

The Synthetic Precipitation Leaching Procedure (SPLP) (EPA SW-846, Method 1312) may also be used.

Criteria should be met as stated where a pollutant is associated with a water quality impairment or Total Maximum Daily Load (TMDL) in any downstream receiving water. Criteria may be waived or modified, at the discretion of the reviewer, where a pollutant does not have a nexus to a water quality impairment or TMDL of downstream receiving water(s).

Note that Saturation Extract and SPLP tests are expected to result in somewhat more leaching than would be experienced with real stormwater; therefore a direct comparison to water quality standards or effluent limitations is not appropriate.

Alternative Mix Components and Proportions

Alternative mix components and proportions may be utilized, provided that the whole blended mix conforms to the criteria identified in the Basic Whole Mix Testing, Infiltration Rate Evaluation, and Chemical Suitability Evaluation, as applicable. Alternative mix designs may include alternative proportions, alternative organic amendments (e.g., peat, coco coir pith) and/or use of natural soils. Alternative mixes are subject to approval by the reviewer. Alternative mixtures may be particularly applicable for systems with underdrains in areas where phosphorus is associated with a water quality impairment or a Total Maximum Daily Load (TMDL) in a downstream receiving water.

Construction Guidelines

- The Contractor should not deliver or place soils in wet or muddy conditions. The Contractor should protect soils and mixes from absorbing excess water and from erosion at all times. The Contractor should not store materials unprotected from rainfall events (>0.25 inches). If water is introduced into the material while it is stockpiled, the Contractor should allow material to drain prior to placement
- BSM should be thoroughly mixed prior to delivery using mechanical mixing methods such as a drum mixer.
- BSM should be lightly compacted and placed in loose lifts approximately 12 inches (300 mm) to ensure reasonable settlement without excessive compaction, such as via a rolling landscaping compaction drum (hand operated). Compaction within the BSM area should not exceed 75 to 85% standard proctor within the designed depth of the BSM. Machinery shouldl not be used in the bioretention facility to place the BSM. A conveyor or spray system should be used for media placement in large facilities. Low ground pressure equipment may be authorized for large facilities at the discretion of the reviewer.

- Placement methods and BSM quantities should account for approximately 10 percent reduction in media volume due to settling. Planting methods and timing should account for settling of media without exposing plant root systems.
- The Permittee construction inspector may request up to three double ring infiltrometer tests (ASTM D3385) or approved alternate tests to confirm that the placed material meets applicable infiltration rate range. In the event that the infiltration rate of placed material does not meet applicable criteria, the Permittee may require replacement and/or decompaction of materials.
- Close adherence to the material quality controls herein are necessary in order to assure sufficient permeability to infiltrate/filter runoff during the life of the facility, support healthy vegetation, and minimize pollutant leaching.
- Acceptance of the material should be based on test results conducted no more than 120 days prior to delivery of the blended BSM to the project site and certified to be representative of the mix composition that is actually used. For projects installing more than 100 cubic yards of BSM, batch-specific tests of the blended mix should be provided to the Permittee inspector for every 100 cubic yards of BSM along with a site plan showing the placement locations of each BSM batch within the facility.

Integration with Other Specifications

BSM specifications are related to, and may depend or have dependency on other specifications, including but not limited to:

- Filter course and drainage layer (See MISC-3)
- Plantings and Hydroseed (See MISC-4)
- Underdrains (See BIO-1)
- Outlet control structures (See BIO-1)

Narrative Guidance for Balancing Plant Growth with Nutrient Leaching

Where the BMP discharges to receiving waters with nutrient impairments or nutrient TMDLs, there is a particular balance that needs to be maintained between providing enough nutrients for plant growth while avoiding chronic leaching of nutrients from the media.

- In general, the potential for leaching of nutrients can be minimized by:
    - Utilizing stable, aged compost (as required of media mixes under all conditions).
    - Utilizing other sources of organic matter, as appropriate, that are safe, non-toxic, and have lower potential for nutrient leaching than compost (e.g., wood compost, peat, coco coir pith).
    - Reducing the content of compost or other organic material in the media mix to the minimum amount necessary to support plant growth and healthy biological processes.
- A botanist, agronomist, and/or landscape architect can be consulted to assist in balancing the interests of plant establishment, water retention capacity (irrigation demand), and the potential for nutrient leaching. The following practices should be considered in developing the media mix design:
    - The actual nutrient content and organic content of the selected compost source should be considered when specifying the proportions of compost and sand. The compost specification allows a range of organic content over approximately a factor of 2 and nutrient content may vary more widely. Therefore determining the actual organic content

and nutrient content of the compost expected to be supplied is important in determining the proportion to be used for amendment.

  - A commitment to periodic soil testing for nutrient content and a commitment to adaptive management of nutrient levels can help reduce the amount of organic amendment that must be provided initially. Generally, nutrients can be added planting areas through the addition of organic mulch, but cannot be removed.
  - Plant palettes and the associated planting mix should be designed with native plants where possible. Native plants generally have a broader tolerance for nutrient content, and can be longer lived in leaner/lower nutrient soils. An additional benefit of lower nutrient levels is that native plants will generally have less competition from weeds.
  - Nutrients are better retained in soils with higher cation exchange capacity (CEC). CEC can be increased through selection of organic material with naturally high CEC, such as peat, and/or selection of inorganic material with high CEC such as some sands or engineered minerals (e.g., low P-index sands, zeolites, rhyolites, etc). Including higher CEC materials would tend to reduce the net leaching of nutrients.
  - Soil structure can be more important than nutrient content in plant survival and biologic health of the system. If a good soil structure can be created with very low amounts of compost, plants survivability should still be provided. Soil structure is loosely defined as the ability of the soil to conduct and store water and nutrients as well as the degree of aeration of the soil. While soil structure generally develops with time, planting/storage media can be designed to promote earlier development of soil structure. Soil structure is enhanced by the use of amendments with high hummus content (as found in well-aged organic material). In addition, soil structure can be enhanced through the use of compost/organic material with a distribution of particle sizes (i.e., a more heterogeneous mix).
  - Younger plants are generally more tolerant of lower nutrient levels and tend to help develop soil structure as they grow. Starting plants from smaller transplants can help reduce the need for organic amendments and improve soil structure. The project should be able to accept a plant mortality rate that is somewhat higher than starting from larger plants and providing high organic content.

- With these considerations, it is anticipated that less than 20 percent compost amendment could be used, while still balancing plant survivability and water retention.

We wish to express our gratitude to following individuals for their feedback on the design of planting/storage media for nutrient sensitive receiving waters in Southern California.

Deborah Deets, City of Los Angeles Bureau of Sanitation

Drew Ready, LA and San Gabriel Rivers Watershed Council

Rick Fisher, ASLA, City of Los Angeles Bureau of Engineering

Dr. Garn Wallace, Wallace Laboratories

Glen Dake, GDML

Jason Schmidt, Tree People

The guidance provided herein does not reflect the individual opinions of any individual listed above and should not be cited or otherwise attributed to those listed.

MISC-2: AMENDED SOILS

Soil amendments alter the soil characteristics to allow it to absorb, infiltrate, and retain more water to help reduce runoff volume and velocity, filter pollutants, increase the quality and quantity of vegetation, and reduce erosion potential more effectively than soils without soil amendments. Mulch is an amendment that is added on the top of the soil, rather than mixed into the soil, which reduces evaporation and adds to the aesthetics of a site. Compost and fertilizers are common soil amendments that must be completely mixed into the soil to function properly.

Soil amended area at U.S. EPA Ariel Rios building.
Source: http://www.epa.gov/oaintrnt/stormwater/hq_projects.htm

General Criteria

- Compost, soil conditioners, and fertilizers should be roto-tilled into the native soil to a minimum depth of 6" (12 inches preferred). Mulch at grade should be spread over all planting areas to a depth of 3".
- Sand can be used as an amendment to improve the drainage rates of amended soils. Sand should be free of stones, stumps, roots or other similar objects larger than 5 mm
- Incorporating compost and other organics into the root zone results in enhanced biological activity, attenuation of envrionemntal contaminants, increased moisture holding capacity, and improved soil structure. Compost should be a well decomposed, stable, weed free organic matter source derived from waste materials including yard debris, wood wastes, or other organic materials not including manure or biosolids meeting standards developed by the US Composting Council (USCC). The product shall be certified through the USCC Seal of Testing Assurance (STA) Program (a compost testing and information disclosure program).
- All soil amendments should be free of stones, stumps, roots or other similar objects larger than 2 inches.
- All soil amendments should be free of glass, plastic, metal, and other deleterious materials.

Accounting for Soil Amendments in Sizing Calculations

Amended soils should be used as part of HSC-2 Impervious Area Dispersion, and to increase the retention volume of Infiltration and Biotreatment BMPs (except where a more specific bioretention soil mix is required as described in MISC-1)

Amending soils can be used to classify an area as self-retaining pervious area per HSC-6.

MISC-3: FILTER COURSE AND UNDERDRAIN PIPE DESIGN

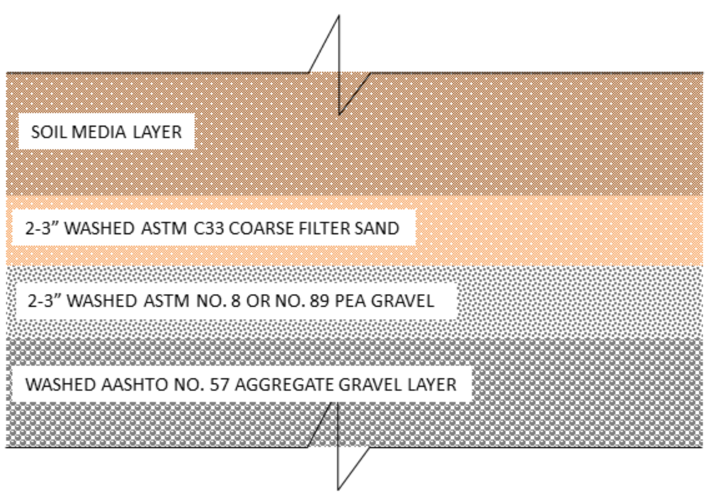
Many LID BMPs include a soil media layer underlain by an aggregate gravel layer that may or may not include an underdrain. To keep the media particles from migrating into the aggregate gravel layer, a filter course is used. While geotextile filter fabrics have been used in the past at the interface of the soil media and gravel aggregate layers, experience has shown that filter fabric is a common point of failure in stormwater BMPs, either by clogging, or by allowing media to migrate into the underdrain system. A 'bridging' or 'choking' layer is preferred to separate the gravel aggregate layer and the soil media. This approach consists of progressively graded layers that progress from finer to coarser materials moving from top to bottom.

This fact sheet provides a recommended filter course that has been estimated to provide appropriate bridging and permeability for typical soil media and aggregate gravel used in LID BMPs. This filter course consists of a coarse sand layer, underlain by pea gravel, underlain by the aggregate gravel. As long as the recommendations below are used for the filter course and aggregate gravel, then no calculations are needed to demonstrate the adequacy of the filter course.

This fact sheet also provides recommended design criteria for slotted underdrain pipe.

Recommended Filter Course and Aggregate Gravel Layer Design

The recommended design for the filter course is shown below. It consists of 2 to 3 inches of ASTM C33 coarse sand at the bottom of the media layer, underlain by 2 to 3 inches of ASTM No. 8 or No. 89 gravel. The design assumes that the aggregate gravel layer consists of AASHTO No. 57 gravel. The gradation limits to meet the standard classifications are shown in the tables below. If the project proposes significantly different gradations of any layer, then calculations showing that the filter course is adequate are required as references in the "Calculations to Support Custom Filter Course" section of this Fact Sheet.



Gradation Limits for ASTM C33 Concrete Sand

Sieve Size	Percent of Particles Smaller than Sieve Size
0.375 inches	100
No. 4 (0.187 inches)	95-100
No. 8 (0.093 inches)	80-100
No. 16 (0.046 inches)	50-85
No. 30 (0.024 inches)	25-60
No. 50 (0.012 inches)	5-30
No. 100 (0.006 inches)	0-10
No. 200 (0.003 inches)	0 [fines should not be present in washed stone]

Gradation Limits for ASTM No. 8 Pea Gravel (aka 3/8" stone)

Sieve Size	Percent of Particles Smaller than Sieve Size
0.5 inches	100
0.375 inches	85-100
No. 4 (0.187 inches)	10-30
No. 8 (0.093 inches)	0-10
No. 16 (0.046 inches)	0-5

Gradation Limits for ASTM No. 89 Pea Gravel (aka 1/4 to 3/8" stone)

Sieve Size	Percent of Particles Smaller than Sieve Size
0.5 inches	100
0.375 inches	90-100
No. 4 (0.187 inches)	20-55
No. 8 (0.093 inches)	5-30
No. 16 (0.046 inches)	0-5
No. 50 (0.046 inches)	0-5

Gradation Limits for AASHTO No. 57 Aggregate Gravel (aka 3/4" open graded base)

Sieve Size	Percent of Particles Smaller than Sieve Size
1.5 inches	100
1 inch	95-100
0.5 inches	25-60
No. 4 (0.187 inches)	0-10
No. 8 (0.093 inches)	0-5

For systems with deeper reservoirs, it is acceptable to utilize another layer of stone below the No. 57 stone, such as 1 ½" inch base or larger.

Custom Filter Course Layer

Other filter course configurations are also acceptable, but thorough descriptions of each of the materials used as well as supporting calculations showing their adequacy to maintain permeability and prevent migration of media particles is required. Methods of completing these calculations can be obtained from:

- Chapter 26 of the Natural Resources Conservation Service Part 633 National Engineering Handbook (**https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=18397.wba**) or
- Table 2 of the United States Golf Association Recommendations for a Method of Putting Green Construction **https://www.usga.org/content/dam/usga/images/course-care/2004%20USGA%20Recommendations%20For%20a%20Method%20of%20Putting%20Green%20Cons.pdf**.

Calculations need to be completed for each interface between media or gravel of different sizes to show adequate choking and permeability. For example, the recommended filter course design included calculations between the coarse sand layer and the pea gravel and between the pea gravel and the aggregate gravel layers.

Slotted Underdrain Pipe

- Underdrains should be slotted, PVC pipe conforming to ASTM D 3034 or equivalent or corrugated, HDPE pipe conforming to AASHTO 252M or equivalent.
- Slots should be 4-6 rows cut perpendicular to the axis of the pipe or right angles to the pitch of corrugations.
- Slots should be 0.04 to 0.1 inches wide and 1 to 1.25 inches long.
- Slots should be longitudinally spaced such that the pipe has a minimum of 2 square inches of "slot open area" in each lineal foot of pipe.
- Slot space is computed as the product of the length, width, number of rows, and number of slots per row in 1 foot of pipe. For example, a pipe containing 6 rows of 1"x 0.067" slots with 12 slots per lineal foot of pipe would have an open area of 6x12x1"x0.067" = 4.8 sq-inch open area per lineal foot of pipe.

MISC-4: RECOMMENDED PLANT LIST

Vegetation is an integral element of biotreatment BMPs in order to help remove pollutants, stabilize soils, support soil microbial communities, and resist clogging. However, not all vegetation will be effective for each BMP type, so selecting a suitable type of vegetation is very important to BMP performance. A recommended plant list is provided in this fact sheet along with general guidelines.

Source: Geosyntec Consultants

General Guidelines for Plant Selection

- Plants should be native or climate-appropriate non-invasive species.
- Multiple species per BMP are recommended to provide diversity. A mix of grasses, bunch grasses, and shrubs should be considered.
- Species should be suited to the conditions the BMP will encounter (periodic inundation, sustained dry periods, relatively course-grained soils, etc. The climate and conditions vary by location within Orange County, by BMP type, by application type, and even within a BMP. For example, within a bioinfiltration BMP, the vegetation at the bottom of the BMP will be regularly inundated, while the vegetation on the side slopes will only rarely be inundated, so different vegetation types may be necessary.
- Species selected should not require regular use of fertilizers and pesticides. Augmentation of surface soils with a stable, well-aged, certified compost is acceptable from time to time. Slow release organic fertilizers applied at a minimum necessary rate may be acceptable.
- Plants should be compatible with the irrigation proposed. Permanent irrigation may be necessary to sustain plants. However, plants should not be dependent on frequent irrigation. Additionally, plants that require or tolerate periodic irrigation should be planted in separate areas from those that do not tolerate seasonal irrigation.
- In any case, the vegetation selected should be suited to the climate and conditions of the BMP, must not cause or contribute to contamination of runoff or invasion of habitat, and, should be selected to remove pollutants and support biological communities that remove pollutants to the extent possible.
- This is not meant to be an exhaustive list of all compatible plant species. Other plant types may be used as long as they are compatible with the purposes of vegetation in the BMP as discussed above.

A qualified landscape architect or agronomist familiar with the stormwater BMPs may be consulted to select a plant palette that fits the needs of the project. Plant selection should fit the constraints and media selected for the BMP.

RECOMMENDED PLANT NAMES, IRRIGATION REQUIREMENTS, BMP LOCATION, AND BMP APPLICABILITY

Plant Name		Irrigation Requirements		Preferred Location in Basin		LID BMP Applicability[3]				
Latin Name	**Common Name**	**Temporary Irrigation during Plant Establishment Period**	**Permanent Irrigation (Drip / Spray)[1]**	**Basin Bottom**	**Basin Side Slopes**	**Biofiltration (BIO-1/BIO-5/ BIO-6/BIO-7/INF-3)**	**Vegetated Swale (BIO-2)[2]**	**Vegetated Filter Strip (BIO-3)[2]**	**Dry Extended Detention Basin (BIO-4)**	**Infiltration Basin (INF-1)**
SHRUBS / BUNCH GRASSES										
Achillea millefolium	Yarrow[2]	X			X	X	X		X	X
Anemopsis californica	Yerba Manza	X			X	X	X		X	X
Baccharis douglasii	Marsh Baccahris	X	Optional	X		X	X		X	X
Carex praegracillis	California Field Sedge	X	Optional	X		X	X		X	X
Carex spissa	San Diego Sedge	X	Optional	X		X	X		X	X
Carex subfusca	Rusty Sedge	X	Optional	X	X	X	X		X	X
Eleocharis macrostachya	Pale Spike Rush	X	Optional	X		X	X		X	X
Iva hayesiana	Hayes Iva[2]	X			X	X	X		X	X
Juncus Mexicana	Mexican Rush	X	Optional	X	X	X	X		X	X
Jucus patens	California Gray Rush	X	Optional	X	X	X	X		X	X
Mahonia nevinii	Nevin's Barberry	X			X	X	X		X	X
Mimulus cardinalis	Scarlet Monkeyflower[2]	X		X	X	X	X		X	X
Ribes speciosum	Fushia Flowering Goose. [2]	X			X	X	X		X	X
Rosa californica	California Wild Rose[2]	X	Optional		X	X	X		X	X
Scirpus cernuus	Low Bullrush	X	Optional	X		X	X		X	X
Sisyrinchium bellum	Blue-eyed Grass[2]	X			X	X	X		X	X
GRASSES/GROUNDCOVER										
Agrostis pallens	Thingrass	X			X	X	X	X	X	X
Distichlis spicata	Salt Grass	X	Optional	X		X	X	X	X	X
Festuca californica	California Fescue[2]	X	Optional		X	X	X	X	X	X
Festuca rubra	Red Fescue[2]	X	Optional	X	X	X	X	X	X	X
Leymus condensatus	Canyon Prince Wild Rye	X	Optional	X	X	X	X	X	X	X
Muhlenburgia rigens	Deergrass	X	Optional	X	X	X	X	X	X	X

1. Some plants will benefit from supplemental irrigation, particularly those on basin side slopes and further inland. However, the irrigation regime should be sparse and allow for complete drying. Excessive watering during the summer can be problematic for native plants. Plants that could benefit from or tolerate periodic irrigation are identified as "optional" in this column.
2. Bunching grasses should be avoided entirely in filter strips as the desire is to provide a very uniform stem structure. Bunching grasses can be used in swales but should be augmented with non-bunching grasses and ground covers.
3. Many of these plants could be applicable to many different BMP types. In general, BMPs such as biofiltration that have mulch on the basin bottom will use shrubs/bunchgrasses on the basin bottom and grasses/groundcover on the side slopes. BMPs that do not use mulch require denser groundcover, so they typically use grasses, but may also incorporate shrubs/bunchgrasses, as needed.

MISC-5: PRETREATMENT GUIDANCE

The fact sheet is intended to define what is meant by various pretreatment approaches and providing ratings of effectiveness of these approaches. See **Section 4.4.2** of the TGD for additional information. This fact sheet contains a replication of some information from **Section 4.4.2**.

Pretreatment Approach or BMP Type	Description	Performance		Appropriate Uses
		Sediment Removal	GW Protection	
Settling chambers or sacrificial forebay	At least 10 percent (preferably 20 percent) additional volume beyond DCV is set aside for pre-settling of particulates at the entry point to the BMP	Moderate	Negligible	Where land use is low risk or in combination with other approaches
Catch basin inserts	Manufactured systems intended to strain coarse solids from stormwater as it enters catch basins.	Negligible	Negligible	For trash control only; no significant benefit for clogging or GW quality.
Sacrificial mulch layer	Mulch layer provided on the surface of vegetated systems with commitments to yearly maintenance of mulch such that sediment will be removed as it is accumulated	Moderate	Limited	Bioretention systems where clogging risk is low
Sacrificial sand layer	A course sand layer above the infiltrating surface with a filtration rate 5 to 10 times higher than underlying soil; Filter layer will be removed and replaced when drawdown rates become impaired	Moderate	Negligible	Non-vegetated surface or subsurface systems where sand layer can be removed and replaced
Amended media layers	An engineered bioretention soil media layer (Meeting specification for MISC-1) installed in the surface of a bioretention BMP or infiltration basin to pre-filter sediment and treat other pollutants. Infiltration rate is at least 5 times higher than underlying soil, up to a maximum of 20 inches per hour. Filter layer will be removed and replace when drawdown rates become impaired	Moderate to high	Medium to high	Bioretention or infiltration systems; Ensure that media layer K_{design} has an appropriate factor of safety over the underlying K_{design} to not become the limiting surface

Pretreatment Approach or BMP Type	Description	Performance		Appropriate Uses
		Sediment Removal	GW Protection	
Approved "pretreatment" devices	A system with an approved General Use Level Designation for "pretreatment" by Washington State TAPE or equivalent. This must be supported by current ratings. Maintenance must be performed at intervals specified in TAPE approval documents.	Moderate	Limited	Underground or surface systems with adequate head for pretreatment device and low to moderate clogging risk
Non-proprietary biotreatment or treatment control BMPs	A biotreatment or treatment control BMP with M or H performance for pollutants of concern. Full design and O&M criteria applicable to the BMP type must be met.	High	Medium to high	Where clogging risk and/or groundwater risks are elevated.
Approved "treatment" or "biofiltration" proprietary BMP devices	A system with an approved General Use Level Designation for "basic treatment" or "enhanced treatment" by Washington State TAPE or equivalent. Full design and O&M criteria applicable to the BMP type must be met.	High	Medium to high	Where clogging risk and/or groundwater risks are elevated.

G.3 Full Infiltration BMP Fact Sheets (INF)

INF-1: INFILTRATION BASIN

Category: Full Infiltration

Also known as:
Recharge Basin
Infiltration Pond

Source: Emily Benson

Infiltration basins are BMPs designed to capture runoff and infiltrate it into the underlying soil. An infiltration basin consists of an earthen basin constructed with a flat bottom. An energy dissipating inlet must be provided, along with an emergency spillway to control excess flows. A forebay settling basin or separate measure must be provided as pretreatment. An infiltration basin retains the full DCV in the basin and allows it to percolate into the underlying soils, so it is only used for DMAs categorized as feasible for full infiltration. The bottom of an infiltration basin is typically vegetated with dryland grasses; however, other types of vegetation are permissible if they can survive periodic inundation and long inter-event dry periods. Vegetation is required as it is helpful in maintaining infiltration rates over time and helps reduce erosion from the side slopes into the basin.

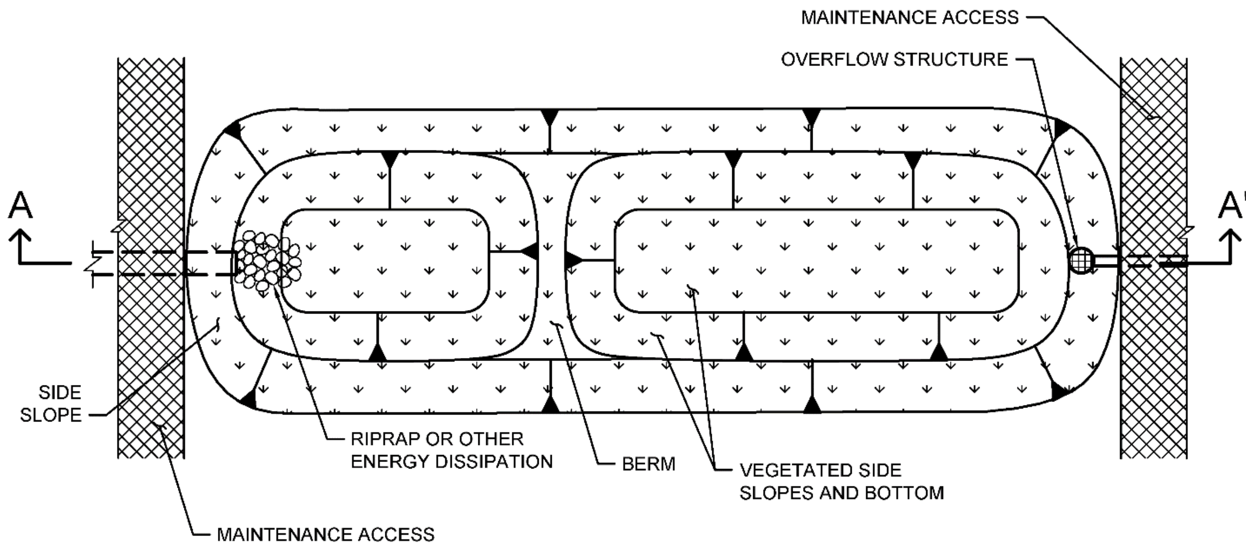
Pollutant Removal Considerations

Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics
H	H	H	H	H	H

Recommended Siting Criteria

	Siting Criteria	Intent/Rationale
☐	BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Must not negatively impact existing site geotechnical concerns.
☐	BMP is located in areas of the site most suitable for full infiltration.	A full infiltration BMP must be sited such that the underlying soil infiltration rates will facilitate infiltration of the full DCV and this can be assured through construction and operation.
☐	BMP should not be located in fill areas, unless permeable engineered fill can be used.	The ability to fully infiltrate the DCV must be determined prior to construction and assured through construction. In areas that will have traditional compacted fill, it is not possible to determine the infiltration rate. Additionally, where the infiltrating surface is deep below existing grade, the quality of investigation may be compromised.
☐	Sediment sources must be controlled prior to operation of the system.	Facility should not be used in areas that will continue to receive elevated sediment loading following construction, such as from open space areas.

Example Schematic Design - Plan and Section View



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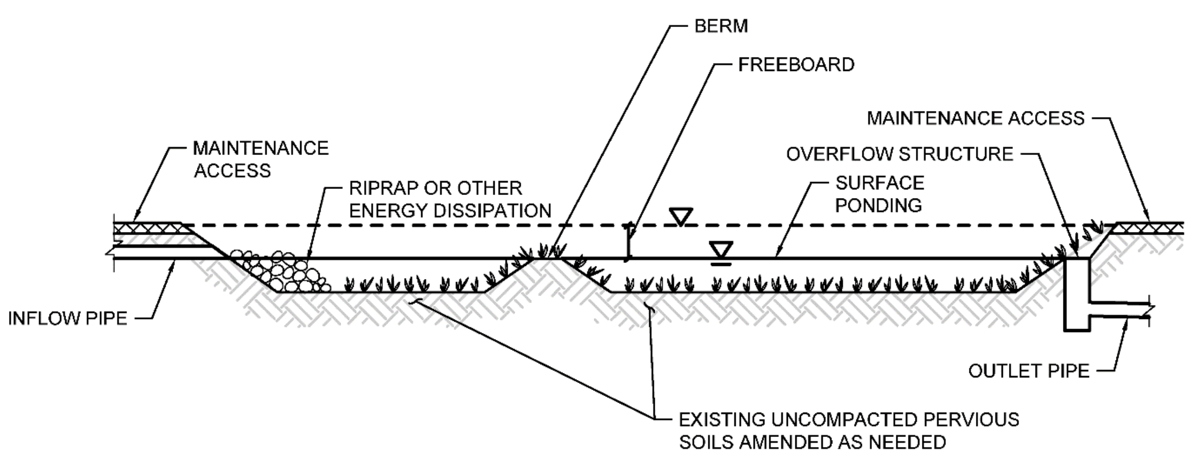

SECTION A-A'
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Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard	≥ 1 foot (offline facilities) ≥ 2 foot (inline facilities)	Freeboard provides room for water to rise above overflow structures and minimizes risk of uncontrolled surface discharge. Lower freeboard is allowable if there is an acceptable alternative overflow method.
Surface Ponding	≤ 3 feet preferred	Increasing ponding depth increases the risk of clogging and mounding. It also increases the sensitivity of the system to declines in infiltration rates.
Ponding Area Side Slopes	3H:1V or shallower	Gentler side slopes are safer, less prone to erosion, establish vegetation more quickly, and are easier to maintain.
Forebay Volume (if forebay used for pretreatment)	20 percent of total volume (not counted in DCV) to provide a moderate level of pretreatment	Provides a dedicated volume for settling and sediment accumulation.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Pretreatment	
☐ Pretreatment is provided to remove coarse sediment and organic debris per criteria in **TGD Chapter 4**.	BMP performance and longevity is increased. Premature clogging is avoided.
☐ Mechanical pretreatment (e.g., hydrodynamic separator, treatment control BMP) are preferred.	A forebay has limited effectiveness and can become clogged rapidly, leading to standing water.
Forebay	
☐ Volume is ≥ 20% of facility volume, if forebay is used.	An adequately sized forebay to trap sediment can decrease frequency of required maintenance.
Surface Ponding	
☐ Finish grade of the facility has ≤3 inches of elevation difference across the bottom of the facility.	Flatter surfaces reduce erosion and channelization within the facility and reduce the potential for development of preferential pathways.
☐ Surface ponding is limited to a maximum 48-hour drawdown time.	A maximum 48-hour drawdown time is recommended for plant health and vector control. A shorter surface ponding drawdown time increases the volume available to capture subsequent storms and can result in smaller required volume.

	Design Criteria	Intent/Rationale
Vegetation		
☐	Temporary irrigation is needed; a permanent irrigation system should be considered to support periodic reestablishment of vegetation after maintenance.	Seasonal irrigation may be needed to ensure robust vegetative processes in relatively coarse-grained media material.
☐	Plant materials should be tolerant of summer drought (unless irrigated), ponding fluctuations, and saturated soil conditions for up to 96 hours (accounting for back to back storms); native plant species and/or hardy cultivars that are not invasive and do not require chemical fertilizers or pesticides should be used to the maximum extent feasible. See recommended plant list in **Fact Sheet MISC-4**.	Plants suited to the climate and ponding depth are more likely to survive.
Inflow and Outflow Structures		
☐	Inflow and outflow structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐	Inflow velocities onto the infiltration basin bottom are held to less than 1 ft/s. Dispersed flow or energy dissipation for piped inlets should be provided at inlet to prevent erosion.	High inflow velocities can cause erosion, scour and/or channeling.
☐	A staff gage is provided (can be attached to a structure) to allow inspection of drawdown time.	This feature is necessary to facilitate inspection and performance confirmation (i.e., the facility is infiltrating).
☐	An overflow device is required at the top of the ponding depth to safely convey overflow to the downstream receiving system.	Planning for controlled overflow lessens the risk of property damage due to flooding.
Soil Amendment (as needed)		
☐	If underlying infiltration rates (prior to factor of safety adjustment) are greater than 12 inch/hour or have less than 3 percent organic content, then amend soil by incorporating 3 inches of compost into the top 12 inches of soil.	In very sandy soils, soil amendment is needed to protect groundwater quality and support plants.
☐	If amendments are used, infiltration rates should be remeasured after amendment.	Amendments can change the infiltration rate of soils. An example amended plot can be used during site investigation rather than measuring after full scale amendment.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. Basin volume below the overflow, excluding the forebay, can be counted towards the DCV. Checks on clogging risk must be conducted as part of sizing.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Conduct earthwork in dry weather or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction.
☐	Avoid compaction of the base and sidewalls of the facility. Alleviate compaction as needed using mechanical tilling equipment (e.g., rototiller).	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction. If the basin will be used as a temporary sediment control measure, it must be lined for this use, and the liner must be removed before placing it into service for post-construction purposes.	Sediment accumulation can impair infiltration rates.
☐	Traffic within the BMP must be avoided entirely. Excavation should occur from outside of the facility or via low-ground pressure equipment.	Compaction of the system must be avoided as much as possible.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can seriously impair the hydraulic conductivity of the basin subgrade soils and require restoration and revegetation of the basin bottom.
☐	Allow plants to stabilize for as long as practicable (preferably several months) prior to placing the finished BMP into service.	Stabilization of the system allows plants to mature before stressing the system with stormwater loading.
☐	As part of verifying the system, conduct infiltration testing to confirm infiltration rates are equal or greater than the design infiltration rate. Require remediation if infiltration rates are lower than design.	The proponent must demonstrate that the BMP is constructed per design. Infiltration rate is an important design parameter.

Adaptability Considerations

This type of BMP has limited adaptability should actual conditions differ from those estimated as part of the design level investigation. Infiltration basins should only be used in locations where the ability to reliably infiltrate can be determined in the design phase. Reliability can be improved through (1) conducting a thorough investigation, (2) minimizing construction impacts that could change conditions, and (3) providing a higher factor of safety in design. If there is uncertainty in the ability to support full infiltration, then a bioretention BMP (INF-3/BIO-1) is strongly recommended, including an underdrain system that can be activated if necessary. In certain cases, a project could consider a contingency plan allowing for conversion to an infiltration/partial dry extended detention basin combination (INF-1/BIO-4). This case would require that the portion designed as BIO-4 be adequately sized to meet biotreatment sizing criteria and addresses the project pollutants of concern.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Identify eroded facility areas	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches
Observe and record drawdown rate	
Estimate degree of sediment accumulation in pretreatment system and infiltration basin	
Identify areas of compromised plant health or density	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Sediment, Trash, and Debris	
Remove trash from facility	Each visit; as needed
Remove sediment from forebay when estimated sediment accumulation exceeds 25% of the forebay volume	As needed
Remove sediment from pretreatment system per manufacturer's recommendations or when sediment storage volume is more than 50% full	Per manufacturer recommendation, or as needed
Vegetation and Infiltration Bed	
Irrigate as recommended by a landscape professional, typically for the first 3 years to establish vegetation	As needed
Remove undesirable vegetation	Four times per year during wet season, including inspection just before the wet season
Replant or reseed areas of thin or missing vegetation	Annually
Scrape soil from top 3 to 6 inches of infiltration bed and reestablished vegetation; augment soil amendment if needed	When infiltration rate drops below design infiltration rate
Inflow and Outflow Structures	
Check energy dissipation function and add riprap	Four times per year during wet season, including

Activity	Frequency
	inspection just before the wet season
Inspect inlets and outlets and remove accumulated sediment	Four times per year during wet season, including inspection just before the wet season
Repair structural damage to inlets and outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

INF-2: INFILTRATION TRENCH

Category: Full Infiltration

Also known as:
French Drain
Rock Trench
Exfiltration Trench

Source: Caltrans

An infiltration trench is a long, narrow, rock-filled trench designed to infiltrate runoff into the underlying soil. An infiltration trench retains the full DCV in the void space between stones and allows it to infiltrate through the bottom and sides of the trench into surrounding soils. Infiltration trenches are only applicable for DMAs in the full infiltration category. These facilties are commonly used adjacent to parking lots, driveways, roadway medians and shoulders. An infiltration trench provides the majority of its pollutant removal benefits through volume reduction. Pretreatment is important for limiting amounts of coarse sediment entering the trench which can clog the soil and render the trench ineffective. Maintenance to restore infiltration rates requires substantial rebuilding of the facility, therefore premature clogging must be avoided.

If an infiltration trench is deeper than its longest surface dimension, it must be classified as a dry well, adhere to associated guidelines, and be registered as a Class V injection well.

Pollutant Removal Considerations

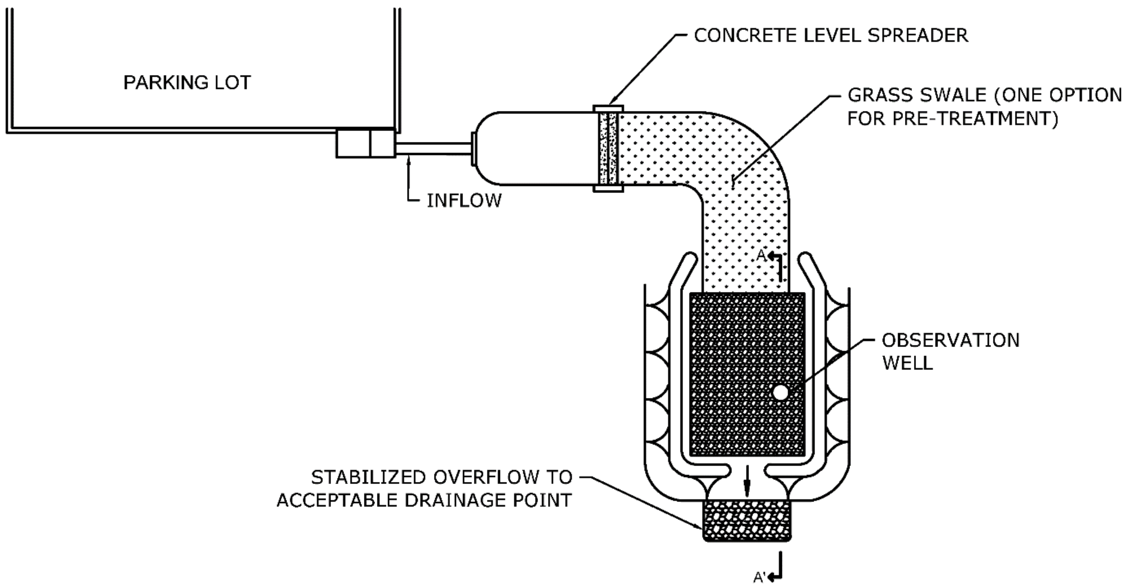
Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics
H	H	H	H	H	H

Recommended Siting Criteria

	Siting Criteria	Intent/Rationale
☐	BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Must not negatively impact existing site geotechnical concerns.
☐	BMP is located in areas of the site most suitable for full infiltration.	A full infiltration BMP must be sited such that the underlying soil infiltration rates will facilitate infiltration of the full DCV and this can be assured through construction and operation.
☐	BMP should not be located in fill areas, unless permeable engineered fill can be used, or in significant cut areas.	The ability to fully infiltrate the DCV must be determined prior to construction and assured through construction. In areas that will have traditional compacted fill, it is not possible to determine the infiltration rate. Additionally,

	where the infiltrating surface is deep below existing grade, the quality of investigation may be compromised.
☐ Sediment sources must be controlled prior to operation of the system.	Facility should not be used in areas that will continue to receive elevated sediment loading following construction, such as from open space area.

Example Schematic Design - Plan and Section View



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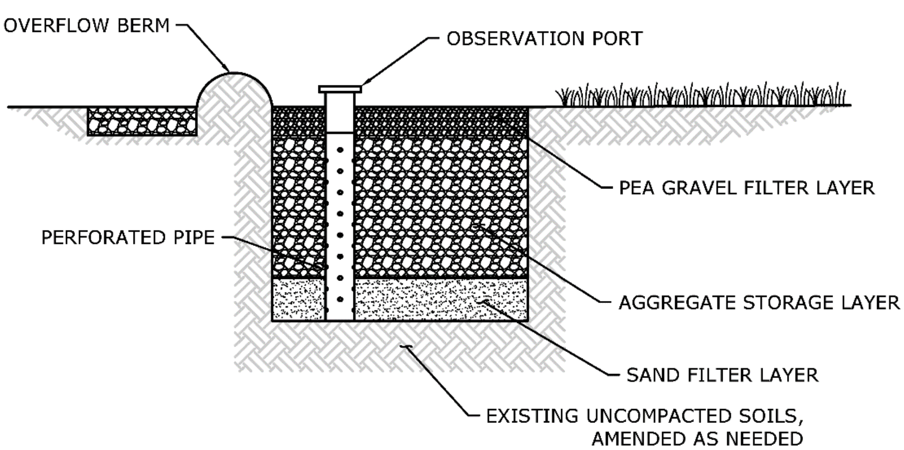


SECTION A-A'
NOT TO SCALE

Other configurations of this BMP are also possible including mechanical pretreatment and inflow coming from a storm drain rather than the surface.

Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Overall Trench Geometry	Depth ≤ Width	If an infiltration trench is deeper than its widest surface dimension, or includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute runoff below the surface of the ground, it would likely be considered a Class V Injection Well under the federal Underground Injection Control (UIC) Program, which is regulated in California by U.S. EPA Region 9. A UIC permit may be required for such a facility.
Surface ponding	3 inches	The overflow elevation should be set to allow 3 inches of surface ponding to avoid premature bypass.
Freeboard	≥ 6 inches	The system should be able to overflow to an acceptable drainage point with adequate freeboard to prevent localized flooding or unacceptable overflow pathways.
Trench Width	≥ 24 inches	Facilitates excavation using conventional equipment
Pea Gravel Filter Layer	≥ 4 inches	Provides filtering of coarse sediment for inflows into the underlying aggregate storage layer
Trench Depth	≥ 3 feet	Infiltration into side walls is the most important pathway; deeper trenches better support side wall infiltration.
Sand Filter Layer	≥ 6 inches	Provides filtering of fine sediment prior to infiltration into subsurface soils. The sand layer can accommodate a greater degree of sedimentation before clogging than the underlying soils.
Observation Port Diameter	≥ 6 inches	Facilitates clear observation and measurement of facility water level to verify drawdown and performance

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Pretreatment	
☐ Pretreatment is provided to remove coarse sediment and organic debris per criteria in **TGD Chapter 4**.	BMP performance and longevity is increased. Premature clogging is avoided.
Pea Gravel Filter Layer	
☐ Longitudinal trench slope is ≤ 3%.	Facilitates runoff interception and capture into the facility.
☐ A pea gravel filter layer is used to prevent migration of coarse sediment into the aggregate storage layer. Filter fabric is not used. See **MISC-3** for criteria for a pea gravel layer	Sediment can cause clogging of the aggregate storage layer void spaces. Filter fabric is more likely to clog.
☐ Pea gravel is washed and free of fines.	Washing aggregate will help eliminate fines that could clog the facility. Washing shall not occur in situ as it could clog the underlying infiltration surface.
Aggregate Storage Layer	
☐ Washed river rock or open-graded, crushed rock with porosity of at least 40 percent.	Washing aggregate will help eliminate fines that could clog the aggregate storage layer void spaces or subgrade.
Sand Filter Layer	
☐ Sand is uniform coarse washed sand, as specified in MISC-3.	Washed coarse sand can withstand greater sediment loading before becoming the limiting clogging surface.
Inflow and Outflow Structures	
☐ Inflow and outflow structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐ At least one observation port is provided in each cell of the trench to allow inspection of subsurface water level.	This feature is necessary to facilitate inspection and performance confirmation (i.e., the facility is infiltrating).
☐ A stabilized overflow is required to safely convey overflow to an acceptable drainage point. This could include an inlet located downstream. An inlet can also be located within the infiltration trench set at a depth of 3 inches above the surface of the trench.	Planning for controlled overflow lessens the risk of property damage due to flooding.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. The pore spaces in the gravel can be claimed as part of the DCV. Infiltration out of the bottom and half of the side wall area may be included in drawdown calculations.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Conduct earthwork in dry weather or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction or smearing.
☐	Avoid compaction of the base and sidewalls of facilities. Alleviate compaction as needed using mechanical tilling equipment (e.g., rototiller) and/or scarification.	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction. If the trench will be used as a temporary sediment control measure, it must be lined for this use, and the liner must be removed before placing it into service for post-construction purposes.	Sediment accumulation can impair infiltration rates.
☐	Traffic within the BMP should be avoided entirely.	Compaction of the system must be avoided as much as possible. There is no reasonable rationale for equipment or traffic within an infiltration trench.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can seriously impair the hydraulic conductivity of the basin subgrade soils and require restoration and revegetation of the basin bottom.
☐	Phase construction to allow each layer of the facility to be inspected before it is covered.	Once layers are covered, they cannot be adequately inspected.
☐	Prior to backfill with gravel, conduct infiltration testing to confirm infiltration rates are equal or greater than the design infiltration rate. Require remediation if infiltration rates are lower than design.	The proponent must assure that the BMP is constructed per design. Infiltration rate is an important design parameter.

Adaptability Considerations

This type of BMP has very limited adaptability should actual conditions differ from those estimated as part of the design level investigation. Infiltration trenches should only be used in locations where the ability to reliably infiltrate can be determined in the design phase.

Reliability can be improved through (1) conducting a thorough investigation, (2) minimizing construction impacts that could change conditions, and (3) providing a higher factor of safety in design. If there is uncertainty in the ability to support full infiltration, then a bioretention BMP (INF-3/BIO-1) is strongly recommended, including an underdrain system that can be activated if necessary. If there is no ability to have an underdrain, then a Vegetated Swale (BIO-2) underlain by a gravel reservoir could be considered as a contingency plan, provided that the vegetated swale would be adequately sized and address pollutants of concern.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Identify eroded facility areas	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches
Observe and record drawdown rate via the observation port	
Estimate degree of sediment accumulation in the pea gravel, thickness of surface layer or depth of penetration	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Pea Gravel Filter Layer	
Remove sediment via scraping of the top layers of this layer and replacement with clean washed pea gravel	Annually or when sediment has accumulated within more than 2 inches of the pea gravel layer
Replace full depth of pea gravel	When full comingled with sediment
Gravel Bed	
Excavate the entire facility, rehabilitate bottom and sides via over-excavation, and replace aggregate layers. Aggregate layers can be reused if they are washed before replacement.	When infiltration rate drops below design infiltration rate
Inflow and Outflow Structures	
Repair structural damage to inlets and outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

INF-3: BIORETENTION WITHOUT UNDERDRAIN

Category: Full Infiltration (“Standard Configuration”)

Adaptable to Partial Infiltration if Capped Underdrain is Included (“Adaptable Configuration”)

Also known as:
Rain Gardens

Source: Geosyntec Consultants

Bioretention BMPs without underdrains are shallow landscaped depressions that capture and filter stormwater runoff prior to infiltrating into underlying soils. These facilities are designed to infiltrate the full DCV and are therefore only used for DMAs in the full infiltration category. With appropriate design features, these BMPs can be adaptable to partial infiltration conditions. They are commonly incorporated into parking lots islands, cul-de-sacs, traffic circles, road shoulders, and road medians. Bioretention without underdrain functions as a soil and plant-based filtration device that removes pollutants primarily through volume reduction, but avoids transport of pollutants to groundwater through a variety of physical, biological, and chemical treatment processes.

This fact sheet is not intended to be standalone. See Fact Sheet BIO-1 for primary guidance on siting, design, construction, and O&M. Only guidance that differs from BIO-1 is provided in this fact sheet. This fact sheet supports two configurations of INF-3:

Adaptable Configuration (preferred): This configuration is designed, constructed, operated and maintained identically to BIO-1, but the underdrain outlet structure is capped. The cap can be removed to convert the system to BIO-1 if actual infiltration rates are less than estimated and drainage rates are deficient.

Standard Configuration: This configuration is designed and constructed similarly to BIO-1, except no underdrains are included. This configuration is not adaptable to partial infiltration should infiltration rates be less than estimated.

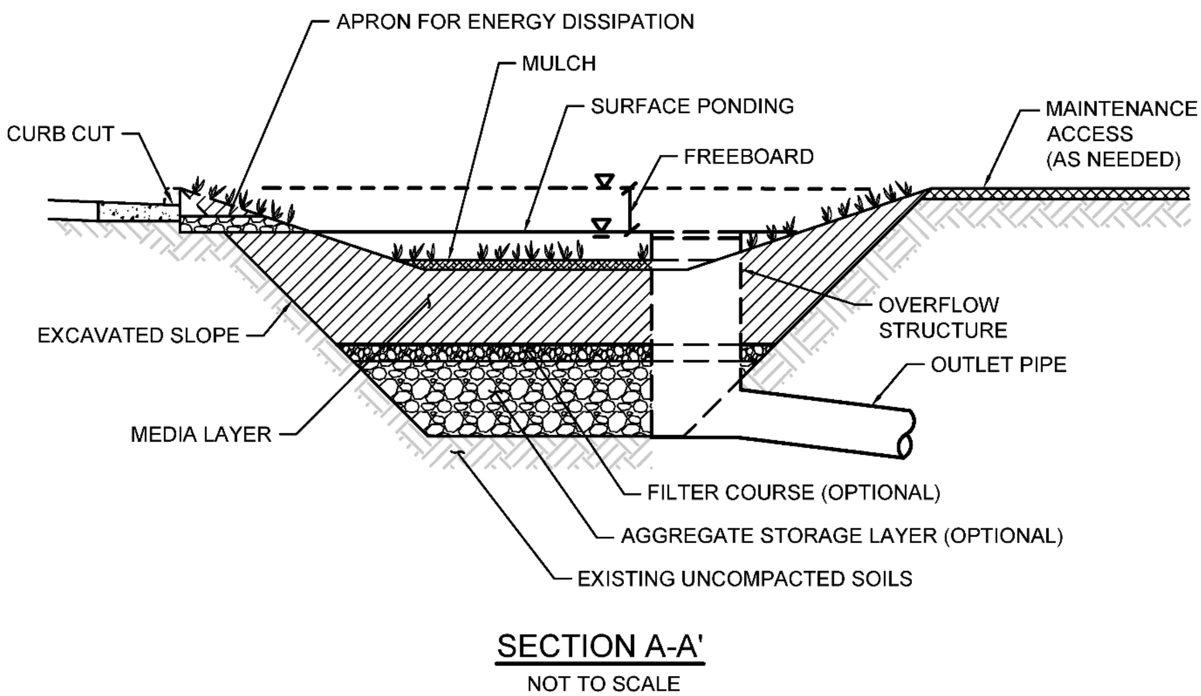
Pollutant Removal Considerations

Configuration	Sediment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics
Full Infiltration (no underdrain or capped underdrain)	H	H	H	H	H	H	H
Partial Infiltration (BIO-1) with underdrain activated	H	M	M	H	M	M	H

Recommended Siting Criteria

	Siting Criteria	Intent/Rationale
☐	See BIO-1, except as follows	
☐	For standard designs without backup underdrains, the BMP should not be located in fill areas. In fill areas, a backup underdrain is required even if potential fill infiltration rates are estimated to be adequate for full infiltration.	The ability to fully infiltrate the DCV must be determined prior to construction and assured through construction. In areas that will have traditional compacted fill, it is not possible to determine the infiltration rate. Additionally, where the infiltrating surface is deep below existing grade, the quality of investigation may be compromised.

Example Schematic Design - Section View (Plan View same as BIO-1)



Section View of Standard Configuration without Backup Underdrain For Adaptable Configuration, see Fact Sheet BIO-1

Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard	≥ 6 inches if system has internal overflow Freeboard not required if offline with acceptable bypass	Freeboard provides for water to enter overflow structures and minimizes risk of uncontrolled surface discharge. Lower freeboard (or no freeboard) is allowable if there is an acceptable bypass pathway when the WQ storage is full, such as flow along the curb line to a storm inlet downstream.
Surface Ponding	≥ 3 inches	A lower limit is needed to provide enough surface storage for water to be able to enter the media. Also, very shallow depths are more susceptible to construction error and change over time with O&M activities.
Surface Ponding	≤ 18 inches	Deeper surface ponding depths may require demonstration that premature clogging is not likely and may require fencing.
Ponding Area Side Slopes	3H:1V or shallower	Gentler side slopes are safer, less prone to erosion, able to establish vegetation more quickly and easier to maintain. Vertical walls may be acceptable with appropriate considerations for safety.
Mulch	2-4 inches (average 3 inches)	Mulch is intended to suppress weeds and maintain moisture for plant growth. Mulch also retains sediment and allows sediment to be removed before it clogs the media bed.
Media Layer	≥ 18 inches (24 to 36 inches preferred)	A deeper media layer provides additional filtration and supports plants with deeper roots. The media layer must extend across the BMP to the waterline at full ponding depth to ensure no infiltrated water bypasses the media.
Filter Course (if stone storage layer is used)	4-6 inches	Typically made up of 2 to 3 inches of coarse sand and 2 to 3 inches of pea gravel, both washed. Thinner layers are less effective and may be more challenging to accurately construct.
Stone Storage Layer Depth (optional, may be used to augment storage)	No limitation	This feature can be included to increase storage capacity. The drawdown time of this storage must be considered in sizing methods.

Recommended Design Criteria and Considerations

	Design Criteria	Intent/Rationale
☐	See BIO-1 for primary guidance. Additional guidance applying to INF-3 is provided in this Fact Sheet	BMP performance and longevity is increased. Premature clogging is avoided.
Differences from BIO-1 for Standard Configuration		
☐	Optionally eliminate filter course rock and stone reservoir	This is not necessary; it may be included to provide additional storage, if desired.
☐	Amended soil media should be tested to ensure permeability at least 4x higher than the design underlying infiltration rate, up to a maximum of 12 inches per hour. But chemical testing of media as described in MISC-1 is not required.	Leaching of pollutants from media is not a significant issue for bioretention without underdrains. However, media should provide adequate permeability without being excessively well drained.
Differences from BIO-1 for Adaptable Configuration		
☐	Include a screw cap on underdrain such that the system operates as a full infiltration BMP unless activation of the underdrain is determined to be needed.	A screw cap, or multiple caps at different levels allows simple adjustment.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. Checks on clogging risk should be conducted as part of sizing. Infiltration volume includes volume in ponding storage and pores of media and gravel. For an adaptable configuration, sizing calculations should be conducted for both the full infiltration condition as well as the partial infiltration condition where underdrains are activated and the system operates as a BIO-1 system.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	See BIO-1 for guidelines. Differences are listed below.	
☐	As part of verifying the system, conduct infiltration testing of underlying soil prior to backfill to confirm infiltration rates are equal or greater than the design infiltration rate. Require remediation of soil infiltration rates or adaptation to BIO-1 if infiltration rates are lower than design.	The proponent must assure that the BMP is constructed per design. Infiltration rate is an important design parameter.

Adaptability Considerations

The "Adaptable Configuration" of this BMP is a preferred option for infiltration in areas where there is uncertainty in long-term, full-scale infiltration rates. The method of adaptation is to remove the underdrain cap and operate the facility as BIO-1. This adaptation could be activated at a number of points in project development or implementation, including:

- Between discretionary approval (Preliminary/Conceptual WQMP) and final grading approval (Final Project WQMP), if needed, based on more detailed investigation.
- During construction, based on measurements taken following excavation of the basin.
- After the system is placed in to service based on observed drainage rates.

In any case, this contingency plan needs to be disclosed and considered as part of the discretionary approval. Also, sizing calculations need to be included in the WQMP to demonstrate that activation of the contingency plan to convert the system to BIO-1 would still conform to LID sizing criteria.

O&M Activities and Frequencies

Activity	Frequency
Same as BIO-1, except:	
For the adaptable configuration, utilize results of drawdown observations to determine the need for adjustment of the outlet structure (i.e., uncapping closed underdrain)	Based on twice-yearly drawdown observations following events 0.5 inch or larger

INF-4: DRY WELL

Category: Full Infiltration

Source: City of Elk Grove, CA

Dry wells consist of an excavated pit, typically lined with a perforated casing and filled with stone, that receives gravity drainage from stormwater piping. During precipitation, the void space in the stone serves as a storage reservoir to detain and equalize stormwater inflows. Stormwater infiltrates from the system into the surrounding soils through bottom and walls of the facilities. As such the system has dynamic storage and loss mechanisms that vary with storm size and intensity. There is no specific ratio of infiltration loss rate versus storage volume that defines a dry well, however volumes tend to be relatively small compared to loss rates and system tend to operate mostly like a "flow-based" BMP. When the storage volume is full and inflow rates exceed infiltration loss rates, the system bypasses water to the downstream conveyance system. A pretreatment and/or isolation system can be an integral element of a dry well design or can be provided separately via an upstream treatment system. Dry wells can be used in combination with other stormwater management approaches, such as being connected to the underdrain discharge of a bioretention area to improve retention of stormwater. Dry wells can be designed to provide infiltration into near-surface soils, or can be designed to infiltrate into deeper soil strata. By definition, the bottom of a dry well is located above the water table.

Pollutant Removal Considerations

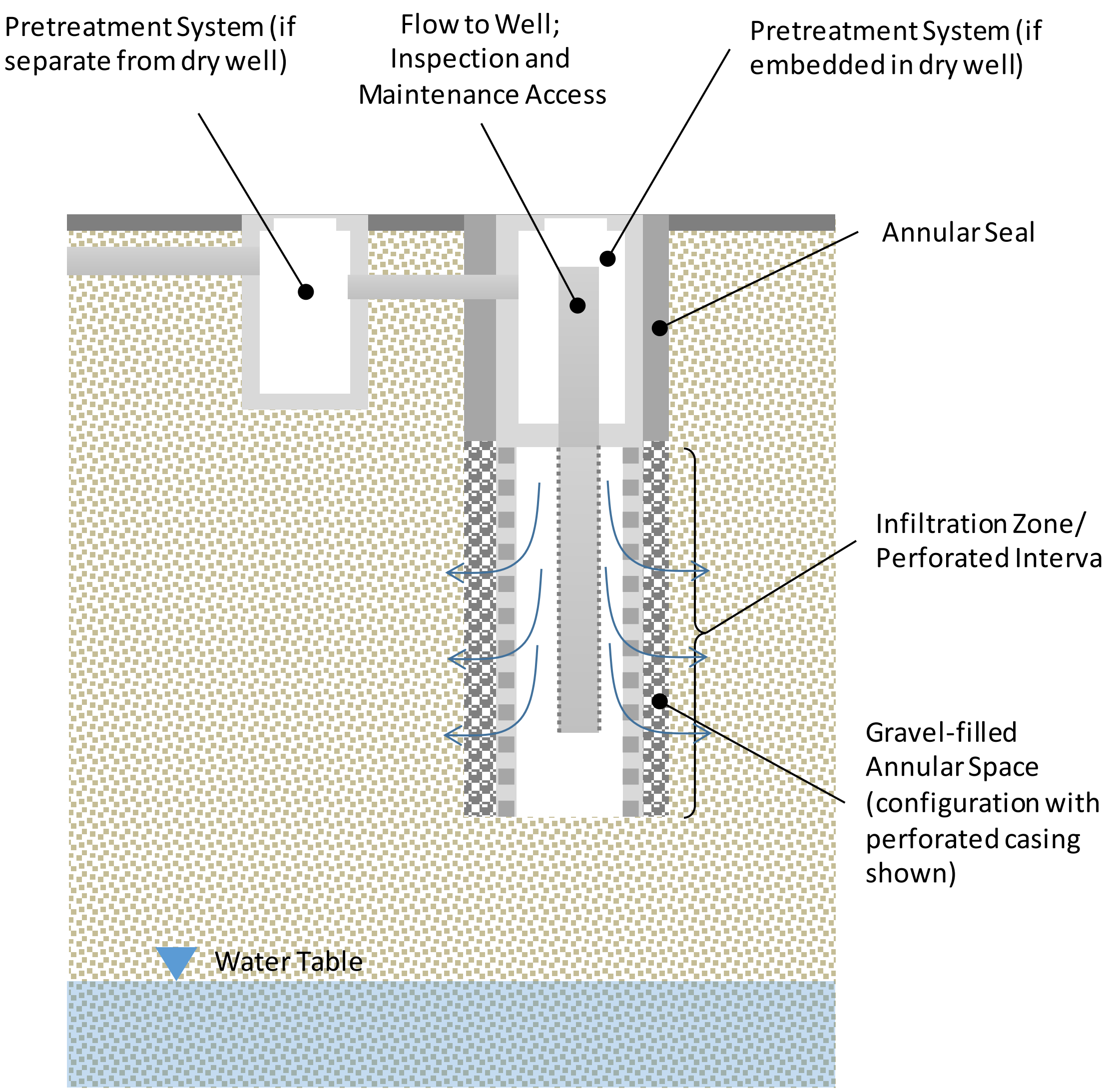
Sediiment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics
H	H	H	H	H	H	H

Recommended Siting Criteria

- Dry wells are only applicable where soils are adequate for infiltration and full infiltration is determined to be feasible based on applicable feasibility criteria.
- Minimum set-backs from foundations and slopes should be observed
- Infiltration should not cause geotechnical concerns related to slope stability or liquefaction.
- Minimum separation to mounded seasonally high groundwater of 10 feet shall be observed.

- Space available for should be available pretreatment where needed.
- Drywells should not receive untreated stormwater runoff, except rooftop runoff.
- Potential for groundwater contamination can be mitigated through isolation of pollutant sources, pretreatment of inflow, and/or demonstration of adequate treatment capacity of underlying soils.
- Infiltration should be into native soil. Where the depth of engineered fill is less than 5 feet from the ground surface to native material and infiltration is approved by a geotechnical professional.

Example Schematic Design - Section View



Conceptual Illustration; Not to Scale
This diagram is not intended to describe or endorse a specific dry well configuration

Recommended Design Criteria and Considerations

- Must comply with local, state, and federal UIC regulations.
- Design and permitting of the dry wells should conform to applicable requirements:
  - California Well Standards California Well Standards (Bulletin 74-81). http://www.water.ca.gov/groundwater/well_info_and_other/california_well_standards/well_standards_content.html
  - Orange County Well Ordinance (No. 2607). http://www.ochealthinfo.com/eh/water/well
  - **USEPA Region 9 Class V Injection Well guidance:** https://www.epa.gov/uic/forms/underground-injection-wells-registration
- Wells should not receive untreated stormwater runoff, except rooftop runoff. Pretreatment of runoff from other surfaces is necessary to prevent premature failure that results from clogging with fine sediment, oil and grease, and/or trash and debris, and to prevent potential groundwater contamination due to nutrients, metals, and hydrocarbons.
- Design infiltration rate should be determined with an appropriate infiltration test at each drywell location.
- Drywell should be encased by 1 foot of coarse (3/4" to 2 ½"), round river rock on sides and bottom of facility.
- An overflow route must be installed for flows that overtop facility.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. Dry wells will typically be sized as flow-based BMPs, but also may be incorporated into volume-based BMP designs.

Adaptability Considerations

This type of BMP can be made more adaptable by including a contingency plan for construction of additional dry wells, if needed, to provide the required design flowrate. Alternatively, more dry wells can be included in primary plans, with a contingency to reduce the number of dry wells if full-scale, as-built infiltration testing supports a reduction in needed number of wells.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Identify and control sources if sediment in tributary areas	Four times per year during wet season, including
Observe and record drawdown rate via the observation port	

Activity	Frequency
Estimate degree of sediment and/or trash and debris accumulation in the pre-treatment system	inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Pre-treatment system	
Remove accumulated material from pre-treatment system	Annually or when material has accumulated to more than 50 percent of capacity of the pre-treatment system. If proprietary pre-treatment is used, then maintain per manufacturer guidance.
Dry Well	
Excavate the entire facility, rehabilitate bottom and sides via over-excavation, and replace system components.	When infiltration rate drops below design infiltration rate
Inflow and Outflow Structures	
Repair structural damage to inlets and outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance

Additional Information

Relevant, published, and generally-accept design guidance from other sources should be followed for design, permitting, construction, and O&M of dry wells. References for guidance on dry wells include, but are not limited to:

http://www.waterboards.ca.gov/board_reference/2014fall/docs/dry_wells_fs.pdf

https://www.epa.gov/uic/forms/underground-injection-wells-registration

http://www.water.ca.gov/groundwater/well_info_and_other/california_well_standards/well_standards_content.html

http://www.ochealthinfo.com/eh/water/well

INF-5: PERMEABLE PAVEMENT

Category: Full Infiltration

Also known as:
Pervious Pavement

Source: Geosyntec Consultants

Permeable pavement is a type of pavement that allows for percolation through void spaces in the pavement surface into subsurface layers. Permeable pavement comes in a variety of forms (concrete, grass and gravel pavers; porous concrete or asphalt) and is designed to retain the full DCV by allowing it to percolate through the pavement and infiltrate into the underlying soil. This facilitates stormwater management while providing the structural and functional features needed for a roadway, parking lot, or sidewalk. Pollutant control is provided via infiltration, filtration, sorption, sedimentation and biodegradation processes. Permeable pavement as a structural LID BMP is designed to capture and infiltrate runoff from surrounding areas. This distinguishes it from permeable pavement as a site design BMP which does not receive significant runoff from other areas, only infiltrating rainfall that falls directly on the permeable pavement.

Pollutant Removal Considerations

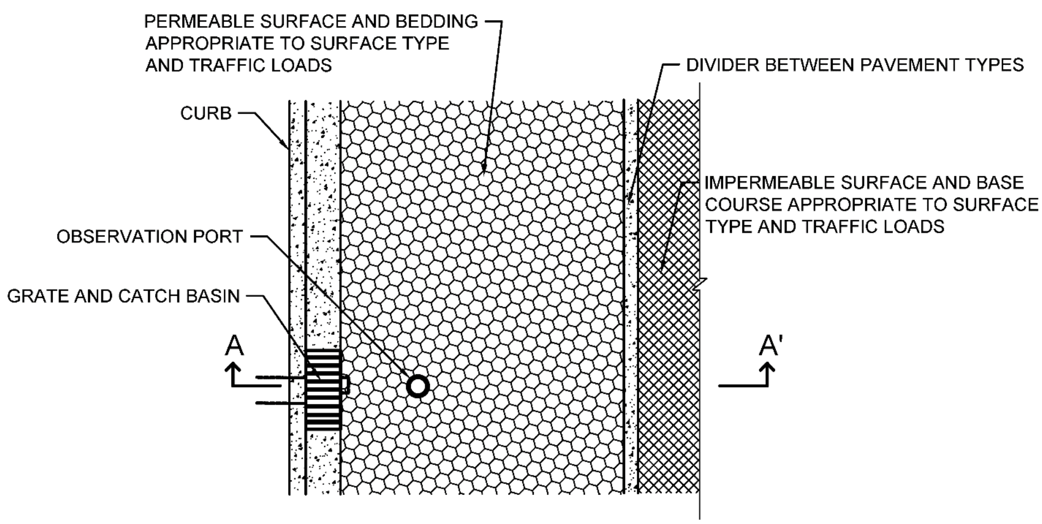
Sediment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics
H	H	H	H	H	H	H

Recommended Siting Criteria

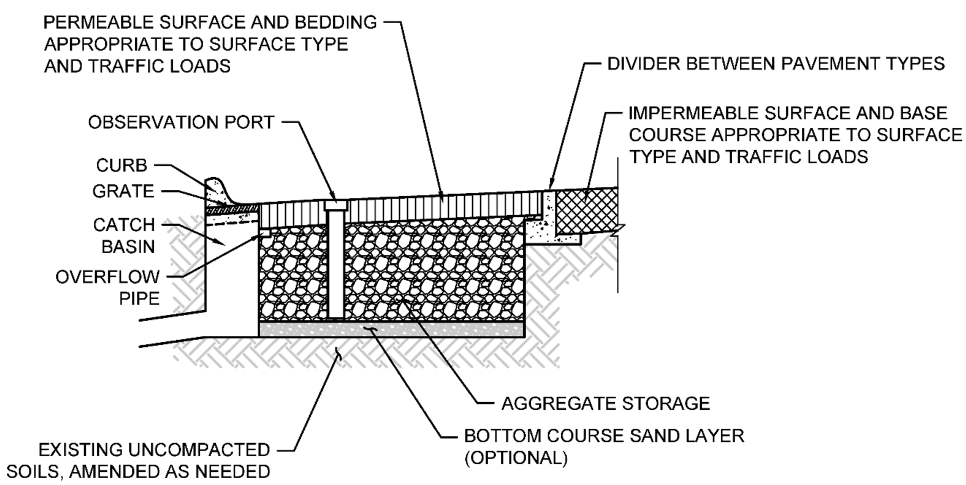
Siting Criteria	Intent/Rationale
☐ BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Must not negatively impact existing site geotechnical concerns.
☐ BMP is located in area of the site most suitable for full infiltration.	A full infiltration BMP must be sited such that in-situ infiltration rates will facilitate infiltration of the full DCV. Permeable pavement can be supported by infiltration rates lower than needed for other infiltration BMP types.
☐ The ratio of the total drainage area (including the permeable pavement) to the permeable pavement should not exceed 4:1.	Higher ratios increase the potential for clogging but may be acceptable for relatively clean tributary areas that do not have any significant sediment sources.
☐ Sediment sources are controlled prior to operation of the system.	Facility should not be used in areas that will continue to receive elevated sediment loading following construction, such as from open space area.

☐	BMP is not placed in an area with significant overhanging trees or other vegetation.	Leaves and organic debris can clog the pores in the pavement surface.
☐	Direct discharges to permeable pavement are only from rooftops or other impervious areas with low pollutant and gross solids loading.	Bypassing the pavement surface increases the risk of clogging underlying layers. Roof runoff typically carries less sediment than runoff from other impervious surfaces and is less likely to cause premature clogging of the underlying soil.

Example Schematic Design - Plan and Section View



PLAN
NOT TO SCALE



SECTION A-A'
NOT TO SCALE

Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Permeable Surface and Bedding Layer Thickness/Properties	Varies by design	This component of the design is specific to the type of permeable surface and the traffic loading. The designer should consult appropriate design references.
Bottom Coarse Sand Layer	≥ 4 inches	Provides filtering of fine sediment prior to infiltration into subsurface soils.
Aggregate Layer Depth	Varies by design	The aggregate layer depth can be controlled by structural requirements or stormwater management requirements. The amount of tributary area and the underlying infiltration rate are the most important factors in selecting an aggregate storage depth for stormwater management goals.
Observation Port Diameter	≥ 6 inches	Facilitates simpler cleaning.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Permeable Surface Layer	
☐ Finish grade of the permeable pavement has a slope ≤ 5%. (the infiltrating surface should be flat or constructed in terraces that are flat)	Flatter surfaces facilitate increased runoff capture.
☐ Permeable surface layer type and thickness are appropriately chosen based on pavement use and expected vehicular loading.	Pavement may wear more quickly if not designed to be durable for expected loads or frequencies. Design criteria vary greatly by pavement type and loading. A designer with experience in permeable pavement design should make and document appropriate design decisions.
☐ Permeable surface layer type is appropriate for expected pedestrian traffic.	Expected demographic and accessibility needs (e.g., adults, children, seniors, runners, high-heeled shoes, wheelchairs, strollers, bikes) requires selection of appropriate surface layer type that will not impede pedestrian needs.
Bedding Layer	
☐ Bedding thickness and material is appropriate for the chosen permeable surface layer type.	Bedding (e.g., sand, aggregate, permeable treated asphalt base, no bedding) is chosen based on the structural and leveling requirements of the permeable pavement form (concrete, grass and gravel pavers; porous concrete or asphalt) and, depending on bedding material gradation, may require an underlying filter course layer to prevent migration to the aggregate storage layer.

Design Criteria	Intent/Rationale
☐ If sand or aggregate is used for a bedding layer, it is washed prior to placement.	Washing bedding will help eliminate fines that could clog the underlying infiltrating surfaces.
Aggregate Storage Layer	
☐ The aggregate storage layer depth below the overflow elevation is determined based on structural and stormwater management objectives.	The intent of this layer is to provide sub-surface storage in order to provide full infiltration of the DCV. Depth requirements for stormwater management depend on the underlying infiltration rate and how much tributary area are routed to the pavement. The aggregate storage layer may also be controlled by structural requirements, particularly if used in heavier traffic areas.
☐ Aggregate storage layer consists of washed river rock or open-graded, crushed rock.	Washing aggregate will help eliminate fines that could clog the aggregate storage layer void spaces or subgrade.
☐ Drain pipes are slotted per MISC-3 if included in the design.	
Bottom Filter Course	
☐ Sand is coarse washed sand as described in the filter course specifications in MISC-3.	Washed sand free of larger objects will help eliminate fines and obstructions that could clog the aggregate storage layer void spaces or subgrade.
Soil Amendment (as needed)	
☐ If underlying infiltration rates (prior to factor of safety adjustment) are greater than 12 inch/hour or have less than 1 percent organic content, then amend soil by incorporating 3 inches of compost into the top 12 inches of soil before constructing pavement.	In very sandy soils, soil amendment is needed to protect groundwater quality.
☐ If amendments are used, infiltration rates should be remeasured after amendment.	Amendments can change the infiltration rate of soils. An example amended plot can be used during site investigation rather than measuring after full scale amendment.
Transition from Adjacent Pavement	
☐ An appropriate transitional design should be used at the transition from adjacent traditional pavement to permeable pavement. This could include a concrete stem wall or a line of pavers.	This can be a necessary structural element. It can also serve to demark the extent of the BMP and help avoid inadvertent overlay of the BMP with traditional pavement.
Outflow Structures	
☐ A piped connection from the aggregate storage layer to the storm drain system should be used, if feasible, to prevent saturation of the permeable pavement surface.	Saturation of the pavement surface during traffic loading can lead to damage to the pavement.
☐ An overflow route should be defined, such as a curb inlet, for events that exceed the design volume.	This helps ensure safe operations, even in larger storms.

	Design Criteria	Intent/Rationale
☐	At least one observation port is provided in each cell/terrace to allow inspection of subsurface water level.	This feature is necessary to facilitate inspection and performance confirmation (i.e., the facility is infiltrating and providing the volume reduction anticipated).

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. The entire volume of the aggregate pores below the overflow elevation can be considered infiltrated volume. If the underlying soil interface is sloped (which is not recommended) sizing calculations must assume a level pool within the aggregate storage reservoir, which may reduce the effective storage.

Unless there are no sediment sources in the watershed, the allowable ratio of adjacent tributary area to permeable pavement area should not exceed 4 to 1. Rainfall on the permeable pavement area should be included as a 100 percent runoff coefficient for sizing purposes.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	The contractor should have recent demonstrated successful experience with permeable pavement installation of the type specified or should utilize a subcontractor that has this experience.	This is intended to improve the chances of success of permeable pavement.
☐	Conduct earthwork in dry weather, or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction.
☐	Avoid compaction of the base and sidewalls of facilities. Alleviate compaction as needed using mechanical tilling equipment (e.g., rototiller).	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction as much as practicable using sediment and erosion control measures (e.g., silt fence, filter logs, check dams).	Sediment accumulation can impair infiltration rates.
☐	Traffic within the BMP should be avoided unless impractical. If traffic within the system is allowed, only wide track and low-ground pressure equipment is allowed.	Compaction of the system must be avoided as much as possible.

Construction Guidance	Intent/Rationale
☐ Use staking, surveying, or other methods to confirm thickness of layers.	A uniform thickness of layers is important for effectiveness.
☐ Establish the construction sequence to allow for inspection of buried infrastructure (e.g., filter course) before it is buried.	It is impractical to inspect buried elements once they are covered.
☐ Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can seriously impair the hydraulic conductivity of the media bed and require restoration and revegetation of the surface of the media bed.
☐ As part of verifying the system, conduct infiltration testing of underlying soil before constructing pavement to confirm infiltration rates are equal or greater than the design infiltration rate. Require remediation if infiltration rates are lower than design.	The proponent must demonstrate that the BMP is constructed per design. Infiltration rate is an important design parameter.

Adaptability Considerations

This type of BMP has limited adaptability should actual conditions differ from those estimated as part of the design level investigation. Permeable pavement should only be used in locations where the ability to reliably infiltrate can be determined in the design phase. Reliability can be improved through (1) conducting a thorough investigation, (2) minimizing construction impacts that could change conditions, and (3) providing a higher factor of safety in design. It is often acceptable to utilize a relatively high factor of safety to improve reliability. Permeable pavement tends to have a larger footprint and lower effective storage depth than other BMPs, which can allow it to infiltrate the full DCV at lower design infiltration rates than other BMPs.

Permeable pavement could potentially be combined with a proprietary biotreatment BMP to provide partial retention of the DCV and biotreatment of 150 percent of the remaining portion of the DCV. Water that overflows the permeable pavement would be treated by the biotreatment BMP before entering the storm drain. In this use, permeable pavement would be part of a treatment train categorized as “Biotreatment with Partial Infiltration.”

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Inspect for areas of sediment accumulation in the pavement surface	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
If sediment accumulation is elevated, inspect for potential sources of sediment in the tributary area and recommend control approaches	
Observe and record drawdown rate via observation port following storm event	
Periodically (every 2 to 5 years) measure the permeability of the surface of the permeable pavement	
Identify any damage to pavement	
Inspect overflow structures	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Permeable Surface Layer	
Remove sediment and leaf litter using a mechanical sweeper (i.e., regenerative air or vacuum-assisted sweeper)	Two to four times per year during wet season including just before the wet season, depending on sediment and debris load
Manually remove weeds	Annually
Power wash surface layer (without using surfactants)	Annually
Patch pavement surface where needed	As needed
Other activities specific to pavement surface type	As needed
Coordinate with maintenance of adjacent pavement to ensure permeable pavement is protected	As needed
Underdrain and Outflow Structures	
Inspect outlets and remove accumulated sediment	Four times per year during wet season, including inspection just before the wet season.
Repair structural damage to outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

INF-6: UNDERGROUND INFILTRATION

Category: Full Infiltration

Also known as:
- Infiltration Vault
- Infiltration Chamber
- Infiltration Gallery
- Recharge Vault

Note, this fact sheet also supports use of infiltration galleries as a supplemental retention BMP in combination with proprietary biotreatment to provide partial infiltration.

Source: Contech

Underground infiltration is a vault or chamber with an open bottom that is used to store runoff and infiltrate it into the underlying soil. These vaults or chambers may be designed using any number of configurations or structural components as long as they meet the requirements of the permit. A number of vendors offer proprietary products that allow for subsurface storage while offering durable prefabricated structures. There are many varieties of proprietary products that can be used to store runoff below roads and parking lots, parks and open spaces, single and multi-family residential, or mixed-use and commercial uses, and infiltrate it into the underlying soil. These facilities can be used to retain and infiltrate the full DCV as stand-alone BMPs or can be used to provide supplemental retention for proprietary biotreatment BMPs. Pretreatment is a mandatory and integral element of underground infiltration, as the ability to remove sediment and scarify the infiltrating surface is limited in most designs. When used as part of a treatment train downstream of biotreatment BMPs, they are used to provide supplemental retention.

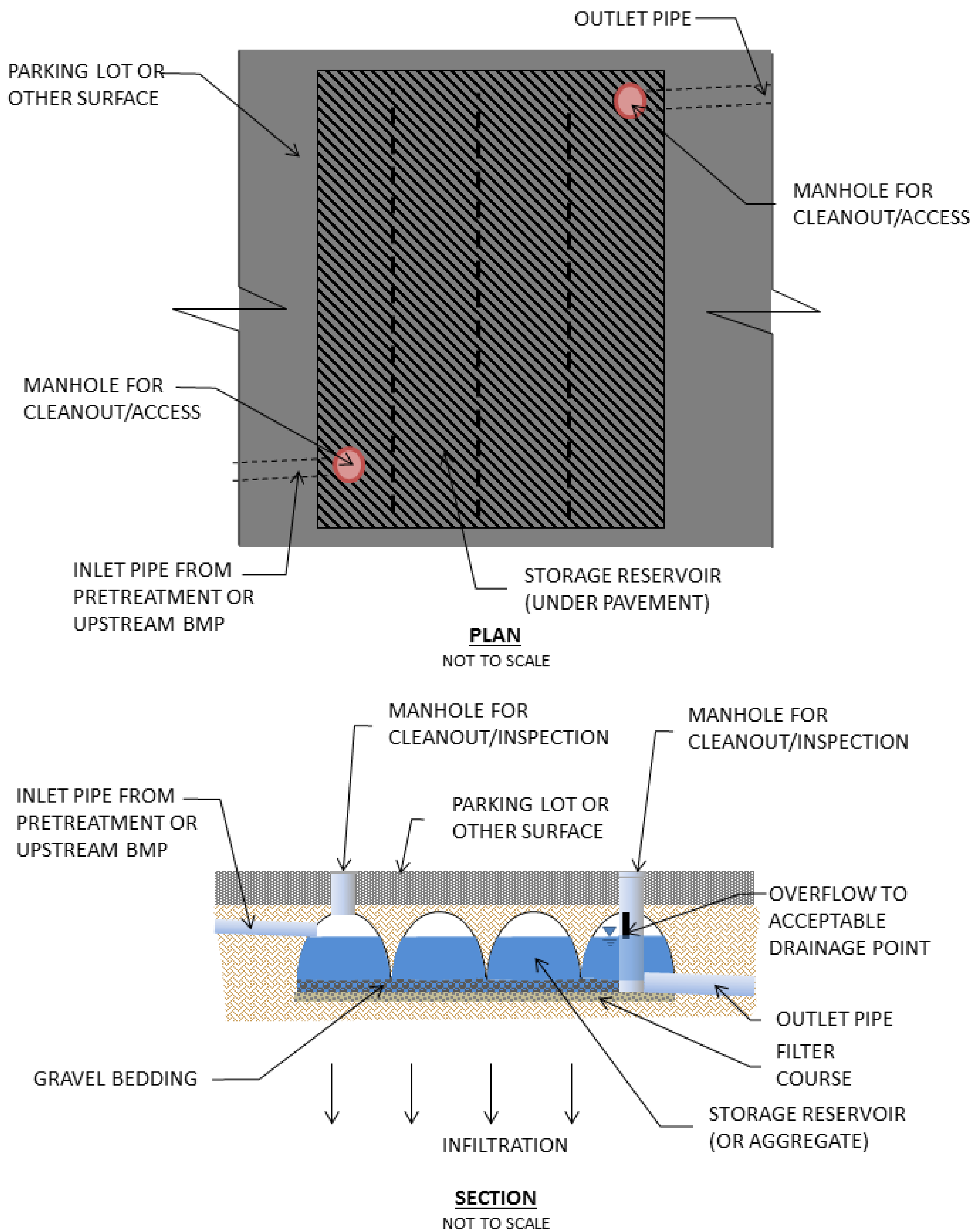
Pollutant Removal Considerations

Sediment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics
H	H	H	H	H	H	H

Recommended Siting Criteria

	Siting Criteria	Intent/Rationale
☐	BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Must not negatively impact existing site geotechnical concerns.
☐	BMP is located in areas of the site most suitable for full infiltration.	A full infiltration BMP must be sited such that the underlying soil infiltration rates will facilitate infiltration of the full DCV and where this can be assured through construction and operation.
☐	BMP should not be located in fill areas or within infiltrating surface more than 10 feet below existing grade.	The ability to fully infiltrate the DCV must be determined prior to construction and assured through construction. In areas that will have fill, it is not possible to determine the infiltration rate prior to construction. Additionally, where the infiltrating surface is too deep below existing grade, the quality of investigation may be compromised. A borehole test provides a poor approximation of full scale infiltration from this BMP.
☐	BMP can be placed beneath roads, parking lots, parks, and athletic fields. For facilities located under roads, traffic loading requirements (e.g., HS-20, H-20) is observed.	This type of facility allows the overlying land use to serve a different purpose other than stormwater management. The overlying land use needs (e.g., structural, geotechnical, aesthetical, etc.) is addressed in the design. The activities over top of the BMP must not interfere with appropriate inspection and maintenance and reconstruction of the system on a 10- to 30-year lifecycle. Placement beneath buildings or other infrastructure is not recommended unless appropriate considerations are given for access and maintenance. .
☐	Sediment sources are controlled prior to operation of the system.	Facility should not be used in areas that will continue to receive elevated sediment loading following construction, such as from open space area.

Example Schematic Design - Plan and Section View



Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard from Grate/Manhole Cover	≥ 1 foot	Freeboard provides room for head over overflow structures and minimizes risk of uncontrolled surface discharge. Lower freeboard is allowable if there is an acceptable alternative overflow method.
Access Hatch Diameter	≥ 24 inches (36 inches preferred)	Facilitates maintenance entry and sediment cleanout.
Bottom Coarse Sand Layer	≥ 4 inches	Typically sand to provide filtering of fine sediment prior to infiltration into subsurface soils.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Pretreatment	
☐ Pretreatment should be appropriately selected based on estimated loading, BMP depth, and target time to clog per guidance provided in **TGD Chapter 4.4 and Appendix E.4**.	Pretreatment is mandatory for underground infiltration due to the elevated risk of failure and cost to restore infiltration capacity if failure occurs.
Storage Reservoir	
☐ Reservoir chamber depth preferably less than 3 feet effective depth. Depth should be selected based on drawdown rate into underlying soils, potential for mounding, and clogging risk.	Deeper systems may take longer to drain, have higher risk of groundwater mounding, and be more susceptible to clogging.
☐ The bottom of the storage reservoir is flat	This allows uniform infiltration.
☐ A wide range of products is potentially acceptable, at the discretion of the reviewing jurisdiction.	Product suitability and durability should be reviewed.
☐ An observation port should be included in each distinct cell of the facility to inspect drawdown. A manhole can serve as an observation port.	This is needed to periodically inspect for drawdown rate.
Bottom Filter Course	
☐ Sand is coarse washed sand as described in the filter course specifications in MISC-3.	Washed sand free of larger objects will help eliminate fines and obstructions that could clog the aggregate storage layer void spaces or subgrade.
Inflow, Outflow, and Access Structures	
☐ Inflow, outflow, and access structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐ A stabilized overflow is required to safely convey overflow to the downstream receiving system.	Planning for controlled overflow lessens the risk of property damage due to flooding.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. The entire volume below the overflow elevation can be tabulated as infiltration volume.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Excavate in dry weather or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction.
☐	Avoid compaction of the base and sidewalls of facilities. Alleviate compaction as needed using mechanical tilling equipment (e.g., rototiller).	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction as much as practicable using sediment and erosion control measures (e.g., silt fence, filter logs, check dams). Remove any confining layer that accumulates as a result of sedimentation. If the location of BMP is used as a temporary erosion and sediment control facility, it should be completely rehabilitated via over excavation, before being placed into service as a post-construction BMP.	Sediment accumulation can impair infiltration rates.
☐	Traffic within the BMP should be avoided unless impractical. If traffic within the system is allowed, only wide track and low-ground pressure equipment is allowed.	Compaction of the system must be avoided as much as possible.
☐	Establish the construction sequence to allow for inspection of buried infrastructure before it is buried.	It is impractical to inspect buried elements once they are covered.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can seriously impair the hydraulic conductivity of the basin subgrade soils and require restoration and revegetation of the basin bottom.
☐	For deep installs, shoring with sheet piling or other methods are used to provide safe excavation. Proper bedding and backfill is used to stabilize the	Facilities must be safely and properly installed.

	Construction Guidance	Intent/Rationale
	structure. Proprietary structures are installed per manufacturer's specifications.	
☐	As part of verifying the system, conduct infiltration testing of underlying soil before placing chambers to confirm infiltration rates are equal or greater than the design infiltration rate. Require remediation if infiltration rates are lower than design.	The proponent must demonstrate that the BMP is constructed per design. Infiltration rate is an important design parameter.

Adaptability Considerations

This type of BMP has limited adaptability should actual conditions differ from those estimated as part of the design level investigation. Infiltration galleries should only be used as standalone BMPs in locations where the ability to reliably infiltrate can be determined in the design phase. Reliability can be improved through (1) conducting a thorough investigation, (2) minimizing construction impacts that could change conditions, and (3) providing a higher factor of safety in design.

The most practical option for adaptability is to utilize a proprietary biotreatment BMP as a pretreatment system. If this BMP is sized for the 150 percent of the DCV (full biotreatment sizing criteria), then the infiltration gallery can serve a complementary volume reduction purpose without being required to fully infiltrate the DCV. This could allow the depth of the infiltration gallery to be reduced should actual infiltration rates be lower than design infiltration rates.

If this option is used, it must be identified as a contingency plan in the Conceptual/ Preliminary WQMP as part of discretionary approval and appropriately supported with design phase and/or construction phase investigation to justify the need to infiltrate less than the full DCV.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Inspect condition of pretreatment BMP to determine need for maintenance	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Inspect degree of sediment accumulation in storage reservoir, if possible	
Observe and record drawdown rate	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Pretreatment System	
Remove accumulated trash and debris	Each visit; as needed
Remove sediment from pretreatment system per manufacturer's recommendations or when sediment storage volume is more than 50% full	Per manufacturer recommendation, or as needed
Storage Reservoir	
It is not typically practical to maintain the storage reservoir or infiltrating surface; plan for overall reconstruction when infiltration falls below the design infiltration rate	Estimate frequency of clogging maintenance using guidance in **Appendix E.4**.
If infiltration has declined and the system has the flexibility to be adapted to serve as a biotreatment BMP with partial infiltration (i.e., through use of a proprietary BMP as a pretreatment system), then adjust outlet to infiltrate a shallower depth of water and operate as biotreatment with partial infiltration system while infiltration rates allow. This can extend the period before rehabilitation is needed.	As needed and acceptable.
Inflow and Outflow Structures	
Inspect inlets and outlets and remove accumulated sediment	Four times per year during wet season, including inspection just before the wet season.
Repair structural damage to inlets and outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

G.4 Harvest and Use BMP Fact Sheet (HU)

HU-1: RAINWATER HARVESTING CISTERNS AND TANKS

Category: Harvest and Use

Source: Sunset Publishing Corporation

Cisterns are containers that can capture rooftop runoff and store it for future use. With controlled timing and volume release, the captured rainwater can be used for irrigation or alternative grey water (e.g., toilet flushing) between storm events, thereby reducing runoff volumes and associated pollutants to downstream water bodies as well as demand for potable water. Cisterns are larger systems (generally>100 gallons), which distinguishes them from distributed hydrologic source controls like rain barrels.

Project applicants should consult **Appendix F** for harvested water demand calculations and design requirements related to the plumbing and building codes based on different end uses of the retained water.

Note: Design of harvest and use systems is highly site specific. Appropriate design expertise is likely to be needed. This fact sheet provides general criteria, but is not intended to replace the need for design expertise and project-specific considerations.

Pollutant Removal Considerations

TSS	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics
H	H	H	H	H	H	H

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Pretreatment	
☐ Pretreatment is provided in the form of screens on gutters and downspouts to remove vegetative debris and sediment from the runoff prior to entering the cistern.	BMP performance and longevity is increased. Premature clogging is avoided.
Storage Reservoir	
☐ Cistern is vented with a screened pipe/opening in the direction of prevailing winds for maximum ventiliation.	Allows fresh air to circulate into the storage reservoir for odor control.
☐ A structurally-sound foundation design for the cistern and supporting calculations must be provided.	Ensures cistern stability and public safety.

Design Criteria	Intent/Rationale
Inflow, Outflow and Access Structures	
☐ Inflow, outflow and access structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐ Water entry holes have child-resistant covers and mosquito screens.	Ensures safety and vector control.
☐ Flow control device such as an orifice or valve is included to limit outflow in accordance with drawdown time requirements.	Flow control provides flow attenuation benefits and limits cistern discharge to downstream facilities during storm events.
Plumbing and Health Code Requirements	
☐ Applicable plumbing and health code requirements are met. See **Appendix F**.	Legal requirements intended to protect public health and property.
☐ A treatment system may be needed to meet applicable plumbing and health code requirements. This requires project-specific design expertise.	System design is highly site-specific.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods.

Construction Guidance

Construction Guidance	Intent/Rationale
☐ Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address BMP installation, inspections, testing and certifications and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.

O&M Activities and Frequencies

Design-specific O&M planning is typically needed for cisterns and rainwater harvesting systems. The following provides general guidance, which will likely need to be augmented.

Activity	Frequency
GENERAL INSPECTIONS	
Check for leaks	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Inspect for minor sediment in cistern bottom	
Inspect for vector control issues	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Clean out gutters, screening, and/or first-flush diverter	As-needed
Remove sediment, trash, debris, and oil accumulation from cistern	Semi-annually or as needed
Clean inside surfaces of cistern and disinfect	Annually
Maintain treatment systems per manufacturer or designer recommendations	As specified
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance

G.5 Biotreatment BMP with Partial Infiltration Fact Sheets (BIO)

BIO-1: BIOINFILTRATION

Category: Biotreatment with Partial Infiltration

[This fact sheet also serves as the base fact sheet for INF-3 and BIO-6.]

Also known as:
- Rain Gardens
- Bioretention with Internal Water Storage
- Bioretention with Elevated Underdrain

Source: Geosyntec Consultants

Bioinfiltration facilities are designed for biotreatment with partial infiltration of runoff. Water is biotreated via filtering through a vegetated bed of engineered media. Water is infiltrated via an aggregate storage layer that is designed to discharge only when the storage layer is full. Bioinfiltration facilities are commonly incorporated into parking lot islands, cul-de-sacs, traffic circles, road shoulders, and road medians. These facilities can be used in areas where there are no hazards associated with partial infiltration but infiltrating the full DCV is infeasible. These facilities may not result in retention of the full DCV, but they can be used to achieve the maximum feasible volume reduction through infiltration and ET while providing biotreatment of the remaining portion of the required treatment volume.

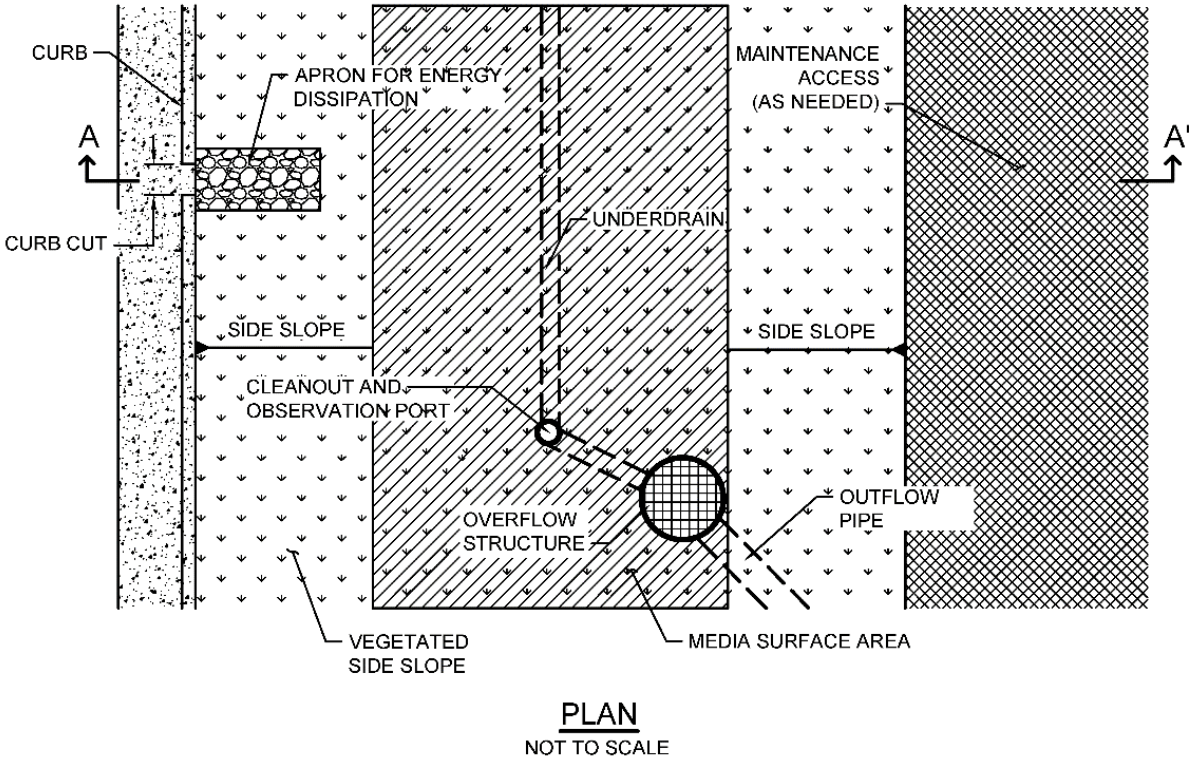
Pollutant Removal Considerations

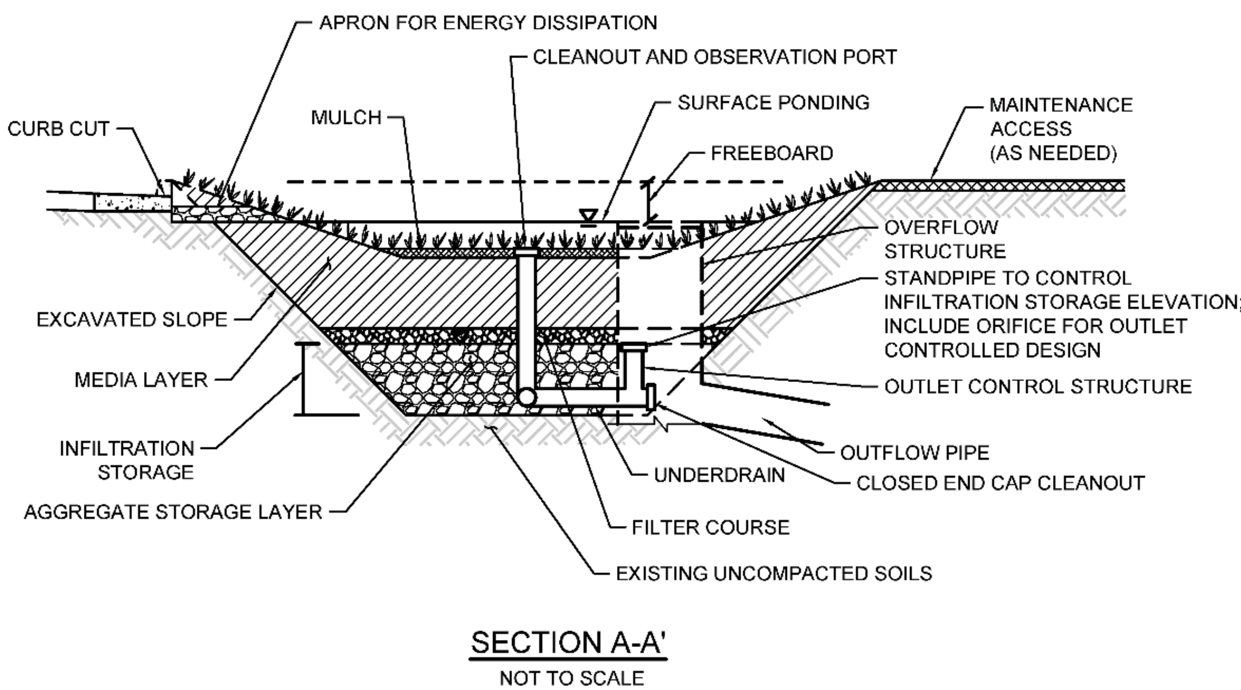
TSS	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
H	M	M	H	M	H	M	H

Recommended Siting Criteria

Siting Criteria	Intent/Rationale
☐ BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Must not negatively impact existing site geotechnical concerns.
☐ BMP is located in an area of the site most suitable for partial infiltration.	To the extent practicable, BMPs must be sited to take advantage of areas where infiltration is likely to be highest.
☐ Tributary area is ≤ 5 acres, preferably ≤ 1 acre.	Larger biofiltration facilities have a higher potential for scour and short circuiting and may require more specific construction methods. **Section 4.4.7** provides specific design considerations for larger facilities.
☐ Sediment sources are controlled prior to operation of the system.	Facility should not be used in areas that will continue to receive elevated sediment loading following construction, such as from open space area.

Example Schematic Design - Plan and Section View





Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard	≥ 6 inches if system has internal overflow Freeboard not required if offline with acceptable bypass	Freeboard provides for water to enter overflow structures and minimizes risk of uncontrolled surface discharge. Lower freeboard (or no freeboard) is allowable if there is an acceptable bypass pathway when the WQ storage is full, such as flow along the curb line to a storm inlet downstream.
Surface Ponding	≥ 3 inches	A lower limit is needed to provide enough surface storage for water to be able to enter the media. Also, very shallow depths are more susceptible to construction error and change over time with O&M activities.
Surface Ponding	≤ 18 inches	Deeper surface ponding depths may require demonstration that premature clogging is not likely and may require fencing.
Ponding Area Side Slopes	3H:1V or shallower	Gentler side slopes are safer, less prone to erosion, able to establish vegetation more quickly and easier to maintain. Vertical walls may be acceptable with appropriate considerations for safety.
Mulch	2-4 inches (average 3 inches)	Mulch is intended to suppress weeds and maintain moisture for plant growth. Mulch also retains sediment and allows sediment to be removed before it clogs the media bed.
Media Layer	≥ 18 inches (24 to 36 inches preferred)	A deeper media layer provides additional filtration and supports plants with deeper roots. The media layer must extend across the BMP to the waterline to ensure no infiltrated water bypasses the media.
Filter Course	4-6 inches	Typically made up of 2 to 3 inches of coarse sand and 2 to 3 inches of pea gravel, both washed. Thinner layers are less effective and may be more challenging to accurately construct.
Infiltration Storage	≥ 18 inches	Provides enhanced volume control. May include the pea gravel portion of the filter course and the full depth of the aggregate storage layer, depending on the outlet control elevation and design.
Underdrain Diameter	≥ 6 inches	Facilitates simpler cleaning.
Cleanout Diameter	≥ 6 inches	Facilitates simpler cleaning.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Pretreatment	
☐ Select pretreatment to provide acceptable clogging timeframe per guidance in Fact Sheet MISC-5 and **Appendix E.4.1**.	BMP performance and longevity is increased. Premature clogging is avoided.
Surface Ponding	
☐ Finish grade of the facility has ≤3 inches of elevation difference across the bottom of the facility.	Flatter surfaces reduce erosion and channelization within the facility and reduce the potential for development of preferential pathways.
☐ Surface ponding is limited to a 24-hour drawdown time.	24-hour drawdown time is recommended for plant health.
Vegetation	
☐ An irrigation system with a connection to water supply should be provided, as needed.	Seasonal irrigation may be needed to ensure robust vegetative processes in relatively coarse-grained media material.
☐ Plant materials should be tolerant of summer drought (unless irrigated), ponding fluctuations, and saturated soil conditions for up to 48 hours; native plant species and/or hardy cultivars that are not invasive and do not require chemical fertilizers or pesticides should be used to the maximum extent feasible. See recommended plant list in **Fact Sheet MISC-4.**	Plants suited to the climate and ponding depth are more likely to survive.
☐ In right of way areas, plant selection should not impair traffic sightlines or vehicle access.	Vegetation should be selected to be compatible with operation of the system and support adjacent uses.
Mulch	
☐ Well-aged, double or triple shredded hardwood mulch that has been stockpiled or stored for at least 12 months. Mulch must be non-floating to avoid clogging of overflow structure.	Mulch provides moisture retention and captures some sediment before it enters the media. Aged hardwood mulch will not rob the soil of nitrogen needed for new plants and will decompose slowly.
Media Layer	
☐ Planting/storage media shall conform to the criteria in **Fact Sheet MISC-1.**	Media is one of the most critical elements of the system and must be specified carefully to avoid pollutant export issues, plant health issues, or premature clogging.
Filter Course Layer	
☐ A filter course is used to prevent migration of fines through layers of the facility. Filter fabric is not used.	Migration of media can cause clogging of the aggregate storage layer void spaces or subgrade. Filter fabric is more likely to clog.
☐ Filter course is washed and free of fines.	Washing aggregate will help eliminate fines that could clog the facility and produce turbidity

Design Criteria	Intent/Rationale
	washout events. For infiltration and partial infiltration systems, washing shall not occur in situ as it could clog the underlying infiltration surface.
☐ Filter course should adhere to guidance provided in **Fact Sheet MISC-3.**	Gradation relationship between layers can evaluate factors (e.g., bridging, permeability, and uniformity) to determine if particle sizing is appropriate or if an intermediate layer is needed.
Aggregate Storage Layer	
☐ The aggregate storage layer depth below the underdrain invert is determined based on a minimum of 18 inches of stone or the depth, which can include the pea gravel portion of the filter course, that will drain within 48 hours at the design infiltration rate of the underlying soil.	The intent of this layer is to maximize incidental volume reduction.
☐ Washed river rock or open-graded, crushed rock.	Washing aggregate will help eliminate fines that could clog the aggregate storage layer void spaces or subgrade.
Inflow, Underdrain and Outflow Structures	
☐ Inflow, underdrains and outflow structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐ Inflow velocities are held to less than 1 ft/s. Dispersed flow or energy dissipation (e.g., riprap, level spreader, curb cut drop and apron) for piped inlets should be provided at inlet to prevent erosion.	High inflow velocities can cause erosion, scour and/or channeling.
☐ An underdrain cleanout with a lockable cap is placed every 100 to 200 feet as required based on underdrain length.	Properly spaced cleanouts will facilitate underdrain maintenance.
☐ At least one observation port is provided in each cell to allow inspection of subsurface water level.	This feature is necessary to facilitate inspection and performance confirmation (i.e., the infiltration storage is draining and providing the volume reduction anticipated).
☐ Underdrain is placed 3 inches above the bottom elevation of the aggregate storage layer.	Separation from subgrade or the liner lessens the risk of fines entering the underdrain and can improve hydraulic performance by allowing perforations to remain unblocked. This configuration allows the system to be fully drained, if needed. Under normal conditions, the water level is controlled via an elbow or standpipe configuration such that the sump storage depth can be adjusted without excavation of the media bed, if needed.
☐ An outlet control approach to maintain subsurface water level and manage flow rates through the media is strongly preferred. To maintain the subsurface water level, an upturned	Outlet control helps prevent preferential pathways and media loss. It also reduces the sensitivity of system performance on the hydraulic conductivity of the media, allowing

Design Criteria		Intent/Rationale
	elbow/standpipe system or equivalent is used in the receiving outlet structure. To control flow rates through the media, an orifice is used, if possible. Orifice size should not be less than 0.5 inches.	media to be specified with a greater factor of safety against clogging.
☐	The outlet control is provided in the catch basin or manhole where the underdrain connects and is accessible for observation and maintenance.	Using outlet control in the receiving catch basin or manhole allows the system to be adapted without requiring excavation.
☐	Underdrains made of are slotted pipe per **MISC-3**.	Slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.
☐	An overflow device is required at the top of the ponding depth to safely convey overflow to the downstream receiving system unless the system is offline and will bypass externally to the facility.	Planning for controlled overflow lessens the risk of property damage due to flooding.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. Checks on footprints associated with clogging risk and volume reduction should be conducted as part of sizing. Retention volume is the volume within the stone reservoir below the underdrain elevation and up to 0.1 inch per inch of pores within the soil (suction/ET storage). Biotreatment volume is the volume in ponded water and soil pores.

Construction Guidance

Construction Guidance		Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Excavate and place media in dry weather, or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction.
☐	Avoid compaction of the base and sidewalls of facilities. Alleviate compaction as needed using mechanical tilling equipment (e.g., rototiller).	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction as much as practicable using sediment and erosion control measures (e.g., silt fence, filter logs, check dams). Remove any confining layer that accumulates as a result of sedimentation. If the location of BMP is used as a temporary erosion and sediment control facility, it	Sediment accumulation can impair infiltration rates.

	Construction Guidance	Intent/Rationale
	should be completely rehabilitated via over excavation, before being placed into service as a post-construction BMP.	
☐	Traffic within the BMP should be avoided unless impractical. If traffic within the system is allowed, only wide track and low-ground pressure equipment is allowed.	Compaction of the system must be avoided as much as possible.
☐	Account for settlement of media when setting finished grades and planting depths.	Media will tend to settle approximately 10 percent. Failure to account for this can result in dimensions different than intended and/or exposure of plant roots.
☐	Use staking, surveying, or other methods to confirm thickness of filter course and media layers.	A uniform thickness of layers is important for effectiveness and to reduce preferential pathways.
☐	Establish the construction sequence to allow for inspection of buried infrastructure (e.g., underdrain, filter course) before it is buried.	It is impractical to inspect buried elements once they are covered.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can seriously impair the hydraulic conductivity of the media bed and require restoration and revegetation of the surface of the media bed.
☐	Allow plants and mulch to stabilize for as long as practicable (preferably several months) prior to placing the finished BMP into service.	Stabilization of the system allows plants to mature and mulch to settle and "knit" before stressing the system with stormwater loading.

Adaptability Considerations

This type of BMP provides a high degree of adaptability. Adjustments to the design and/or operation of the system may be needed if observations from more detailed investigation, construction, or operation are different than what was estimated in design and permitting.

Adjust standpipe elevation and/or uncap lower underdrain (pre- or post-construction) – this can be done to reduce the amount of infiltrated volume and make the system act as bioretention with underdrains (BIO-6). This adaptation could take place between the Preliminary/Conceptual WQMP and the Final Project WQMP should issues with infiltration be identified or following construction should infiltration rates be determined to be lower than estimated.

Add a liner as part of detailed design (prior to construction) – this can be done to further limit infiltration if issues with any level of infiltration are identified as part of detailed design. This adaptation could take place between the Preliminary/Conceptual WQMP and the Final Project WQMP.

To allow for these adaptations, calculations in the WQMP should demonstrate that the system will still be adequately sized if the retention compartment is converted to biofiltration.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Remove trash and debris	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Repair eroded facility areas	
Inspect and maintain access roads	
Inspect and resolve areas of standing water	
Remove minor sediment in facility bottom	
Provide vector control if needed	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Vegetation	
Irrigate as recommended by a landscape professional, typically for the first 3 years to establish vegetation	As needed
Remove undesirable vegetation	Four times per year during wet season, including inspection just before the wet season.
Reseed or replant areas of thin or missing vegetation	Annually
Mulch	
Remove and replace mulch in areas where significant sediment (>1 inch) has accumulated	Annually
Add an additional 1-2 inches of mulch; replace any mulch that is removed	Annually
Media Layer	
Scarify media to promote infiltration while removing mulch	Annually
Replace top 3-6 inches of media layer and replace vegetation	Estimated every 10 years (highly site specific)
Replace full depth of media and replace vegetation	Estimated every 30 years (highly site specific)
Inflow, Underdrain and Outflow Structures	
Check energy dissipation function and add riprap	Four times per year during wet season, including inspection just before the wet season.
Inspect inlets and outlets and remove accumulated sediment	Four times per year during wet season, including

Activity	Frequency
	inspection just before the wet season.
Flush underdrain	As needed
Repair structural damage to inlets, outlets, and underdrain	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

BIO-2: VEGETATED SWALE

Category: Biotreatment (Treatment Control)

Vegetated swales do not meet the definition of biofiltration BMPs, so they are not considered LID BMPs for the purposes of fulfilling LID requirements. They may be used as treatment control BMPs or pretreatment BMPs.

Also known as:
- Grass Swale
- Bioswale
- Bioinfiltration swale

Source: Geosyntec Consultants

Vegetated swales are open, shallow channels designed to provide pollutant removal through settling and filtration in the vegetation, usually grasses, and promote volume reduction, via infiltration and ET, where feasible. An effective vegetated swale achieves uniform sheet flow through a densely vegetated areas. Where soil conditions allow, volume reduction in vegetated swales should be enhanced by adding aggregate storage layer underneath the swale and/or check dams in the swale surface, allowing additional runoff volume to be retained and infiltrated. Where slopes are shallow and there is no appreciable infiltration that will occur or be allowed, an underdrain system or low flow channel for dry weather flows may be required to minimize ponding and convey treated and/or dry weather flows to an acceptable discharge point. Vegetated swales do not meet the required definition of biofiltration and may only be used for pretreatment or as a treatment control BMP.

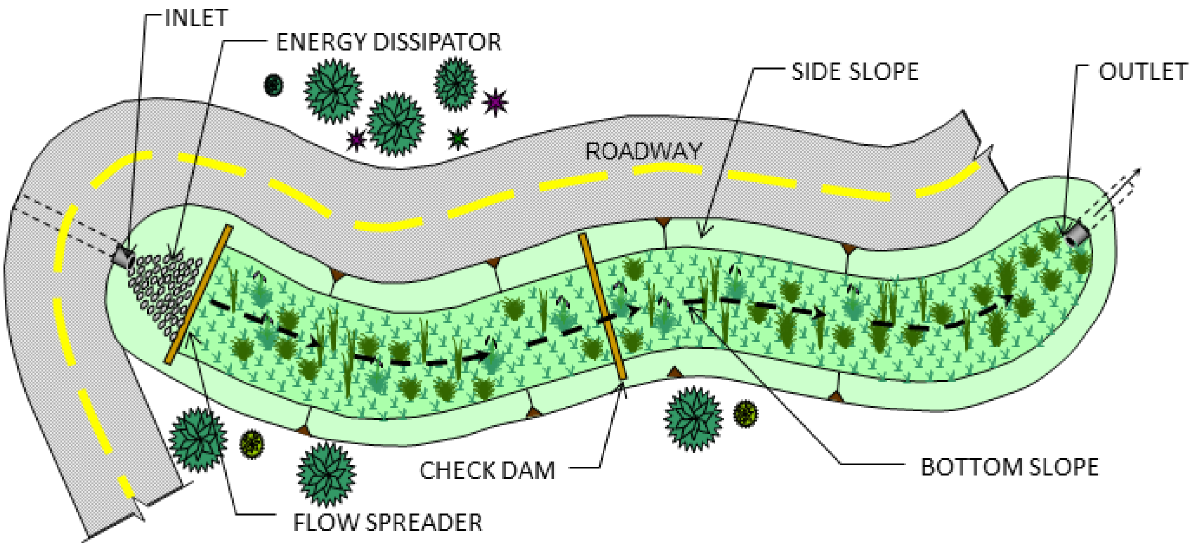
Pollutant Removal Considerations

	TSS	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
Partial Infiltration Configuration (with enhanced infiltration)	M	M	M	M	L	M	M	M
Standard Configuration (no enhanced infiltration)	M	L	L	M	L	M	M	M

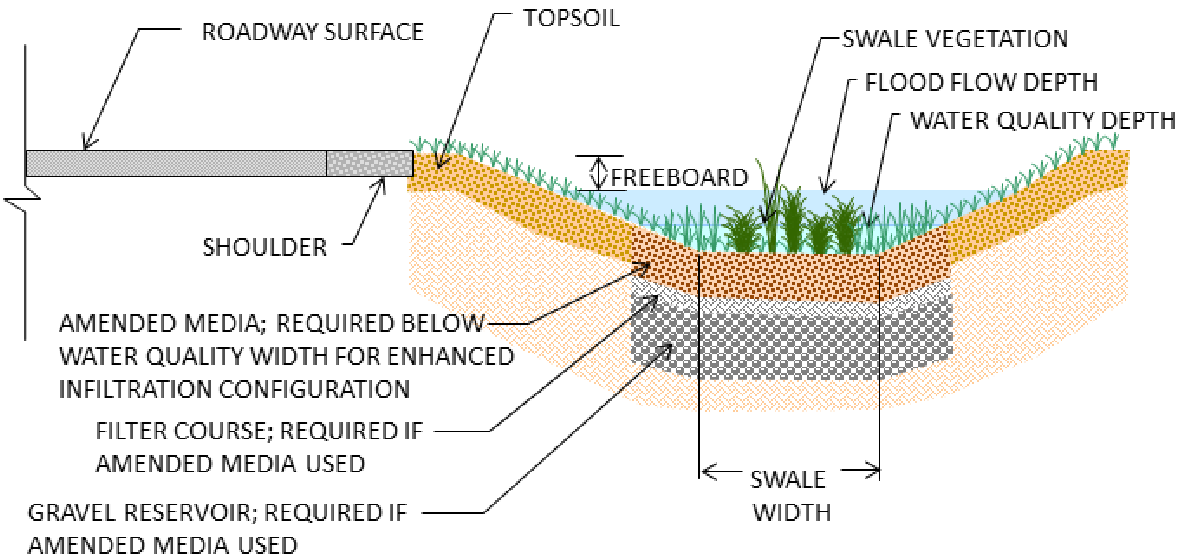
Recommended Siting Criteria

	Siting Criteria	Intent/Rationale
☐	If designed for enhanced infiltration, BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Must not negatively impact existing site geotechnical concerns.
☐	BMP is located in area of the site most suitable for partial infiltration.	To the extent practicable, BMPs must be sited to take advantage of areas where infiltration is likely to be highest.
☐	Tributary area is ≤ 5 acres, preferably ≤ 2 acre.	Larger facilities have a higher potential for scour near inflows and may increase the potential for clogging of infiltration surfaces. Additionally, they require more specific construction methods. See Section 4.4.7.

Example Schematic Design - Plan and Section View



PLAN
NOT TO SCALE



SECTION
NOT TO SCALE

Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard	≥ 0.5 foot	Freeboard provides room for head over overflow structures and minimizes risk of uncontrolled surface discharge. Lower freeboard is allowable if there is an acceptable alternative overflow method.
Water Quality Depth (Surface Flow Depth under maximum treatment flowrate)	≤ 6 inches or ≤ 2/3rd the height of vegetation, whichever is smaller. (≥ 2 inches below shortest plant species preferred).	Flow depth must fall within the height range of the vegetation for effective water quality treatment via filtering.
Surface Flow Length	≥ 100 feet	Minimum swale length for biotreatment. Alternate length may be used if residence time is at least 10 minutes.
Finish Grade Longitudinal Slope	≤ 3% (up to 6% with check dams provided)	Reduces average velocity and associated potential for erosion and preferential flow paths.
Side Slopes	3H:1V or shallower	Gentler side slopes are safer, less prone to erosion, able to establish vegetation more quickly and easier to maintain.
Amended Soil (partial infiltration configuration)	≥ 12 inches underlain by 18 inches gravel	Supports healthy vegetation and provides sump storage for enhanced infiltration; amended soil has higher infiltration rate than top soil to promote conveyance of water into the infiltration sump.
Topsoil/Amended Soils (standard configuration)	≥ 6 inches	Supports healthy vegetation.
Swale Width	2 ≥ and ≤ 8 feet	A minimum of 2 feet minimizes erosion. A maximum of 8 feet prevents channel braiding. Swales greater than 8 feet should have a central berm divider.
Underdrain Diameter (if used)	≥ 6 inches	Facilitates simpler cleaning.
Cleanout Diameter (if underdrain used)	≥ 6 inches	Facilitates simpler cleaning.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Pretreatment	
☐ Swales do not typically require pretreatment.	
Surface Flow	
☐ Flow velocity ≤ 1 ft/s for design water quality flowrate.	Lower flow velocities provide increased pollutant removal via filtration and minimize erosion.
☐ Minimum hydraulic residence time ≥ 10 minutes.	Longer hydraulic residence time increases pollutant removal.
☐ Swale is designed to safely convey the 10-yr storm event unless a flow splitter is included to allow only the water quality event. Flow velocity for 10-yr storm event is ≤ 3 ft/s.	Planning for larger storm events lessens the risk of property damage due to flooding. If the system is online, the velocity through the system should not result in erosion.
Vegetation	
☐ An irrigation system with a connection to water supply should be provided, as needed.	Seasonal irrigation may be needed to ensure robust vegetative processes in relatively coarse-grained media material.
☐ Plant materials should be tolerant of summer drought (unless irrigated), ponding fluctuations, and saturated soil conditions for up to 48 hours; native plant species and/or hardy cultivars that are not invasive and do not require chemical fertilizers or pesticides should be used to the maximum extent feasible. See recommended plant list in **Fact Sheet MISC-4**.	Plants suited to the climate and ponding depth are more likely to survive.
☐ In right of way areas, plant selection should not impair traffic sightlines or vehicle access.	Vegetation should be compatible with operations and adjacent uses.
Soil Amendment and Gravel Reservoir (for enhanced infiltration configuration)	
☐ System should be designed serve primarily as an infiltration system during smaller storms equal to approximately one-third of the DCV or DCF as a target.	In order to be considered a biotreatment BMP, specific design provisions need to be included to promote incidental infiltration loss where feasible.
☐ Soils should be imported or amended to provide an estimated infiltration rate of at least 5 inches per hour over a depth of at least 12 inches over the entire wetted footprint of the swale.	This promotes plant growth and provides permeability for water to flow into the underlying gravel reservoir.
☐ The aggregate storage layer depth below the amended media should be at least 18 inches thick over the entire wetted footprint of the swale.	The intent of this layer is to maximize incidental volume reduction.
☐ The aggregate storage layer should be comprised of washed aggregate with a porosity of at least 40 percent.	Washing aggregate will help eliminate fines that could clog the aggregate storage layer void spaces or subgrade.

Design Criteria	Intent/Rationale
Topsoil/Amended Soils (for standard configuration)	
☐ Topsoil should be decompacted to 6 inches.	This supports healthy plant growth.
☐ Unless soils have adequate fertility, amend soil with at least 2 inches of compost mixed into the top 6 inches of in-situ soils.	This supports healthy plant growth.
Check Dams	
☐ Where slopes are 3% or steeper, check dams should be provided at necessary increments to ensure no more than 12 inches of drop between check dams. For example, at 4 percent slope, check dams would be needed every 25 feet.	Check dams prevent erosion and increase pollutant removal, volume reduction, and hydraulic residence time by lowering flow velocities and providing ponding opportunities.
Filter Course (Only Applicable When Aggregate Reservoir or Underdrain is Used)	
☐ A filter course should be used to prevent migration of fines through layers of the facility. Filter fabric is not used.	Migration of media can cause clogging of the aggregate storage layer void spaces or subgrade. Filter fabric is more likely to clog.
☐ Filter course should be washed and free of fines.	Washing aggregate will help eliminate fines that could clog the facility and impede infiltration.
☐ Filter course should adhere to guidance provided in **Fact Sheet MISC-3.**	Gradation relationship between layers determine bridging and permeability to determine if particle sizing is appropriate or if an intermediate layer is needed.
Inflow, Outlet, and Underdrain Structures (as applicable)	
☐ If slope is less than 1.0% and underlying soils do not support partial infiltration, provide an underdrain over the length of the swale.	Provides adequate drainage for flatter swales to prevent standing water. In conditions with moderately permeable underlying soils (i.e., partial infiltration conditions) an underdrain is not necessary.
☐ Design inflow and underdrains to be accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐ Provide flow dispersion or energy dissipation approaches (e.g., riprap, level spreader, curb cut drop and apron) for piped inlets.	Minimizes erosion, scour and/or channeling.
☐ Provide an underdrain cleanout with a lockable cap every 100 feet or partial increment of 100 feet.	Properly spaced cleanouts will facilitate underdrain maintenance.
☐ Underdrain is placed 3 inches above the bottom elevation of the aggregate storage layer.	A minimal separation from subgrade or the liner lessens the risk of fines entering the underdrain and can improve hydraulic performance by allowing perforations to remain unblocked.
☐ Underdrains are made of slotted pipe per **MISC-3**.	Slotted underdrains provide greater intake capacity, clog resistant drainage, and reduced entrance velocity into the pipe, thereby reducing the chances of solids migration.

Calculations and Sizing Method

See **Appendix E** for acceptable methods for determining the required design flowrate. The Flow-Based Capture Efficiency via Nomograph Method for Sizing Treatment Control BMPs (**Section E.3.7**) is the most applicable method for determining the design flowrate for vegetated swales because they may only be used as treatment control BMPs. After the swale is sized using the methods in **Section E.3**, the user then selects the design flow depth and longitudinal slope and uses the sizing steps below to determine the required length and width of the swale.

- **Step 1: Estimate the Swale Bottom Width**

For shallow flow depths, channel side slopes can be ignored and the bottom width can be calculated using a simplified form of Manning's formula:

$b = (Q \times n_{WQ}) / (1.49 \times y^{1.67} \times s^{0.5})$

Where:

b = estimated swale bottom width, ft

Q = design flowrate, cfs

n_{WQ} = Manning's roughness coefficient for shallow flow conditions, use 0.2 unless other information is available

y = design flow depth, ft (not to exceed 4 inches or 0.33 ft)

s = longitudinal slope in flow direction, ft/ft (not to exceed 0.06)

If b is between 2 and 8 feet, proceed to step 3.

If b is less than 2 feet, increase b to 2 feet and recalculate design flow depth using the following:

$y = ((Q \times n_{WQ}) / (1.49 \times b \times s^{0.5}))^{0.6}$

If b is greater than 10 feet, one of the following steps is necessary:

- Increase design flow depth to a maximum of 4 inches or 0.33 ft, and recalculate b
- Install a divider lengthwise along swale bottom at least three-quarters of the swale length, beginning at the inlet. The swale width can be increased to 16 feet if a divider is provided.

- **Step 2: Determine Design Flow Velocity**

Calculate the design flow velocity using the following equation:

$V_{WQ} = Q / A_{WQ}$

Where:

V_{WQ} = design flow velocity, fps

Q = design flowrate, cfs

$A_{WQ} = by + Zy^2$, cross sectional area of flow at design depth

Z = side slope length per unit height

If the design flow velocity exceeds 1 foot per second, design parameters in Step 2 should be adjusted (slope, bottom width, or design flow depth) until V_{WQ} is equal or less than 1 fps.

- **Step 3: Calculate Swale Length**

Calculate the swale length needed to achieve a minimum hydraulic residence time of 10 minutes using the following equation:

$L = 60 \times t_{HR} \times V_{WQ}$

Where:

L = swale length, ft

t_{HR} = hydraulic residence time, min (minimum 10 minutes)

V_{WQ} = design flow velocity, fps

- **Step 4: If Needed, Adjust Swale Length to Site Constraints**

Note that oftentimes swale length can be accomodated by providing a meandering swale. However, if swale length is too large for the site, the length can be adjusted as follows:

- Calculate the swale treatment top area (A_{top}), based on the swale length calculated in Step 3:

$$A_{TOP} = (b_i + b_{SLOPE}) \times L_i$$

Where:

A_{TOP} = top area (ft^2) at the design treatment depth

b_i = bottom width (ft), calculated in Step 1

b_{SLOPE} = the additional top width (ft) above the side slope for the design water depth (for 3:1 side slopes and a 4-inch water depth, b_{slope} = 2 feet)

L_i = initial length (ft) calculated in Step 3

- Use the swale top area and a reduced swale length (L_f) to increase the bottom width, using the following equation:

$$L_F = A_{TOP} / (b_F + b_{SLOPE})$$

Where:

L_F = reduced swale length (ft)

b_F = increased bottom width (ft)

- Recalculate V_{WQ} according to Step 2 using the revised cross-sectional area A_{WQ} based on the increased bottom width (b_F). Revise the design as necessary if the design flow velocity exceeds 1 foot per second.
- Recalculate to ensure that the 10 minute retention time is retained.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	If amended media is used, handle and place media in dry weather, or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction.
☐	Avoid compaction of the base and sidewalls of facilities that are not designed as lined facilities. Alleviate compaction as needed using mechanical tilling equipment (e.g., rototiller).	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction as much as practicable using sediment and erosion control measures (e.g., silt fence, filter logs, check dams).	Sediment accumulation can impair infiltration rates. If needed, remove sediment and rehabilitate underlying soil, as needed.
☐	Traffic within the BMP should be avoided unless impractical. If traffic within the system is allowed, only wide track and low-ground pressure equipment is allowed.	Compaction of the system must be avoided as much as possible.
☐	Is using media, account for settlement of media when setting finished grades and planting depths.	Media will tend to settle approximately 10 percent. Failure to account for this can result in dimensions different than intended and/or exposure of plant roots.
☐	Use staking, surveying, or other methods to confirm thickness of filter course and media layers, if applicable.	A uniform thickness of layers is important for effectiveness and to reduce preferential pathways.
☐	Establish construction phasing to allow for inspection of buried infrastructure (e.g., underdrain, filter course) before it is buried.	It is impractical to inspect buried elements once they are covered.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can seriously impair the hydraulic conductivity of the media bed and require restoration and revegetation.
☐	Allow plants and mulch to stabilize for as long as practicable (preferably several months) prior to placing the finished BMP into service.	Stabilization of the system allows plants to mature and mulch to settle and “knit” before stressing the system with stormwater loading.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Remove trash and debris	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Repair eroded facility areas	
Inspect and maintain access roads	
Inspect and resolve areas of standing water	
Remove minor sediment in facility bottom	
Provide vector control if needed	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Vegetation	
Irrigate as recommended by a landscape professional, typically for the first 3 years to establish vegetation	As needed
Remove undesirable vegetation	Four times per year during wet season, including inspection just before the wet season.
Repair areas of thin or missing vegetation	Annually
Topsoil/Amended Soils/Media Layer	
Replace top 3-6 inches of top soil or media layer and replace vegetation	Estimated every 10 years (highly site specific)
Replace full depth of top soil, media, aggregate storage (if provided) and replace vegetation	Estimated every 30 years (highly site specific)
Inflow, Underdrain and Outflow Structures	
Check energy dissipation function and add riprap	Four times per year during wet season, including inspection just before the wet season.
Inspect inlets and outlets and remove accumulated sediment	Four times per year during wet season, including inspection just before the wet season.
Flush underdrain, if included in design	As needed
Repair structural damage to inlets, outlets, and underdrain	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance

Activity	Frequency
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

BIO-3: VEGETATED FILTER STRIP

Category: Biotreatment with Partial Infiltration (Treatment Control)

Also known as:

Buffer Strip

Vegetated Buffer

Vegetated filter strips do not meet the definition of biofiltration BMPs, so they are not considered LID BMPs for the purposes of fulfilling LID requirements. They may be used as treatment control BMPs or pretreatment BMPs.

Source: Geosyntec Consultants

Vegetated filter strips are designed to treat sheet flow runoff from adjacent impervious surfaces or intensive landscaped areas such as golf courses. Filter strips decrease runoff velocity, filter out total suspended solids and associated pollutants, and provide infiltration into underlying soils, particularly for smaller storm events. While some assimilation of dissolved constituents may occur, filter strips are generally more effective in trapping sediment and particulate-bound metals, nutrients, and pesticides. Filter strips are more effective when the runoff passes through the vegetation and thatch layer in the form of shallow, uniform flow. Biological and chemical processes may help break down pesticides, absorb metals, and utilize nutrients that are trapped in the filter. These facilities may not result in retention of the full DCV, but they can be used to achieve the maximum feasible infiltration and ET while providing treatment of the remaining portion of the required treatment volume. Vegetated filter strips do not meet the required definition of biofiltration and are therefore only used for pretreatment or as a treatment control BMP.

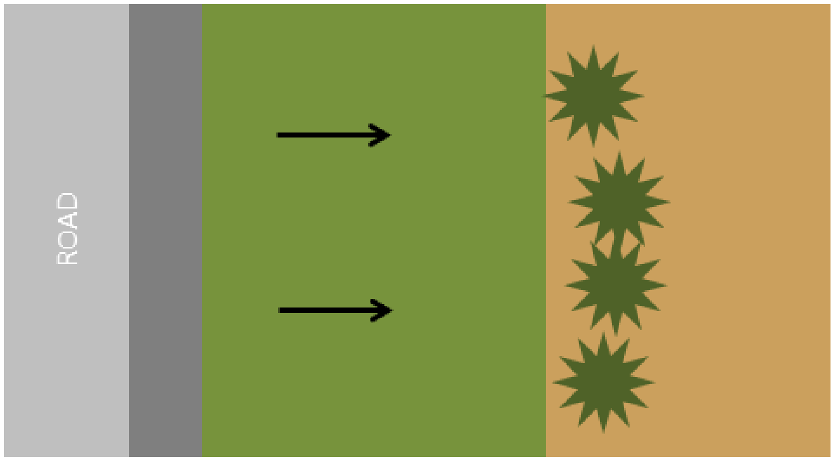
Pollutant Removal Considerations

TSS	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
M	L	L	M	L	M	M	L

Recommended Siting Criteria

	Siting Criteria	Intent/Rationale
☐	BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Some amount of infiltration will tend to occur below a BMP; must not negatively impact existing site geotechnical concerns.
☐	BMP is located in area of the site most suitable for partial infiltration.	To the extent practicable, BMPs must be sited to take advantage of areas where infiltration is likely to be highest.
☐	BMP is adjacent to impervious surfaces.	This type of BMP only operates via sheet flow; it is not practical to disperse pipe flow onto a filter strip.
☐	Width of flow tributary to filter strip does not exceed 50 feet	It is rare for runoff to remain in sheet flow for longer than 50 feet.
☐	Site slope is $\leq$ 2% along edge of filter strip	Helps ensure uniform sheet flow onto the upper edge of the BMP.

Example Schematic Design - Plan and Section View



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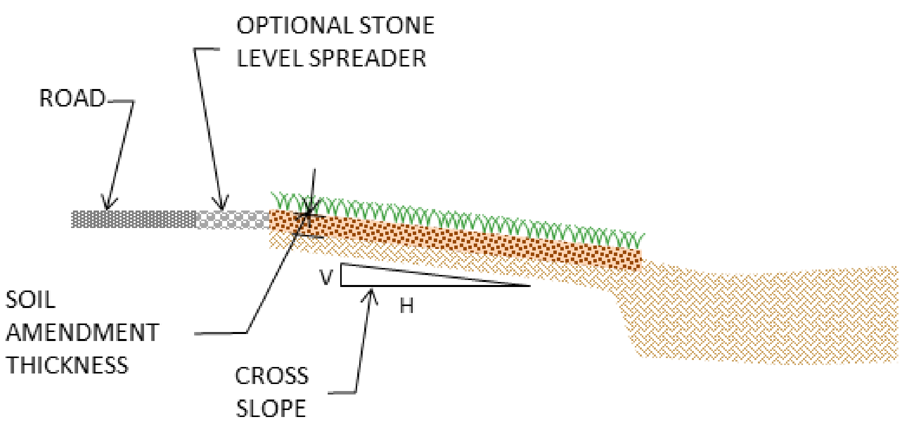

SECTION
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Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Drop from Impervious Area	≥ 2 and ≤ 5 inches	Allows for vegetation and sediment accumulation at the edge of the strip. A beveled transition is acceptable and may be required per roadside design specifications.
Surface Flow Depth	≤ 1 inch	Flow depth must be very shallow for effective treatment.
Surface Flow Length	≤ 50 feet	Helps ensure even sheet flow onto BMP.
Finish Grade Longitudinal Slope (in direction of flow)	Between 1% and 6%	Controls velocities to reduce rill erosion while providing measurable slope for surface drainage.
Finish Grade Cross Slope (perpendicular to flow)	≤ 2%	Helps ensure even sheet flow onto BMP.
Amended Soil Depth	≥ 12 inches	Supports healthy vegetation and enhanced volume reduction.

Recommended Design Criteria and Considerations

	Design Criteria	Intent/Rationale
Surface Flow		
☐	Flow velocity ≤ 0.5 ft/s for water quality event.	Lower flow velocities provide increased pollutant removal via filtration and minimize erosion.
☐	Minimum hydraulic residence time ≥ 10 minutes.	Longer hydraulic residence time increases pollutant removal.
Vegetation		
☐	An irrigation system with a connection to water supply should be provided, as needed.	Seasonal irrigation may be needed to ensure robust vegetative processes necessary to support this BMP type. Where dense, uniform vegetation cannot be established, this BMP should not be used.
☐	Native grasses with uniform stem spacing (non-bunching) are preferred in this application.	Uniform stem spacing is necessary. Native grasses form a thatch that can be beneficial for treatment. Bunching varieties do not provide appropriate uniformity of stems.
Topsoil/Amended Soils (amendment with media is Optional)		
☐	Amend soils to 12-inch minimum depth per criteria in **Fact Sheet MISC-2**.	Provides increased porosity and permeability to support volume reduction and robust plant growth.

Calculations and Sizing Method

See **Appendix E** for acceptable methods for determining the design flowrate. The Flow-Based Capture Efficiency via Nomograph Method for Sizing Treatment Control BMPs (**Section E.3.7**) is the most applicable method for determining the design flowrate for vegetated filter strips because they may only be used as treatment control BMPs. In addition to the design flowrate, filter strips have other sizing aspects that must be met including the minimum filter strip width, the design flow depth, the filter strip design velocity, and the filter strip length. After determining the design flow rate, follow the steps below to determine the other sizing aspects.

- **Step 1: Calculate the Minimum Filter Strip Width**

$W_{MIN} = Q / q_{A,MIN}$

Where:

W_{MIN} = minimum width of filter strip (and tributary area), ft

Q = design flow, cfs

$q_{A,MIN}$ = minimum linear unit application rate, 0.005 cfs/ft

- **Step 2: Calculate the Design Flow Depth**

$d_F = 12 \times ((Q \times n_{WQ}) / (1.49 \times W_{TRIB} \times s^{0.5}))^{0.6}$

Where:

d_F = design flow depth, in

Q = design flow, cfs

n_{WQ} = Manning's roughness coefficient for shallow flow conditions, use 0.2 unless other information is available

W = width of strip (and tributary area), ft (should be equal or greater than W_{MIN})

s = longitudinal slope in flow direction, ft/ft (not to exceed 0.06)

- **Step 3: Calculate the Filter Strip Design Velocity**

Calculate the filter strip design velocity using the following equation:

$V_{WQ} = Q / (d_F \times W)$

Where:

V_{WQ} = filter strip design flow velocity, fps

d_F = design flow depth, in

Q = design flow, cfs

W = width of strip (and tributary area), ft

The design flow velocity should not exceed 1 foot per second. If the velocity exceeds 1 fps, adjust the strip longitudinal slope to decrease the velocity.

- **Step 4: Calculate Filter Strip Length**

Calculate the filter strip length required to achieve the required minimum residence time using the following equation:

$L = 60 \times t_{HR} \times V_{WQ}$

Where:

L = filter strip length, ft (must be 15 ft to 150 ft for biotreatment)

t_{HR} = hydraulic residence time, min (minimum 10 minutes for biotreatment)

V_{WQ} = design flow velocity, fps

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Conduct soil amendment in dry weather, or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction.
☐	Avoid compaction of the filter strip.	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction as much as practicable using sediment and erosion control measures (e.g., silt fence, filter logs, check dams).	Sediment accumulation can impair infiltration rates. Remove any accumulated sediment prior to amending and vegetating the system.
☐	Traffic within the BMP should be avoided unless impractical. If traffic within the system is allowed, only wide track and low-ground pressure equipment is allowed.	Compaction of the system must be avoided as much as possible.
☐	Account for settlement of amended top soil when establishing finished grades and planting depths.	Amended soils will tend to settle approximately 10 percent. Failure to account for this can result in dimensions different than intended.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can seriously impair the hydraulic conductivity of the media bed and require restoration and revegetation of the surface of the media bed.
☐	Allow grass to establish for as long as practicable (preferably several months) prior to placing the finished BMP into service.	Grass must be established for the system to provide treatment.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Remove trash and debris	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Check for eroded facility areas or areas with sparse or dead vegetation	
Inspect for signs of concentrated flow into level spreader or into filter strip	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Repair eroded areas	Four times per year during wet season, including inspection just before the wet season.
Maintain level spreader by making local adjustments to elevations to improve flow distribution over filter strip	Annually
Vegetation	
Irrigate as recommended by a landscape professional, typically for the first 3 years to establish vegetation	As needed
Remove undesirable vegetation (i.e., weeds)	Four times per year during wet season, including inspection just before the wet season.
Reseed areas of thin or missing vegetation	Annually
Topsoil/Amended Soils	
Decompact/aerate to at least a 6-inch depth and reseed to maintain porosity and robust vegetation replace vegetation	Estimated every 10 to 15 years (highly site specific)
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

BIO-4: DRY EXTENDED DETENTION BASIN

Category: Biotreatment (Treatment Control)

Also known as:
Dry Ponds
Detention Basins

Source: Geosyntec Consultants

Dry extended detention basins do not meet the definition of biofiltration BMPs, so they are not considered LID BMPs for the purposes of fulfilling LID requirements. They may be used as treatment control BMPs or pretreatment BMPs.

Dry extended detention basins (DEDBs) are basins that have been designed to detain storm water for an extended period to allow sedimentation. DEDBs do not have a permanent pool; they are designed to drain completely between storm events. They can also be used to provide hydromodification and/or flood control by modifying the outlet control structure and providing additional detention storage. The slopes, bottom, and forebay of DEDBs are typically vegetated. Considerable infiltration can occur in DEDBs when they are located in permeable soils and are not lined with an impermeable barrier. These facilities may not result in retention of the full DCV, but they can be used to achieve the maximum feasible infiltration and ET while providing treatment of the remaining portion of the required treatment volume. DEDBs do not meet the required definition of biofiltration and may only be used as a treatment control BMP.

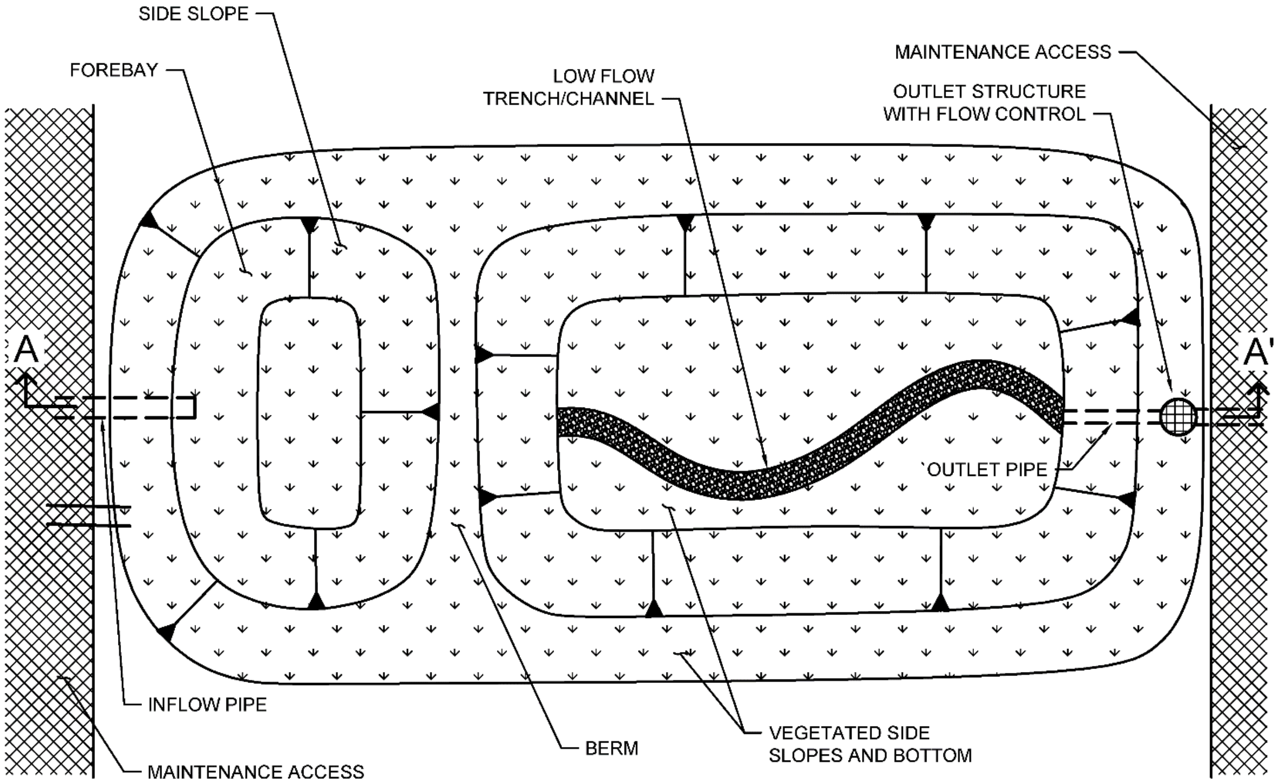
Pollutant Removal Considerations

TSS	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
M	M	L	M	L	M	L	H

Recommended Siting Criteria

Siting Criteria	Intent/Rationale
☐ BMP placement adheres to geotechnical recommendations with respect to geological hazards and setbacks.	Unless lined, some infiltration will occur; must not negatively impact existing site geotechnical concerns.
☐ BMP is located in area of the site most suitable for partial infiltration.	To the extent practicable, BMP must be sited to take advantage of areas where infiltration is likely to be highest.
☐ Any tributary area is acceptable	No significant scaling issues.
☐ Provide space for shallower (<4-foot depth) systems when designing for enhanced infiltration.	Facility footprint is an important factor for volume reduction.

Example Schematic Design - Plan and Section View



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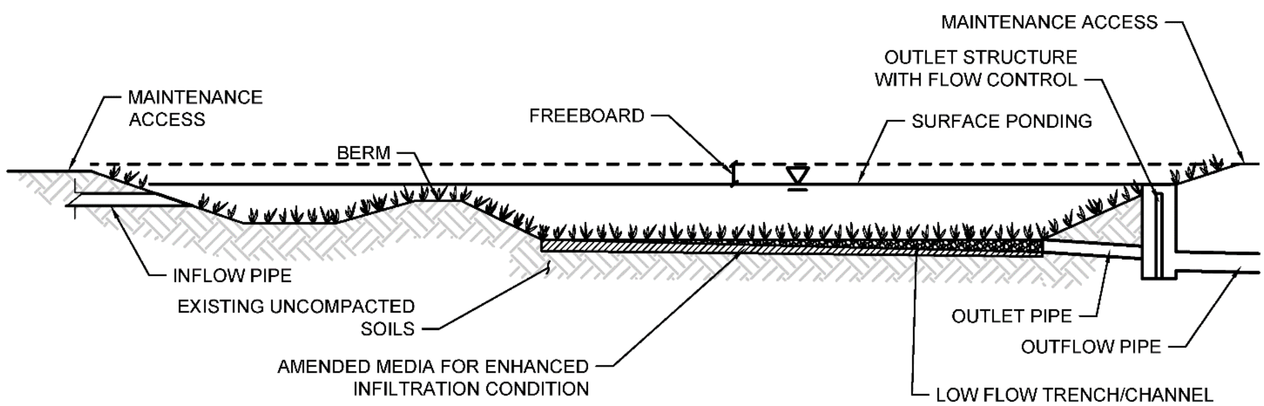

SECTION A-A'
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Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard	≥ 1 foot (offline facilities) ≥ 2 foot (inline facilities)	Freeboard provides room for head over overflow structures and minimizes risk of uncontrolled surface discharge.
Surface Ponding	≤ 4 feet for enhanced infiltration ≤ 8 feet	Ponding limits are guidelines; shallower depth is encouraged to promote a greater portion of losses to infiltration.
Side Slopes	3H:1V or shallower	Gentler side slopes are safer, less prone to erosion, able to establish vegetation more quickly and easier to maintain.
Basin Length: Width Ratio	2:1 or greater is preferred	A larger length to width ratio provides a longer flow path to promote settling.
Longitudinal Basin Bottom Slope	0-2%	Flatter slopes promote ponding and settling of particles.
Low Flow Channel Slope	≥ 2%	Aids in draining dry weather flows.
Forebay Volume	10 percent of total volume	Concentrates accumulation and maintenance of coarser sediment
Forebay Depth/Berm Height	Half of Ponding Depth	Provides a dedicated volume for sediment accumulation.
Amended Media Depth	12 inches	Enhanced volume reduction
Gravel Trench for Low Flows	24-inch-deep by 24-inch wide	Provides pathway for low flows to infiltrate or be treated through the facility.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Forebay	
☐ Volume prior to overflow is ≥ 10% of facility volume.	An adequately sized forebay to trap sediment can decrease frequency of required maintenance and keep efforts more spatially isolated.
Surface Ponding	
☐ Surface ponding has a 36-48 hour drawdown time.	A maximum 48-hour drawdown time is recommended for plant health and vector control. However, shorter drawdown time reduces settling efficiency.
☐ Low flow channel includes a 24-inch wide by 24-inch deep gravel trench.	Promotes infiltration of dry weather flows.
Vegetation	
☐ An irrigation system with a connection to water supply should be provided, as needed.	Seasonal irrigation may be needed to ensure robust vegetative processes in relatively coarse-grained media material.

	Design Criteria	Intent/Rationale
☐	Plant materials should be tolerant of summer drought (unless irrigated), ponding fluctuations, and saturated soil conditions for up to 96 hours during back to back storms. Select from native plant species and/or hardy cultivars that are not invasive and do not require chemical fertilizers or pesticides. See recommended plant list in **Fact Sheet MISC-4**.	Plants suited to the climate and ponding depth are more likely to survive.
Soil Amendment (for enhanced infiltration configuration)		
☐	System should be designed to promote infiltration and ET losses.	In order to be considered a biotreatment BMP, specific design provisions need to be included to promote incidental infiltration loss where feasible.
☐	Soils should be imported or amended to provide an estimated infiltration rate of at least 5 inches per hour over a depth of at least 12 inches over the entire wetted footprint of the basin.	This promotes plant growth and provides permeability for water to flow into the underlying soil.
Inflow and Outflow Structures		
☐	Inlets and outlets are positioned to maximize the length of flow paths through the facility.	Facilitates increased hydraulic residence time (prevents short-circuiting of treatment).
☐	Inflow and outflow structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐	An overflow device is required at the top of the ponding depth to safely convey overflow to the downstream receiving system.	Planning for controlled overflow lessens the risk of property damage due to flooding.
☐	Design outlet structure with desired hydraulics, based on detailed design guidance acceptable to the local jurisdiction	This manual does not provide detailed design guidance for detention basin outlet structures.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Excavate in dry weather, or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction.
☐	Avoid compaction of the base and sidewalls of facilities. Alleviate compaction as needed using mechanical tilling equipment (e.g., rototiller).	Infiltration rates are typically very susceptible to compaction. Infiltration should be maximized.
☐	Keep sediment out of the facility during construction as much as practicable using sediment and erosion control measures (e.g., silt fence, filter logs, check dams).	Sediment accumulation can impair infiltration rates. Remove any sediment that accumulates in the facility during construction.
☐	Traffic within the BMP should be avoided unless impractical. If traffic within the system is allowed, only wide track and low-ground pressure equipment is allowed.	Compaction of the system must be avoided as much as possible.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Sediment accumulation can interfere with vegetation establishment
☐	Allow plants to stabilize for as long as practicable (preferably several months) prior to placing the finished BMP into service.	Stabilization of the system allows plants to mature before stressing the system with stormwater loading.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Remove trash and debris	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Areas of erosion or scour facility areas	
Areas of standing water	
Need for vegetation management	
Need for vector control efforts	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Repair areas of erosion, scour, or standing water	As needed
Sediment	
Remove sediment from forebay when sediment volume exceeds 25% of the sediment storage volume	As needed
Vegetation	
Irrigate as recommended by a landscape professional, typically for the first 3 years to establish vegetation	As needed
Remove undesirable vegetation	Four times per year during wet season, including inspection just before the wet season.
Reseed or replant areas of thin or missing vegetation	Annually
Inflow and Outflow Structures	
Check energy dissipation function and add riprap as needed	Four times per year during wet season, including inspection just before the wet season.
Inspect inlets and outlets and remove accumulated sediment	Four times per year during wet season, including inspection just before the wet season.
Repair structural damage to inlets and outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

BIO-5/BIO-7: PROPRIETARY BIOTREATMENT

Category: Biotreatment with Partial Infiltration (when accompanied by supplemental retention)

Biotreatment with No Infiltration (when used without supplemental retention)

Proprietary biotreatment BMPs are proprietary devices that are manufactured to treat stormwater. **Acceptance criteria for proprietary biotreatment BMPs are defined in Appendix J**. Proprietary BMPs that do not meet these acceptance criteria are not permitted. In addition, proprietary biotreatment BMPs must meet the definition of biofiltration in order to be used as LID biotreatment BMPs. There are two configurations of proprietary biotreatment, as explained in the following subsections.

BIO-5: Proprietary Biotreatment with Enhanced Retention Configuration

As standalone systems, proprietary biotreatment BMPs typically provide negligible volume reduction. To be used as a "biotreatment BMP with partial infiltration," these BMPs must be accompanied by a retention compartment. This could consist of several options:

- Permeable pavement upstream of the proprietary BMPl
- Shallow infiltration gallery or chambers downstream of the BMP, connected to underdrains.
- Proprietary biotreatment downstream of a cistern for harvest and use.
- Use of adequate hydrologic source controls in the watershed to meet volume reduction targets (see Sizing section of this Fact Sheet).
- Other configurations that are determined to be appropriate to maximize the feasible volume reduction for the DMA.

Guidance for retention compartments is provided in other fact sheets, such as INF-5 (Permeable Pavement) and INF-6 (Underground Infiltration).

BIO-7: Standard Configuration without Supplemental Retention

For conditions that do not require partial infiltration, volume retention is not a performance goal. Acceptable proprietary biotreatment BMPs may be used as standalone systems. Guidance related to complementary retention can be disregarded.

Pollutant Removal Considerations

BMPs that meet the acceptance criteria in **Appendix J** are considered to provide adequate treatment for pollutants of concern. According to these critera, there are different levels of treatment certification needed for different pollutants of concern.

Recommended Design Criteria and Considerations

	Design Criteria	Intent/Rationale
☐	Sediment sources should be controlled prior to operation of the system.	Proprietary systems are susceptible to clogging similar to other BMPs. Systems should not be used in areas that will continue to receive elevated sediment loading following construction, such as from open space area.
☐	When accompanied by infiltration compartments, the ponding should not be higher than the underdrain elevation of the proprietary BMP.	This is intended to ensure that the complementary retention compartment does not reduce the hydraulic capacity of the proprietary biotreatment BMP.
☐	When accompanied by infiltration compartments, these infiltration BMPs must adhere to siting guidance found in the respective fact sheet for the BMP	Specific siting considerations apply to infiltration BMPs.
☐	Proprietary biotreatment systems typically do not require separate pretreatment	These BMPs typically include integrated mechanisms for pretreatment.
☐	Proprietary BMPs must be designed in a manner consistent with manufacturer recommendations and consistent with the design configuration that was tested as part of the BMP certification	Proprietary devices have device-specific design, installation, and maintenance details which must be followed for proper treatment results.
☐	In right of way areas, plant selection should not impair traffic sightlines or vehicle access.	Vegetation must not be prohibitive for typical vehicular movement and parking access needs.
☐	Manufacturer guidance on vegetation selection and establishment should be followed	Manufacturers have experience with plant survival in specific climates for the BMP-specific conditions.

Calculations and Sizing Method

Proprietary Biotreatment BMPs are flow-based BMPs. See **Appendix E** for acceptable sizing methods.

Supplemental retention elements (for BIO-5 configuration) should be sized for one of the following targets, where possible:

- Approximately 40 percent long term volume reduction.
- Retention storage provided for approximately one-third of the DCV.
- Infiltration footprint (collective of all infiltrating elements of the project design) meeting target defined in **Section E.4.2**.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Provide for inspection of buried infrastructure (e.g., underdrain, filter course) before it is buried.	It is impractical to inspect buried elements once they are covered.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Sediment loading can seriously impair the capacity of the BMP.
☐	Allow plants and mulch to stabilize for as long as practicable (preferably several months) prior to placing the finished BMP into service.	Stabilization of the system allows plants to mature before stressing the system with stormwater loading.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Remove trash and debris	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Identify excess erosion or scour	
Identify sediment accumulation that requires maintenance	
Inspect during storm event, when possible, to estimate treatment capacity and determine if premature bypass is occurring	
Evaluate plant health and need for corrective action	
Identify any needed corrective maintenance that will require site-specific planning or design	
OPERATION AND MAINTENANCE	
• O&M of proprietary BMPs must follow established manufacturer guidelines • O&M of accompanying retention BMPs should follow the guidelines established in the associated fact sheet for that BMP.	

G.6 Biotreatment BMP without Infiltration Fact Sheets (BIO)

BIO-6: BIORETENTION WITH UNDERDRAIN

Category: Biotreatment

Also known as:
Biofiltration
Planter Box

Source: Geosyntec Consultants

This BMP is very similar to BIO-1, but is tailored to be located in conditions that do not support a significant level of infiltration or where infiltration must be avoided.

Fact Sheet BIO-1 should be the primary resource for guidelines about this BMP. Fact Sheet BIO-6 does not repeat this guidance; it only presents the specific differences that should be considered in design, construction, and O&M in cases where there is not appreciable infiltration.

There are three primary options for adapting the guidance from BIO-1 to serve in conditions where no appreciable level of infiltration is feasible.

No changes to BIO-1 - Where minor incidental infiltration is permissible from the perspective of risks, but does not occur in a significant rate, it is acceptable to simply design the system following the guidance in BIO-1. Standing water in the underdrains for an extended period is an acceptable design variation known as “Internal Water Storage.” This configuration improves nutrient and bacteria removal. It can also result in minor volume reduction even in very tight soils.

Add liner to BIO-1 – Where infiltration must be avoided due to risk of impacts, an impermeable liner of some sort should be used. Continuing to provide aggregate storage layer and internal water storage, as included in BIO-1 is preferred due to pollutant removal benefits.

Eliminate internal water storage – In conditions not suitable for partial infiltration and that do not have nutrients as a pollutant of concern, is is acceptable to eliminate the internal water storage zone. This can reduce the thickness of the gravel storage layer compared to BIO-1. It reduces the effectiveness of the BMP to remove nutrients (from M to L) and bacteria (from H to M).

Pollutant Removal Considerations

Config	Sediment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
With Internal Water Storage	H	M	M	H	H	H	M	H

Without Internal Water Storage	H	L	L	H	M	H	M	H

Recommended Design Criteria and Considerations (only differences from BIO-1 are listed)

Aggregate Storage Layer – Internal Water Storage Configuration Only		
☐	The aggregate storage layer depth below the underdrain invert is a minimum of 18 inches of stone.	The intent of this layer is to provide treatment processes associated with an internal water storage zone.
Underdrain Aggregate Layer –No Internal Water Storage Configuration Only		
☐	The aggregate underdrain layer must provide at least 6 inches of cover on the top and sides of the underdrain pipe and 3 inches below the pipe	The intent of this layer is to provide treatment processes associated with an internal water storage zone.
☐	Underdrains, aggregate, and filter course material maybe located in trenches rather than over the entire bottom of the BMP.	Because volume reduction and/or internal water storage is not a goal, it is not necessary to provide a storage layer.
Impermeable Liner		
☐	Liner has a minimum thickness of 30 mils.	Minimizes tearing and penetration by aggregate or other protrusions.
☐	Liner is free of holes, blisters, undispersed raw materials, contamination by foreign matter, and other defects.	Minimizes facility stormwater loss and contamination.
☐	Liner withstands the range of temperature encountered by open exposure at the site without degradation or deterioration of the lining system.	Minimizes liner deterioration.
☐	Liner, and all other parts of the lining system in contact with liquid is resistant to stormwater pollutants including small concentrations of floating hydrocarbons such as hydraulic oil, diesel fuel, and gasoline.	Minimizes liner deterioration.
☐	Liner is bedded between appropriate material at least 6 inches above and below liner, or greater subject to manufacturer recommendations.	Appropriate bedding materials should be free of sharp objects and any objects larger than 1 inch in dimension. Sand, clean soil, and/or rounded pea gravel are typically appropriate bedding materials.
Observation Port		
☐	An observation port is not necessary for BIO-6.	It is not necessary to inspect the rate of drawdown of infiltration storage.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. Sizing calculations should not take credit for any amount of infiltration. The internal water storage zone should be assumed to be full and not included in sizing calculations.

Construction Guidance (only differences from BIO-1 are listed)

Construction Guidance	Intent/Rationale
☐ Same as BIO-1, except it is not necessary to protect the BMP location from compaction or construction-phase sedimentation. All other provisions from BIO-1 apply.	It is not necessary preserve infiltration capacity of underlying soils.

O&M Activities and Frequencies

No differences in O&M activities compared to BIO-1.

BIO-7: PROPRIETARY BIOTREATMENT

The fact sheet for proprietary biotreatment without supplemental retention is included as part of BIO-5. This page is a placeholder to direct users to see BIO-5.

BIO-8: WET DETENTION BASIN

Category: Biotreatment (Treatment Control)

Also known as:
Wet Ponds
Retention Ponds

Wet detention basins do not meet the definition of biofiltration BMPs, so they are not considered LID BMPs for the purposes of fulfilling LID requirements. They may be used as treatment control BMPs or pretreatment BMPs.

Source: Geosyntec Consultants

Wet detention basins are constructed, naturalistic ponds with a permanent or seasonal pool of water (also called a "wet pool" or "dead storage"). Wet detention basins can be single-celled or two-celled to include a forebay and main basin. Wet ponds must be designed with outlet control to maintain a permanent pool. Stormwater enters the wet detention basin and displaces treated stormwater from the permanent pool, which discharges to the outlet, typically located at the opposite end of the basin (and in the second cell of a two-celled system). The effectiveness of pollutant removal capabilities in wet ponds depends greatly on the hydraulic residence time in the permanent pool. Detention storage ("live storage") can be designed above the permanent pool to provide flow control. Wet detention basins typically achieve little to no volume reduction because they are either lined or in very poorly draining soils in order to maintain the permanent pool. They can, therefore, be used to achieve full treatment of the required treatment volume for DMAs in which biotreatment is not feasible. Wet detention basins do not meet the required definition of biofiltration and may only be used for pretreatment or as a treatment control BMP.

Pollutant Removal Considerations

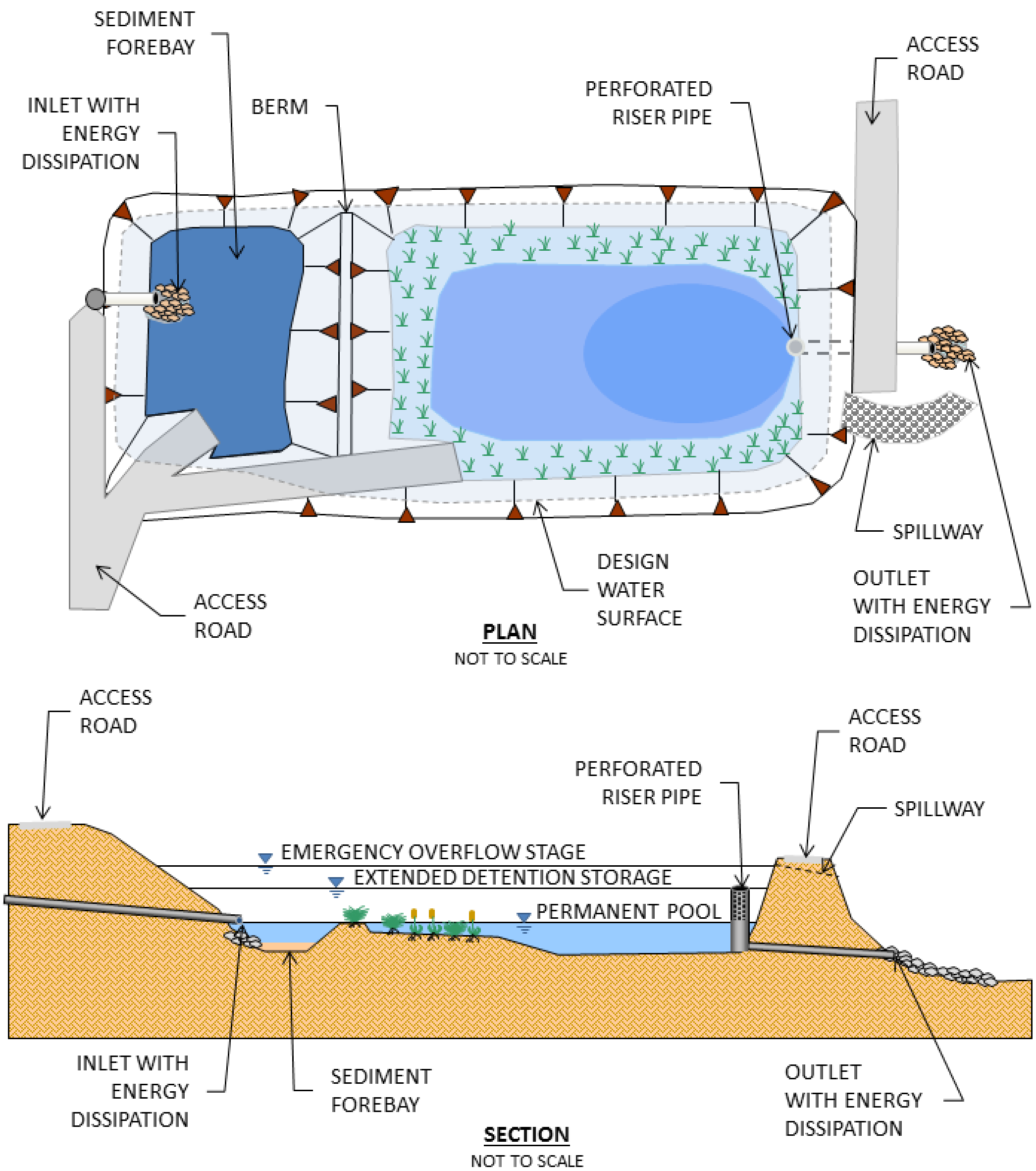
Sediment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
H	M	M	M	M	H	M	H

Recommended Selection and Siting Criteria

Siting Criteria	Intent/Rationale
☐ Soil conditions and base inflow should support the establishment of a permanent pool for the duration of the wet season	The function of wet ponds requires that the permanent remains mostly full, at least during the wet season.
☐ Potable "make-up" water should not be required.	A design that relies on make-up water is generally not acceptable.

☐	Sediment sources are controlled prior to operation of the system.	Major sediment accumulation can interfere with operations and plant establishment
☐	Where seepage could result in risks, a liner should be used.	Continual seepage can result in significant quantities of water infiltrated.

Example Schematic Design - Section View



Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard	≥ 1 foot (offline facilities) ≥ 2 foot (inline facilities)	Freeboard provides room for head over overflow structures and minimizes risk of uncontrolled surface discharge. Lower freeboard is allowable if there is an acceptable alternative overflow method.
Permanent Pool Depth	≥3 feet or at least half of overall depth	Allows for sediment accumulation. Providing approximately half of storage in permanent pool improves residence time.
Side Slopes	3H:1V or shallower	Gentler side slopes are safer, less prone to erosion, able to establish vegetation more quickly and easier to maintain.
Basin Length: Width Ratio	≥ 2:1 (3:1 preferred)	A larger length to width ratio provides a longer flow path to promote settling.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Forebay	
☐ If settling forebay is included (recommended), volume of forebay is ≥ 10% of facility volume.	An adequately sized forebay to trap sediment can decrease frequency of required maintenance.
Vector Management	
☐ A plan for vector management approach (e.g., mosquito) must be developed in consultation with the Orange County Mosquito and Vector Control District	This type of BMP can be a source of mosquitos if not properly designed, operated and maintained.
Extended Detention Storage (above Permanent Pool elevation)	
☐ Detention storage has a 36-48-hour drawdown time.	A 36 to 48-hour drawdown time is recommended to balance settling performance with the ability to treat back-to-back storms
Vegetation	
☐ For vegetation above the permanent pool elevation, an irrigation system with a connection to water supply should be provided, as needed.	Seasonal irrigation may be needed to ensure vegetation establishment and coverage.
☐ Vegetation should be tolerant of the conditions in the zone where it is planted. Native plant species and/or hardy cultivars that are not invasive and do not require chemical fertilizers or pesticides should be used to the maximum extent feasible.	Plants suited to the climate and ponding depth are more likely to survive.

	Design Criteria	Intent/Rationale
Inflow and Outflow Structures		
☐	Inlets and outlets are positioned to maximize flow paths through the facility.	Facilitates increased hydraulic residence time (prevents short-circuiting of treatment).
☐	Inflow and outflow structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐	Outlet control structure is designed to achieve target water quality flow control using acceptable hydraulic design methods	Numerous acceptable methods are available,
☐	An overflow device is required at the top of the ponding depth to safely convey overflow to the downstream receiving system.	Planning for controlled overflow lessens the risk of property damage due to flooding.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. The permanent pool and extended detention storage may be counted as part of the treatment storage volume.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can prematurely compromise sediment storage within the BMP.
☐	Allow plants to stabilize for as long as practicable (preferably several months) prior to placing the finished BMP into service.	Stabilization of the system allows plants to mature before stressing the system with stormwater loading.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Identify eroded facility areas	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Identify needs to improve vector control if needed	
Estimate degree of sediment accumulation	
Identify areas of compromised plant health or density	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Sediment, Trash, and Debris	
Remove trash from facility	Each visit; as needed
Remove sediment from forebay when estimated sediment accumulation exceeds 25% of the forebay volume	As needed
Remove sediment from basin bottom when estimated sediment accumulation exceeds 10% of total volume.	As needed
Vegetation	
Irrigate as recommended by a landscape professional, typically for the first 3 years to establish vegetation	As needed
Remove undesirable vegetation	Four times per year during wet season, including inspection just before the wet season.
Reseed or replant areas of thin or missing vegetation	Annually
Remove algae mats when algae coverage is more than 20% of the water surface	As needed
Inflow and Outflow Structures	
Check energy dissipation function and add riprap, as needed	Four times per year during wet season, including inspection just before the wet season.
Inspect inlets and outlets and remove accumulated sediment	Four times per year during wet season, including inspection just before the wet season.
Repair structural damage to inlets and outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

BIO-9: CONSTRUCTED WETLAND

Category: Treatment Control (most configurations)

Constructed wetlands, in most cases, do not meet the definition of biofiltration BMPs, so they are not considered LID BMPs for the purposes of fulfilling LID requirements. They may be used as treatment control BMPs. Subsurface-flow wetlands can meet the definition of biofiltration BMPs and may be used to fulfill LID requirements. These types of wetlands are not directly supported by this fact sheet but could be designed based on other design resources. They are not common in land development projects as they require a continual baseflow for proper function.

Also known as:
Stormwater Wetlands
Wetland Basins

Source: Geosyntec Consultants

A constructed wetland is a system that mimics the processes within natural wetlands to provide treatment. Constructed treatment wetlands typically include components such as an inlet with energy dissipation, a sediment forebay for settling out coarse solids and to facilitate maintenance, shallow sections (1 to 2 feet deep) planted with emergent vegetation, deeper areas or micro pools (3 to 5 feet deep), and an outlet structure designed to maintain a permanent pool. The interactions between the incoming stormwater runoff, aquatic vegetation, wetland soils, and the associated physical, chemical, and biological unit processes are a fundamental part of constructed wetlands. Constructed wetlands can be used to treat the required treatment volume. Constructed wetlands that are not subsurface-flow wetlands do not meet the required definition of biofiltration and may only be used as a treatment control BMPs.

Pollutant Removal Considerations

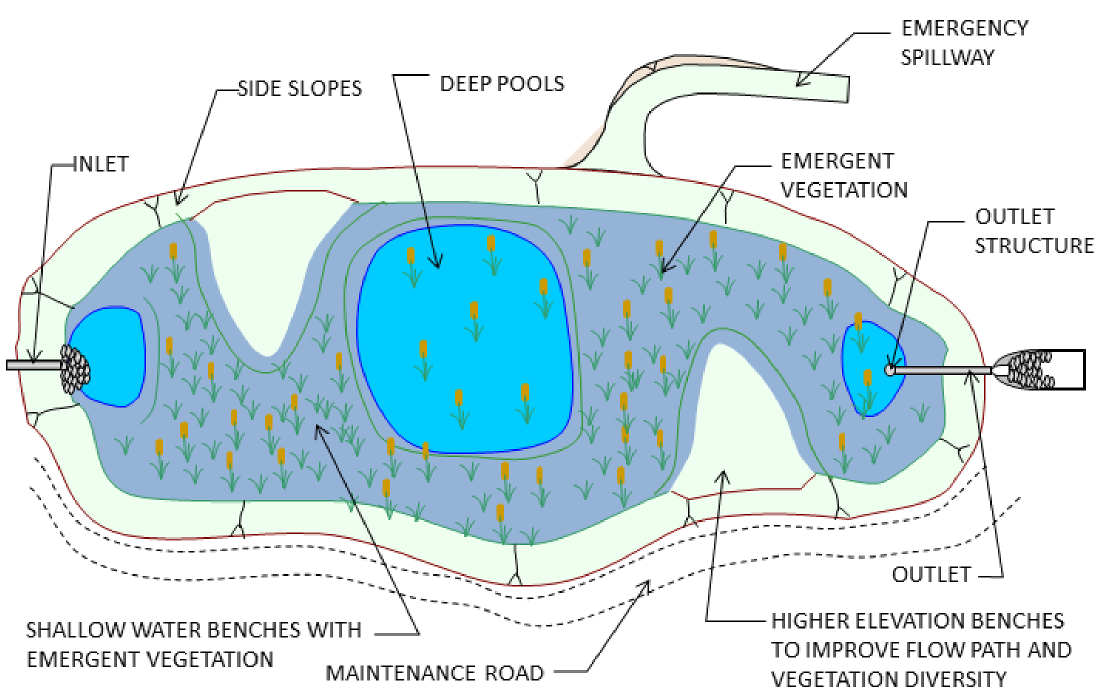
Sediment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
H	M	M	M	M	H	M	H

Recommended Siting Criteria

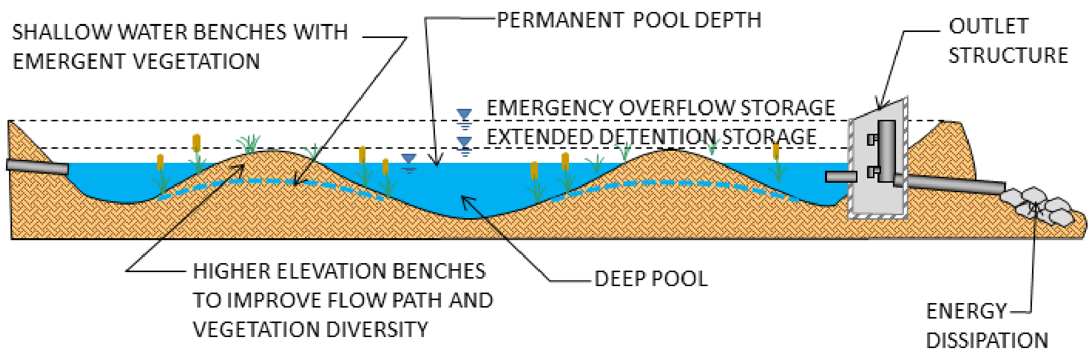
Siting Criteria	Intent/Rationale
☐ Soil conditions and base inflow should support the establishment of a permanent pool year-round.	The function of constructed wetlands requires that the permanent remains mostly full. It is possible that wetlands could be allowed to go seasonally dry, but this is not preferred.
☐ Potable “make-up” water should not be required.	A design that relies on make-up water is generally not acceptable.
☐ Sediment sources are controlled prior to operation of the system.	Major sediment accumulation can interfere with operations and plant establishment

☐	Where seepage could result in risks, a liner should be used.	Continual seepage can result in significant quantities of water infiltrated below normally-wet facilities.

Example Schematic Design – Plan and Section View



PLAN
NOT TO SCALE



SECTION
NOT TO SCALE

Recommended BMP Component Dimensions

BMP Component	Dimension	Intent/Rationale
Freeboard	≥ 1 foot (offline facilities) ≥ 2 foot (inline facilities)	Freeboard provides room for head over overflow structures and minimizes risk of uncontrolled surface discharge. Lower freeboard is allowable if there is an acceptable alternative overflow method.
Permanent Pool Depth	Vary between 4 to 6 feet for deeper pools and 2 to 4 feet for shallower areas	The intent is to provide a mix of emergent vegetation and deep water areas for varied treatment processes.
Side Slopes	3H:1V or shallower	Gentler side slopes are safer, less prone to erosion, able to establish vegetation more quickly and easier to maintain.
Basin Length: Width Ratio	≥ 2:1 (3:1 preferred)	A larger length to width ratio provides a longer flow path to promote settling and allow time for natural treatment processes to remove pollutants prior to discharge. Berms can also be used to increase flow path length.

Recommended Design Criteria and Considerations

Design Criteria	Intent/Rationale
Forebay	
☐ A deeper pool near the inlet can serve as a forebay and energy dissipation	This helps concentrate sediment removal efforts in a specific location.
Vector Management	
☐ A plan for vector management approach (e.g., mosquito) must be developed in consultation with the Orange County Mosquito and Vector Control District	This type of BMP can be a source of mosquitos if not properly designed, operated and maintained.
Permanent Pool	
☐ A natural shape and range of alternating, intermixed, irregular depths is recommended.	Enhances diversity of wetland vegetation and redox conditions which enhances the subsequent treatment capabilities.
☐ A wetland scientist or other appropriate discipline should review the design of the constructed wetland.	Wetlands are complex and require specialized experience to support design.
☐ A source of water during dry weather to sustain the wetland is necessary.	Sustained wetland vegetation and treatment are dependent on a continuous water source.
Extended Detention Storage (above Permanent Pool elevation)	
☐ If detention storage is provided, this storage has a 36-48-hour drawdown time.	A 36 to 48-hour drawdown time is recommended to balance settling performance with the ability to treat back-to-back storms

	Design Criteria	Intent/Rationale
Vegetation		
☐	For vegetation above the permanent pool elevation, an irrigation system with a connection to water supply should be provided, as needed.	Seasonal irrigation may be needed to ensure robust vegetative processes in relatively coarse grained media material.
☐	Wetland plantings should be selected by a wetland scientist or other appropriate discipline, specific to each zone of the wetland. Plants should be native or non-invasive.	Plants suited to the climate and ponding depth are more likely to survive.
Inflow and Outflow Structures		
☐	Inlets and outlets are positioned to maximize flow paths through the facility.	Facilitates increased hydraulic residence time (prevents short-circuiting of treatment).
☐	Inflow and outflow structures are accessible for inspection and maintenance.	Maintenance access is essential to ensure long-term performance.
☐	An overflow device is required at the top of the ponding depth to safely convey overflow to the downstream receiving system.	Planning for controlled overflow lessens the risk of property damage due to flooding.

Calculations and Sizing Method

See **Appendix E** for acceptable sizing methods. The permanent pool and extended detention storage may be counted as part of the treatment storage volume.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, final grading, vegetation, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Conduct earthwork in dry weather, or at least 48 hours after the end of rainfall.	Wetter soil is typically more susceptible to compaction, which can negatively impact plant establishment
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Erosion and sedimentation can sacrifice sediment storage within the BMP.
☐	Allow plants to stabilize for as long as practicable (preferably several months to a year) prior to placing the finished BMP into service.	Stabilization of the system allows plants to establish before stressing the system with stormwater loading.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Identify eroded facility areas	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches.
Identify needs to improve vector control if needed	
Estimate degree of sediment accumulation	
Identify areas of compromised plant health or density	
Identify any needed corrective maintenance that will require site-specific planning or design	
ROUTINE MAINTENANCE	
Sediment, Trash, and Debris	
Remove trash from facility	Each visit; as needed
Remove sediment from forebay when estimated sediment accumulation exceeds 25% of the forebay volume	As needed
Remove sediment from basin bottom when estimated sediment accumulation exceeds 10% of total volume.	As needed
Vegetation	
Irrigate as recommended by a landscape professional, typically for the first 3 years to establish vegetation	As needed
Remove undesirable vegetation	Four times per year during wet season, including inspection just before the wet season.
Replant or reseed areas of thin or missing vegetation	Annually
Remove algae mats when algae coverage is more than 20% of the water surface	As needed
Inflow and Outflow Structures	
Check energy dissipation function and add riprap	Four times per year during wet season, including inspection just before the wet season.
Inspect inlets and outlets and remove accumulated sediment	Four times per year during wet season, including inspection just before the wet season.
Repair structural damage to inlets and outlets	As needed
CORRECTIVE (MAJOR) MAINTENANCE	
Prepare documentation of issues and resolutions for review by appropriate parties; modify WQMP if needed.	Before major maintenance
Document major maintenance activities; record modified WQMP and as-built plan set if needed	After major maintenance
Take photographs before and after from the same vantage point	Before and after

BIO-10: BIOTREATMENT BMPS WITH IMPERVIOUS LINER

Any of the biotreatment BMPs which include partial infiltration (BIO-1 through BIO-5) can be retrofitted for a No Infiltration condition by including an impervious liner below the BMP to prevent infiltration. Any biotreatment BMP must still meet the definition of biofiltration BMP to be used to fulfill LID requirements.

G.7 Treatment Control BMP Fact Sheets (TRT)

TRT-1: SAND FILTER

Category: Treatment Control BMP

Also known as:
Media Bed Filter

Source: CASQA Stormwater BMP Handbook

A sand filter operates by filtering stormwater through a constructed sand bed with an underdrain system. Runoff enters the filter and spreads over the surface. Sand filter beds can be enclosed within concrete or eathen containment. As flows increase, water backs up on the surface of the filter where it is held until it can percolate through the sand. The treatment pathway is downward (vertical) through the media to an engineered underdrain system that is connected to the downstream storm drain system. As stormwater passes through the sand, pollutants are trapped on the surface of the filter, in the small pore spaces between sand grains, or are adsorbed to the sand surface. Because a sand filter lacks vegetation and the associated biologial processes and provides little to no volume reduction, it is a treatment control BMP, not an LID BMP. Treatment control BMPs can be used as pretreatment for other BMPs or to fulfill pollutant removal requirements, but cannot be used as standalone BMPs to fulfill LID requirements. See Section 3 of the Model WQMP for details.

Sand filters have limited role in WQMPs for typical sites. A detailed fact sheet is not provided. Other design references may be used to support sand filter design should a project determine that a sand filter is appropriate.

Pollutant Removal Considerations

Confi	Sediment	Phosphorus	Nitrogen	Metals	Bacteria	Oil & Grease	Organics	Trash
Sand media	H	M	M	M	M	H	M	H
Specialized media	H	M	M	H	M	H	M	H

TRT-2: PROPRIETARY TREATMENT CONTROL BMPS

Category: Treatment Control BMP

Proprietary treatment controls BMPs are proprietary devices that are manufactured to treat stormwater. They do not meet the criteria to be biotreatment. These BMPs can take many different forms depending on the manufacturer, but usually include filtration through engineered, proprietary media mixes and/or filtration through cartridge filters. **Acceptance criteria for proprietary treatment control BMPs are defined in Appendix J**. Proprietary BMPs that do not meet these acceptance criteria are not permitted.

Treatment control BMPs can be used to fulfill pollutant removal requirements and can be used as pretreatment for LID BMPs, but cannot, alone, be used to meet LID requirements. Section 3 of the Model WQMPs provides further details.

Because there are so many different potential types of proprietary treatment control BMPs, this fact sheet provides only general guidance. Specific guidance including pollutant removal, design considerations, construction guidance, and O&M activities is provided by the manufacturer.

Pollutant Removal Considerations

BMPs that meet the acceptance criteria in **Appendix J** are considered to provide adequate treatment for pollutants of concern. According to these critera, there are different levels of treatment certification needed for different pollutants of concern.

Recommended Design Criteria and Considerations

	Design Criteria	Intent/Rationale
☐	Sediment sources should be controlled prior to operation of the system.	Proprietary systems are susceptible to clogging similar to other BMPs. Systems should not be used in areas that will continue to receive elevated sediment loading following construction, such as from open space area.
☐	Proprietary treatment control systems typically do not require separate pretreatment	These BMPs typically include integrated mechanisms for pretreatment.
☐	Proprietary treatment control BMPs must be designed in a manner consistent with manufacturer recommendations and consistent with the design configuration that was tested as part of the BMP certification	Proprietary devices have device-specific design, installation, and maintenance details which must be followed for proper treatment results.

Calculations and Sizing Method

Proprietary Treatment Control BMPs are flow-based BMPs with specific sizing requirements separate from biofiltration BMPs. See **Appendix E** for acceptable sizing methods.

Construction Guidance

	Construction Guidance	Intent/Rationale
☐	Plans should include a construction sequence for the BMP. Revisions proposed by the contractor should be reviewed by the engineer. The construction sequence should address erosion control, utilities, BMP installation, inspections, testing and certifications, stabilization, and post-construction monitoring.	Construction sequencing is critical to avoid issues/damage and allow appropriate inspections, testing, and certifications to be performed.
☐	Provide for inspection of buried infrastructure (e.g., underdrain, filter course) before it is buried.	It is impractical to inspect buried elements once they are covered.
☐	Fully stabilize sources of sediment within the tributary area (i.e., no exposed soil) prior to placing the finished BMP into service.	Sediment loading can seriously impair the capacity of the BMP.

O&M Activities and Frequencies

Activity	Frequency
GENERAL INSPECTIONS	
Remove trash and debris	Four times per year during wet season, including inspection just before the wet season and within 24 hours after at least two storm events ≥ 0.5 inches
Identify excess erosion or scour	
Identify sediment accumulation that requires maintenance	
Inspect during storm event, when possible, to estimate treatment capacity and determine if premature bypass is occurring	
Identify any needed corrective maintenance that will require site-specific planning or design	
OPERATION AND MAINTENANCE	
O&M of proprietary treatment control BMPs must follow established manufacturer guidelines	

APPENDIX H. TECHNICAL BASIS FOR GREEN ROOF DESIGN CRITERIA

The purpose of this appendix is to present minimum criteria for green roofs (roofs with growing media and vegetation) to be considered "self-retaining" for new development and significant redevelopment projects in Orange County. Self-retaining areas are designed to retain the DCV and no further management of these areas is required to meet LID and treatment control performance criteria. This category also includes brown roofs, which are designed with vegetation intended to go seasonally dormant during dry periods. This document describes the functional definition of "self-retaining" that has been applied to green roofs, presents an overview of the analytical methods used to evaluate performance of a range of design criteria, and presents the results of this analysis in terms of the minimum design criteria for green roofs to be considered self-retaining.

H.1 Functional Definition of "Self-Retaining" for Green roofs

HSCs are group of low-tech stormwater management measures that reduce stormwater runoff volume through landscape dispersion and interception of stormwater. As described above, if an HSC is to be considered "self-retaining," it should fully retain the volume from the LID design storm event.

Green roofs are a form of HSC. These systems reduce stormwater runoff volume by retaining a portion of rainfall in soil pores and surface and plant depression storage during storm events and making it available for subsequent ET. Green roofs also provide biotreatment/ biofiltration of water draining through and over roofs, removing pollutants deposited from the atmosphere or from adjacent transportation land uses. Finally, green roofs can have additional benefits beyond stormwater management, including reductions in building heating and cooling costs and reductions in urban heat island effects. As such, green roofs should be encouraged where they can provide appreciable benefit for stormwater management. They do require irrigation, so their effects on water demand should be considered. In addition, green roofs may use reclaimed water for irrigation and measures may be required to mitigate the risk of discharges leaving the site. Green roofs are considered to be self-retaining on the basis that they provide the maximum feasible area for ET and provide biotreatment for the remaining portion of the DCV. Ground-level LID BMPs must still be provided for ground level drainage areas, where feasible, and optionally can be sized to provide additional volume reduction and biotreatment of runoff from green roofs.

The volume reduction potential of green roofs is relatively limited in the southern California climate because of typical patterns of precipitation and ET: during winter months when most rainfall occurs, and particularly during the typical short periods of back-to-back rainfall events, ET rates are relatively low, and pore space is recovered relatively slowly. As such, it is not generally possible for green roofs to provide reliable reduction of the entire DCV within the timeframe criteria applied to other HSCs. To recognize this limitation and still encourage the use of these system, a green roof would be considered to be "self-retaining" (i.e., requiring no other stormwater mitigation measures for the DCV) if the roof retains at least 40 percent of average long term precipitation volume and biotreats the remaining volume.

H.2 Analysis Inputs

To determine the minimum design criteria for a green roof to be considered self-retaining, a simple modeling analysis of precipitation, ET patterns, and green roof design parameters was conducted. This analysis included the following inputs:

- **60 year of hourly precipitation data** from the NCDC Los Angeles International Airport (LAX) climate station (COOP ID: 045114)[10]. The average annual precipitation at LAX is 12 inches, which is approximately the same as observed over much of Orange County, therefore this analysis is applicable to Orange County.
- **Monthly normal reference ET data** from the NCDC Cooperative Summary of the Day at LAX (COOP ID: 045114) (See note 10).
- **Ranges of green roof extensiveness.** Extensiveness is defined as the ratio of the area covered by green roof to the area tributary to the roof (including the roof itself). Extensiveness has a maximum of 1.0. For the study, extensiveness varied from 0.5 (half the roof occupied by green roof with the remaining area draining to the green roof) to 1.0 (the full roof covered by the green roof, or the green roof portion not receiving any "run-on" from other areas).
- **Ranges of landscape coefficients.** The landscape coefficient (K_L) is a multiplier on the ET rate that accounts for the plant species, micro climate (exposure, etc.), and the density of vegetative cover. For the study, landscape coefficients of 0.5 and 0.75 were evaluated, representing low water use species and moderate water use species, respectively. Landscape coefficients are generally believed to be higher on roof tops than for ground-level landscaping because of high exposure to sun and wind. It is not recommended that high water use species be used in green roofs because of the high irrigation demand exerted during summer months and winter dry periods.
- **Ranges of soil moisture retention depth.** Green roof moisture retention depth is the equivalent depth of water that a green roof can hold long enough for ET to have an appreciable effect. For engineered extensive or intensive roofs, this is defined as the field capacity (FC, the volumetric water content retained in soil after a prolonged period of

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[10] This analysis was prepared from data originally developed for another Geosyntec project; therefore different input data sources have been used than were used for other analyses described in this TGD. The input data used for this analysis is believed to be representative of Orange County and differences are very likely within the range of model sensitivity/uncertainty.

draining) minus the wilting point (WP, the lowest volumetric water content that can be achieved via plant transpiration processes). This is generally 15 to 20 percent of the actual thickness of the green roof, depending on the characteristics of the growing media. Some proprietary green roof systems utilized specialized light weight media with enhanced soil moisture retention properties or synthetic materials such as plastic cup layers and wicking materials. These systems are generally specified in terms of the effective depth of water they retain (i.e., the soil moisture retention depth). Soil moisture retention depth was varied from 0 up to 4 inches for this study, representing simple green roofs up to approximately 30 inches deep.

H.3 Analysis Methods

For the purpose of this analysis, Geosyntec developed a model written in VBA (Excel) that incorporates the inputs described above on an hourly basis and tracks the transient storage contained in soil moisture storage. The model can best be thought of as physically representing a bucket of water, where the water level in the bucket corresponds to the amount of moisture held in the green roof soil. Precipitation is applied over the roof and other areas tributary to the roof at hourly time steps corresponding to historical records. When the capacity of the soil moisture layer is exceeded, runoff occurs. During and between events, the monthly normal ET rate is applied to the stored water to recover the storage in the soil moisture layer (i.e., empty the bucket). The precipitation and runoff is tracked and totaled for the model run, yielding the average fraction volume removed.

H.4 Results

Results are presented in terms of the soil moisture retention depth required to achieve at least 40 percent reduction in volume. Results are presented in **Table H-1**. Graphical output of model results is shown in **Table H-1** and **Figure H-2**, and are expressed in terms of landscape coefficient. The landscape coefficient describes the fraction of reference ET that can be assumed to be evapotranspired for a given plant palette. The higher the landscape coefficient, the shallower the depth of the green roof needs to be to achieve 40 percent retention. This would be expected, since water lost to ET is retained (does not run off) and higher landscape coefficient increases the rate of ET. Likewise increasing the extensiveness of a roof has the same effect, since larger green roof surface area per unit of stored volume yields faster moisture recovery rates.

It should be noted that when designing a green roof, consideration should be given to summer irrigation demands as well as wet season performance. While a higher landscape coefficient and more extensive area would theoretically increase wet season performance, this would also tend to increase irrigation demand during the dry season and during dry periods of the wet season.

Table H-1: Green Roof Moisture Retention Depth Required for 40 Percent Volume Reduction, Los Angeles/Orange County

Landscape Coefficient (K_L) = 0.5						
Extensiveness	0.5	0.6	0.7	0.8	0.9	1.0
Minimum Required Moisture Retention Depth, inches	1.3	1.05	0.9	0.8	0.7	0.6
Typical Soil Depth Required to Provide Minimum Moisture Retention Depth (FC - WP = 0.15)	8.7	7.0	6.0	5.3	4.7	4.0
Landscape Coefficient (K_L) = 0.75						
Extensiveness	0.5	0.6	0.7	0.8	0.9	1.0
Minimum Required Moisture Retention Depth, inches	0.9	0.75	0.65	0.55	0.5	0.45
Typical Soil Depth Required to Provide Minimum Moisture Retention Depth (FC - WP = 0.15)	6.0	5.0	4.3	3.7	3.3	3.0

K_L = Landscape Coefficient; WP = soil wilting point; FC = soil field capacity

Figure H-1: Green Roof Performance Relationships for Los Angeles and Orange County, Landscape Coefficient (KL) = 0.5 (Low water use plant palette)

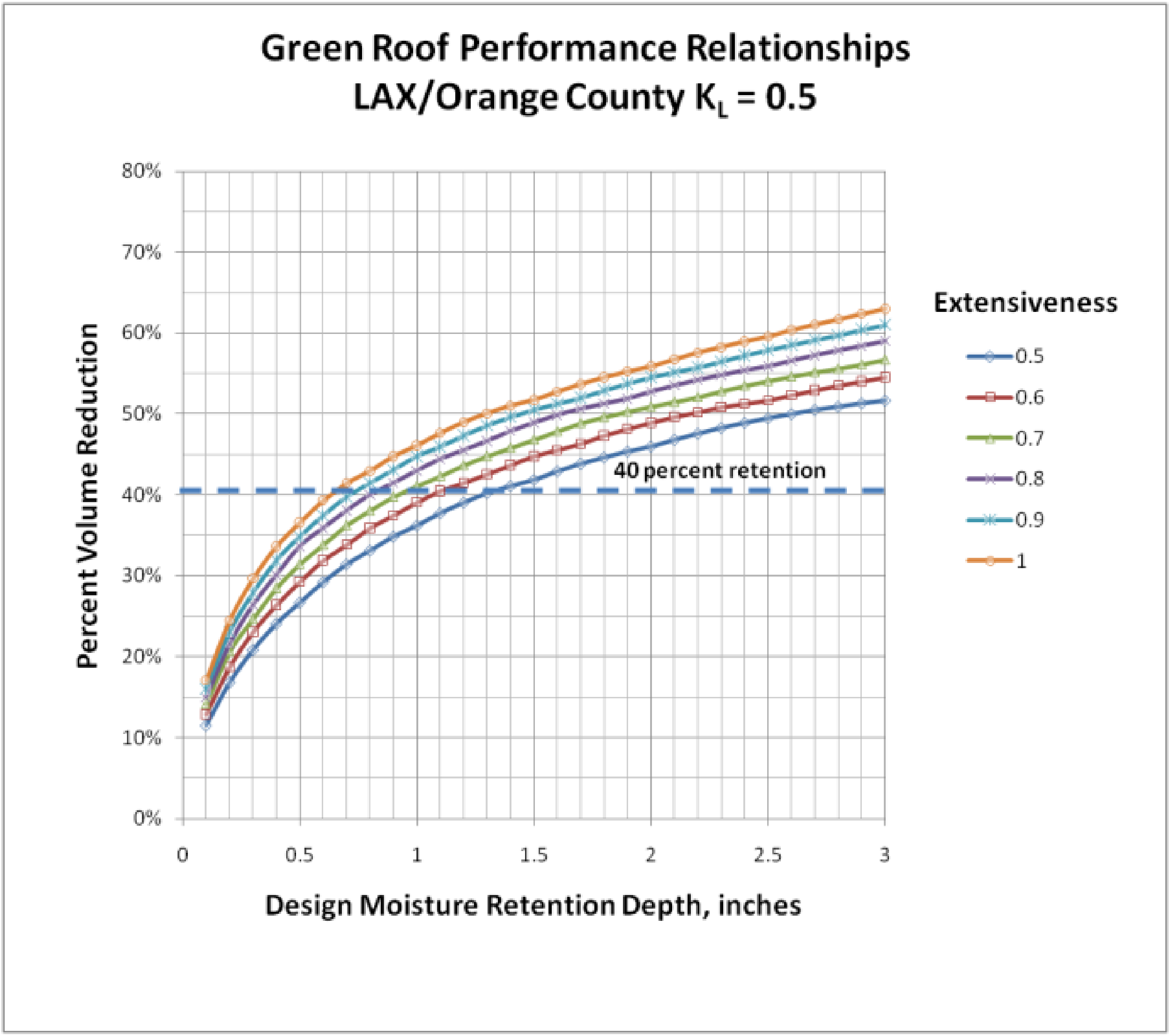
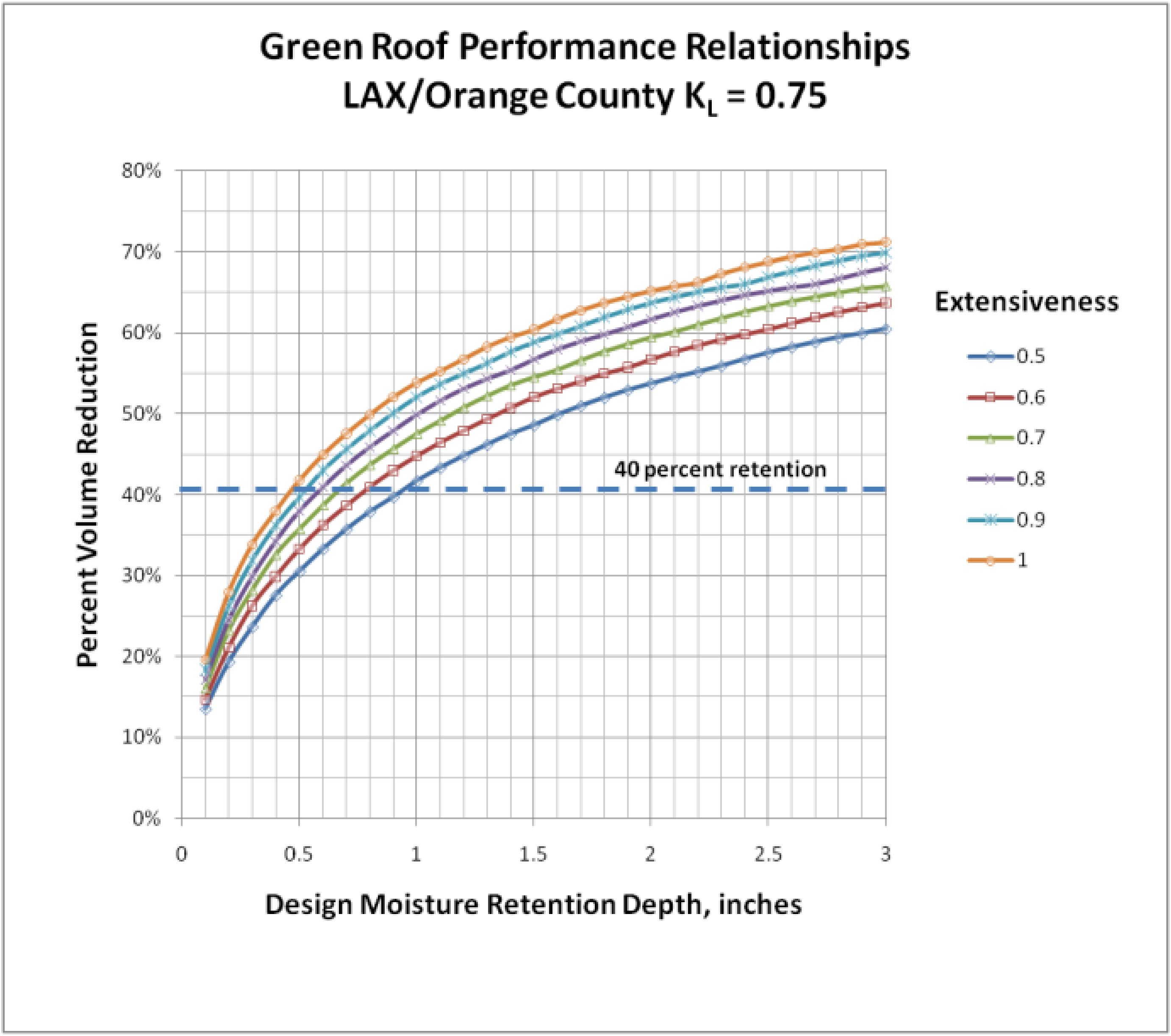


Figure H-2: Green Roof Performance Relationships for Los Angeles and Orange County, Landscape Coefficient (K_L) = 0.75 (Moderate water use plant palette)



APPENDIX I. NOT IN USE

[Placeholder for potential future addition..]

APPENDIX J. PROPRIETARY BMP ACCEPTANCE PROCESS

J.1 Introduction

In the preparation of a Project WQMP, the preparer may determine that the use of a certified proprietary BMP is appropriate. There are three potential roles that proprietary treatment BMPs may serve as part of a Project WQMP:

- Pretreatment;
- Biotreatment, under certain conditions; or
- Treatment control, under certain conditions.

Section 2.5 and **Section 4** of the TGD support the determination of when it is appropriate to use a certified proprietary BMP in any form. This appendix is intended to describe the criteria for determining that particular proprietary BMP has the needed certifications to be used in the intended role.

Acceptance should be evaluated by the reviewing agency on a case by case basis for each Priority Project. Past approvals of a BMP technology for other projects or in other jurisdictions does not provide basis for automatic acceptance or waiver of project-specific review.

J.2 Acceptance Process

The acceptance process for proprietary BMPs is as follows:

1. The Project WQMP must adequately demonstrate that it is appropriate to use a proprietary BMP in the intended role. This shall be done per the BMP selection and design process described in **Section 2.5** and **Section 4**. For example, in a case where it is feasible to provide full or partial infiltration and the project does not have a demonstrated space constraint justifying the use of a compact system, it is not acceptable to use a proprietary biotreatment BMP system unless it is complemented with an infiltration system.
2. The selected proprietary BMP must have adequate certifications or field-scale third party performance demonstration to serve the intended role. The acceptance process relies primarily on third-party assessments of performance and certification standards. The performance standards for determining adequacy are based on the Washington State Technology Acceptance Protocol-Ecology (WA TAPE). Only BMPs with General Use Level Designation (GULD), or equivalent, for a treatment category that is appropriate for the identified BMP role will be considered valid. **Section J.3** identifies the treatment performance category that is valid in each role. The treatment performance standards associated with each performance category are documented in **Section J.4**. Where field-scale data reviewed by a recognized third party testing or

verification agency demonstrates performance equivalent to the WA TAPE standards, then this may be acceptable at the discretion of the reviewing agency. The Technology Acceptance Reciprocity Partnership (TARP) or New Jersey Corporation for Advance Testing (NJCAT) programs are examples of programs that evaluated technologies for performance but did not establish standards for acceptance.

3. The BMP must be used in a manner consistent with manufacturer guidelines and conditions of its third-party certification. Practically, what this means is that the BMP is used in the same way in which it was tested and certified. For example, it is not acceptable for a BMP of a given size to be certified/verified with a 100 gallon per minute treatment rate and be applied at a 150 gallon per minute treatment rate in a design. Certifications or verifications issued by the Washington Technology Acceptance Protocol-Ecology program and the Technology Acceptance Reciprocity Partnership or New Jersey Corporation for Advance Testing programs are typically accompanied by a set of guidelines regarding appropriate design and maintenance conditions that would be consistent with the certification/verification. It is common for these approvals to specify the specific model of BMP, design capacity for given unit sizes, type of media that is the basis for approval, and/or other parameters. The applicant must demonstrate conclusively that the proposed application of the BMP is consistent with these criteria.
4. The acceptability of any proprietary BMP is ultimately at the discretion of the reviewing agency. In addition to demonstrated performance, the reviewing agency may consider other factors such as the ability to inspect the BMP and determine the need for maintenance, the ability to maintain the system with available equipment and staff, the ability to procure a replacement BMP in a similar footprint should a vendor no longer be in business at the time of required replacement, relevant local experience with operation and maintenance of the BMP, and other potential factors. If a proprietary BMP is rejected, the basis for rejection should be provided to the applicant.

The basis and acceptability for the use of proprietary BMPs must be documented in the Project WQMP.

J.3 Acceptable Certifications Based on BMP Role

J.3.1 <u>Proprietary Pretreatment BMPs</u>

Within this TGD, two levels of proprietary BMP certification apply.

- Standard Pretreatment: Any BMP with a GULD approval for “pretreatment” via the WA TAPE program, or demonstrated equivalent performance via a third-party review agency, may be used to provide a standard level of pretreatment.
- Advanced Pretreatment (Basic Treatment): Any BMP with a GULD approval for “basic treatment” via the WA TAPE program, or demonstrated equivalent performance via a third-party review agency, may be used to provide a standard level of pretreatment.

The level of pretreatment should be selected based on clogging risk and contamination risk, as discussed in **Section 4.4.2** of the TGD, Fact Sheet MISC-5 and **Appendix C**.

J.3.2 Proprietary Biotreatment BMPs

Proprietary biotreatment BMPs must be selected based on their ability to effectively remove pollutants of concern. **Table J-1** identifies the WA TAPE treatment levels, or equivalent, that are appropriate for each category of pollutant of concern.

Additionally, to be considered biofiltration, the BMP needs to provide features such as media and plants that meet the applicable definitions that apply in each region. No system is perfectly sterile (i.e., some form of biology is present in all BMPs); however, systems such as cartridge media filters and hydrodynamic separators do not meet the definition of a biotreatment or biofiltration BMP, and many biotreatment BMPs do not meet the definition of a biofiltration BMP. To be used to fulfill LID requirements, a biotreatment BMP must meet the definition of a biofiltration BMP. Additionally, the BMP needs to meet one of the applicable sizing standards for biofiltration.

Table J-1. Acceptable WA TAPE Certifications, or Equivalent, for Polltuants of Concern

Project Pollutant of Concern	Acceptable Technology Acceptance Protocol-Ecology Certification, or Equivalent
Trash	Pretreatment, Basic Treatment, Phosphorus Treatment, or Enhanced Treatment
Sediments	Basic Treatment, Phosphorus Treatment, or Enhanced Treatment
Oil and Grease	Basic Treatment, Oil Treatment, Phosphorus Treatment, or Enhanced Treatment
Nutrients	Phosphorus Treatment[1]
Metals	Enhanced Treatment
Pesticides	Basic Treatment (including filtration)[2] Phosphorus Treatment, or Enhanced Treatment
Organics	Basic Treatment (including filtration)[2] Phosphorus Treatment, or Enhanced Treatment
Bacteria and Viruses	Basic Treatment (including bacteria removal processes)[3], Phosphorus Treatment, or Enhanced Treatment

1 – There is no Technology Acceptance Protocol-Ecology equivalent for nitrogen compounds; however, systems that are designed to retain phosphorus (as well as meet basic treatment designation), generally also provide treatment of nitrogen compounds. Where nitrogen is a pollutant of concern, relative performance of available certified systems for nitrogen removal should be considered in BMP selection.
2 – Pesticides, organics, and oxygen demanding substances are typically addressed by particle filtration; if a system with Basic treatment certification does not provide filtration, it is not acceptable for pesticides, organics or oxygen demanding substances.

3 – There is no Technology Acceptance Protocol-Ecology equivalent for pathogens (viruses and bacteria), and testing data are limited because of typical sample hold times. Systems with Basic Treatment certification must also include one or more significant bacteria removal process such as media filtration, physical sorption, predation, reduced redox conditions, and/or solar inactivation.

J.3.3 Proprietary Treatment Control BMPs

Proprietary treatment control BMPs must be selected based on their ability to effectively remove pollutants of concern. **Table J-1** identifies the WA TAPE treatment levels, or equivalent, that are appropriate for each category of pollutant of concern. These BMPs do not need to meet the definition of biofiltration. Biotreatment BMPs that do not meet the definition of biofiltration BMPs are considered treatment control BMPs. They must be sized per applicable sizing standards for treatment control.

J.4 TAPE Performance Standards

Table J-2 describes the underlying performance standards for each category of WA TAPE approval. Where a different source of third-party data is considered, it should be evaluated against these standards and be based on a similarly-rigorous testing and statistical analysis protocol to the WA TAPE program.

Table J-2. Performance Standards for WA TAPE Performance Categories

Performance Goal	Influent Range	Criteria
Basic Treatment	20 – 100 mg/L TSS	Effluent goal ≤ 20 mg/L TSS
	100 – 200 mg/L TSS	≥ 80% TSS removal
	>200 mg/L TSS	> 80% TSS removal
Enhanced (Dissolved Metals) Treatment	Dissolved copper 0.005 – 0.02 mg/L	Must meet basic treatment goal and better than basic treatment currently defined as >30% dissolved copper removal
	Dissolved zinc 0.02 – 0.3 mg/L	Must meet basic treatment goal and better than basic treatment currently defined as >60% dissolved zinc removal
Phosphorous Treatment	Total phosphorous 0.1 – 0.5 mg/L	Must meet basic treatment goal and exhibit ≥50% total phosphorous removal
Oil Treatment	Total petroleum hydrocarbon > 10 mg/L	No ongoing or recurring visible sheen in effluent. Daily average effluent Total petroleum hydrocarbon concentration < 10 mg/L Maximum effluent Total petroleum hydrocarbon concentration for a 15 mg/L for a discrete (grab) sample
Pretreatment	50 – 100 mg/L TSS	≤ 50 mg/L TSS
	≥ 200 mg/L TSS	≥ 50% TSS removal

APPENDIX K. APPROVED METHODS FOR QUANTIFYING AND MITIGATING HCOCS IN NORTH ORANGE COUNTY [PLACEHOLDER]

[This appendix does not apply to projects in the South Orange County Permit Region. This appendix is a placeholder for the addition of content specific to North Orange County after adoption of the 5th Term North Orange County MS4 Permit. This content would be added through a subsequent reissuance of this TGD.]

APPENDIX L. ADDITIONAL GUIDANCE ON HYDROMODIFICATION MANAGEMENT IN SOUTH ORANGE COUNTY

See the South Orange County HMP (dated September 28, 2017, or subsequent update) for guidance on hydromodification management.

If a priority new development project is located within a potential critical coarse sediment area per Appendix N.8 of this TGD, see Section 4 of the HMP for guidance on site-specific evaluation of critical coarse sediment.

Consult the HMP for criteria and guidance for the use of the Southern Orange County Hydrology Model (SOHM) for hydromodification BMP sizing.

No other guidance is provided at this time.

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APPENDIX M. WORKSHEETS

This section provides hyperlinks to each of the worksheets embedded in text of this TGD.

Worksheet 1: Infiltration Feasibility Categorization

Worksheet 2: Summary of Groundwater-related Feasibility Criteria

Worksheet 3: Factor of Safety and Design Infiltration Rate and Worksheet

Worksheet 4: Hydrologic Source Control Calculation Form

Worksheet 5: Simple Design Capture Volume Sizing Method for Full Infiltration BMPs

Worksheet 6: Capture Efficiency Method for Full Infiltration, Constant Drawdown BMPs

Worksheet 7: Biofiltration Routing Method for Sizing Bioretention BMPs with Underdrains

Worksheet 8: Static Volume Method for Sizing Bioretention BMPs with Underdrains in SOC

Worksheet 9: Flow-Based Compact Biofiltration with Supplemental Retention Method

Worksheet 10: Nomograph Method for Determining Capture Efficiency of Harvest and Use BMPs

Worksheet 11: Capture Efficiency and Multiplier Method for Flow-Based Biotreatment BMPs

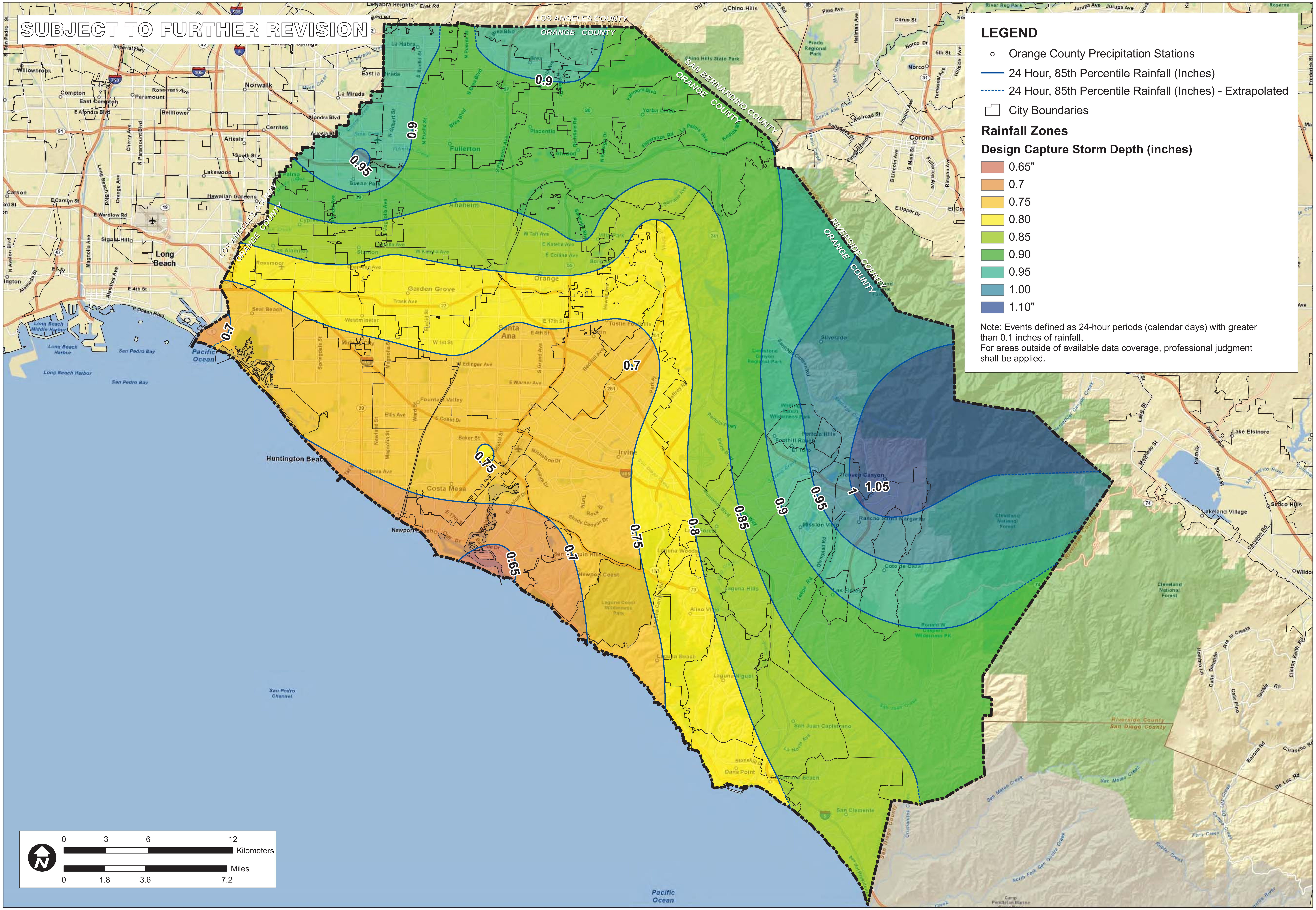
APPENDIX N. EXHIBITS

This appendix includes exhibits relevant to South Orange County which provide information useful in development of a Project WQMP. The first three exhibits cover all of Orange County and are carried over from the previous version of this TGD. The rest of the exhibits are specific to individual watersheds within South Orange County. These are excerpts from the Watershed Infiltration Hydromodification Management Plan or the Watershed Management Area Analysis which is part of the Water Quality Improvement Plan. The table below lists the exhibits provided in this appendix and some of their potential uses in the WQMP development process.

Table N-1: Inventory of Exhibits and Potential Uses in WQMP Development

Exhibit	Potential Uses in WQMP Development
Whole County (Appendix N.1)	
Orange County Rainfall Zones Map from 2013 TGD	Used in sizing structural BMPs
Orange County Hydrologic Soil Group Map from 2013 TGD	Used in infiltration feasibility categorization
Orange County Seismic Hazards Map from 2013 TGD	Used in infiltration feasibility categorization
Each South Orange County Subwatershed (Appendix N.2 through N.6): Laguna Coastal Streams, Aliso Creek, Dana Point Coastal Streams, San Juan Creek, San Clemente Coastal Streams)	
Rainfall Zones Map from WIHMP	Used in sizing structural BMPs in Laguna Coast Watershed
Infiltration Constraints Map from WIHMP	Used in infiltration feasibility categorization
Low Permeability Soils Map from WIHMP	Used in infiltration feasibility categorization
Landslide Areas Map from WIHMP	Used in infiltration feasibility categorization
Physiographic Features Map from WIHMP	Used in infiltration feasibility categorization
Hydromodification Susceptibility and Potential Critical Course Sediment Yield Maps (Appendix N.7 and N.8)	
N.7 Hydromodification Susceptibility Maps from HMP with Adjustments for Permanent Hydromodification Exemptions per Approved WMAA	Determine applicability of hydromodification requirements
N.8 Potential Critical Course Sediment Yield Maps from WMAA	Help assess whether critical coarse sediment may be present within the project. Note that these exhibits are not conclusive. The appropriate usage of these maps is explained in WMAA.

N.1 Countywide Precipitation and Infiltration Feasibility Exhibits



TITLE
RAINFALL ZONES

JOB
ORANGE COUNTY TECHNICAL GUIDANCE DOCUMENT
ORANGE CO. CA

SCALE 1" = 1.8 miles
DESIGNED TH
DRAWING TH
CHECKED BMP
DATE 04/22/10
JOB NO. 9526-E

PACE Advanced Water Engineering

FIGURE
XVI-1

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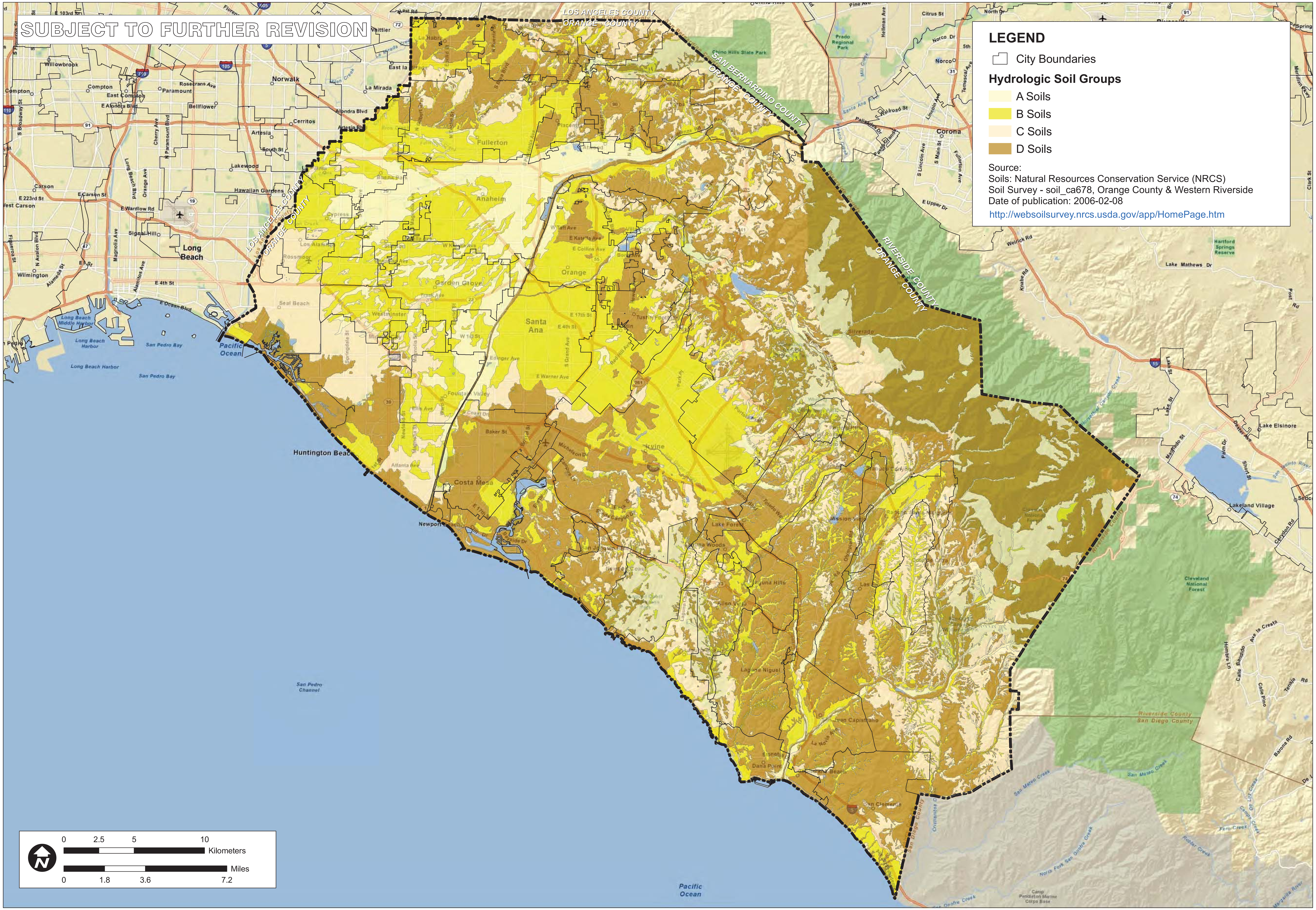

TITLE

NRCS HYDROLOGIC SOILS GROUPS

JOB

ORANGE COUNTY INFILTRATION STUDY

ORANGE CO. CA

SCALE 1" = 1.8 miles
DESIGNED TH
DRAWING TH
CHECKED BMP
DATE 02/09/11
JOB NO. 9526-E

PACE Advanced Water Engineering

FIGURE

XVI-2a

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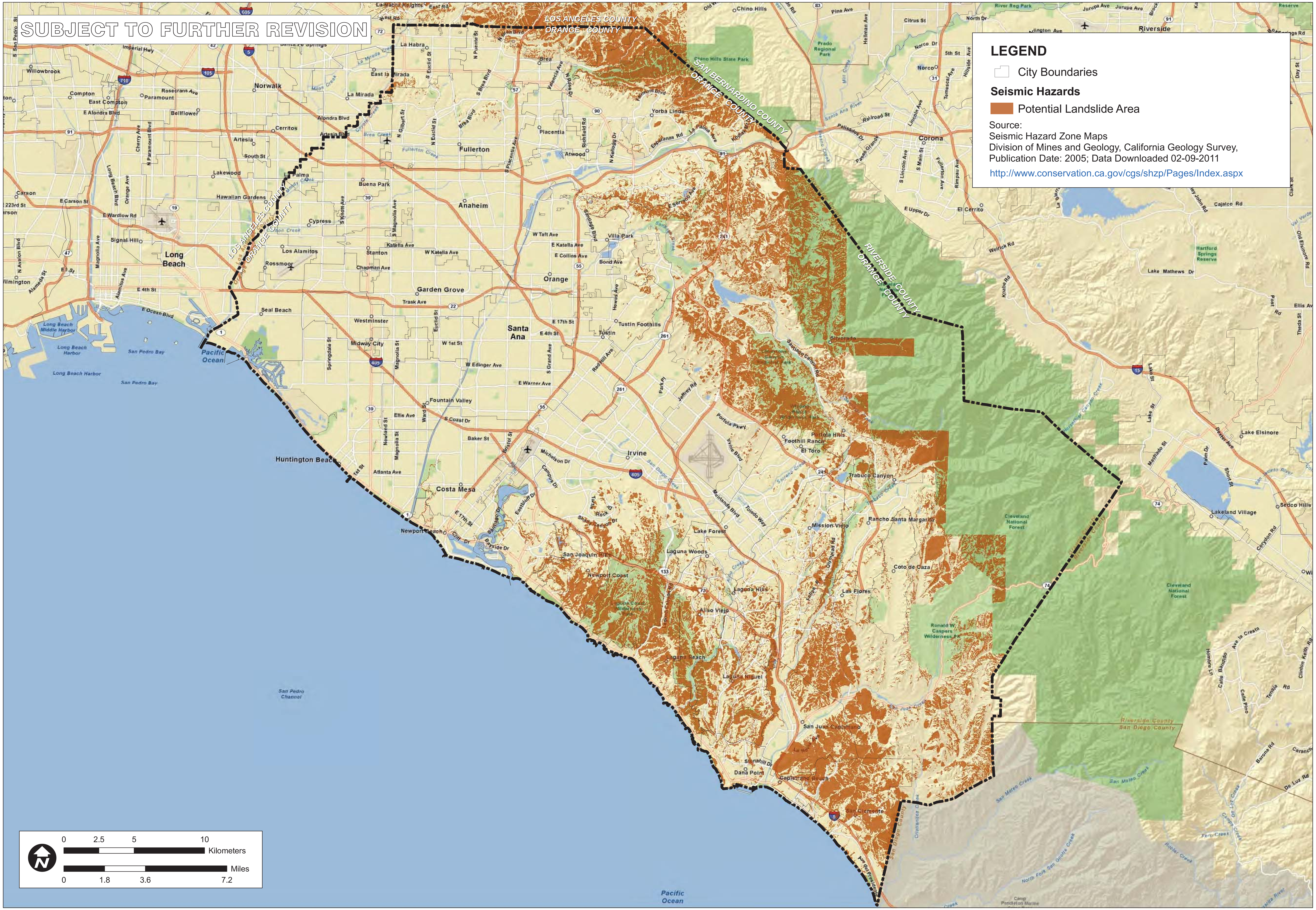

TITLE

HYDROLOGIC SOIL GROUP
TYPE D NRCS SOIL SURVEY

JOB

ORANGE COUNTY
INFILTRATION STUDY

ORANGE CO. CA

SCALE	1" = 1.25 miles
DESIGNED	TH
DRAWING	TH
CHECKED	BMP
DATE	02/09/11
JOB NO.	9526-E

PACE
Advanced Water Engineering

FIGURE

XVI-2c

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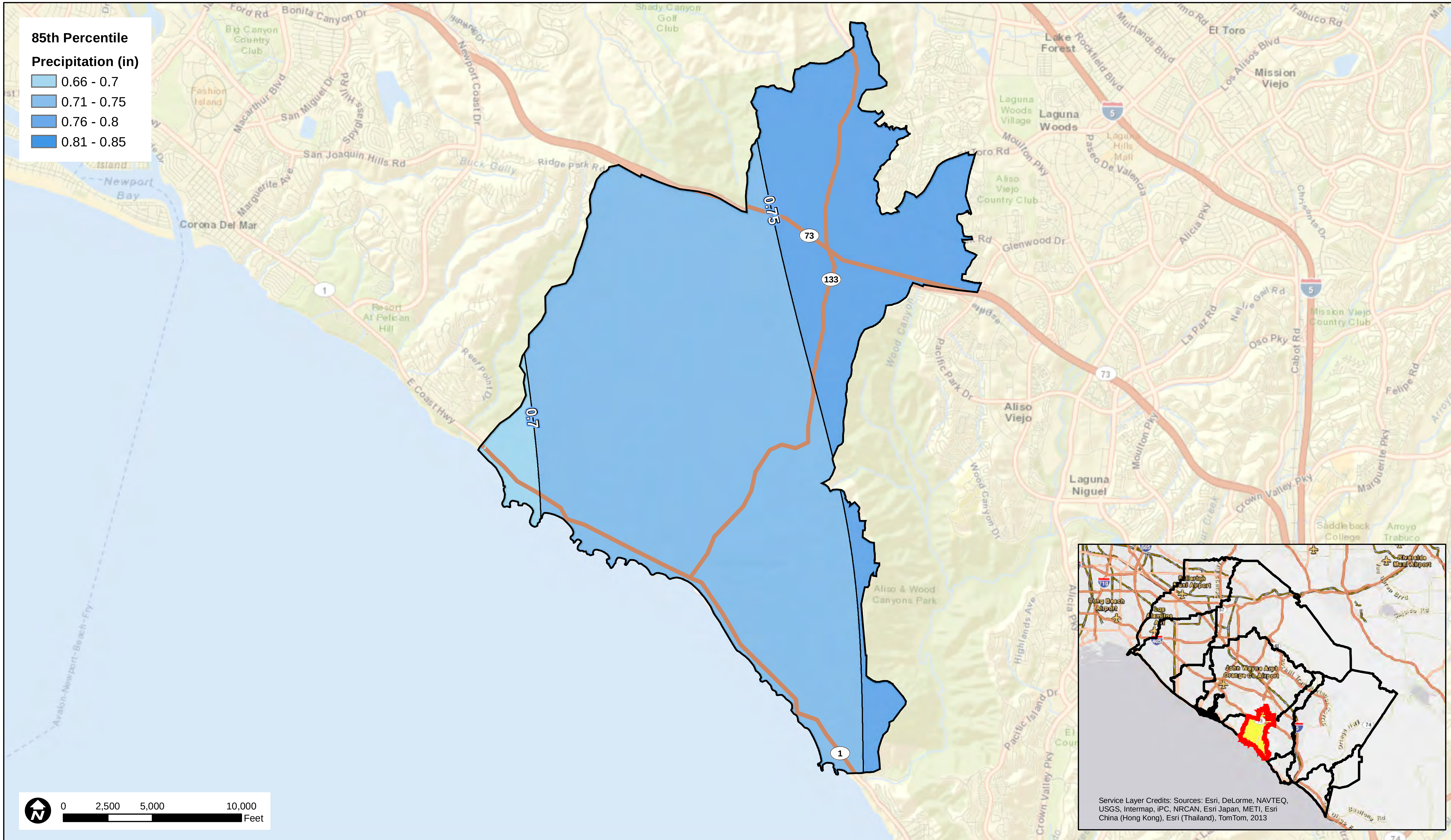
N.2 Laguna Coastal Streams Rainfall and Infiltration Feasibility Exhibits

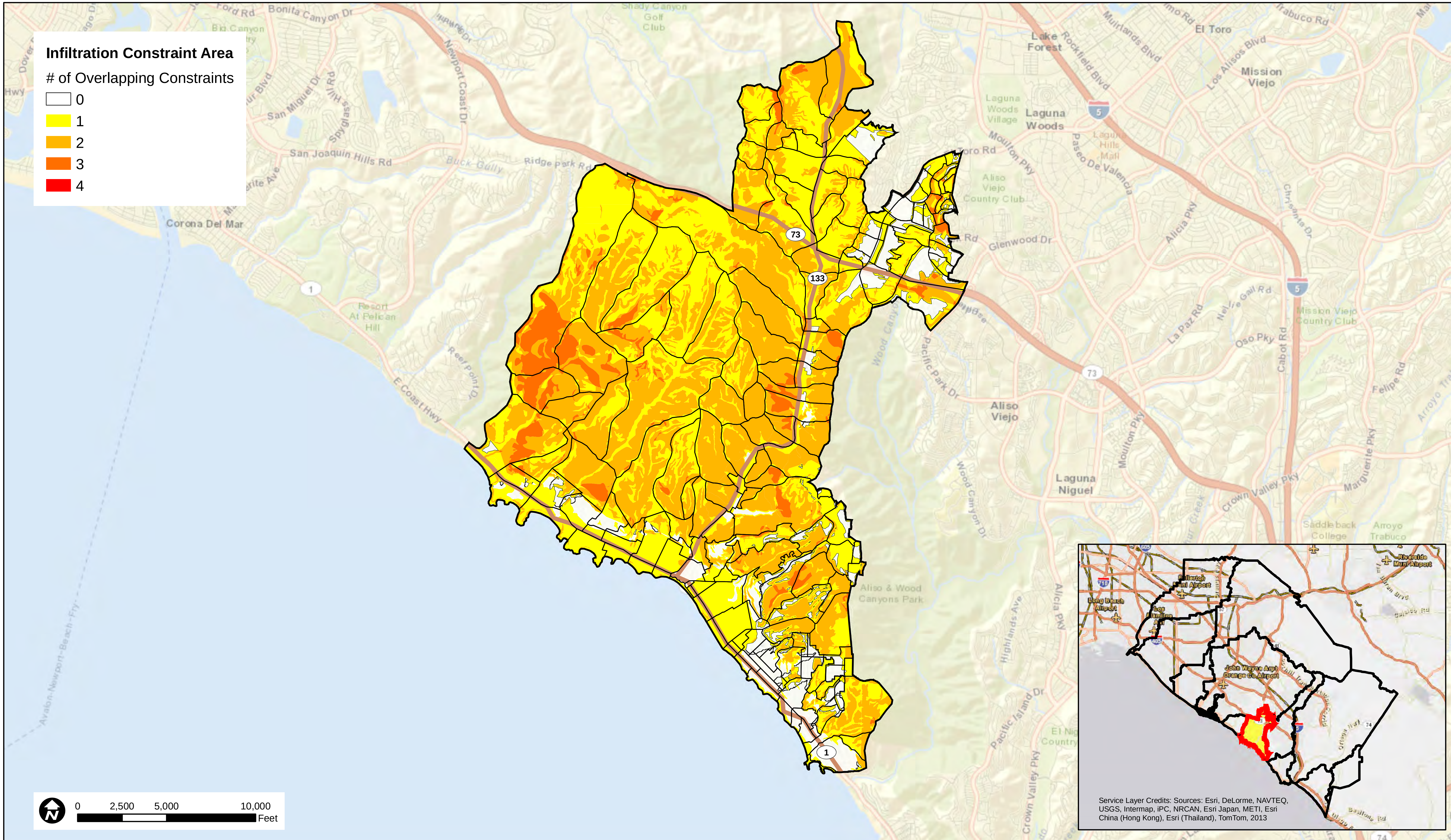


P:\9526E\6-GIS\Mxds\Reports\WIHMP_20131029\9526E_Fig6-8_WIHMP_85thPercentileRainfall_LagunaCoast_20131029.mxd

COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 6.8

PRECIPITATION - 85TH PERCENTILE
LAGUNA COAST WATERSHED



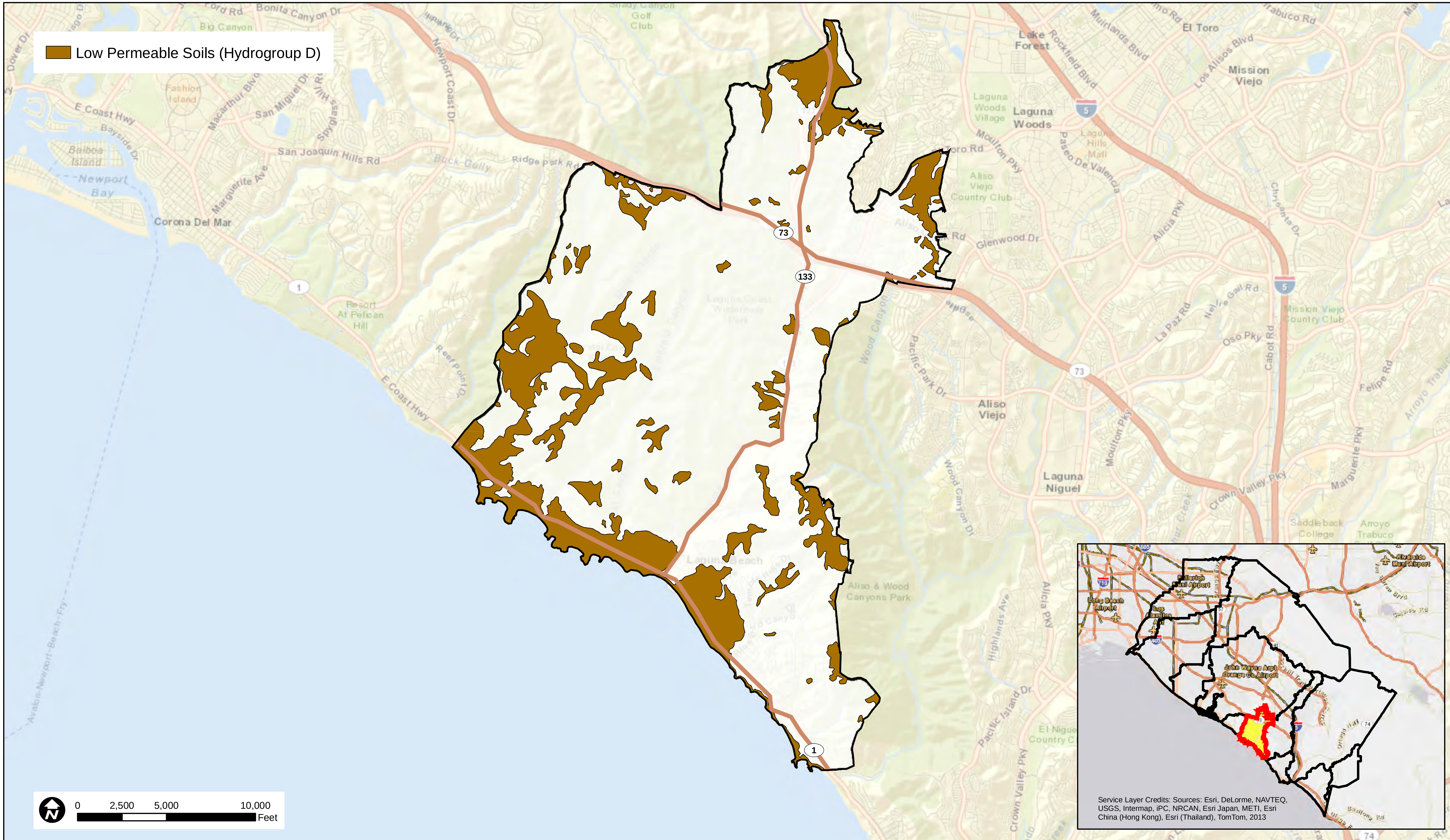
P:\9526E\6-GIS\Mxds\Reports\WIHMP_20131029\9526E_Fig6-9_WIHMP_OverallInfiltrationConstraints_LagunaCoast_20131029.mxd

PACE Advanced Water Engineering

COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 6.9

INFILTRATION CONSTRAINT - OVERALL CONSTRAINTS
LAGUNA COAST WATERSHED



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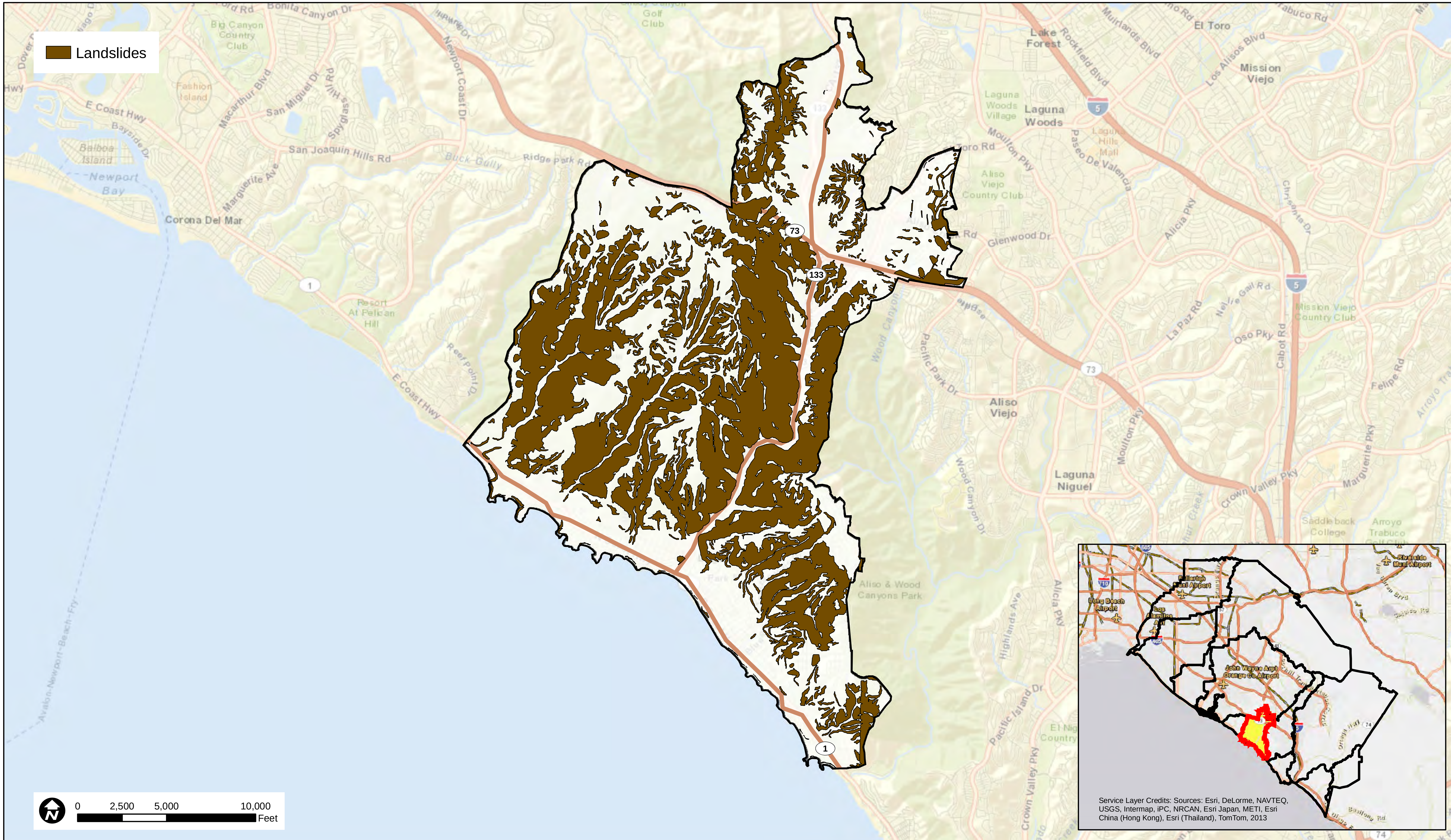
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 6.9a

INFILTRATION CONSTRAINT - D SOILS (LOW PERMEABLITY)
LAGUNA COAST WATERSHED



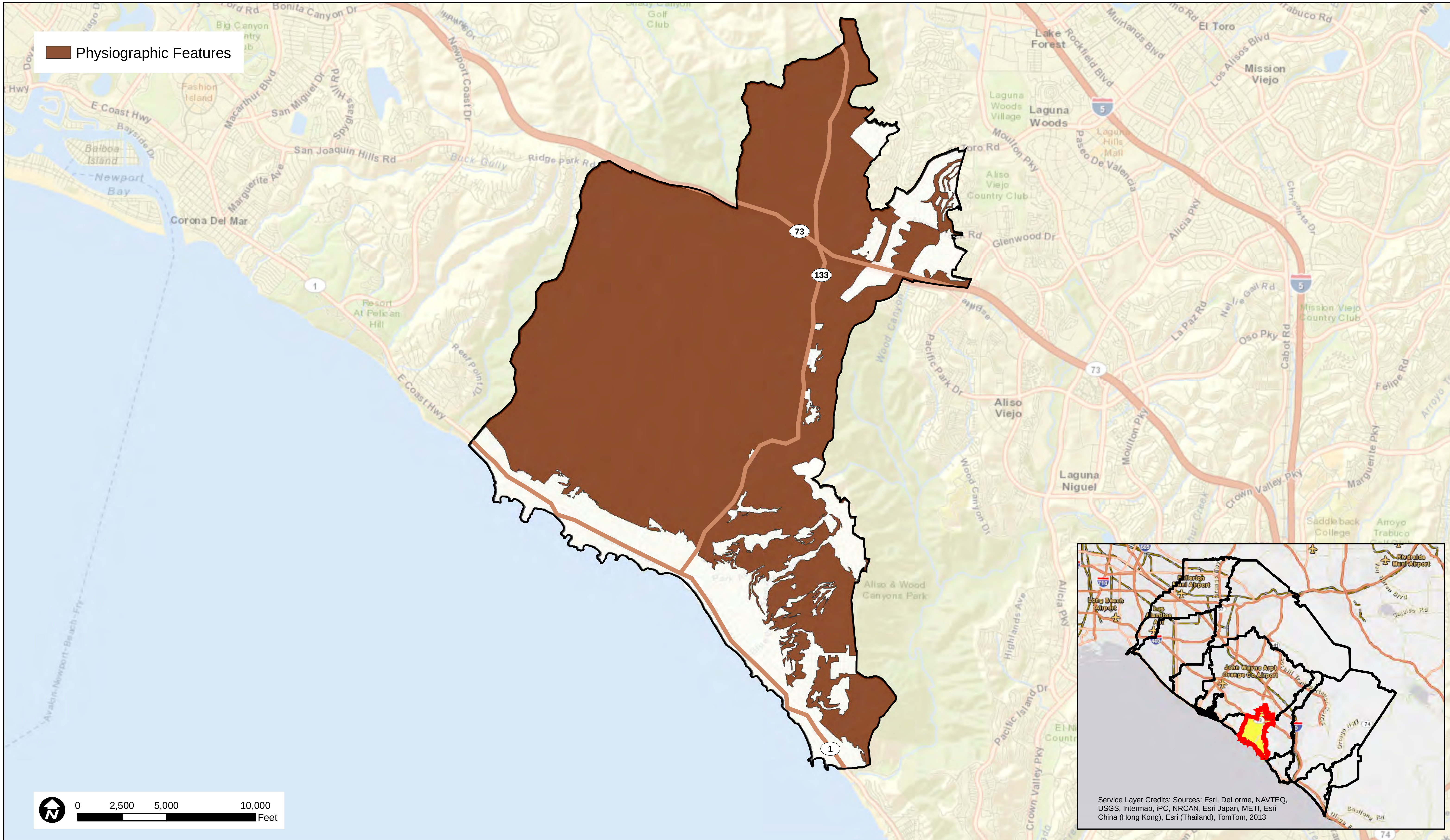
P:\9526E\6-GIS\Mxds\Reports\WIHMP_20131029\9526E_Fig6-9b_WIHMP_Landslides_LagunaCoast_20131029.mxd

FIGURE 6.9b

INFILTRATION CONSTRAINT - LANDSLIDES
LAGUNA COAST WATERSHED

PACE Advanced Water Engineering

COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

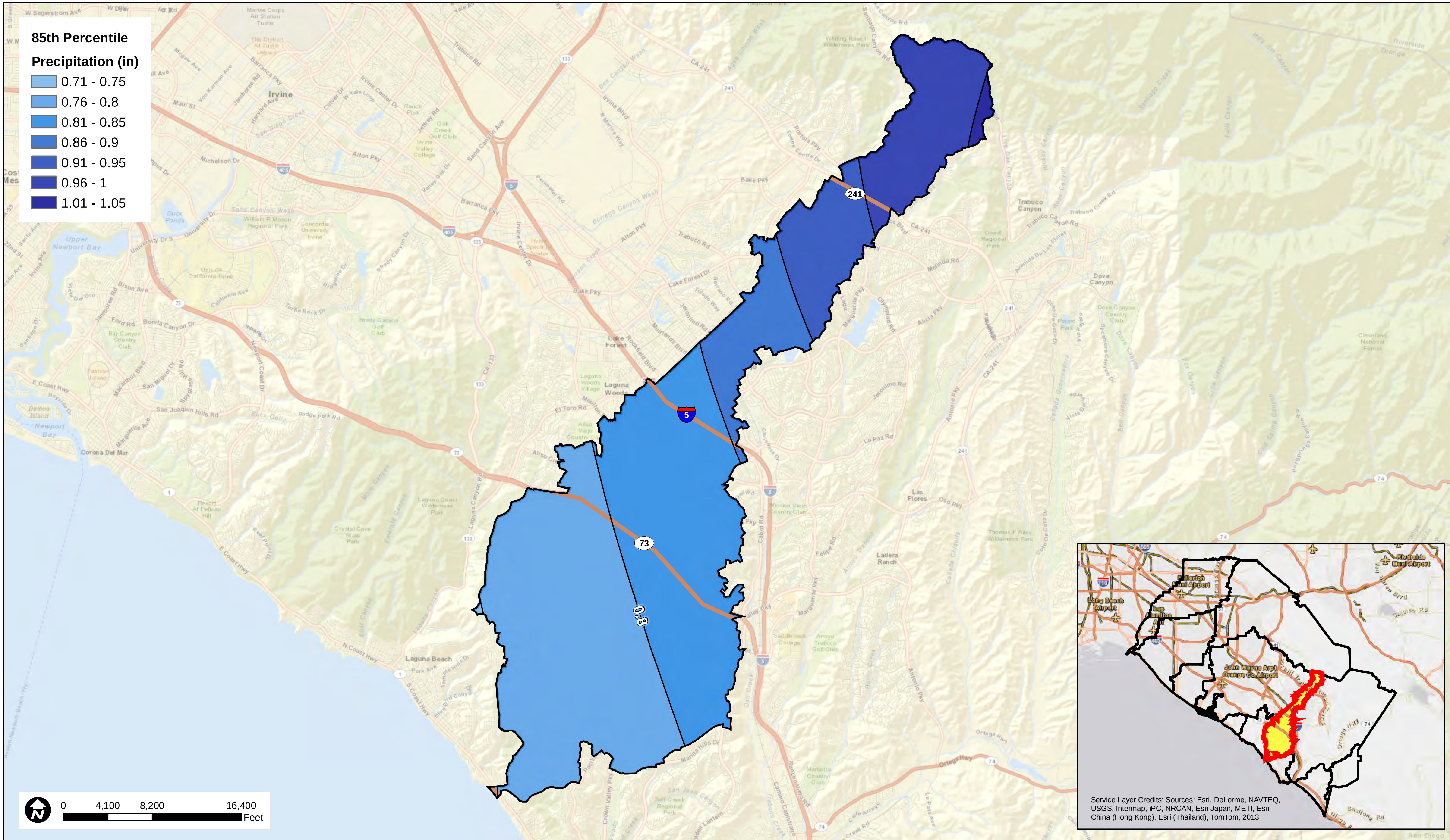


COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 6.9c

INFILTRATION CONSTRAINT - PHYSIOGRAPHIC FEATURES
LAGUNA COAST WATERSHED

N.3 Aliso Creek Watershed Rainfall and Infiltration Feasibility Exhibits



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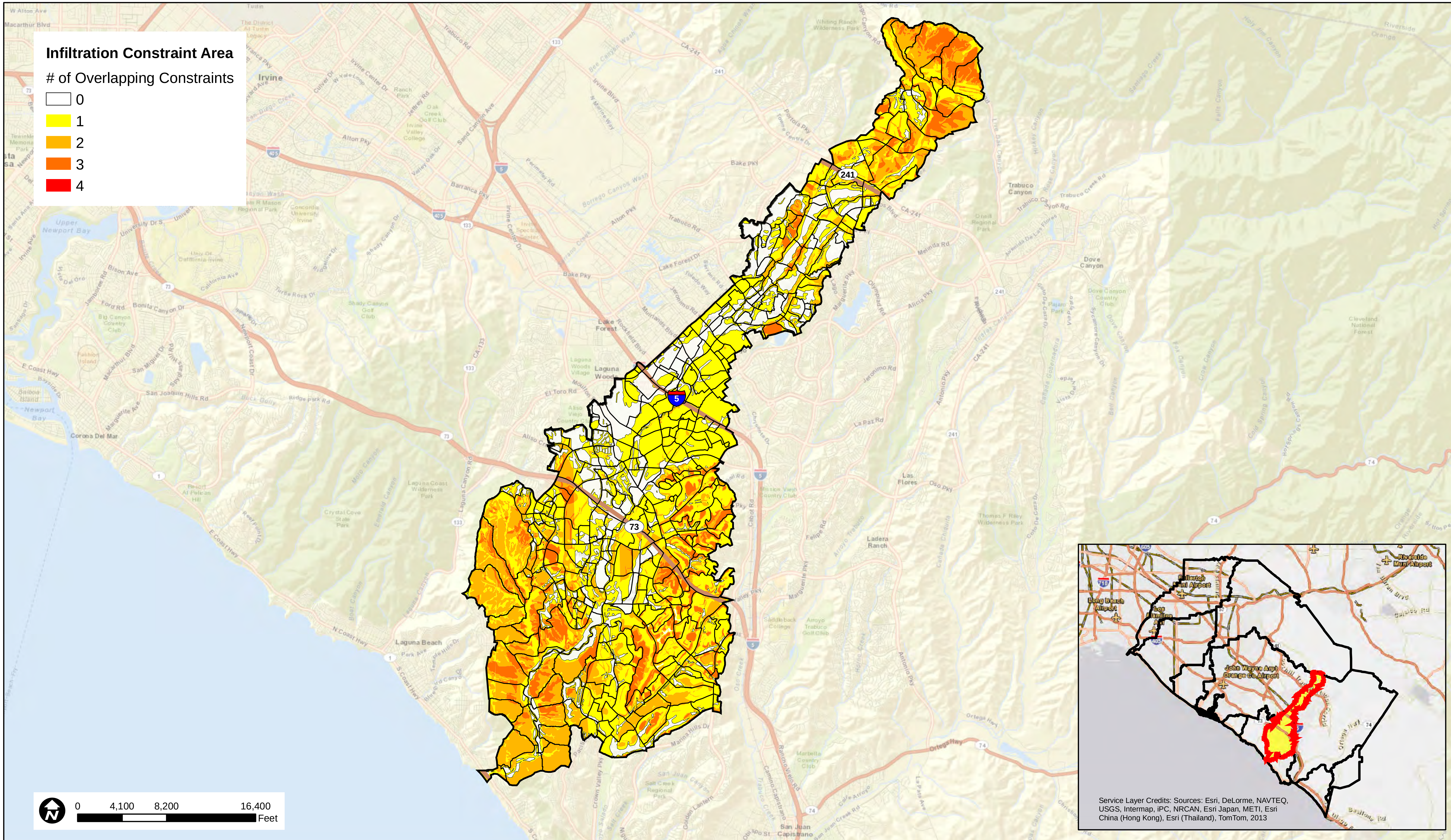
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 7.8

PRECIPITATION - 85TH PERCENTILE
ALISO CREEK WATERSHED

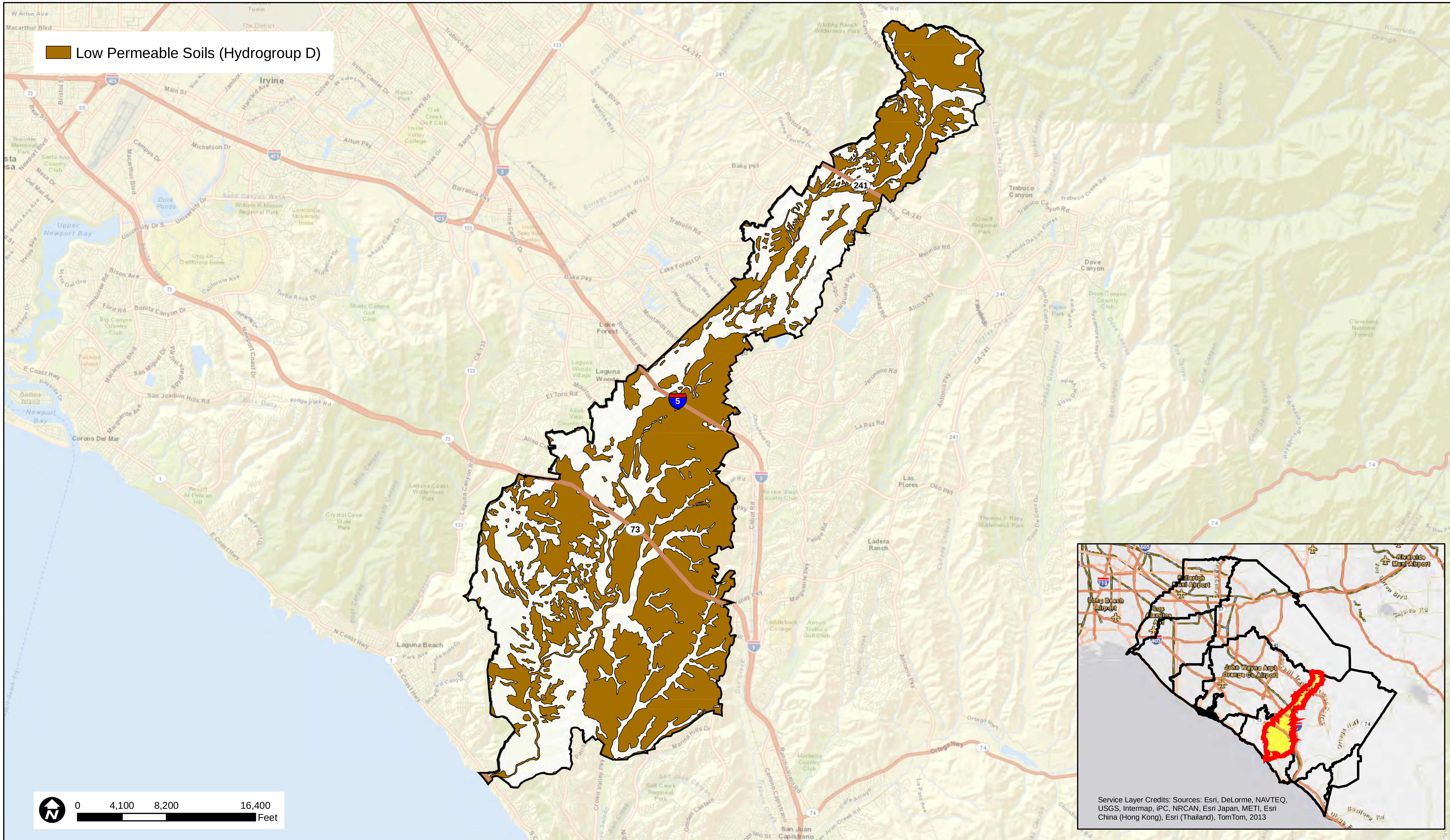


P:\9526E\6-GIS\Mxds\Reports\WIHMP_20131029\9526E_Fig7-9_WIHMP_OverallInfiltrationConstraints_AlisoCreek_20131029.mxd

COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 7.9

INFILTRATION CONSTRAINT - OVERALL CONSTRAINTS
ALISO CREEK WATERSHED



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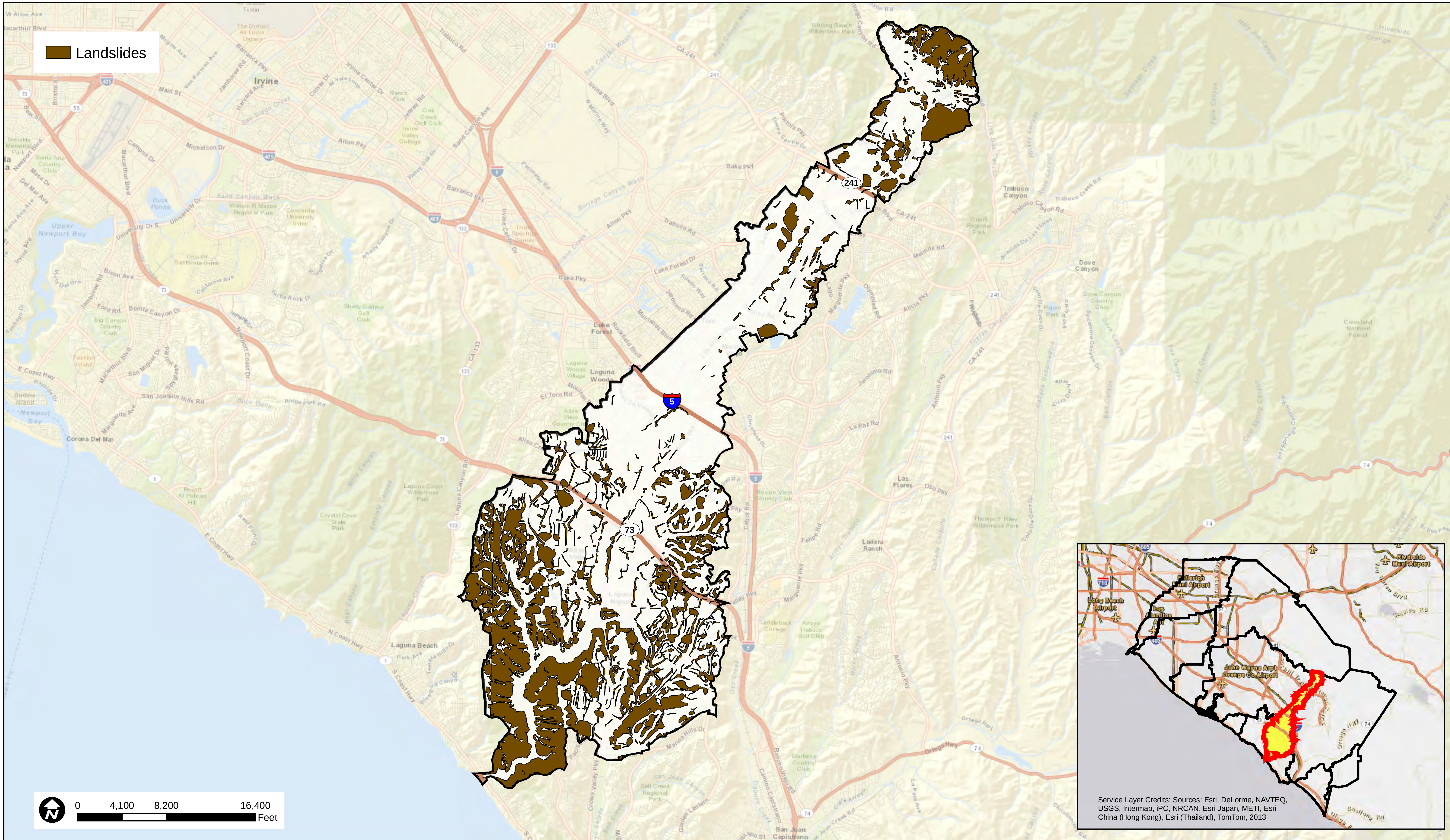
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 7.9a

INFILTRATION CONSTRAINT - D SOILS (LOW PERMEABLITY)
ALISO CREEK WATERSHED



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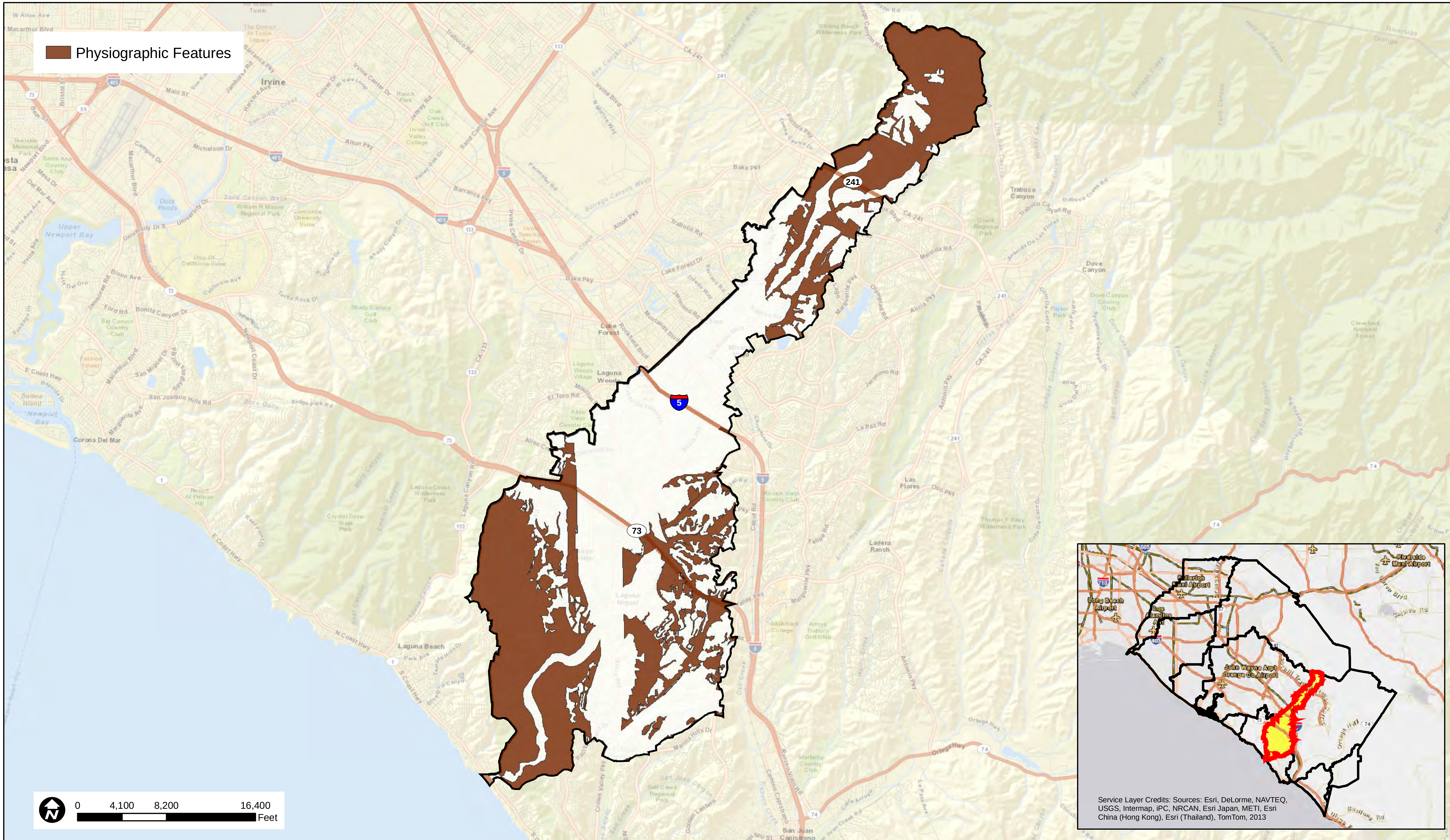
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 7.9b

INFILTRATION CONSTRAINT - LANDSLIDES
ALISO CREEK WATERSHED



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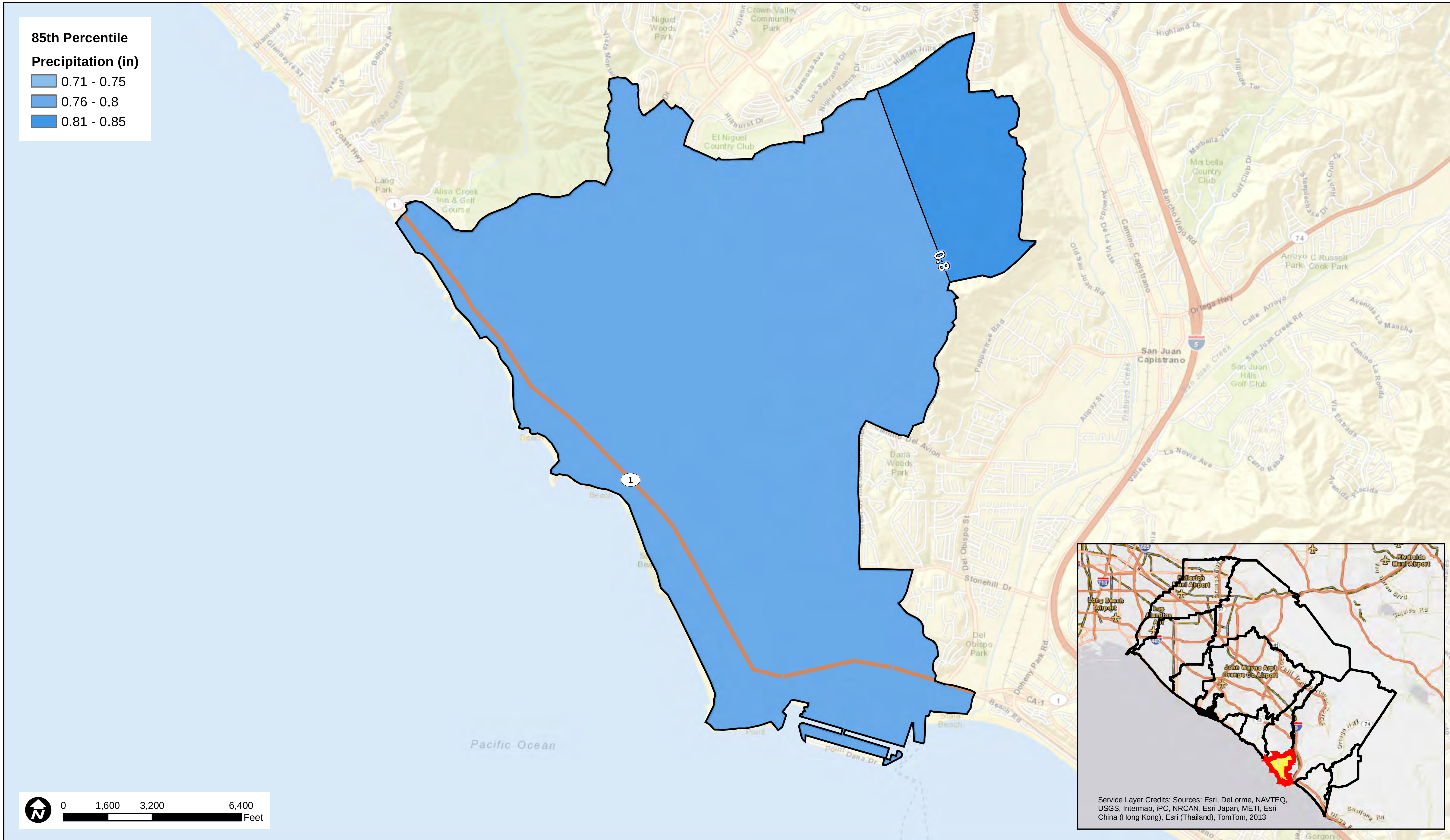
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 7.9c

INFILTRATION CONSTRAINT - PHYSIOGRAPHIC FEATURES
ALISO CREEK WATERSHED

N.4 Dana Point Coastal Streams Rainfall and Infiltration Feasibility Exhibits



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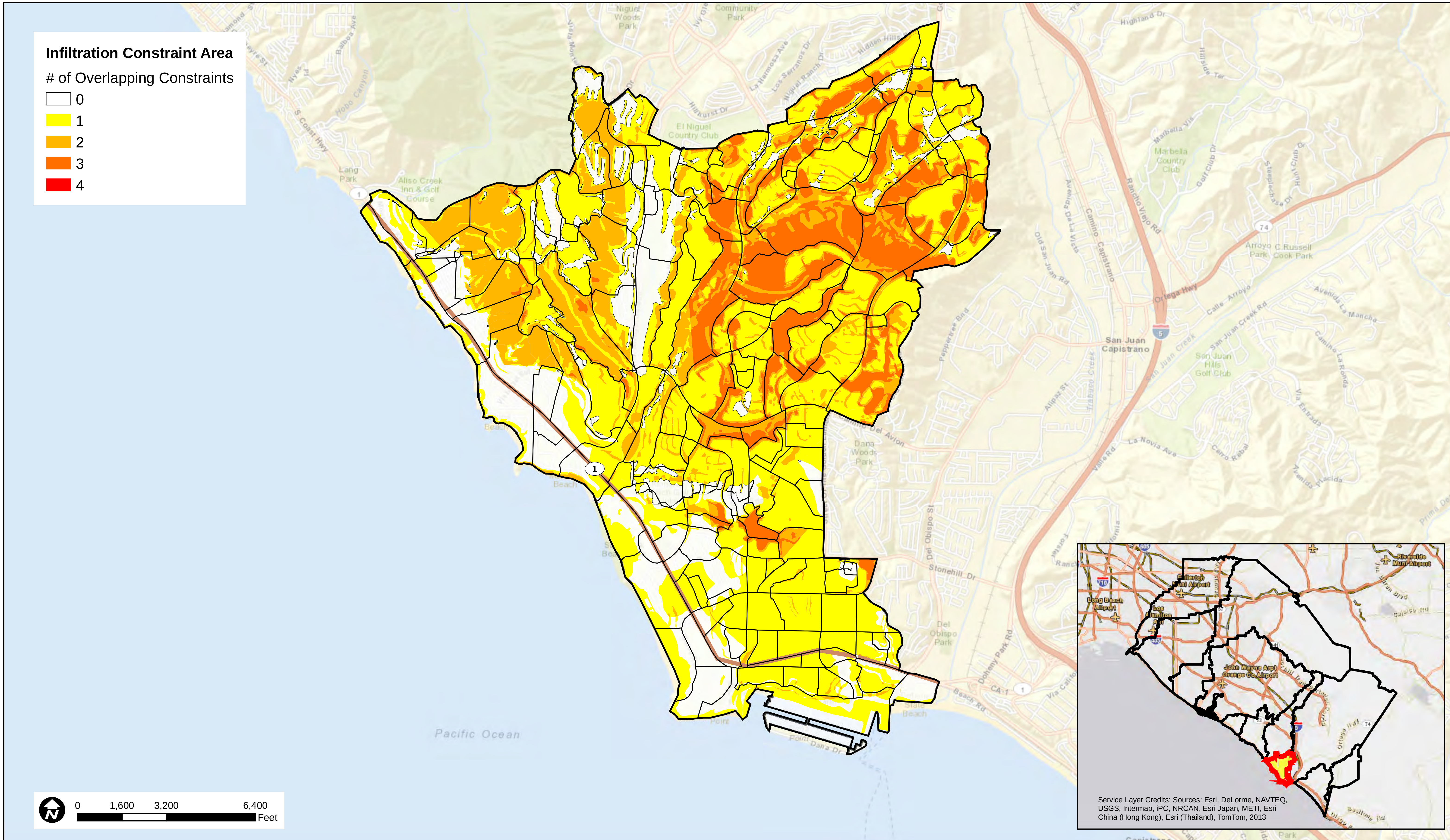
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 8.8

PRECIPITATION - 85TH PERCENTILE
DANA POINT WATERSHED



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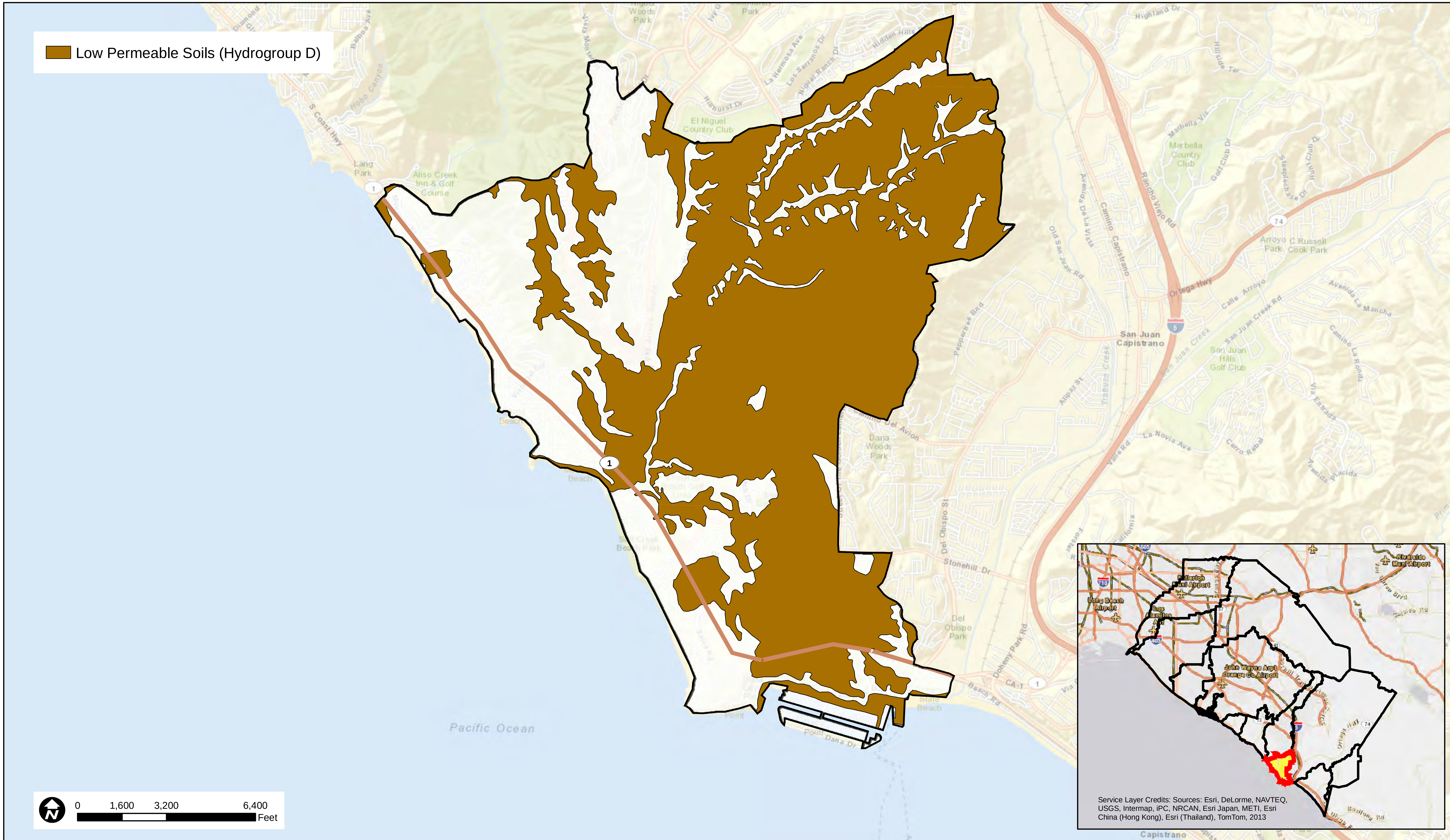
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 8.9

INFILTRATION CONSTRAINT - OVERALL CONSTRAINTS
DANA POINT WATERSHED



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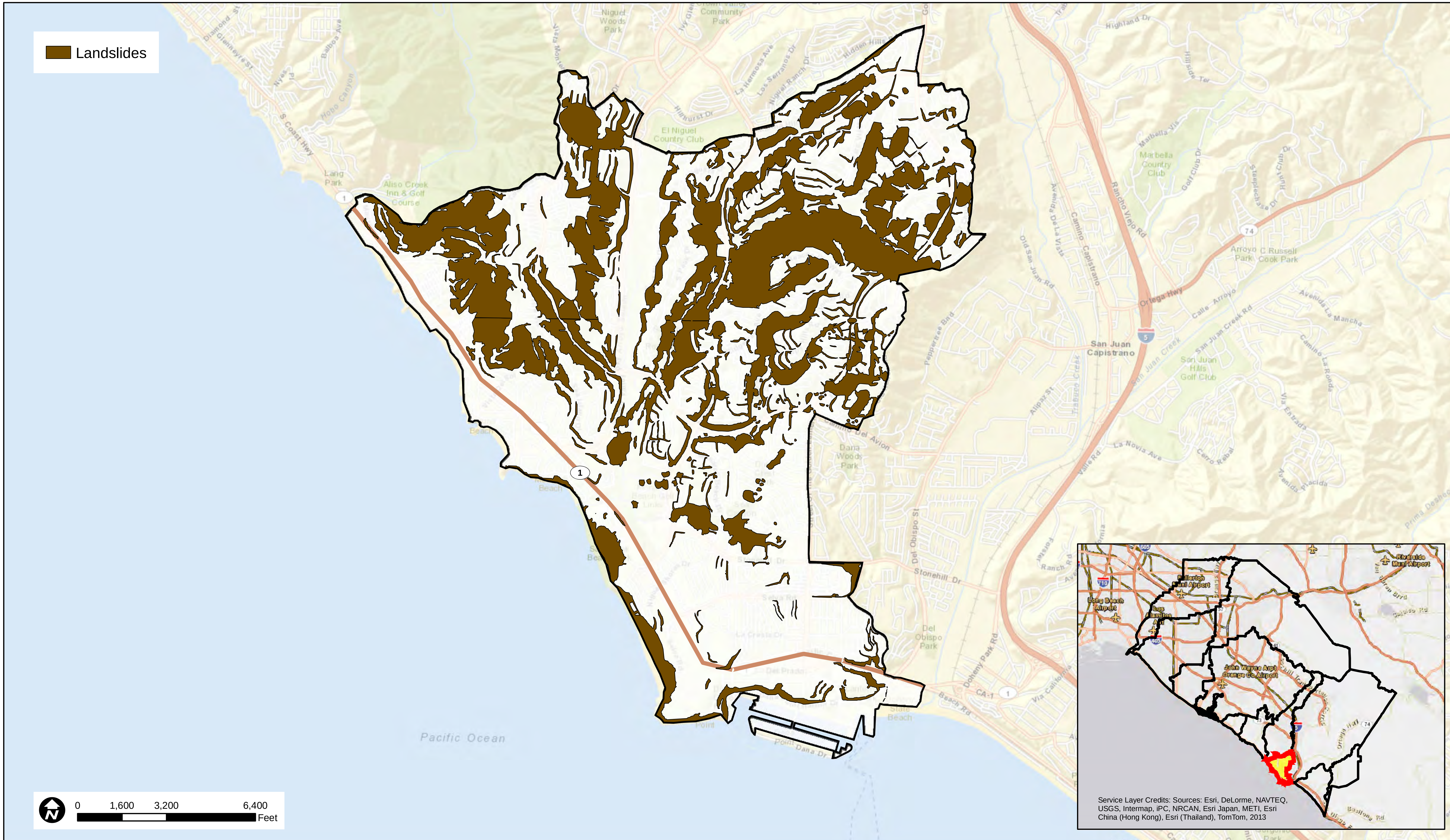
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 8.9a

INFILTRATION CONSTRAINT - D SOILS (LOW PERMEABLITY)
DANA POINT WATERSHED



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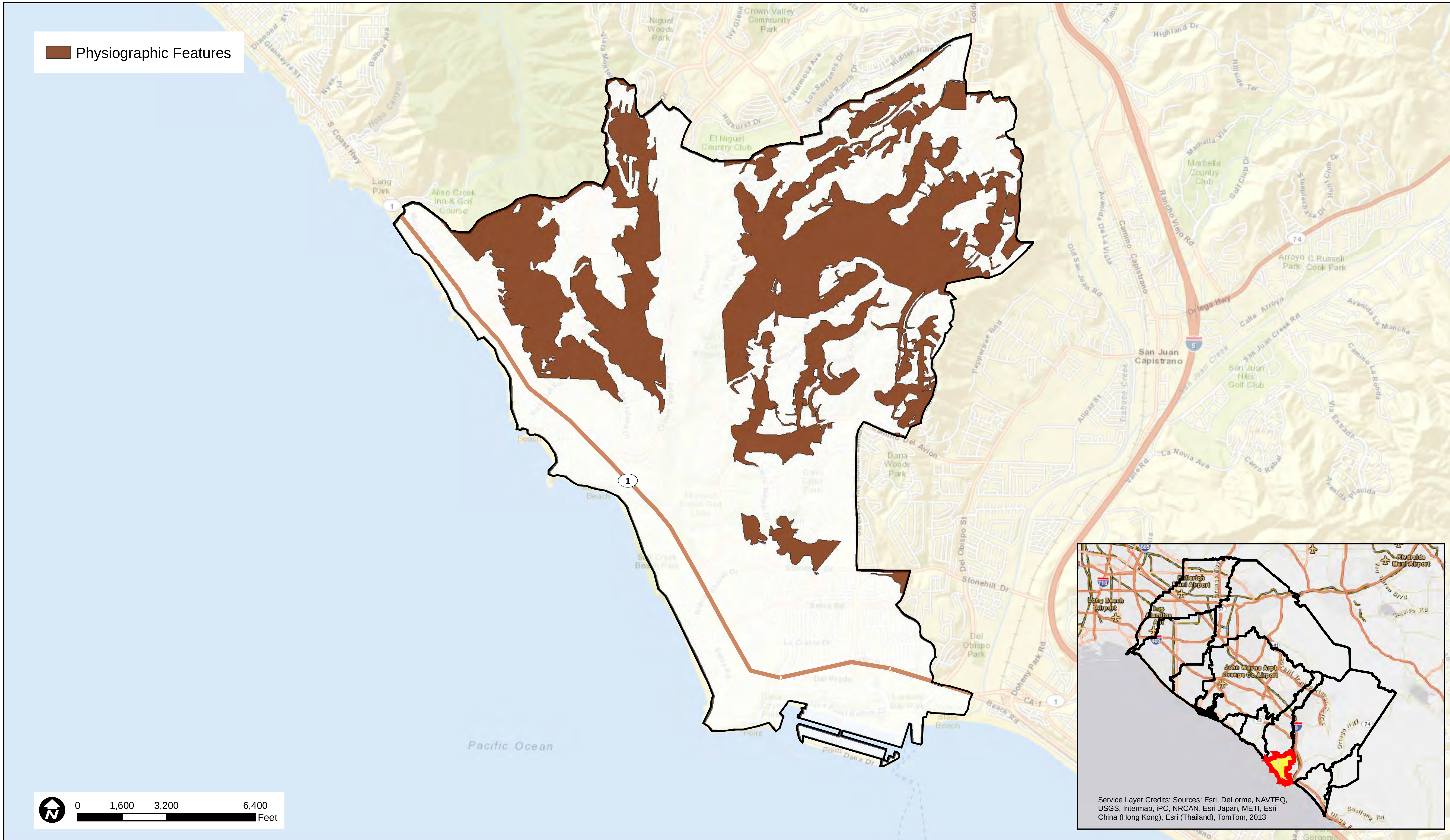
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 8.5b

INFILTRATION CONSTRAINT - LANDSLIDES
DANA POINT WATERSHED



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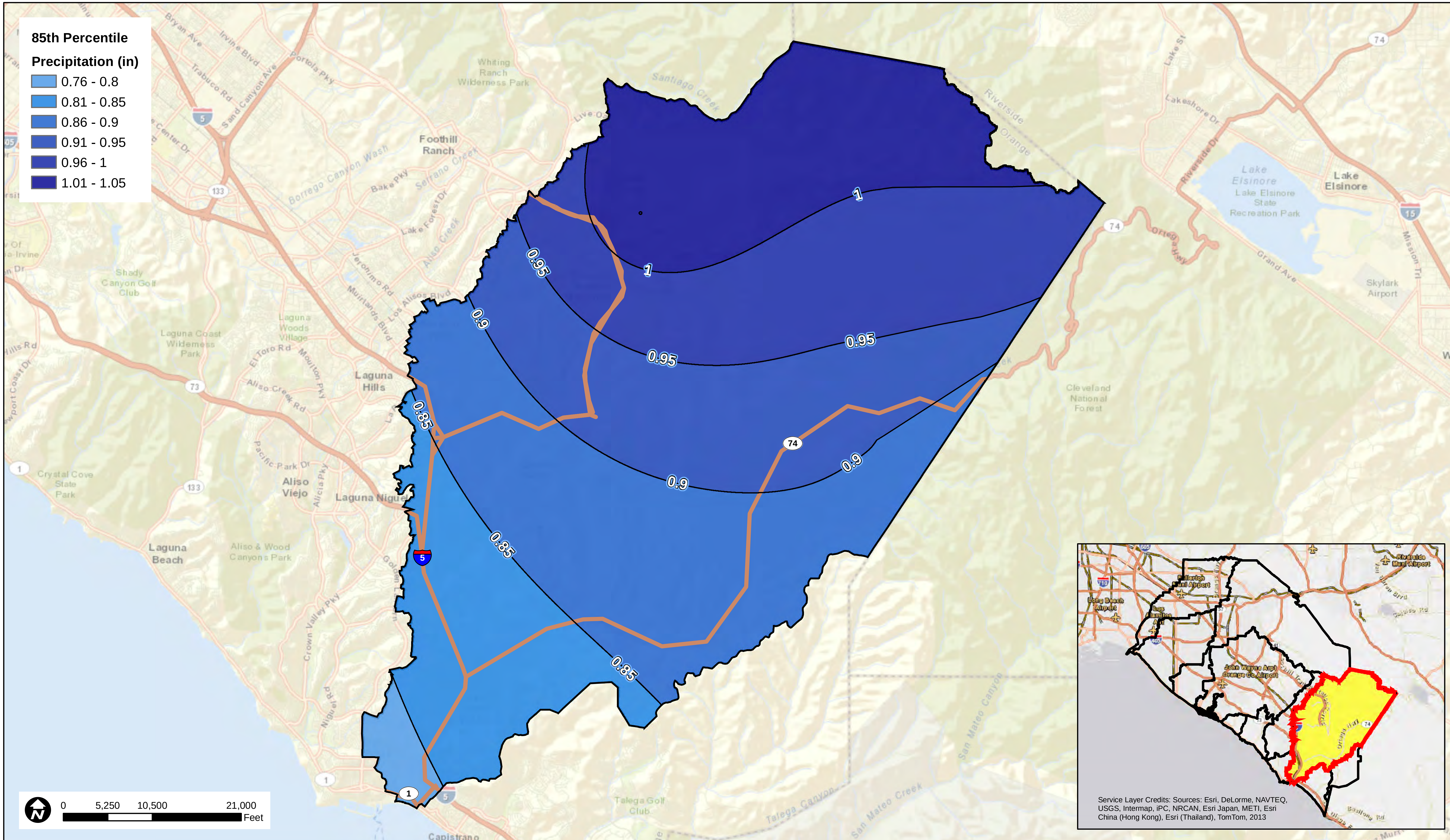
PACE Advanced Water Engineering

COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 8.9c

INFILTRATION CONSTRAINT - PHYSIOGRAPHIC FEATURES
DANA POINT WATERSHED

N.5 San Juan Creek Rainfall and Infiltration Feasibility Exhibits



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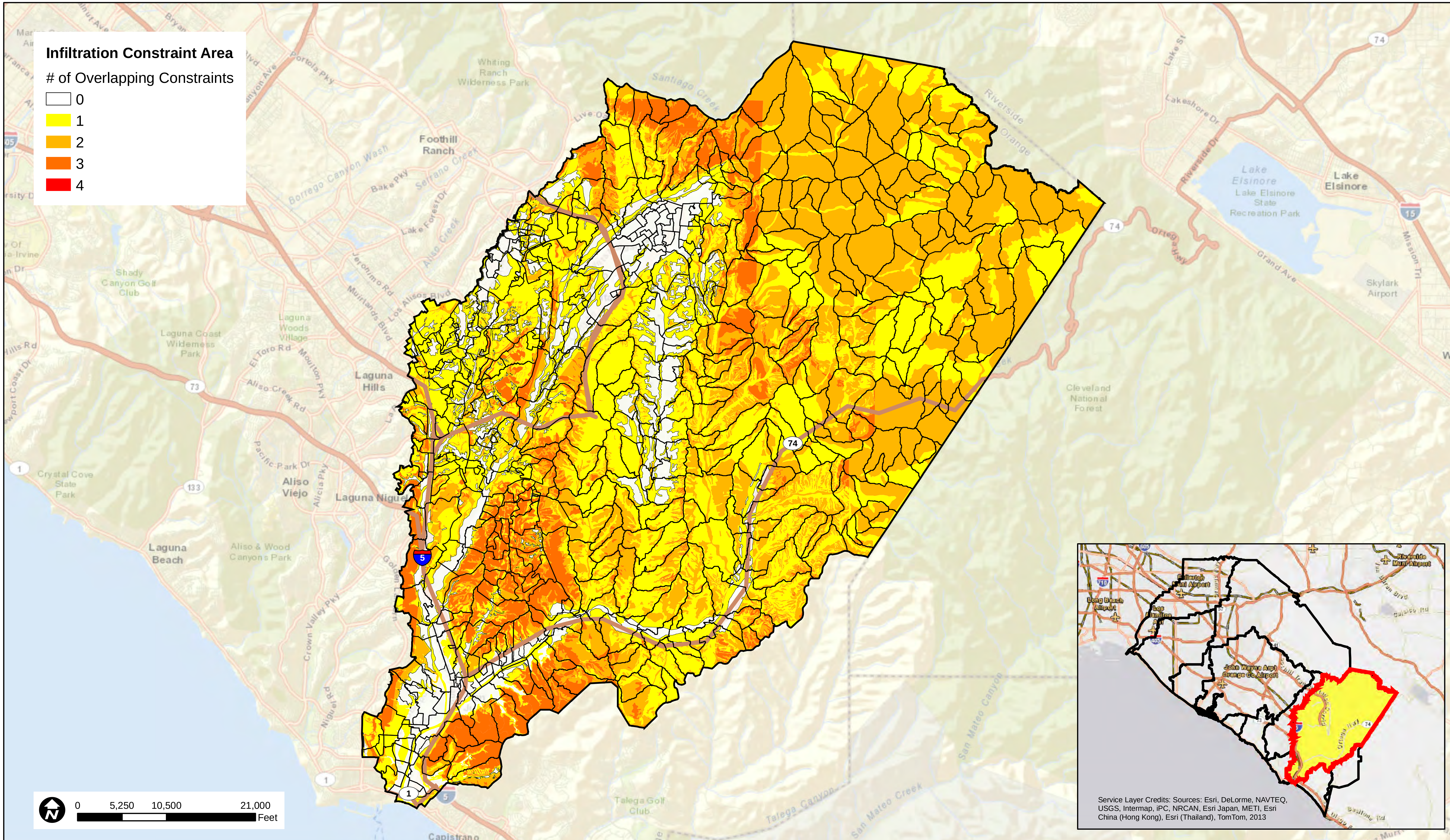
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 9.8

PRECIPITATION - 85TH PERCENTILE
SAN JUAN CREEK WATERSHED



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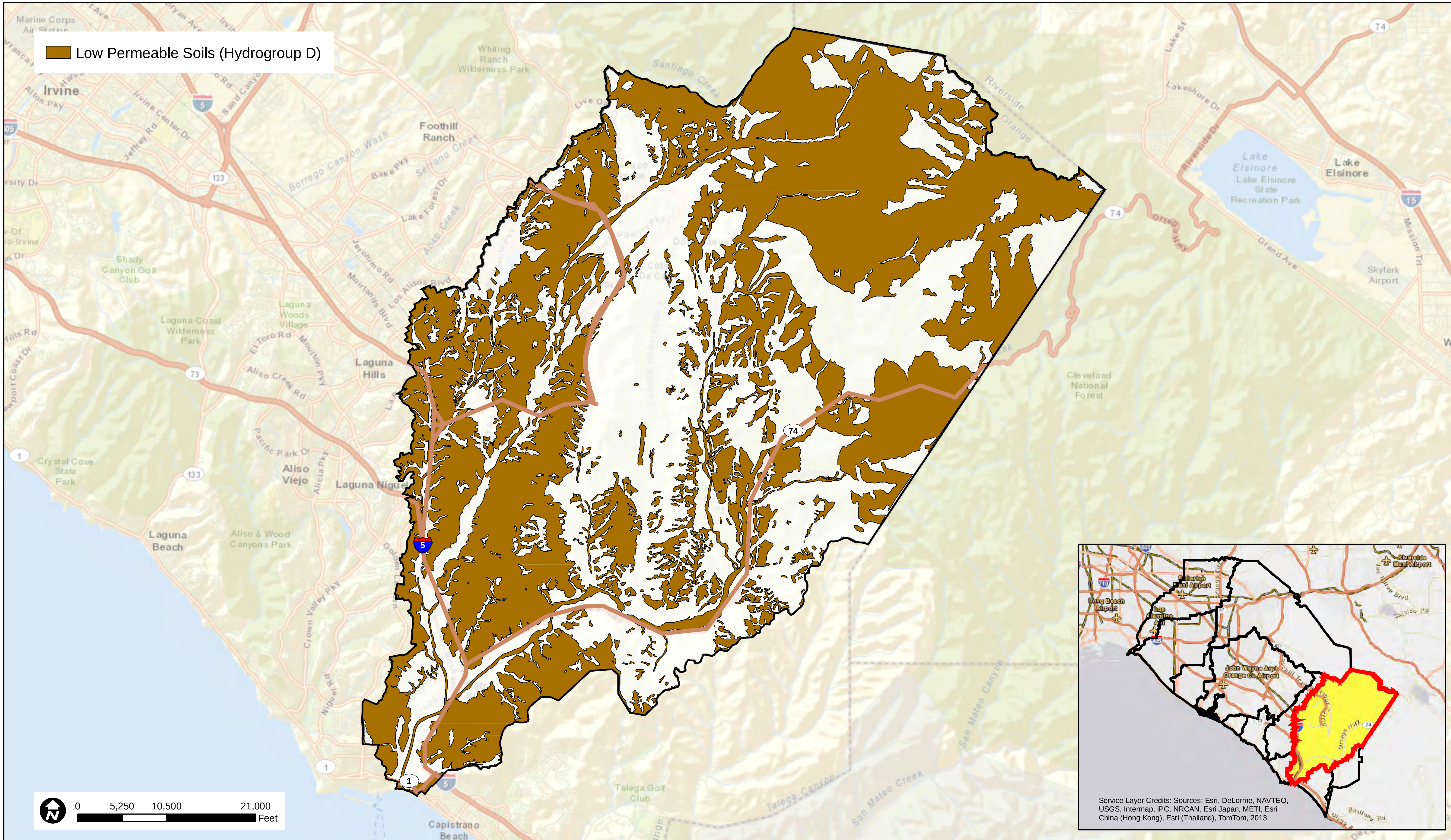
PACE Advanced Water Engineering

COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 9.9

INFILTRATION CONSTRAINT - OVERALL CONSTRAINTS
SAN JUAN CREEK WATERSHED



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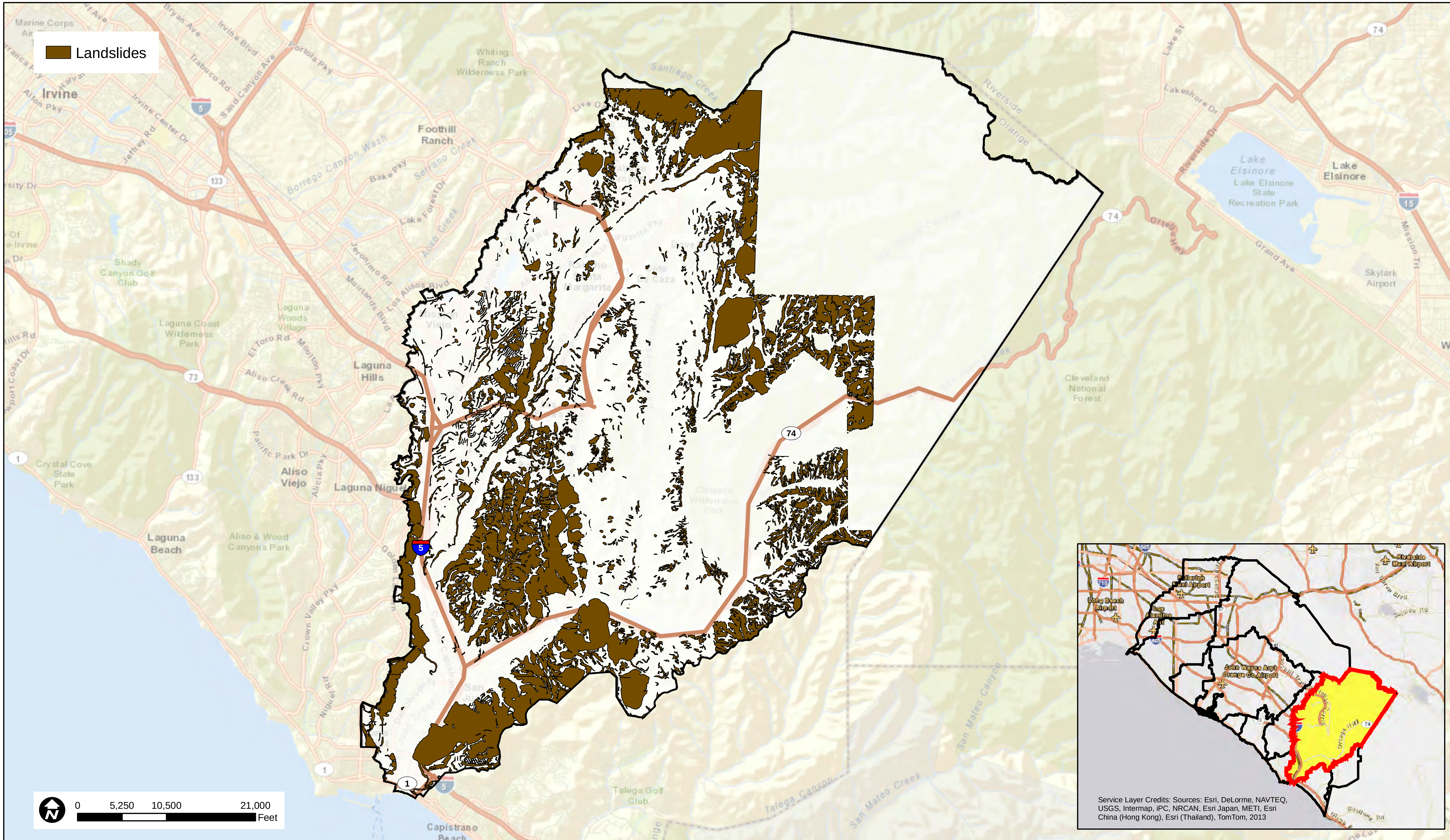
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 9.9a

INFILTRATION CONSTRAINT - D SOILS (LOW PERMEABLITY)
SAN JUAN CREEK WATERSHED



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COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 9.9b

INFILTRATION CONSTRAINT - LANDSLIDES
SAN JUAN CREEK WATERSHED

P:\9526E\6-GIS\Mxds\Reports\WIHMP_20131029\9526E_Fig9-9c_WIHMP_PhysiographicFeatures_SanJuanCreek_20131029.mxd

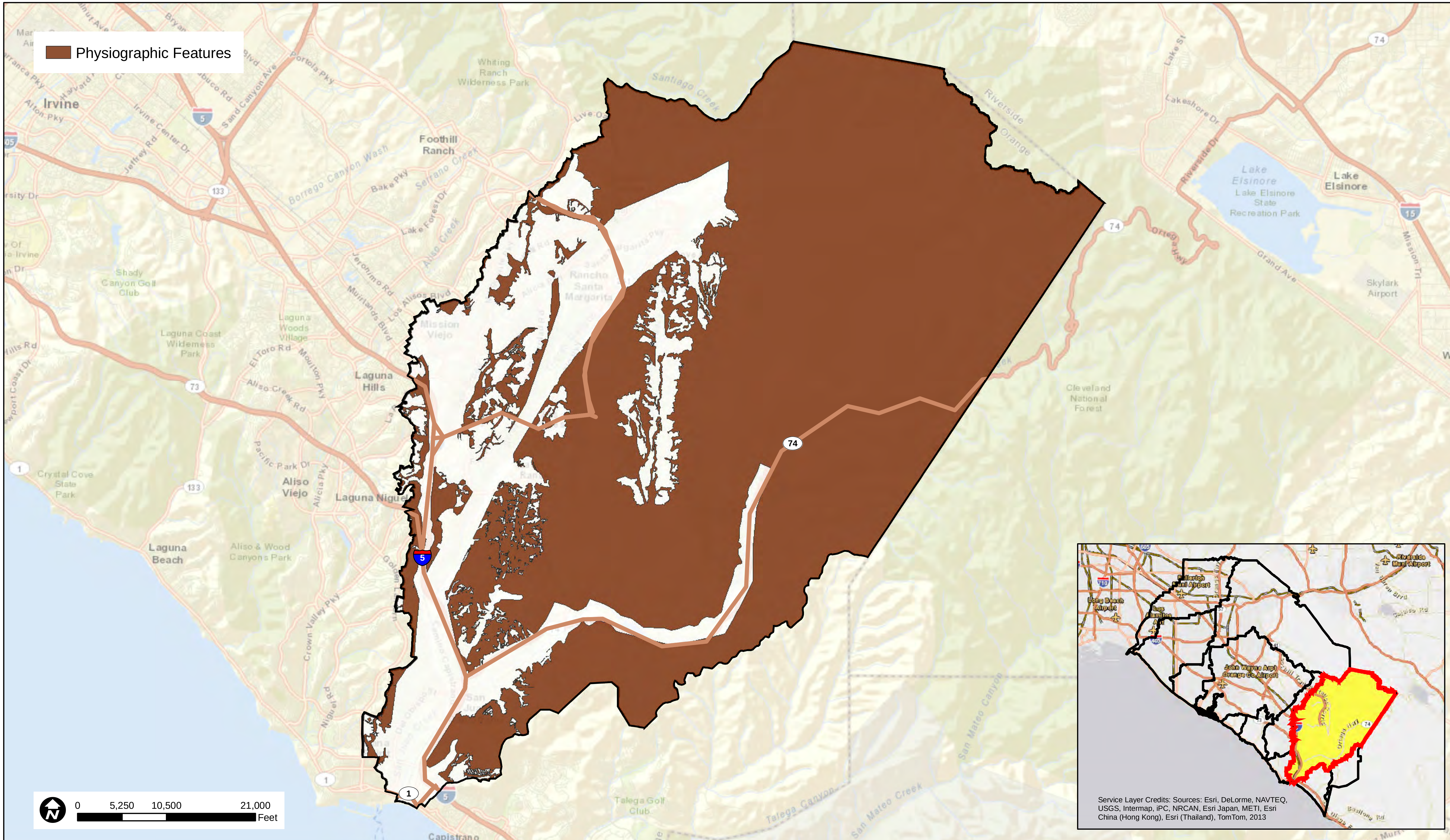

FIGURE 9.9c

INFILTRATION CONSTRAINT - PHYSIOGRAPHIC FEATURES
SAN JUAN CREEK WATERSHED

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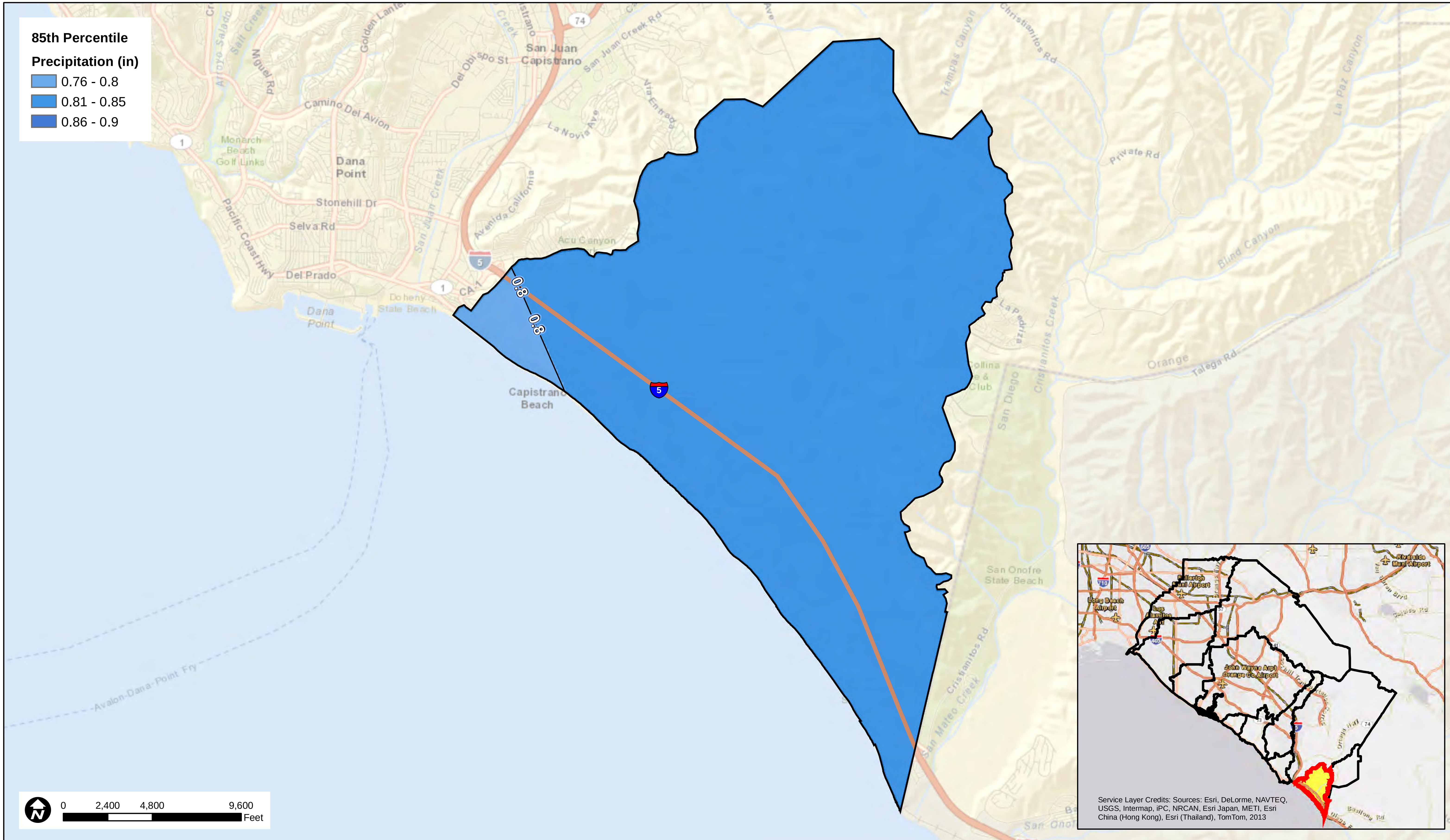
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

N.6 San Clemente Coastal Streams Rainfall and Infiltration Feasibility Exhibits



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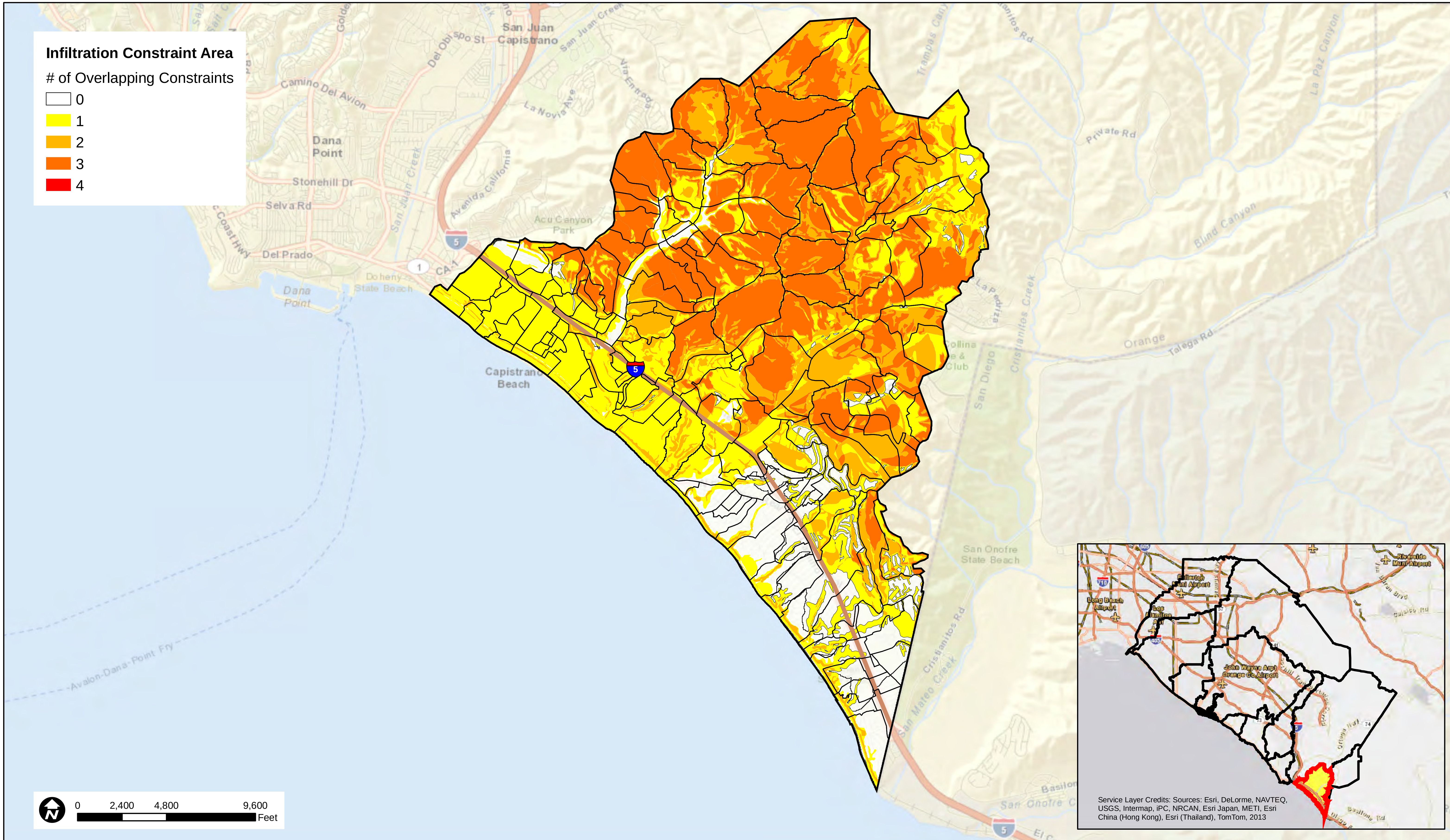
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 10.8

PRECIPITATION - 85TH PERCENTILE
SAN CLEMENTE CREEK WATERSHED



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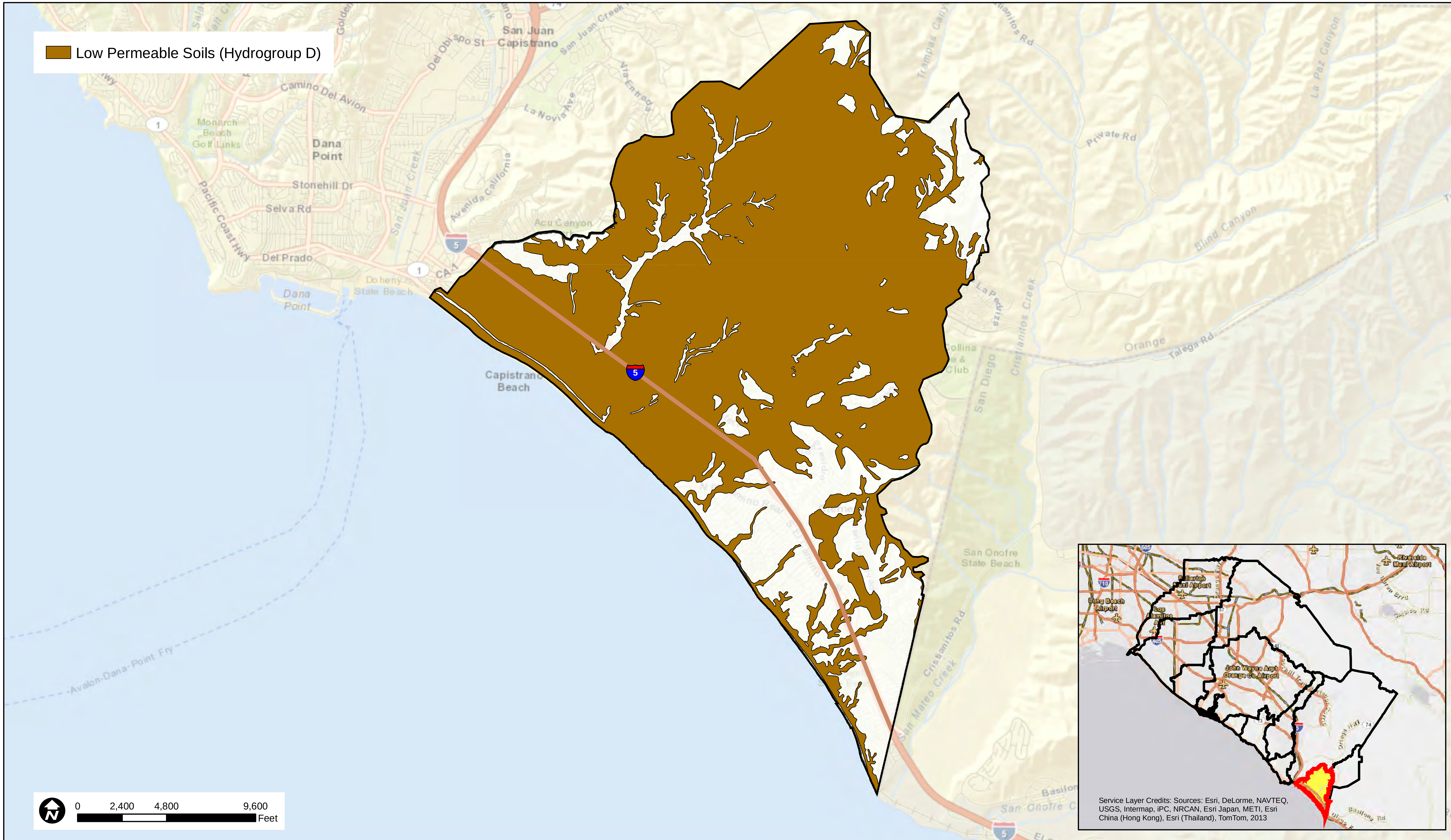
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 10.9

INFILTRATION CONSTRAINT - OVERALL CONSTRAINTS
SAN CLEMENTE CREEK WATERSHED



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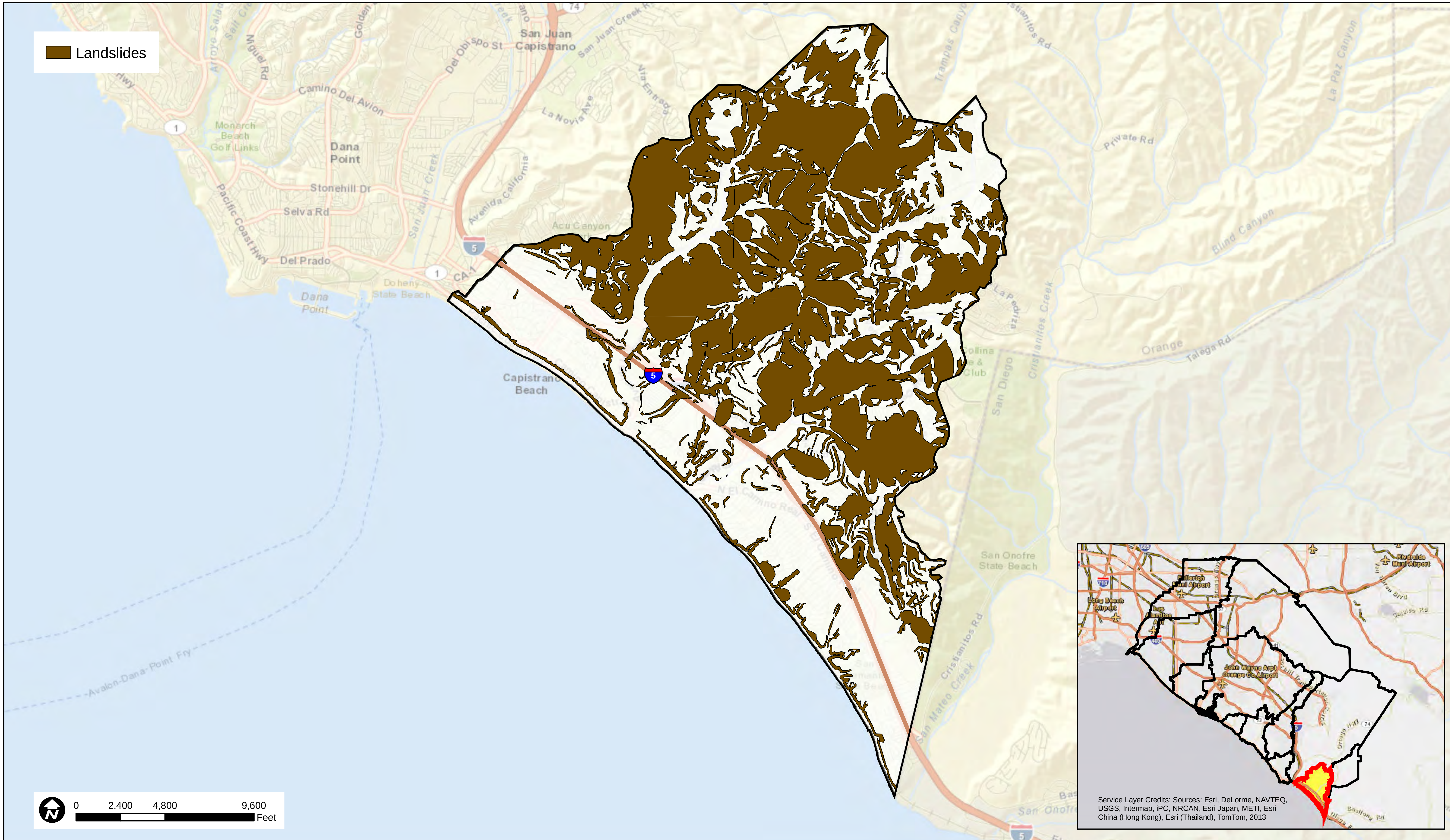
PACE Advanced Water Engineering

COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 10.9a

INFILTRATION CONSTRAINT - D SOILS (LOW PERMEABLITY)
SAN CLEMENTE CREEK WATERSHED



P:\9526E\6-GIS\Mxds\Reports\WIHMP_20131029\9526E_Fig10-9b_WIHMP_Landslides_SanClementeCreek_20131029.mxd

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COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION MANAGEMENT PLAN (WIHMP)

FIGURE 10.9b

INFILTRATION CONSTRAINT - LANDSLIDES
SAN CLEMENTE CREEK WATERSHED

P:\9526E\6-GIS\Mxds\Reports\WIHMP_20131029\9526E_Fig10-9c_WIHMP_PhysiographicFeatures_SanClementeCreek_20131029.mxd

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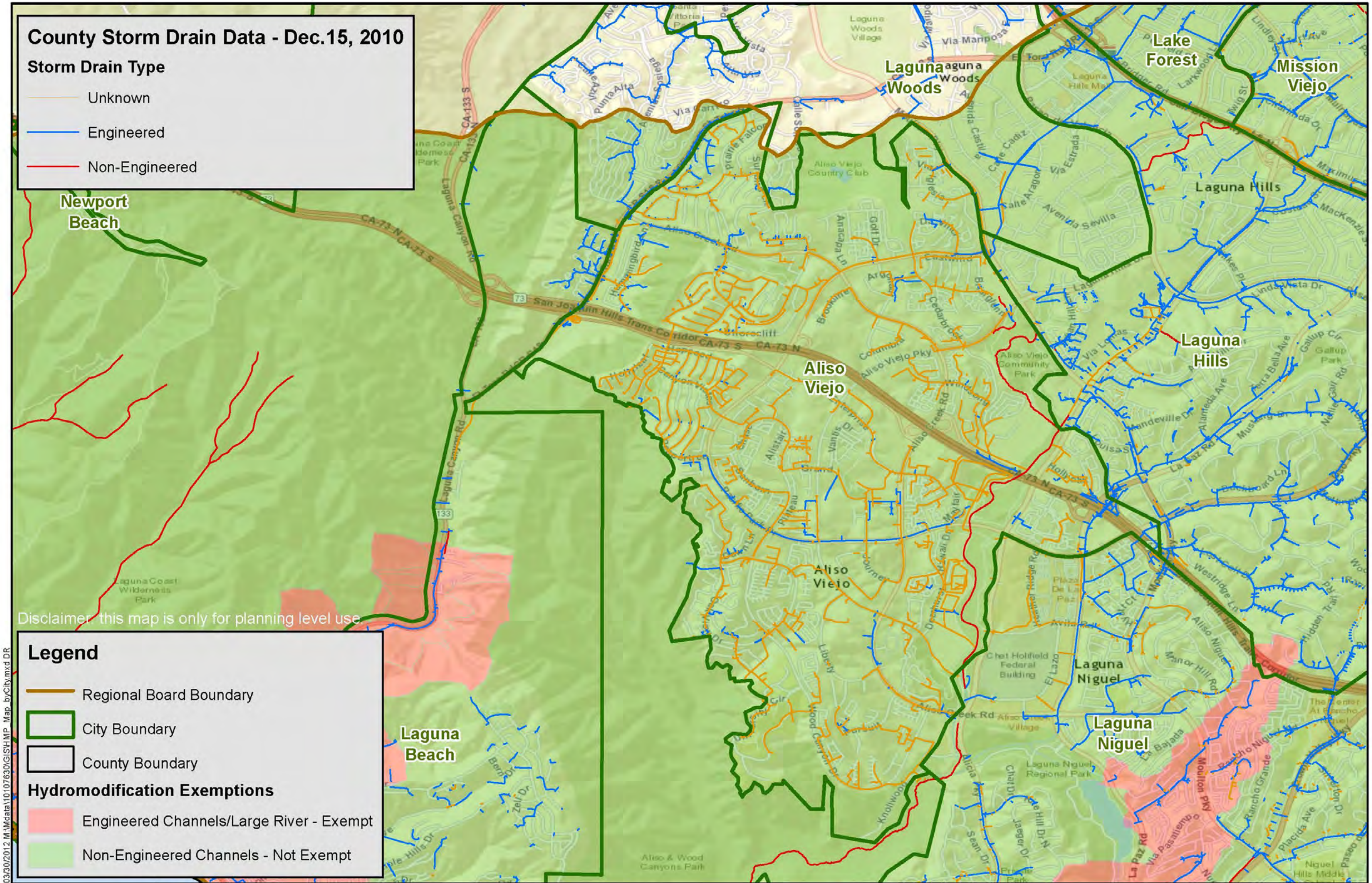
COUNTY OF ORANGE
WATERSHED INFILTRATION HYDROMODIFICATION
MANAGEMENT PLAN (WIHMP)

FIGURE 10.9c

INFILTRATION CONSTRAINT - PHYSIOGRAPHIC FEATURES
SAN CLEMENTE CREEK WATERSHED

N.7 Hydromodification Susceptibility Maps by Jurisdiction



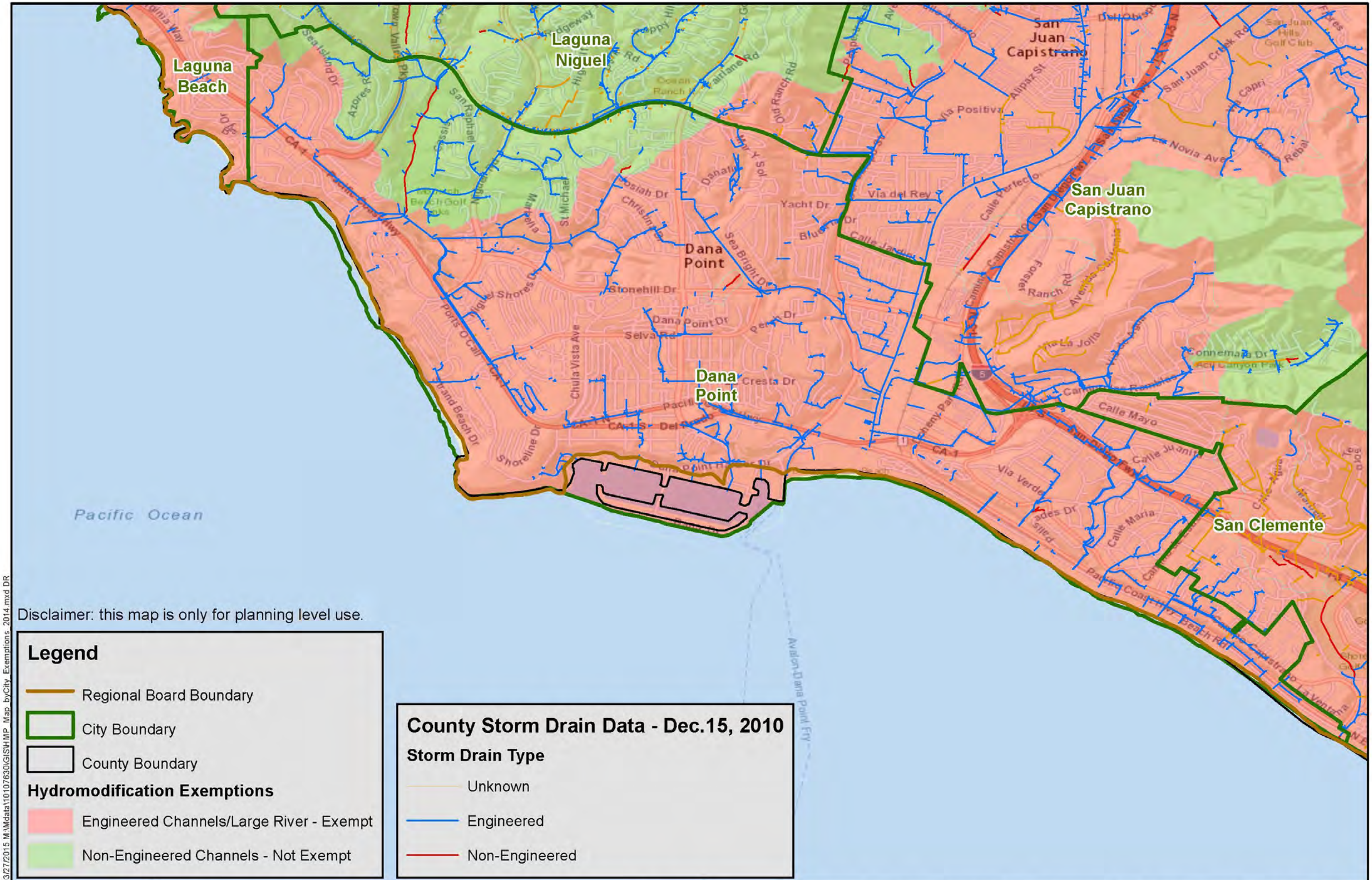
South Orange County Engineered Channel Exemption Areas

Aliso Viejo Exemption Map

0 0.5 1 Miles

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

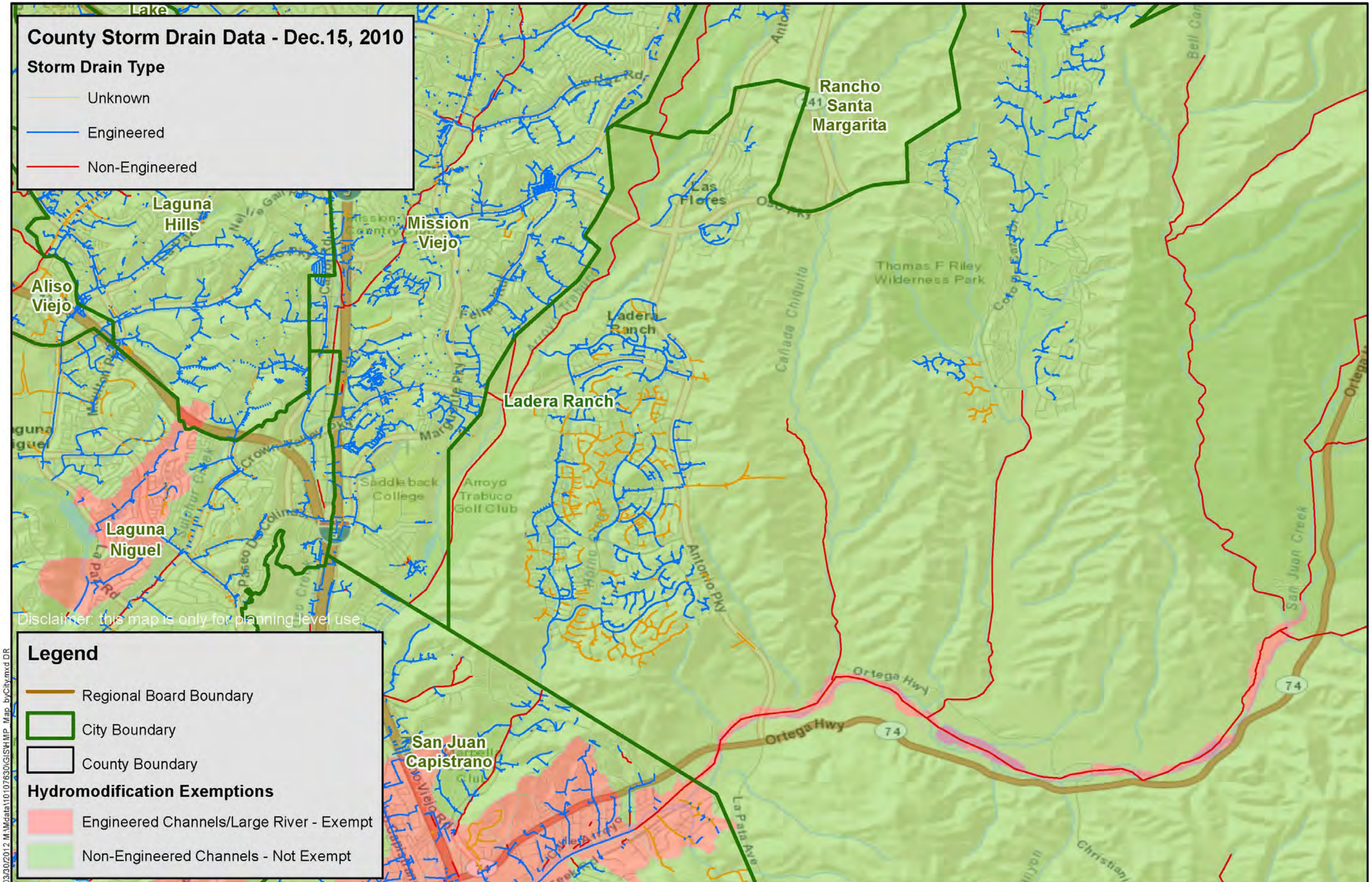
RBF CONSULTING A Baker Company



0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas
Dana Point Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

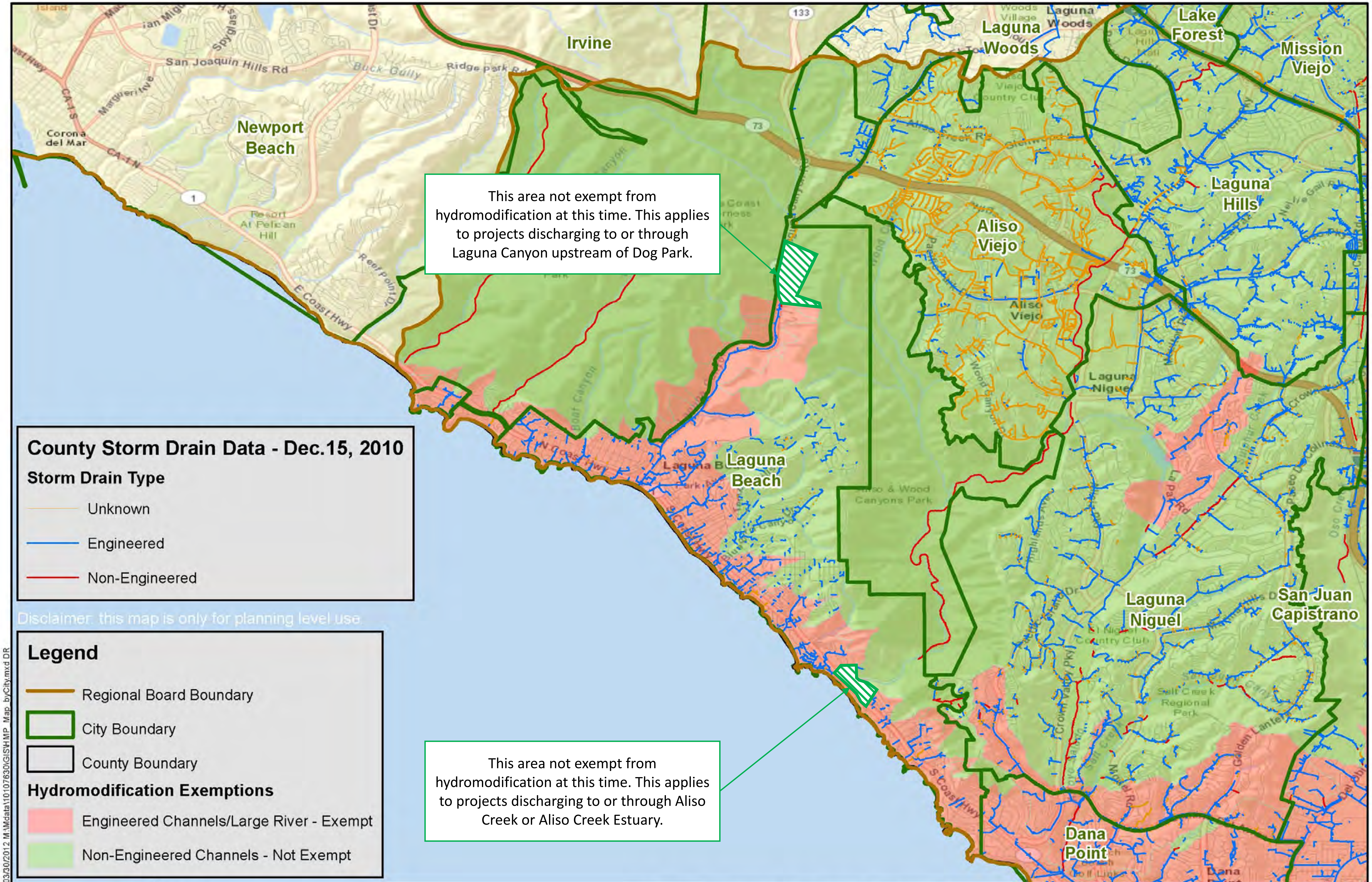


RBF CONSULTING A Baker Company GIS

0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas
Ladera Ranch and Unicorporated Area Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

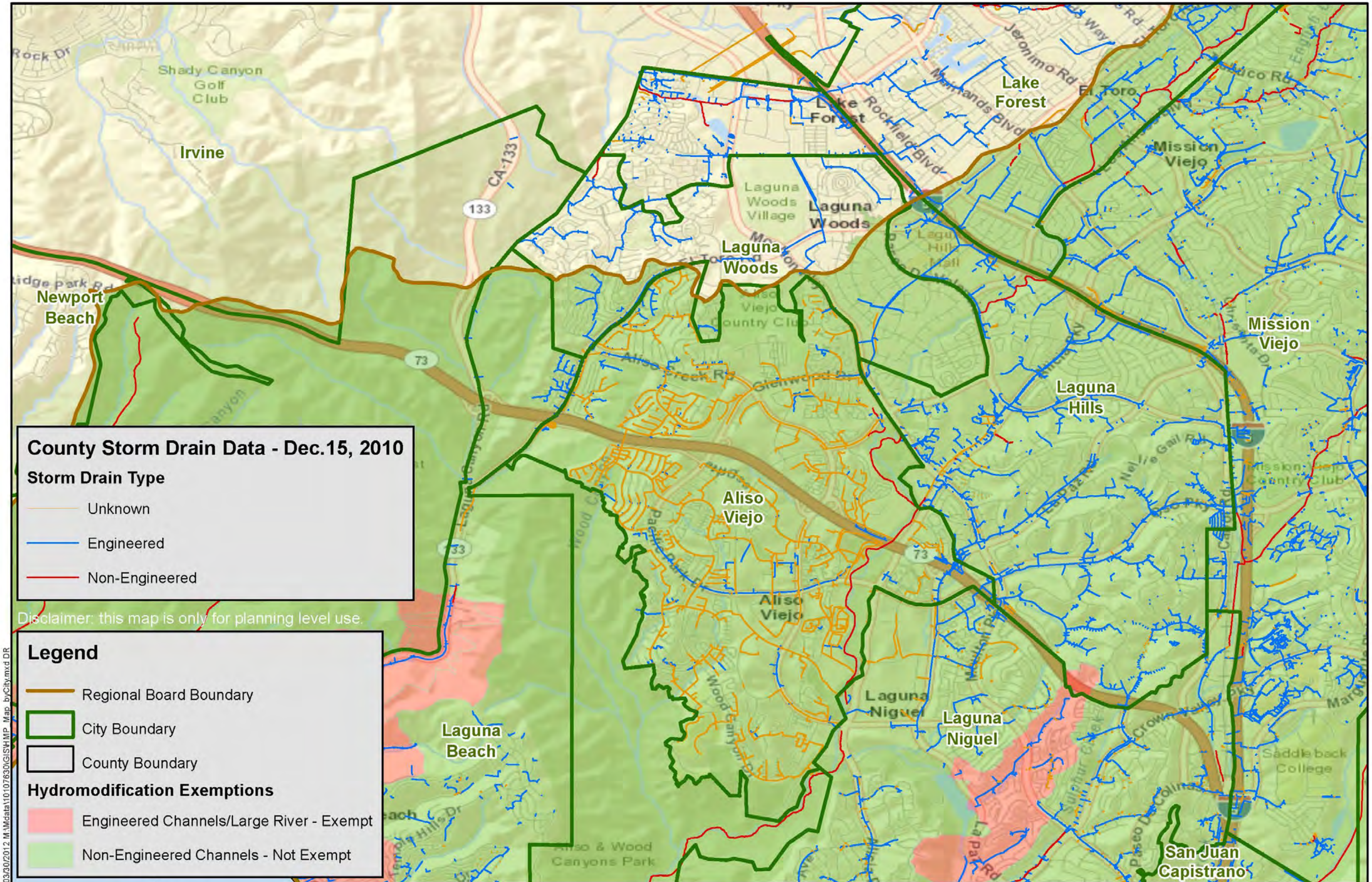


RBF CONSULTING A Baker Company GIS

0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas
Laguna Beach Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB



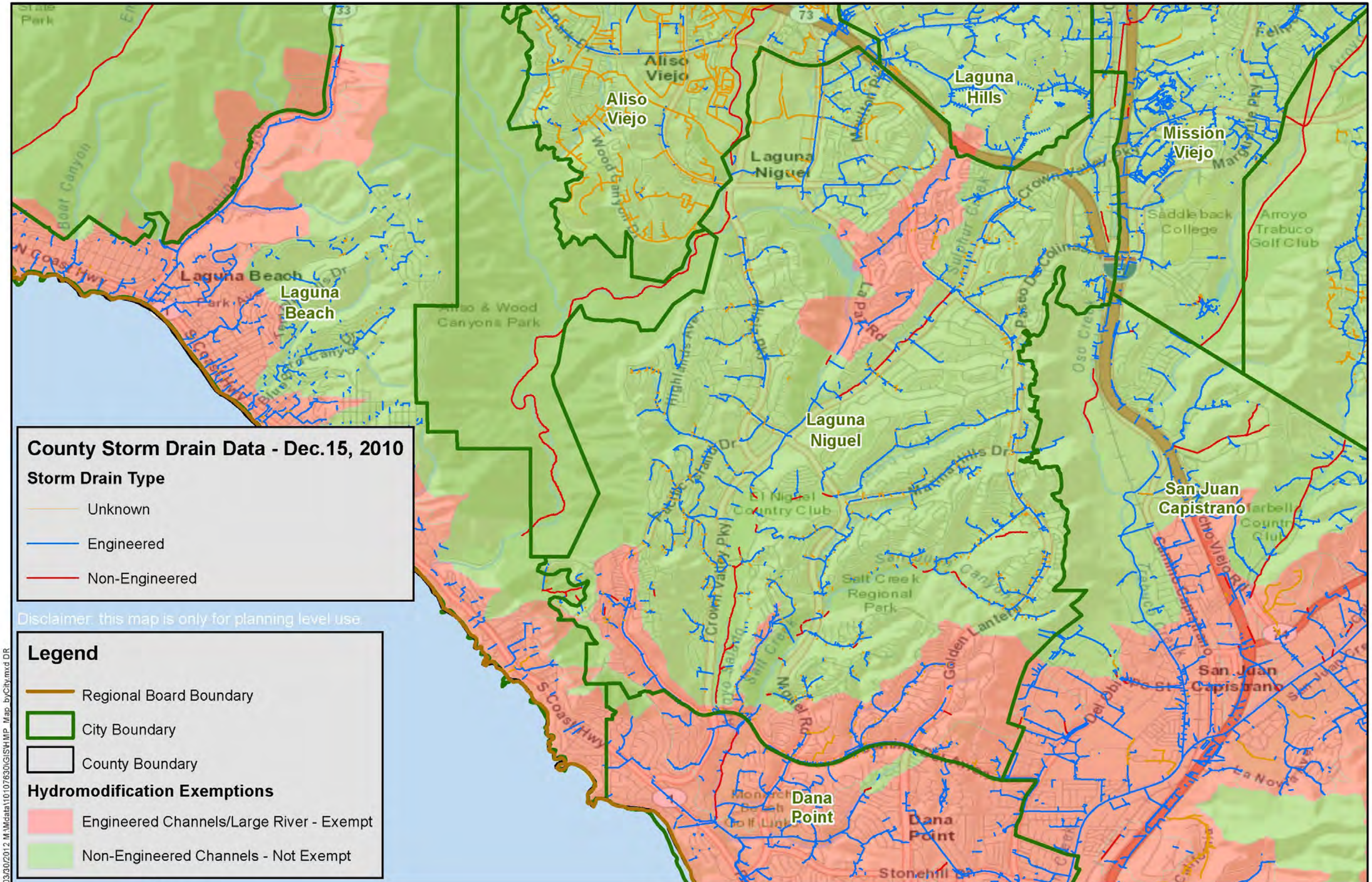
0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas

Laguna Hills Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

03/30/2012 M:\Mdata\10107630\GIS\HMP_Map_byCity.mxd DR



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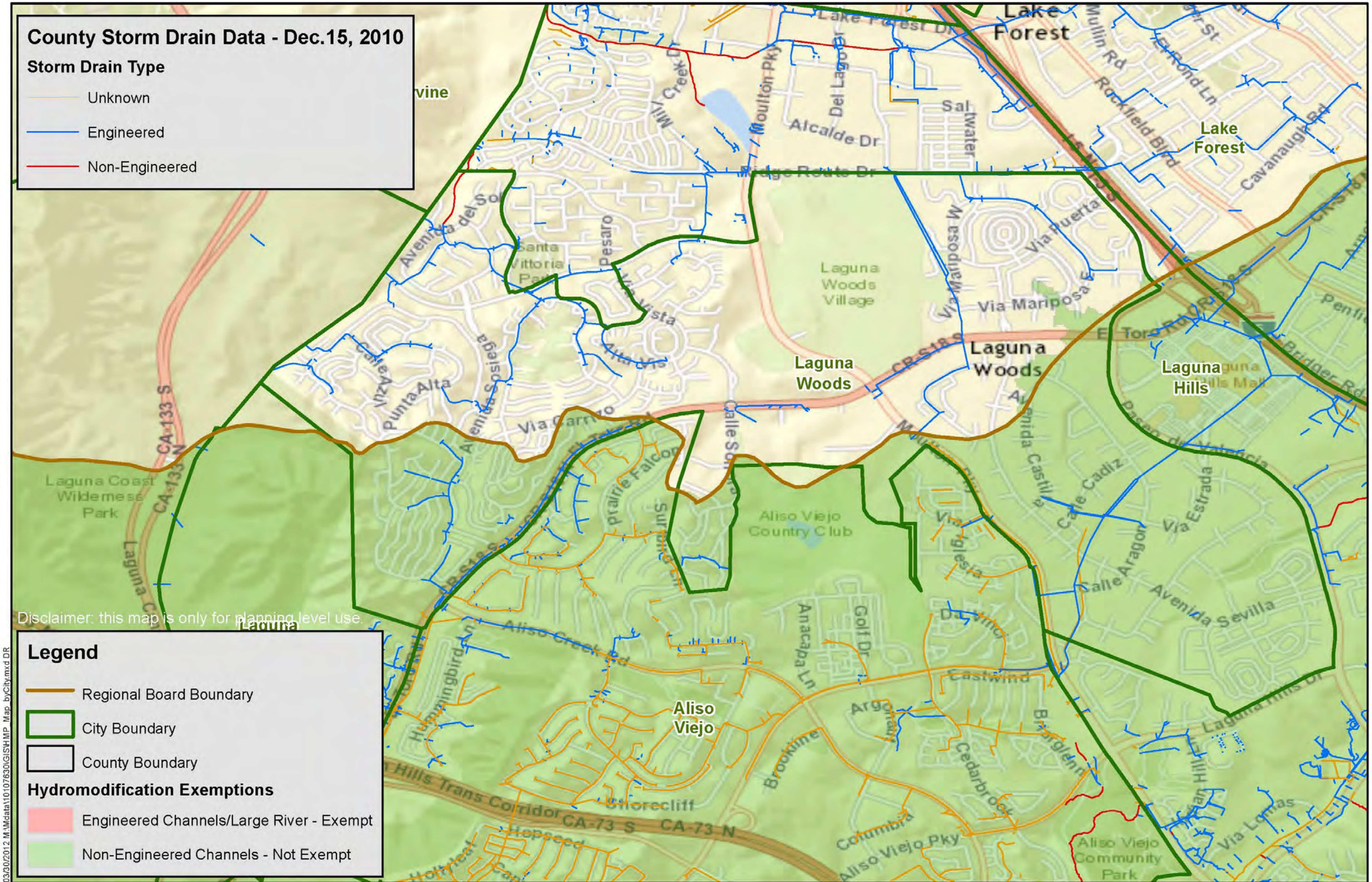
RBF CONSULTING A Baker Company

0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas
Laguna Niguel Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB



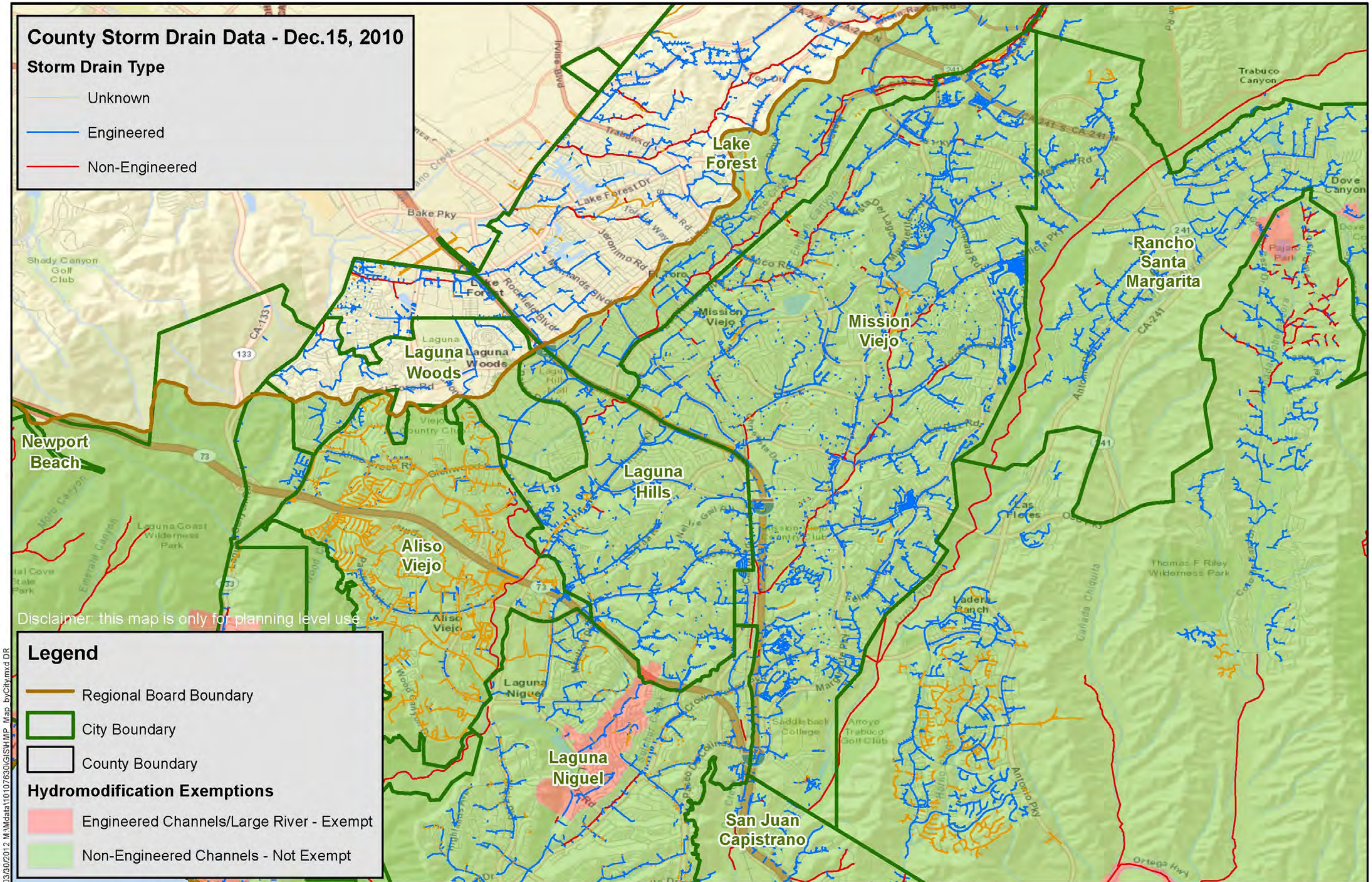
Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas
Laguna Woods Exemption Map

RBF CONSULTING A Baker Company

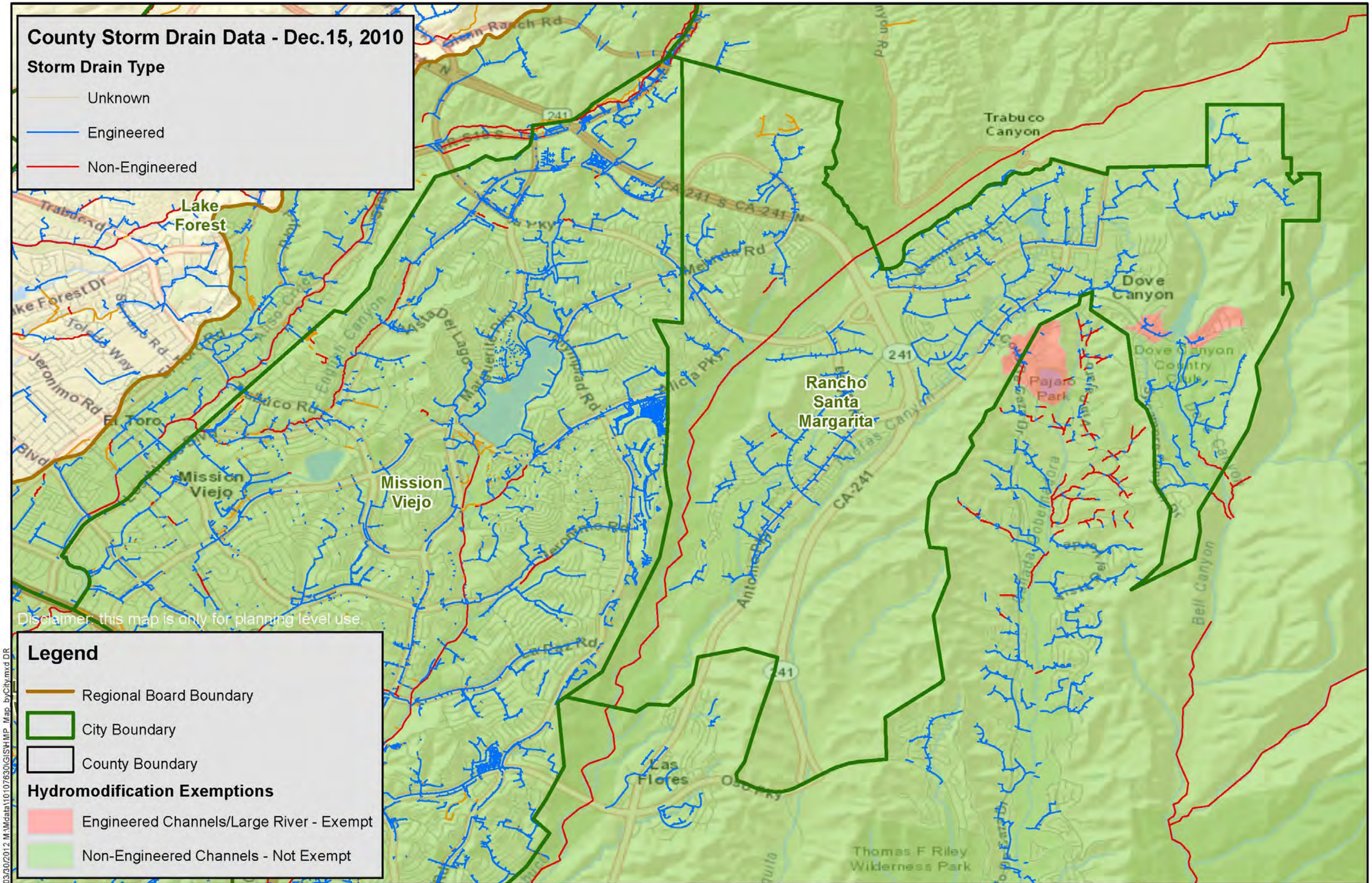
03/30/2012 M:\Mdata\10107630\GIS\HMP_Map_byCity.mxd DR



0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas
Mission Viejo Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

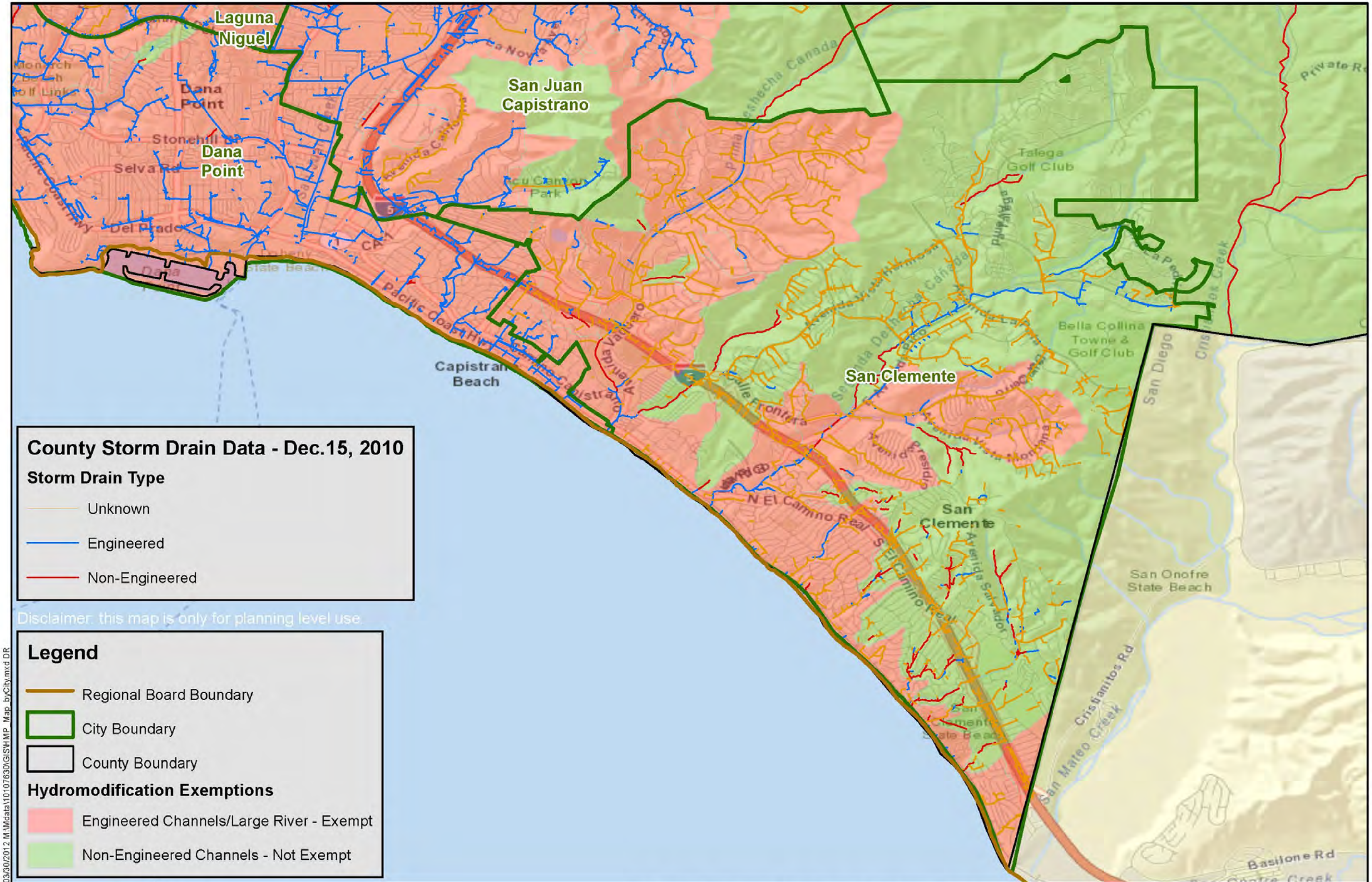


South Orange County Engineered Channel Exemption Areas

Rancho Santa Margarita Exemption Map

RBF CONSULTING A Baker Company
GIS

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

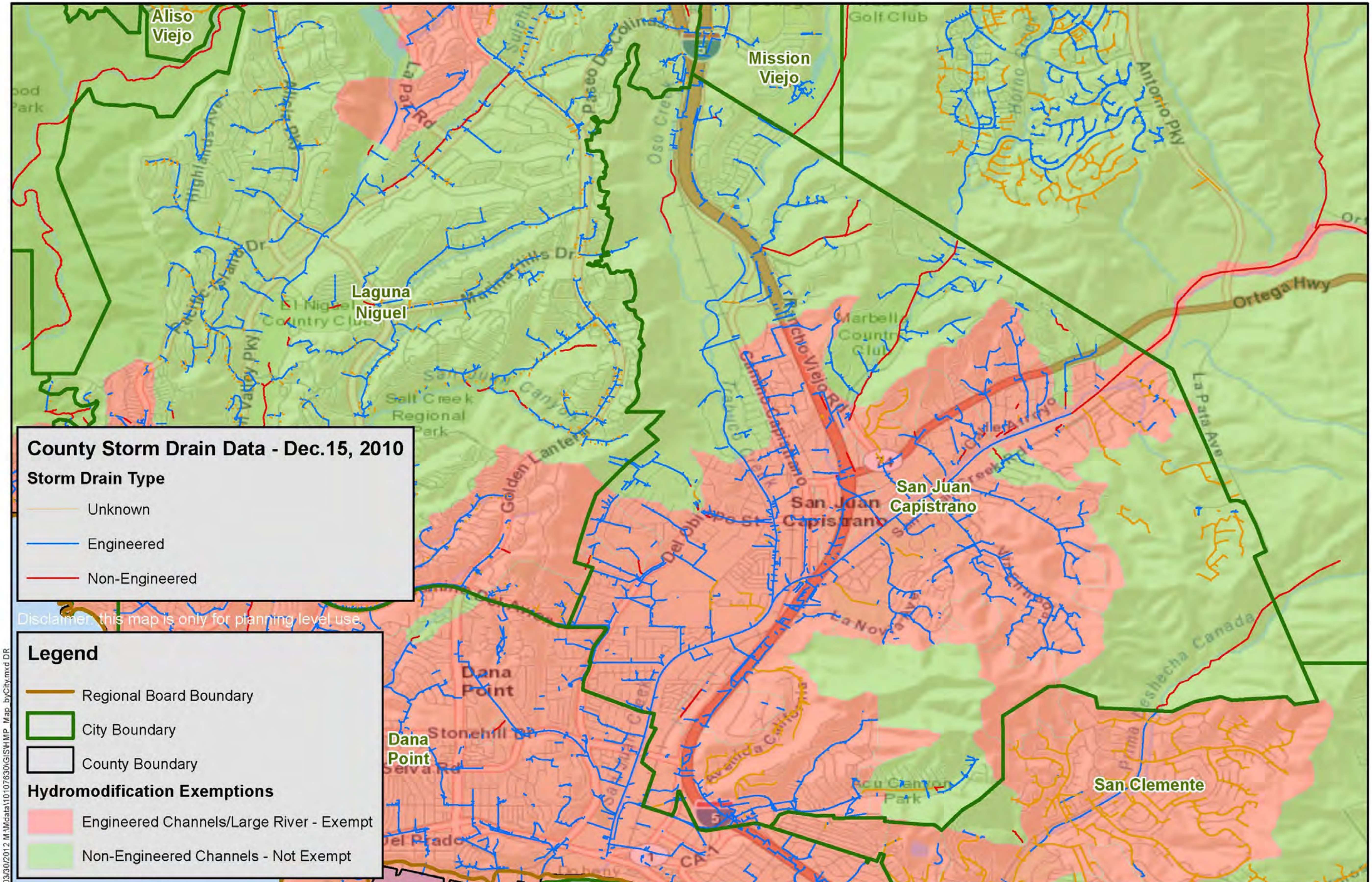


0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas

San Clemente Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB



03/30/2012 M:\Mdata\10107630\GIS\HMP_Map_byCity.mxd DR

RBF CONSULTING A Baker Company

GIS

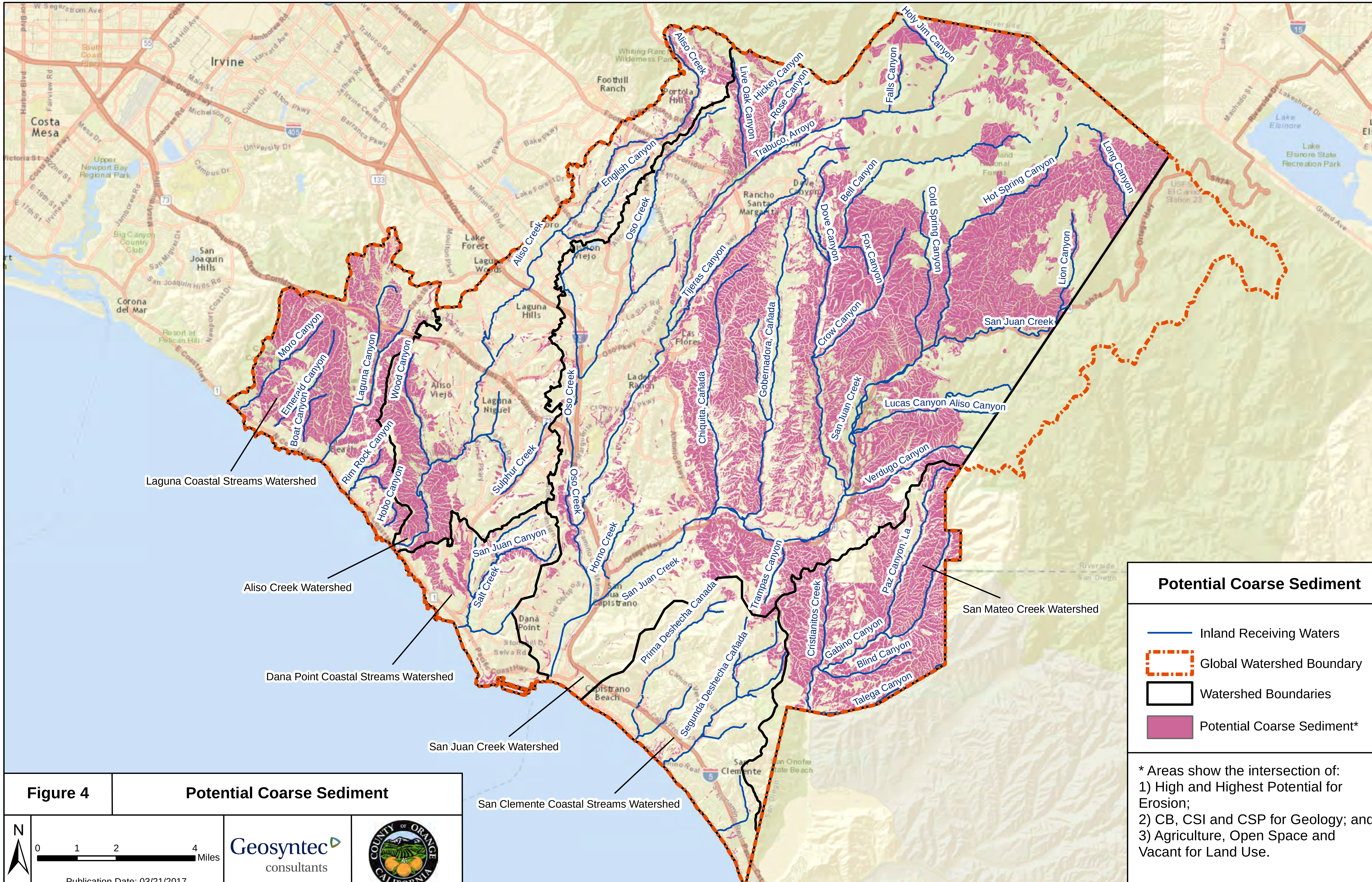
0 0.5 1 Miles

South Orange County Engineered Channel Exemption Areas

San Juan Capistrano Exemption Map

Sources: County of Orange; Caltrans; ESRI; RBF Consulting; San Diego RWQCB; SWRCB

N.8 Potential Critical Coarse Sediment Yield Areas by Watershed



* Areas show the intersection of:
1) High and Highest Potential for Erosion;
2) CB, CSI and CSP for Geology; and
3) Agriculture, Open Space and Vacant for Land Use.

Figure 4 | **Potential Coarse Sediment**

Publication Date: 03/21/2017

Geosyntec consultants

County of Orange California

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

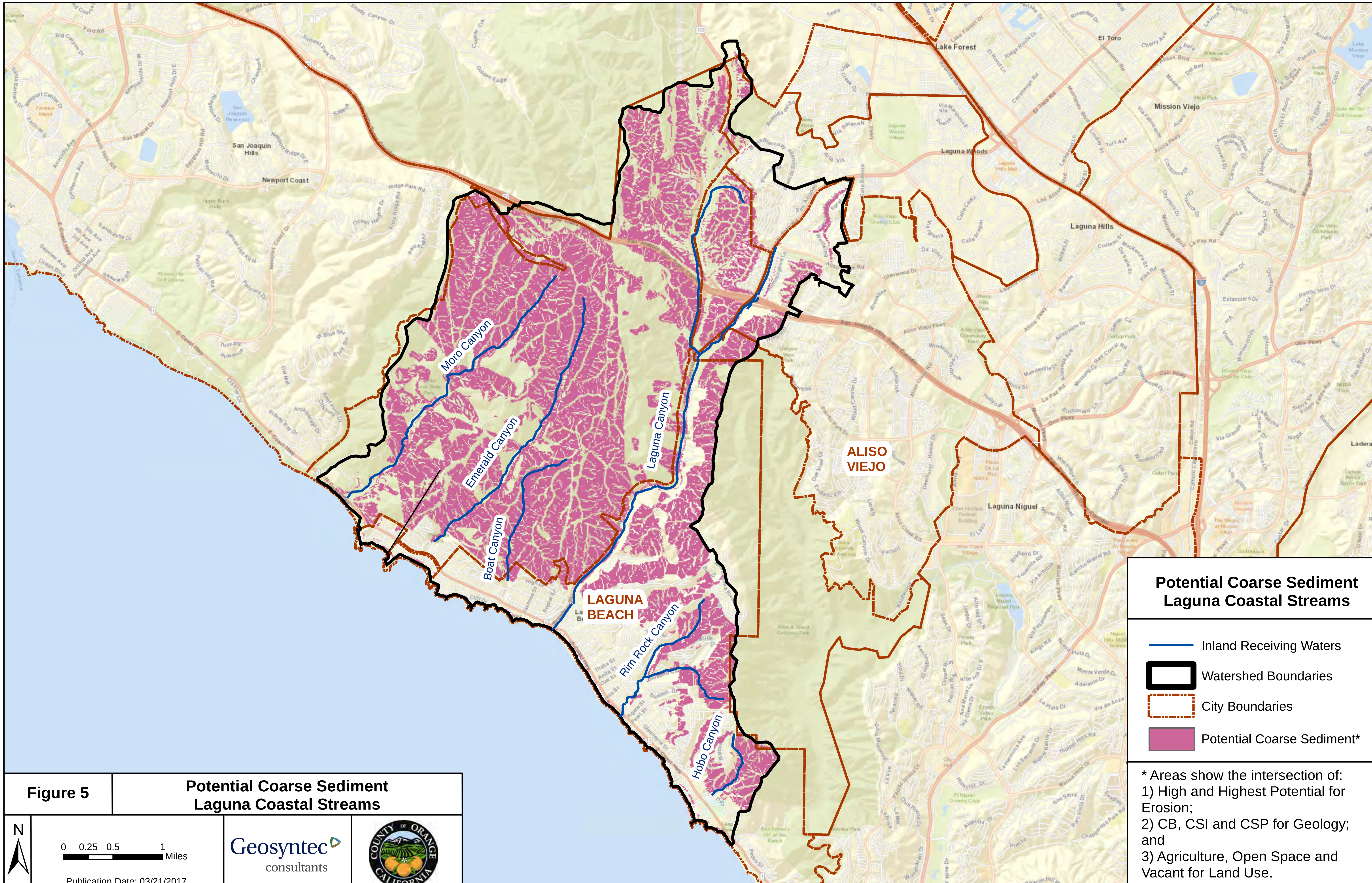


Figure 5 | **Potential Coarse Sediment Laguna Coastal Streams**

Publication Date: 03/21/2017

Geosyntec consultants

County of Orange California

Potential Coarse Sediment Laguna Coastal Streams

- Inland Receiving Waters
- Watershed Boundaries
- City Boundaries
- Potential Coarse Sediment*

* Areas show the intersection of:
1) High and Highest Potential for Erosion;
2) CB, CSI and CSP for Geology; and
3) Agriculture, Open Space and Vacant for Land Use.

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

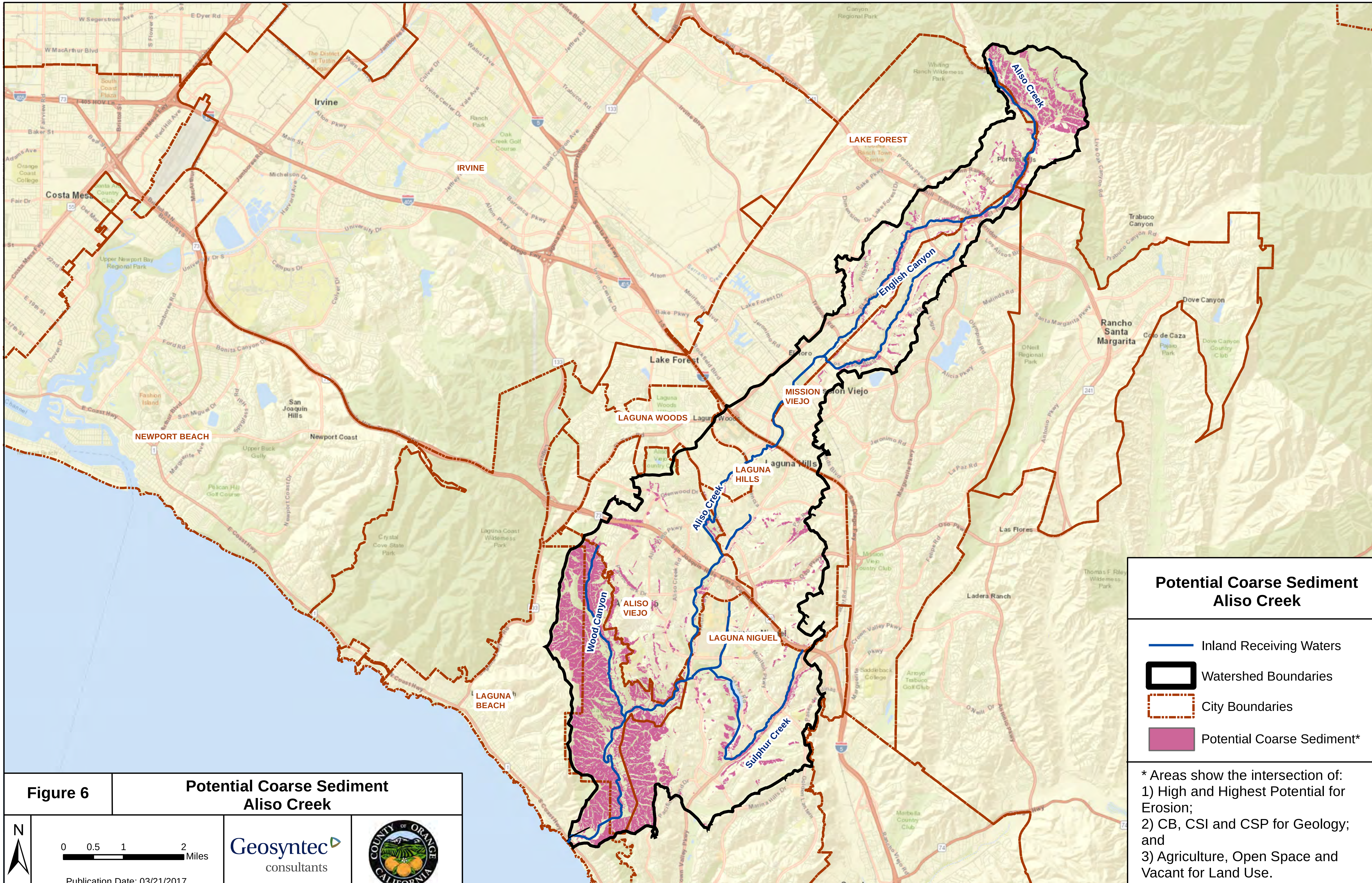


Figure 6 Potential Coarse Sediment Aliso Creek

Potential Coarse Sediment Aliso Creek

- Inland Receiving Waters
- Watershed Boundaries
- City Boundaries
- Potential Coarse Sediment*

* Areas show the intersection of:
1) High and Highest Potential for Erosion;
2) CB, CSI and CSP for Geology; and
3) Agriculture, Open Space and Vacant for Land Use.

Publication Date: 03/21/2017

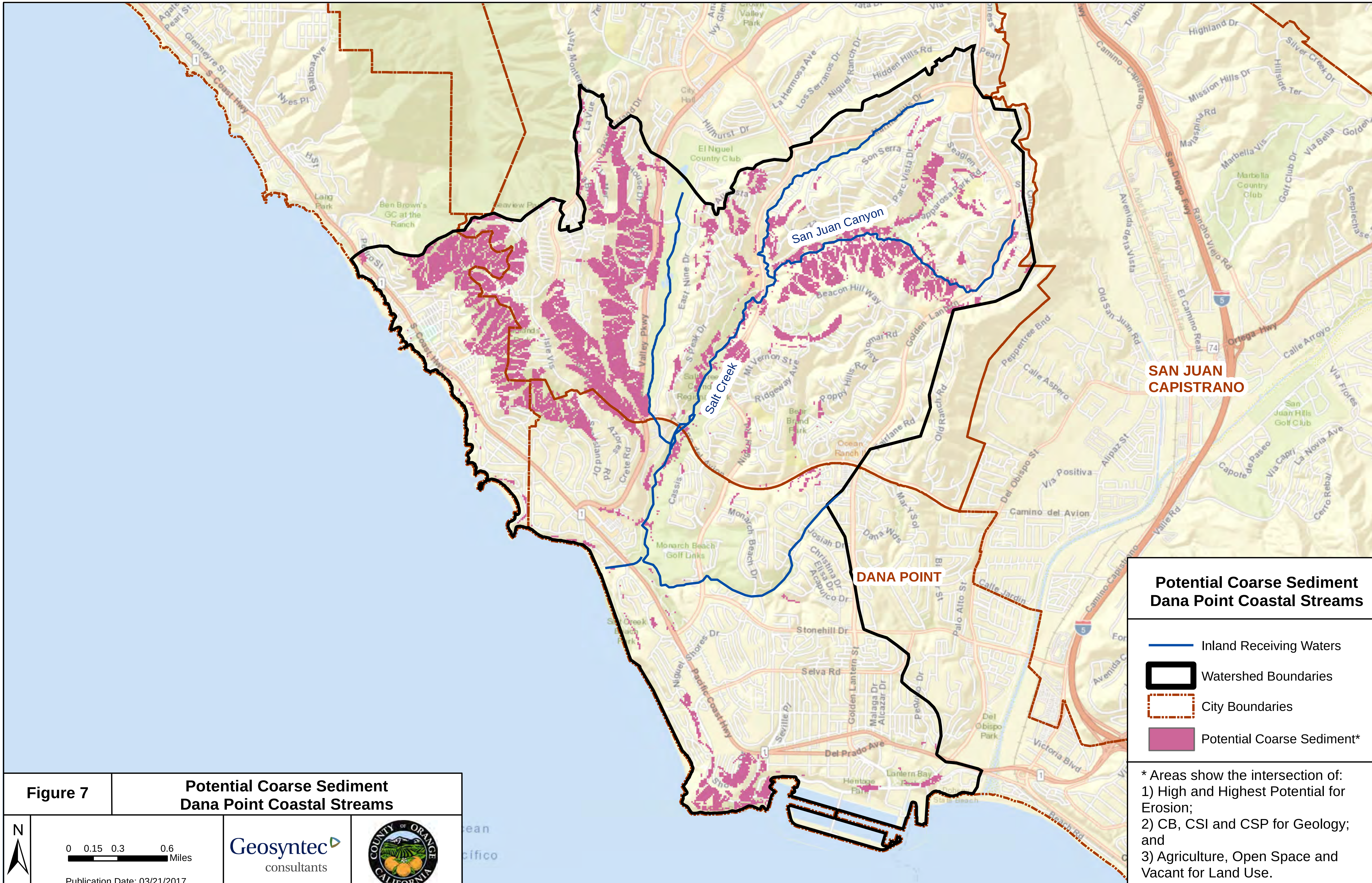
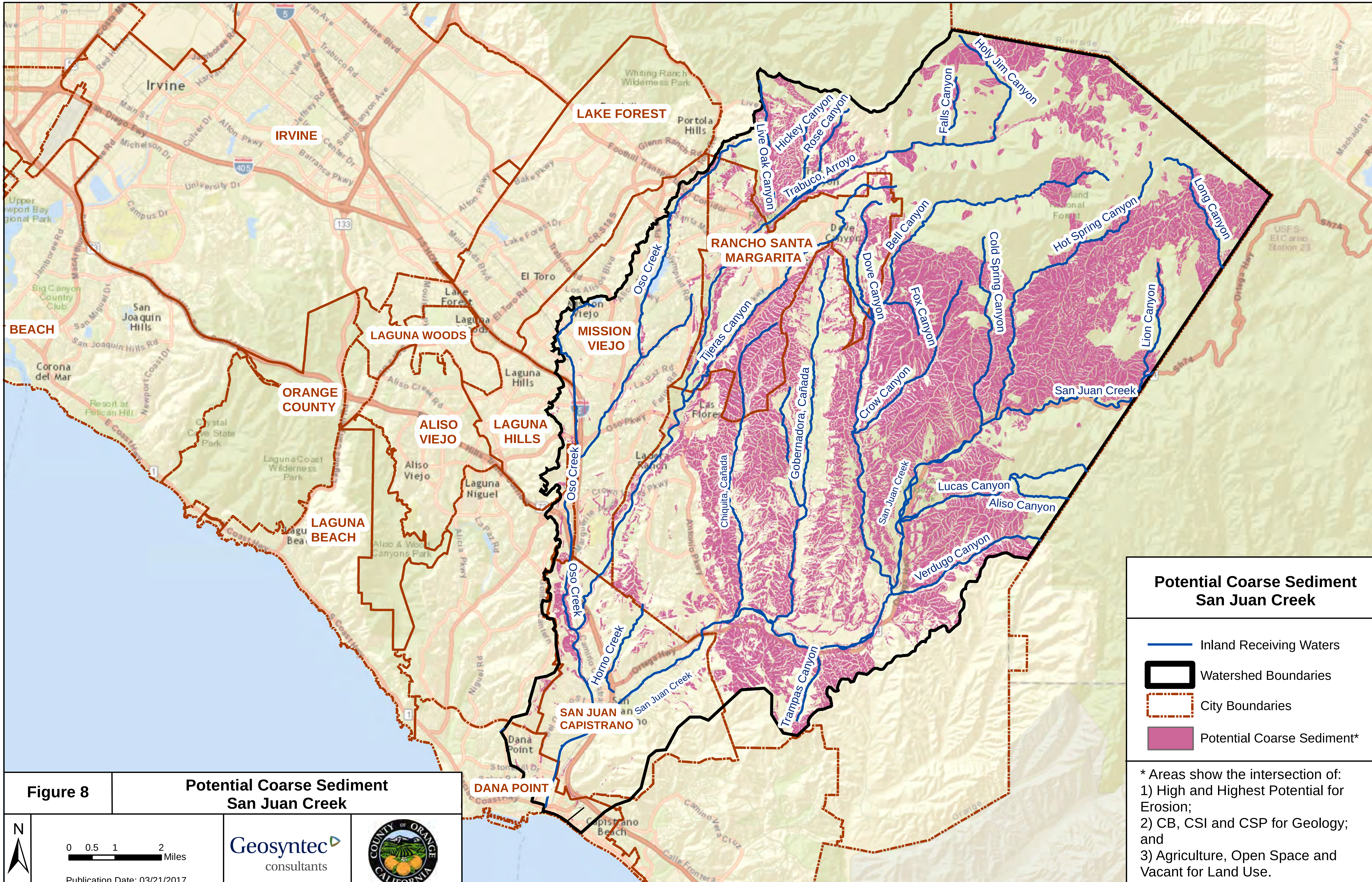


Figure 7 Potential Coarse Sediment Dana Point Coastal Streams

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community



Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

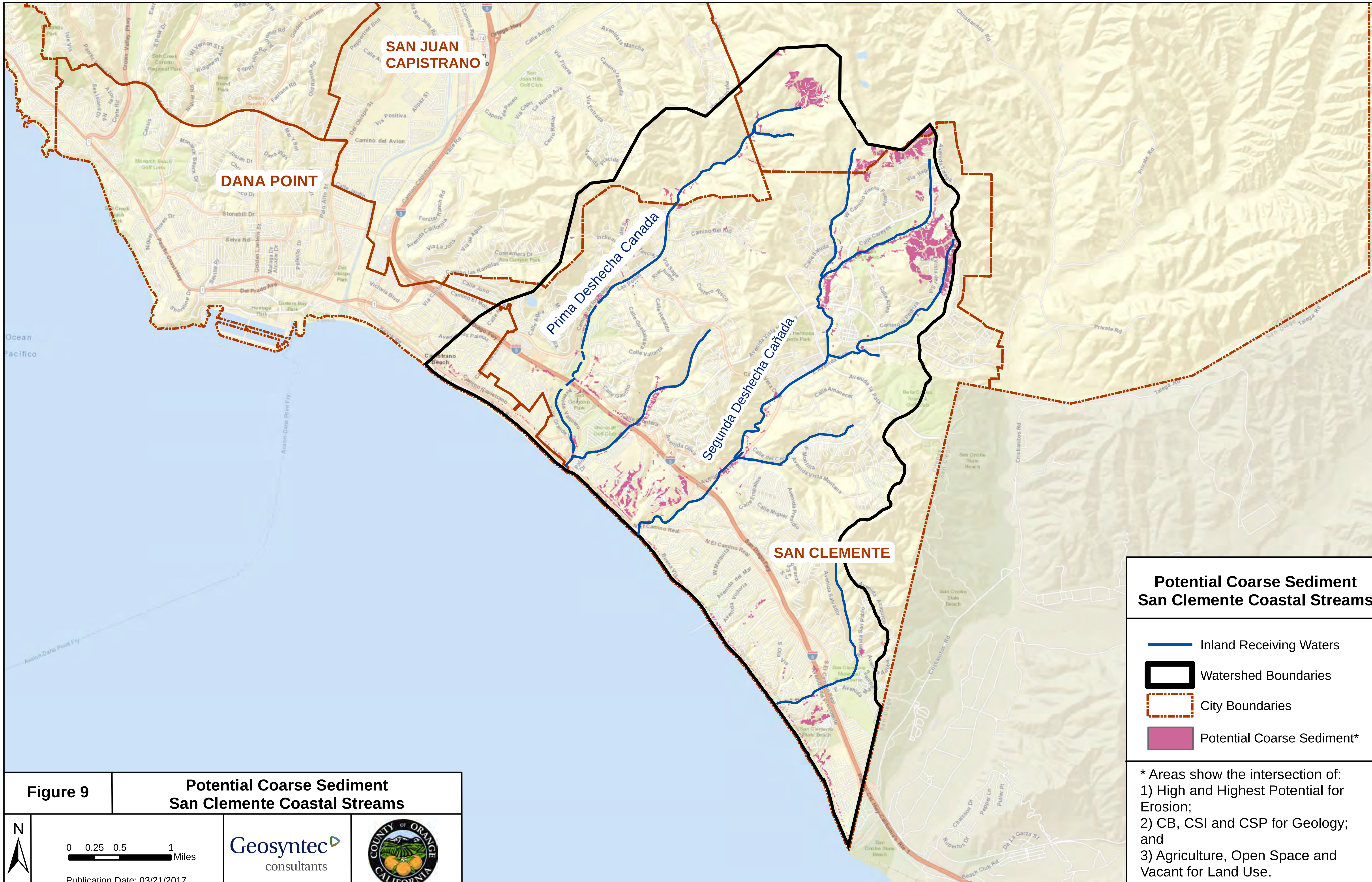


Figure 9 Potential Coarse Sediment San Clemente Coastal Streams

* Areas show the intersection of:
1) High and Highest Potential for Erosion;
2) CB, CSI and CSP for Geology; and
3) Agriculture, Open Space and Vacant for Land Use.

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

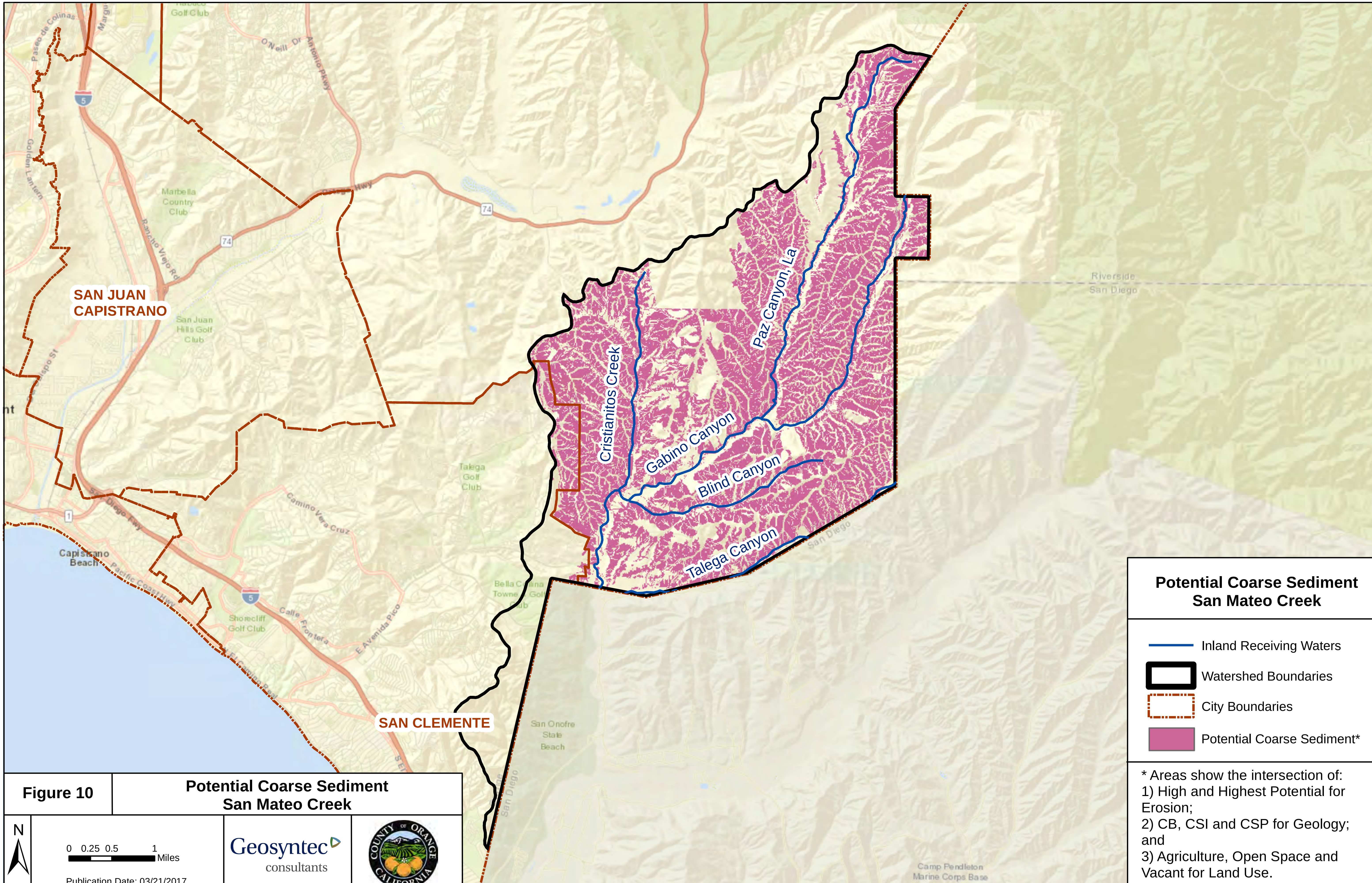


Figure 10 Potential Coarse Sediment San Mateo Creek

Publication Date: 03/21/2017

Geosyntec consultants

County of Orange California

Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community