SOUTH ORANGE COUNTY HYDROMODIFICATION MANAGEMENT PLAN

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CONTENTS

TABLES

FIGURES

ACRONYMS

ACCCMP	Alameda Countywide Clean Water Program	OCHM	Orange County Hydrology Manual
BAHM	Bay Area Hydrology Model	PDP	Priority Development Project
BEHI	Bank Erosion Hazard Index	PLS	Pervious Land Surface
BMI	Benthic Macroinvertebrates Index	PWA	Philip Williams & Associates
BMP	Best Management Practice	S	Slope in Lane's equation
CASQA	California Stormwater Quality Association	Q or Qw	Flow
CCCWP	Contra Costa Clean Water Program	Qcrit - Qc	Critical flow
CEM	Channel Evolution Model	Qcp	Geomorphically critical flow – 10 percent of the 2-year flow
CEQA	California Environmental Quality Act	Qs	Sediment discharge in Lane's equation
D_{50}	Median grain size diameter	RWQCB	Regional Water Quality Control Board
Ep	Erosion potential index	SCCWRP	Southern California Coastal Water Research Project
ET	Evapotranspiration	SCVURPPP	Santa Clara Valley Urban Runoff Pollution Prevention Program
FSURMP	Fairfield-Suisun Urban Runoff Management Program	SMCWPPP	San Mateo Countywide Water Pollution Prevention Program
GIS	Geographical Information System	STOPPP	San Mateo County Stormwater Pollution Prevention Program
HEC-HMS	Hydrologic Modeling System; distributed by the US Army Corps of Engineers Hydrologic Engineering Center	SSMP	Standard Stormwater Mitigation Plan
HMP	Hydromodification Management Plan	SUSMP	Standard Urban Stormwater Mitigation Plan
HR	Hydraulic Radius	SWM SWMM	Stanford Watershed Model Storm Water Management Model; distributed by USEPA
HSPF	Hydrologic Simulation Program FORTRAN, distributed by USEPA	SWMP	Storm Water Management Plan
IMP	Integrated Management Practices	SWWM	Storm Water Management Model
LEED	Leadership in Energy and Environmental Design	TMDL	Total Maximum Daily Load
LID	Low Impact Development	USACE	United States Army Corps of Engineers
LSPC	Loading Simulation Program in C++	USEPA	United States Environmental Protection Agency
MHHW	Mean Higher High Water	USGS	United States Geological Survey
NOAA	National Oceanic and Atmospheric Administration		
NPDES	National Pollutant Discharge Elimination System		
NRCS	Natural Resource Conservation Service		

1.0 Introduction

Hydromodification refers to changes in the magnitude and frequency of stream flows due to urbanization and the resulting impacts on receiving channels, such as erosion, sedimentation, and potentially degradation of in-stream habitat. The degree to which a channel will erode or aggrade is a function of the increase or decrease in work (shear stress), the resistance of the channel bed and bank materials – including vegetation (critical shear stress), the change in sediment delivery, and the geomorphic condition (soil lithology) of the channel. Critical shear stress is the shear stress threshold above which motion of bed material load is initiated. Not all flows cause significant movement of bed material—only those that generate shear stress in excess of the critical shear stress of the bank and bed materials. Urbanization increases the discharge rate, amount and timing of runoff, and associated shear stress exerted on the channel by stream flows and can trigger erosion in the form of incision (channel downcutting), widening (bank erosion), or both. Depths that generate shear below critical shear stress levels have little or no effect on the channel stability.

Program Provision F.1.h of the San Diego California Regional Water Quality Control Board (SDRWQCB) Permit Order R9-2009-0002 (Permit) requires "…the Permittees to develop and implement a Hydromodification Management Plan (HMP) to manage increases in runoff discharge rates and durations from all Priority Development Projects." Where receiving stream channels are already unstable, hydromodification management can be thought of as a method to avoid accelerating or exacerbating existing problems. Where receiving stream channels are in a state of dynamic equilibrium, hydromodification management may prevent the onset of erosion, sedimentation, lateral bank migration, or impacts to in-stream vegetation.
The Permit contains certain requirements that strongly influence the methodology chosen in development of the HMP. The Permit requires the Permittees to develop an HMP for all Priority Development Projects (with certain exemptions) and develop a performance standard including a geomorphically-significant flow range that ensures the geomorphic stability within the channel. Supporting analyses must be based on continuous hydrologic simulation modeling. Similarly, the loss of sediment supply due to the development must be considered.

The SDRWQCB jurisdiction area covers the southern portion of Orange County. The northern portion of Orange County is under the jurisdiction of the Santa Ana Regional Water Quality Control Board (SARWQCB) and is not subject to this HMP. MS4 Permittees or dischargers directly or indirectly discharging runoff into waters of the United States within the San Diego Region include the Cities of Aliso Viejo, Dana Point, Laguna Beach, Laguna Hills, Laguna Niguel, Laguna Woods, Lake Forest, Mission Viejo, Rancho Santa Margarita, San Clemente, and San Juan Capistrano, as well as the County of Orange and the Orange County Flood Control District.

2.0 Permittee HMP Development Process

Although the County of Orange serves as the lead agency for development of the HMP, all 13 Permittees have participated in its development, both financially and through participation in HMP workshops scheduled over the course of the project at times corresponding with key decision points in developing the HMP. Participants in the HMP Workshops created a Permittee HMP Workgroup to provide input on the development of the HMP.

The Permittees will continue to meet to discuss and resolve any issues that may arise during the HMP implementation phase. The Permittee HMP Workgroup will also assist in refining and reinforcing methodologies, criteria, and standards established in the HMP.

The Permittee HMP Workgroup has met three times since August 2011. **Table 2-1** shows meeting dates, locations, and agenda items. In addition to the formal meetings, the Permittee HMP Workgroup coordinated via email to review and discuss technical documents, deliberate on specific HMP-related topics and concur on issues.

Table 2-1: HMP Workgroup Meetings

Date	Location	Agenda
August 8, 2011	Laguna Hills City Hall	Kickoff Workshop Discussion of the proposed South Orange County HMP (SOCHMP) Approach and Methodology
October 12, 2011	RBF Consulting Irvine/Webcast	Presentation of the San Diego Hydrology Model Tool by Clear Creek Solution (Doug Beyerlein) Presentation of the HMP Framework by RBF Consulting (Scott Taylor & Daniel Apt)
November 17, 2011	RBF Consulting Irvine	Draft HMP Document Review

No later than 90 days after receiving a finding of adequacy from the San Diego Regional Water Quality Control Board Executive Officer, the Final South Orange County HMP requirements will be incorporated into the Model Water Quality Management Plan (Model WQMP). The Permittees will use the revised Model WQMP to incorporate the HMP requirements into the local approval processes through their local WQMPs and municipal ordinances. This will also be completed within 90 days after receiving a finding of adequacy from the San Diego Regional Water Quality Control Board Executive Officer.

It should be noted that this HMP has in large part been based on the San Diego HMP, which was developed by the County of San Diego and the Permittees for San Diego County. The San Diego HMP was approved by the San Diego Regional Board and served as the starting point for development of the South OC HMP.

3.0 Literature Review

Pursuant to Permit Section F.1.h(1)(e), this section provides the results of a literature review conducted as a basis for the development of the HMP.

Hydromodification in the context of this Plan refers to changes in the magnitude and frequency of stream flows due to urbanization and the resulting impacts on the receiving channels in terms of erosion, sedimentation, and degradation of in-stream habitat. The processes involved in aggradation and degradation are complex, but are caused by an alteration of the hydrologic regime of a watershed due to increases in impervious surfaces, more efficient storm drain networks, and a change in historic sediment supply sources. The study of hydromodification is an evolving field, and regulations to manage the impacts of hydromodification must be grounded in the latest science available.

HMPs seek ways to mitigate erosion impacts by establishing requirements for controlling runoff from new development. In order to establish appropriate regulations, it is important to understand 1) how land use changes alter storm water runoff; and 2) how these changes can impact stream channels. These and other issues central to HMPs adopted in California have been addressed in numerous journal articles, books, and reports. This report builds upon previous literature reviews developed for the San Diego County HMP, including recent studies or information relevant to Southern California.

3.1 Managing Hydromodification

There are many different approaches to managing hydromodification impacts from urbanization and most HMPs provide multiple options for achieving and documenting compliance with National Pollutant Discharge Elimination System (NPDES) permit requirements. In general, hydrograph management approaches focus on managing runoff from a developed area to not increase instability in a channel, and in-stream solutions focus on managing the receiving channel to accept an altered flow regime without becoming unstable. This section briefly summarizes various approaches for HMP compliance.

Hydrograph Management Solutions

Facilities that detain or infiltrate runoff to mitigate development impacts are the focus of most HMP implementation guidance. They work by either reducing the volume of runoff (infiltration facilities) or holding water and releasing it below Q_c (detention facilities). These facilities, also referred to as BMPs, can range from regional detention basins designed solely for flow control, to bioretention facilities that serve a number of functions. A number of BMPs, including swales, bioretention, flow-through planters, and extended detention basins have been developed to manage storm water quality, and several resources describe the design of storm water quality BMPs (CASQA 2003; Richman et al. 2004). In many cases, these facilities can be designed to also meet hydromodification management requirements.

Many HMPs also provide guidance for applying LID approaches to site design and land use planning to preserve the hydrologic cycle of a watershed and mitigate hydromodification impacts. These plans typically include decentralized storm water management systems and protection of natural drainage features, such as wetlands and stream corridors. Runoff is typically directed toward infiltration-based storm water BMPs that slow and treat runoff. The following sections summarize how hydromodification management BMPs developed for existing HMPs have been designed and implemented.

Sizing Hydromodification BMPs

Hydromodification BMPs differ slightly from those used to meet water quality objectives in that they focus more on matching undeveloped flow-regimes than on removing potential pollutants, although these two functions can be combined into one facility. Various methods exist for sizing hydromodification BMPs.

- **Hydrograph Matching** uses an outflow hydrograph for a particular site that matches closely with the pre-project hydrograph for a design storm. This method is most traditionally used to design flood-detention facilities to mitigate for a particular storm recurrence interval (e.g., the 100-year storm). Although hydrograph matching can be employed for multiple storm recurrence intervals, this method generally does not take into account the smaller, more frequent storms where a majority of the erosive work in stream channel is done and is therefore not widely accepted for HMP compliance nor recommended for use as a part of this plan.
- **Volume Control** matches the pre-project and post-construction runoff volume for a project site. Any increase in runoff volume is either infiltrated on site, or discharged to another location where streams will not be impacted. The magnitude of peak flows and time of concentration is not controlled, so while this method ensures there is no increase in total volume of runoff, it can result in higher erosive forces during storms.
- **Flow Duration Control** matches both the duration and magnitude of a specified range of storms. The entire hydrologic record is taken into account, and pre-project and post-construction runoff magnitudes and volumes are matched as closely as possible. Excess runoff is either infiltrated onsite or discharged below Q_{cp} (Geomorphically critical flow – 10 percent of the 2-year flow).

The Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVUPPP) HMP reviewed each of these methods and concluded that a Flow Duration Control approach was the most effective in controlling erosive flows. Two examples were evaluated using this approach, one on the Thompson Creek subwatershed in Santa Clara Valley and one on the Gobernadora Creek watershed in Orange County. The evaluation approach used continuous simulation modeling to generate flow-duration curves, and then designed a test hydromodification management facility to match pre-project durations and flows.

In addition to the SCVURPP HMP, the flow duration control approach has been applied by the Alameda Countywide Clean Water Program (ACCWP), SMCWPPP, the Fairfield-Suisun Urban Runoff Management Program (FSURMP), Contra Costa Clean Water Program (CCCWP), and San Diego County. Among these agencies, different approaches have emerged on how to demonstrate that proposed BMPs meet flow-duration control guidelines. Both methods employ continuous simulation to match flow-durations, but differences exist in how continuous simulation is used (site-specific simulation vs. unit area simulation). Differences also exist in the focus of the two approaches (regional detention facilities vs. on-site LID facilities). Both approaches were evaluated by the different RWQCBs and deemed valid (Butcher 2007).

BAHM Approach

The Bay Area Hydrology Model (BAHM) is a continuous simulation rainfall-runoff hydrology model developed for ACCWP, SMCWPPP, and SCVURPP. It was developed from the Western Washington Hydrology Model, which focuses primarily on meeting hydromodification management requirements using storm water detention ponds alone or combined with LID facilities (Butcher 2007). The Western Washington Hydrology model is based on the Hydrologic Simulation Program – FORTRAN (HSPF) modeling platform, developed by the United States Environmental Protection Agency (U.S. EPA), and uses HSPF parameters in modeling watersheds.

Project proponents who want to size a hydromodification BMP select the location of their project site from a map of the county and BAHM correlates the project location to the nearest rainfall gauge and applies an adjustment factor to the hourly rainfall for the nearest gauge, to produce a weighted hourly rainfall at the project site. The user then enters parameters for the proposed project site describing soil types, slope, and land uses. BAHM then runs the continuous rainfall-runoff simulation for both the pre-project and the post-construction conditions of the project site. Output is provided in the form of flow-duration curves that compare the magnitude and timing of storms between the pre-project and the post-construction modeling runs.

If an increase in flow durations is predicted, the user can select and size mitigation BMPs from a list of modeling elements. An automatic sizing subroutine is available for sizing detention basins and outlet orifices that matches the flow duration curves between the pre-project scenario and a post-construction mitigation scenario. Manual sizing is necessary for other BMPs included in the program, such as storage vaults, bioretention areas, and infiltration trenches. The program is designed so that, once a BMP is selected and sized, the modeling run can be transferred to the local agency for approval. The model reviewer at the local agency can launch the program and verify modeling parameters and sizing techniques.

A HMP tool was also developed to support developers and applicants with the San Diego County HMP. The San Diego Hydrology Model (SDHM) derives from the BAHM, and integrates parameters that are specific to the San Diego region.

A similar approach will be used for the South Orange County HMP. The Western Washington Continuous Simulation Hydrology Model (WWHM) has been modified to include local rainfall and loss rate information, in addition to preferred local BMP selection to provide project proponents a user-friendly tool to develop a hydromodification mitigation strategy. The South Orange County Hydrology Model (SOCHM) allows the user to match the flow duration curve for the selected range of flows using locally preferred BMPs.

Contra Costa Clean Water Program (CCCWP) Approach

The CCCWP developed a protocol for selecting and sizing hydromodification BMPs, which are referred to as Integrated Management Practices (IMPs) in their guidebook. Instead of a project proponent running a site-specific continuous simulation to size hydromodification control facilities, the CCCWP provides sizing factors for designing site level IMPs. Sizing factors are based on the soil type of the project site and are adjusted for Mean Annual Precipitation. Sizing factors are provided for bioretention facilities, flow-through planters, dry wells and a combination cistern and bioretention facility.

Sizing factors were developed through continuous-simulation HSPF modeling runs for a variety of development scenarios. Flow-durations were developed for a range of soil types, vegetation and land use types, and rainfall patterns for development areas in Contra Costa County. Then, based on a unit area (one acre) of impervious surface, flow-durations were modeled using several IMP designs. These IMPs were then sized to achieve flow control for the range of storms required, (from 10 percent of the 2-year storm up to the 10-year storm). These sizing factors were then transferred to a spreadsheet form for use by project proponents.

The primary difference between the CCCWP approach and the BAHM approach is the level of modeling required. The CCCWP approach is simplified for the project proponent in that both hydromodification and water quality mitigation are incorporated into the IMP sizing factors. The BAHM allows for more flexibility in that regional BMPs may be used for hydromodification, and if desired, water quality, in addition to site level approaches. The South Orange County NPDES Permit allows for regional mitigation of hydromodification impacts. Therefore, an approach that uses continuous simulation to assess regional or neighborhood level BMP implementation is preferred for this Plan.

Sediment Management Solutions

Sediment discharge is one of the fundamental independent variables impacting stream stability. Lane (1955) described alluvial channel stability in the relation:

$$Q_s \times D_{50} \propto Q_w \times S$$

Where:

Q_s = Sediment discharge
D_{50} = Median sediment size
Q_w = Flow
S = Channel Slope

As seen by Lane's relationship, if any of the four variables are altered, one or more of the remaining variables must change. In the case of urbanization, runoff usually is increased, causing a reduction in channel slope (S) through downcutting or increased channel meander. Urbanization may also result in a change in sediment discharge (Q_s). Streambed material is derived from the channel bed and banks. If channels are altered by development in such a way as to reduce or increase sediment discharge, instability may occur.

Only a portion of the total sediment load in a channel is important for stream stability. Total channel sediment load may be classified by size or transport mechanism. The wash load commonly refers to the portion of the total sediment load that remains continuously in suspension (based on particle size). The wash load has a nominal impact on channel stability. Bed material load refers to the material that moves along the channel bed via saltation, and is continuously in contact or exchange with the channel bed. Bed material load is the critical portion of total sediment discharge for channel stability.

Urbanization can reduce the mass of bed material transported through the elimination of alluvial channel sections. This occurs in site development when first order and particularly larger streams are lined or placed into underground conduits. There are two general approaches for managing the bed material load relative to urbanization and channel stability. The first approach attempts to correct for the change in bed material load by increasing or decreasing the discharge rate as appropriate to generally maintain the balance described by Lanes relation. While theoretically a sound approach, this option requires a significant amount of detailed information that is difficult to obtain and requires good calibration of sediment models. Sediment transport models are non-linear and relatively sensitive to the rate of sediment supply and particle size distribution. Guidance for site specific analysis is provided in **Appendix D**.

The second approach to maintaining sediment supply is physically based, relying on a field assessment of site locations that may supply bed material load to the receiving channel, and protecting those sources during the site planning and development process. With this approach, the project proponent need only provide engineered solutions for flow mitigation. Protection of site bed material sources is the preferred approach since it is physically based and potentially less prone to error. Guidelines for field assessment of bed material sources are provided with the Sediment Supply Management approach, which is described in **Section 5.1**.

In-Stream Stabilization Solutions

In-stream solutions focus on managing the stream corridor to provide stability, modifying the stream channel to accept an altered flow regime. In cases where development is proposed in a watershed with an impacted stream it may be beneficial to focus on rehabilitating the stream channel to match the new independent variables of channel cross section, sediment discharge, flow discharge and channel slope rather than retrofitting the watershed or only controlling a percentage of the runoff with on-site controls. This type of approach can restore stream functions, beneficial uses, and values at a much more rapid pace, especially in locations that cannot physically be returned to their natural state due to changes in stream channel alignment and restrictions on the channel cross section due to adjacent development. In addition, in some cases where a master-planned watershed development plan is being implemented it may be more feasible to design a new channel to be stable under the proposed watershed land use rather than to construct distributed on-site facilities.

In-stream stabilization and restoration solutions are available as alternative compliance as a part of the South OC HMP. In-stream restoration projects are available if on-site controls are not feasible and it has been determined that the receiving water that the project discharges to has impacts due to hydromodification. Tiered benefits (benthic communities, morphology) of such in-stream restoration projects must offset the hydrologic and sediment changes induced by the associated PDP(s).

Other Methods

A number of methods exist for managing channels to accept altered flow regimes and higher shear forces. These have been covered in detail in a number of sources available to watershed groups and public agencies. (A few helpful sources include Riley 1998, Watson and Annable 2003, and FISRWG 1998.)

Stream Susceptibility - Domain of Analysis

Southern California Coastal Water Research Project (SCCWRP) has developed a series of screening tools that evaluate the susceptibility of a stream to hydromodification impacts (SCCWRP, 2010). These screening tools allow a project proponent to rate the susceptibility of the evaluated stream to erosion for a variety of geomorphic scenarios including alluvial fans, broad valley bottoms, incised headwaters, etc.

The development of HMPs in most Southern California counties is correlated to the ultimate findings of SCCWRP studies on hydromodification (SCCWRP, 2008 through 2011). It is generally acknowledged that SCCWRP's formulation of regional standards for hydromodification management may serve as a baseline for development of HMPs for specific regions in Southern California.

When evaluating the stream susceptibility though the SCCWRP screening tools, a domain of analysis is defined. This domain of analysis corresponds to the reach lengths upstream and downstream from a project from which hydromodification assessment is required. The domain of analysis determination includes an assessment of the incremental flow accumulations downstream of the site, identification of grade control points in the downstream conveyance system, and quantification of downstream tributary influences. The south Orange County program elected not to perform the extensive susceptibility mapping required to correlate channel reaches with variable low-flow discharge thresholds, since the return on investment for this type of analysis appears to be very low.

The effects of hydromodification may propagate for significant distances downstream (and sometimes upstream) from a point of impact such as a stormwater outfall. Accordingly, the domain of analysis serves as a representative buffer domain across which the susceptibility of a stream should be evaluated. This representative domain spans multiple channel types/settings, and is defined as follows in this HMP (SCCWRP, 2010):

- Proceed downstream until reaching the closest of the following:
  - at least one reach downstream of the first grade-control point (but preferably the second downstream grade-control location)
  - tidal backwater/lentic waterbody
  - equal order tributary (Strahler 1952)
  - a 2-fold increase in drainage area

OR demonstrate sufficient flow attenuation through existing hydrologic modeling.

- Proceed upstream to extend the domain:

- upstream for a distance equal to 20 channel widths OR to grade control in good condition – whichever comes first. Within that reach, identify hard points that could check headward migration, evidence that head cutting is active or could propagate unchecked upstream

Within the analysis domain there may be several reaches that should be assessed independently based on either length or change in physical characteristics. In more urban settings, segments may be logically divided by road crossings (Chin and Gregory 2005), which may offer grade control, cause discontinuities in the conveyance of water or sediment, etc.

The domain of analysis is discussed here since it may be relevant for use in site-specific analysis as discussed in **Appendix D**. It is not used in this HMP as a discriminator for HMP applicability to a specific project except in the case of urban infill projects.

3.2 Flow Control Approach

HMPs that have been developed in the San Francisco Bay Area, Northern California (Contra Costa, Santa Clara, and Alameda Counties and the Sacramento area), and San Diego County vary with regard to the emphasis placed on lower flow control thresholds as compared to other approaches, such as distributed low impact development (LID) methods. The South Orange County HMP was developed using the lower flow control threshold approach. There is consensus in that both the frequency and duration of flows must be controlled using continuous simulation hydrologic modeling (rather than the standard design storm approach used for flood control design) to mitigate for potential development impacts. It is also generally accepted that events more frequent than the 10-year flow are the most critical for hydromodification management, since flows within this range of return period (up to the 10-year event) perform the most work on the channel bed and banks.

The Santa Clara HMP focused on using detention basins for hydromodification management and emphasized the lower flow control limit for site runoff. Extended detention flow control basins can be constructed with multi-stage outlets to mitigate both the duration and magnitude of flows within a prescribed range. To avoid the erosive effects of extended low flows, the maximum rate (depth) at which runoff is discharged is set below the erosive threshold. Per the Santa Clara HMP, the lower flow control limit was defined as the flow rate that generates critical shear stress on the channel bed and banks. Both Santa Clara and Alameda Counties correlated the lower flow control limit to a value equal to 10 percent of the 2-year runoff event.

The Contra Costa HMP emphasized the importance of using LID methods to meet hydromodification management criteria. LID approaches to hydromodification management rely on site design and distributed LID Best Management Practices (BMPs) to control the frequency and duration of flows and to mitigate hydrograph modification impacts. By minimizing directly connected impervious areas and promoting infiltration, LID approaches mimic natural hydrologic conditions to counteract the hydrologic impacts of development. LID systems are sized to achieve flow control for the range of storms required (from 10 percent of the 2-year storm up to the 10-year storm).

The County of San Diego HMP defined an adaptive lower flow threshold based on the channel susceptibility rating (High, Medium, or Low). Receiving streams in San Diego County were individually classified by their susceptibility to channel erosion impacts using a critical flow calculator and a channel screening tool developed by Southern California Coastal Water Research Project (SCCWRP). This classification produced three lower flow thresholds which are 0.1Q2, 0.3Q2, and 0.5Q2. The upper range of the mitigation flow was considered the pre-project 10-year storm event.

The approach developed for the San Diego County HMP was approved by the SDRWQCB and selected as the base approach for the South Orange County HMP. However, the South Orange County program elected not to perform the extensive susceptibility mapping required to correlate channel reaches with variable low-flow discharge thresholds. The implementation of HMPs in Northern California and in San Diego has shown that numerically larger low flow thresholds generally have very limited applicability in practice. Accordingly, a base low flow threshold ($0.1Q_2$) was selected for this HMP. Nonetheless, the applicant may compute a site-specific low flow threshold at their option.

3.2.1 Previous Studies

Previous hydromodification literature reviews were conducted by Geosyntec Consultants (Mangarella and Palhegyi, 2002) for the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and by the Contra Costa Clean Water Program (CCCWP 2004). Mangarella and Palhegyi provide a detailed overview of the geomorphic and hydrologic processes involved in hydromodification (see **Section 3.2.3**) for additional details on the mechanics of stream erosion). Channel assessment methods described in Section 6 of this HMP rely heavily on those reviewed by Bledsoe et al. (2008) for SCCWRP.

To date, six approved HMPs have been published. These include HMPs for SCVURPPP (2005), the CCCWP (2005), the Fairfield-Suisun Urban Runoff Management Program FSURMP (2005), the Alameda Countywide Clean Water Program (ACCCMP 2005), the San Mateo Countywide Stormwater Pollution Prevention Program (SMCWPPP [formerly STOPPP] 2005), and the San Diego County Hydromodification Plan (2009). In addition, a number of HMPs were implemented while agencies developed their final plans. Interim HMPs are not detailed in this report because these plans have adopted findings from the above listed HMPs.

3.2.2 Hydrograph Modification Processes

The effects of urbanization on channel response have been the focus of many studies (see Paul and Meyer, 2001 for a review), and the widely accepted consensus is that increases in impervious surfaces associated with urbanizing land uses can cause channel degradation. Urbanization generally leads to a change in the amount and timing of runoff in a watershed, which increases erosive forces on channel bank and bed material and can cause large-scale channel enlargement, general scour, stream bank failure, loss of aquatic habitat and degradation of water quality.

Channel erosion, like most physical processes, is a complex system based on a variety of influences. Channel erosion is non-linear (Philips 2003), meaning the response of streams is not directly proportional to changes in land use and flow regimes. Small changes or temporary disturbances in a watershed may lead to unrecoverable channel instability (Kirkby 1995). These disturbances may give rise to feedback systems whereby small instabilities can be propagated into larger and larger instabilities (Thomas 2001).

A number of studies have sought to correlate the amount of urbanization in a watershed and stream instability (Bledsoe 2001; Booth 1990, 1991; Both and Jackson 1997; MacRae 1992; 1993; 1996; Coleman et al. 2005). Evidence from these studies suggests that below a certain threshold of watershed imperviousness, streams maintain stability. This threshold or imperviousness transition zone appears to be around seven to ten percent watershed urbanization for perennial streams (Schueler 1998 and Booth 1997), but may begin at a lower level for intermittent streams such as those found in Southern California. Studies done in Santa Fe, New Mexico (Leopold and Dunne 1978) suggest that changes occur at four percent impervious area of the watershed. Initial studies by Coleman et al. (2005) suggest that a response in the stream channel may begin to occur at two to three percent watershed imperviousness for intermittent streams in Southern California. It is important to understand that use of impermeable cover alone is a poor predictor of channel erosion due to differences in storm water detention and infiltration within regions. In highly urbanized watersheds returning a stream to a natural condition is infeasible due to existing development in the watershed. In these scenarios the focus should be on in-stream restoration to restore the beneficial uses of the receiving water.

Though it is well established that watershed urbanization causes channel degradation, a detailed understanding of how development alters runoff and how this altered runoff in turn causes erosion is still being developed. This section briefly describes these processes and summarizes methods used to quantify hydromodification impacts.

Effective Work

The ability of a stream to transport sediment is proportional to the amount of flow in the stream: as flow increases, the amount of sediment moved within a channel also increases. The ability of a stream channel to transport sediment is termed stream power, which integrated over time is work. Leopold (1964) introduced the concept of effective work, whereby the flow-frequency relationship of a channel is multiplied by sediment transport rate. This gives a mass-frequency relationship for erosion rates in a channel. Flows on the lower end of the relationship (e.g., two-year flows) may transport less material, but occur more frequently than higher flows, thereby having a greater overall effect on the work within the channel. Conversely, higher magnitude events, while transporting more material, occur infrequently so cause less effective work. Leopold found that the maximum point on the effective work curve occurred around the 1-to 2-year frequency range. This maximum point is commonly referred to as the dominant discharge. It corresponds roughly to a bankfull event (a flow that fills the active portion of the channel up to a well-defined break in the bank slope).

Urbanization tends to have the greatest relative impact on flows that are frequent and small, and which tend to generate less-than-bankfull flows. Change is greatest in these events because prior to urbanization, infiltration would have absorbed much or all of the potential runoff, but following urbanization, a high percent of the rainfall runs off. Thus, events that might have generated little or no flow in a non-urbanized watershed can contribute flow in urban settings.

These smaller less-than-bankfull events have been found to cause a significant proportion of the work in urban streams (MacRae 1993) due to their high frequency, and can lead to channel instability. Less frequent, larger magnitude flows (e.g., flows greater than Q_{10}) are less strongly affected by urbanization because during such infrequent storm events, the ground rapidly becomes saturated, and acts (for purposes of runoff generation) in a similar manner as impervious surfaces.

Estimating Critical Q_c

Due to the increase in impervious surfaces and fewer opportunities for infiltration of storm water, urbanization creates a higher runoff rate and more runoff volume than an un-urbanized watershed. Opportunities for infiltration of excess storm water exist in urbanized areas, but many times are infeasible due to cost, technical barriers or land use constraints. Therefore, some of the excess storm water must be discharged to a receiving stream. In order to achieve a comparable E_p to a pre-developed condition, this excess runoff volume must be discharged at a rate at which insignificant effective stream work is done.

Bed load sediment moves through transmission of shear stress from the flow of water on the channel bed. An increase in the hydraulic radius (measure of channel flow efficiency through a ratio of the channel's cross sectional area of the flow to its wetted perimeter) corresponds to an increase in shear stress. In order to initiate movement of bed material, however, a shear stress threshold must be exceeded. This is commonly referred to as critical shear stress, and is dependent on sediment and channel characteristics. For a given point on a channel where the bed composition and cross-section is known, the critical shear can be related to a stream flow. The flow that corresponds to the critical shear is known as the critical flow, or Q_c. For a given cross-section, flows that are below the value for Q_c do not initiate bed movement, while flows above this value do initiate bed movement.

SCVURPPP expressed Q_c as a percentage of the two-year flow in order to develop a common metric across watersheds of different size, and allow for easy application of HMP requirements. For the two watersheds studied in detail in the SCVURPPP study, a similar relationship was found where Q_c corresponded to 10 percent of the two-year flow. This became the basis for the lower range of geomorphically significant flows under the SCVURPPP HMP and is referred to as Q_{cp} to indicate that it is a percentage of flow. That program also adopted the 10-year flow as the upper end of the range of flows to control with the justification that increases in stream work above the 10-year flow were small for urbanized areas.

A similar study was conducted for the FSURMP on two watersheds in Fairfield, California following a geomorphic assessment. That study found Q_{cp} to be 20 percent of the pre-development two-year flow. The differences in the two values may be attributable to differences in watershed characteristics in Santa Clara County and Fairfield, the number of streams studied, and the precision of the modeling tools. Channels in Fairfield were found to have a more densely vegetated riparian corridor and may have a higher resistance to increases in shear stresses (FSURMP). Values for Q_{cp} appear to be similar among neighboring watersheds, but there appears to be a range of appropriate Q_{cp} values. The characteristics of individual biomes (climatically and geographically defined areas of ecologically similar climatic conditions, such as communities of plants, animals, and soil organisms, often referred to as ecosystems) should be taken into account when developing a Q_{cp}. For example, Western Washington State, which has more densely vegetated riparian zones than either Fairfield or Santa Clara County, has adopted a Q_{cp} of 50 percent of the 2-year flow.

A summary of flow control standards adopted in each of the approved HMPs in California and western Washington is given in **Table 3-1**.

Table 3-1: Summary of Flow Control Standards – Approved HMPs

Permitting Agency	Q_{cp}	Largest Managed Flow
Alameda County	10 percent of the 2-year flow (0.1Q2)	10-year flow (Q10)
Contra Costa County	10 percent of the 2-year flow (0.1Q2)	10-year flow (Q10)
Fairfield-Suisun Urban Runoff Management Program	20 percent of the 2-year flow (0.2Q2)	10-year flow (Q10)
San Diego County	10, 30, or 50 percent of the 2-year flow (0.1Q2, 0.3Q2, or 0.5Q2)	10-year flow (Q10)
San Mateo County	10 percent of the 2-year flow (0.1Q2)	10-year flow (Q10)
Santa Clara County	10 percent of the 2-year flow (0.1Q2)	10-year flow (Q10)
Western Washington State	50 percent of the 2-year flow (0.5Q2)	50-year flow (Q50)

As noted previously the South Orange County HMP has selected a low flow threshold ($0.1Q_2$) as a default value. The project proponent may put forth other low flow thresholds for individual projects, but other low flow thresholds will require site-specific justification using modeling or field tests to support the unique threshold value.

3.2.3 Stream Channel Stability

Numerous stream channel stability assessment methods have been proposed to help distinguish which channels are most at risk from hydrograph modification impacts and/or define where HMP requirements should apply. Assessment strategies range from purely empirical approaches to channel evolution models to energy-based models (see Simon et al., 2007 for a critical evaluation). Stream channel stability assessment methods are useful in assessing the impact of urbanization, or control programs over time. Their value lies in showing trends as changes in a watershed occur, rather than classifying the reach of a discrete channel section at a given point in time.

Stream Classification Systems

A recent study by Bledsoe et al. (2008) for SCCWRP describes nine types of classification and mapping systems with an emphasis on assessing stream channel susceptibility in Southern California. The summary below is taken from that study. Bledsoe also provides a summary of the implications of these classification and mapping systems to the development of hydromodification tools for Southern California. The article provides a detailed breakdown of guidelines for developing hydromodification tools given the advantages and disadvantages of each system previously assessed.

Planform Classifications and Predictors

Alluvial channels form a continuum of channel types whose lateral variability is primarily governed by three factors: flow magnitude, bank erodibility, and relative sediment supply. Though many natural channels conform to a gradual continuum between straight and intermediate, meandering, and braided patterns, abrupt transitions in lateral variability imply the existence of geomorphic thresholds where sudden change can occur. The conceptual framework for geomorphic thresholds has proven integral to the study of the effects of disturbance on river and stream patterns. Many empirical and theoretical thresholds have been proposed relating stream power, sediment supply and channel gradient to the transition between braiding and meandering channels. Accounting for the effects of bed material size has been shown to provide a vital modification to the traditional approach of defining a discharge-slope combination as the threshold between meandering and braided channel patterns. The many braided planforms in Southern California indicate the need to refine and calibrate established thresholds to river networks of interest. However, at this time there is not a well-accepted model to predict how hydromodification affects channel planform.

Energy-Based Classifications

The link between channel degradation and urbanization has been studied; however, impervious area is not the solitary factor influencing channel response. Studies have shown that the ratio between specific stream power and median bed material size D50b, where b is approximately 0.4 to 0.5 for both sand-and gravel-bed channels, can be used as a valuable predictor of channel form. Stream power, which is related to the square root of total discharge, is the most comprehensive descriptor of hydraulic conditions and sedimentation processes in stream channels. Several studies have been performed relating channel stability to a combination of parameters such as discharge, median bed-material size, and bed slope, as an analog for stream power.

General Stability Assessment Procedures

By assessing an array of qualitative and quantitative parameters of stream channels and floodplains, several investigators have developed qualitative assessment systems for stream and river networks. These assessment methods have been incorporated into models used to analyze channel evolution and stability. Many parameters used to establish methodologies such as the Rosgen approach are extendable to a qualitative assessment of channel response in Californian river networks. Field investigations in Southern California have shown that grade control can be the most important factor in assessing the severity of channel response to hydromodification. Qualitative methodologies have proven extendable to many regions, and they use many parameters that may provide valuable information for similar assessments in California.

Sand vs. Gravel Behavior / Threshold vs. Live-Bed Contrasts

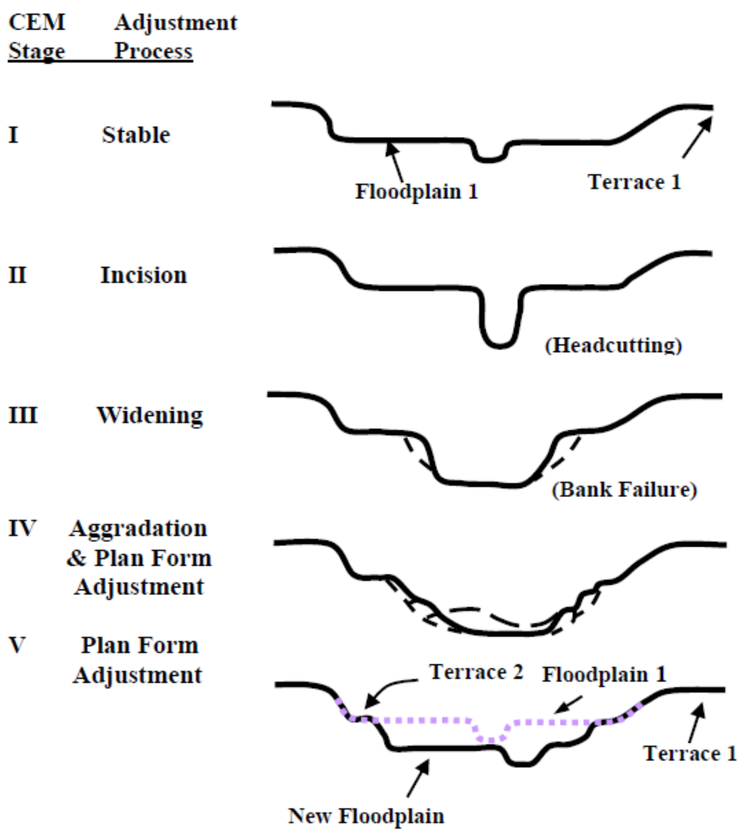
It is well recognized that the fluvial-geomorphic behavior varies greatly between sand and gravel/cobble systems. Live bed channels (of which sand channels are good examples) are systems where sediment moves at low flows, and where sediment is frequently in motion.

Threshold channels, such as gravel streams, by contrast, require considerable flow to initiate bedload movement. Live bed channels are more sensitive to increases in flow and decreases in sediment supply than threshold channels. Scientific consensus shows that sand bed streams lacking vertical control show greater sensitivity to changes in flow and sediment transport regimes than do their gravel/cobble counterparts. Factors such as slope, and sedimentation regimes are known to have greater impact on sand-bed streams. This can be an important issue for storm water systems receiving runoff from watersheds composed primarily of streams with sandy substrate. The transition between sand and gravel bed behavior can be rapid, enabling the use of geographic mapping methods to prioritize channel segments according to their susceptibility to the effects of hydromodification.

Channel Evolution Models of Incising Channels

The Channel Evolution Model (CEM) developed by Schumm et al. (1984) posits five stages of incised channel instability organized by increasing degrees of instability severity, followed by a final stage of quasi-equilibrium (**Figure 3-1**). Work has been done to quantify channel parameters, such as sediment load and specific stream power, through each phase of the CEM. A dimensionless stability diagram was developed by Watson et al. (2002) to represent thresholds in hydraulic and bank stability. This conceptual diagram can be useful for engineering planning and design purposes in stream restoration projects requiring an understanding of the potential for shifts in bank stability.

Figure 3-1: Five Stages of the Channel Evolution Model (CEM)



(Schumm et al. 1984)

Channel Evolution models Combining Vertical and Lateral Adjustment Trajectories

Originally, CEMs focused primarily on incised channels with geotechnically, rather than fluvially, driven bank failure. Several CEMs have been proposed that incorporate channel responses to erosion and sediment transport into the original framework for channel instability. In these new systems, an emphasis is placed on geomorphic adjustments and stability phases that consider both fluvial and geomorphic factors. The state of Vermont has developed a system of stability classification that suggests channel susceptibility is primarily a function of the existing Rosgen stream type and the current stream condition referenced to a range of variability. This system places more weight on entrenchment (vertical erosion of a channel that occurs faster than the channel can widen, resulting in a more confined channel) and slope than differentiation between bed types.

Equilibrium Models of Supply vs. Transport-capacity / Qualitative Response

The qualitative response model builds on an understanding of the dynamic relationship between the erosive forces of flow and slope relative to the resistive forces of grain size and sediment supply to describe channel responses to adjustments in these parameters. In this system, qualitative schematics provide predictions for channel response to positive or negative fluctuations in physical channel characteristics and bed material. Refinements to such frameworks have been made to account for channel susceptibility relative to existing capacity and riparian vegetation among other influential characteristics.

Bank Instability Classifications

Early investigations provided the groundwork for bank instability classifications by analyzing shear, beam, and tensile failure mechanisms. The dimensionless stability approach developed by Watson characterized bank stability as a function of hydraulic and geotechnical stability. Rosgen (1996) proposed the widely applied Bank Erosion Hazard Index (BEHI) as a qualitative approach based on the general stability assessment procedures outlined above. Other classification systems, like the CEM, determine bank instability according to channel characteristics that control hydrogeomorphic behavior.

Hierarchical Approaches to Mapping Using Aerial Photographs / GIS

It has become increasingly common practice to characterize stream networks as hierarchical systems. This practice has presented the value in collecting channel and floodplain attributes on a regional scale. Multiple studies have exploited geographical information systems (GIS) to assess hydrogeomorphic behavior at a basin scale. Important valley scale indices such as valley slope, confinement, entrenchment, riparian vegetation influences, and overbank deposits can provide information for river networks in California. Many agencies are developing protocols for geomorphic assessment using GIS and other database associated mapping methodologies. These tools may be useful as they are further developed in a monitoring program, but are not viable at a scale useful for reach-by-reach channel analysis.

The approach taken by this HMP to monitor its effectiveness is embedded in a derivative of the channel classification approach defined by Rosgen (1996). The author distinguishes three different levels of stream classification including (1) level I that generally describes stream relief, landform, and valley morphology ; (2) level II that describes the morphology of stream and associates the later to a stream type based on channel form and bed composition. Field measurements of entrenchment, width-to-depth ratio, sinuosity, slope, and representative sampling of channel material may be suitable ; (3) level III that assesses stream condition and departure. A stream that is geomorphically stable per Rosgen's definition is characterized by two elements: dimension, pattern, and profile of a stream are maintained over time; the transport capacity of a watershed's flows and detritus is maintained. As such, physical and biological functions of a geomorphologically stable stream remain at an optimum.

3.3 Continuous Simulation Modeling

As part of the HMP development, an integrated flow control sizing tool has been prepared. The tool offers the same interface as that of the San Diego Hydrology Model, which has been approved by the SDRWQCB. The SOCHM has been developed to help applicants comply with hydromodification requirements. This modeling approach is different from Orange County's calibrated rainfall-runoff procedures and criteria for flood control design and mitigation purposes. HMP requirements from the Regional Board are separate from Orange County's requirement for mitigation within the drainage system of development effects on runoff per the Orange County Hydrology Manual (OCHM). Specific evaluation criteria were developed for the design and analysis of hydromodification controls using continuous simulation hydrologic modeling. Evaluation criteria discussed herein focuses on the following items:

- Continuous Simulation Hydrologic Modeling
- Continuous Simulation Modeling Software
- Long-Term Hourly Precipitation Gauge Data
- Parameter Validation for Rainfall Losses
- Hydromodification Control Processes
- Peak Flow and Flow Duration Statistics

Pursuant to criteria set forth by the SDRWQCB and by the South Orange County Permittees in the hydromodification criteria, the use of continuous simulation hydrologic modeling is required to size storm water facilities to mitigate hydromodification effects. Continuous simulation modeling uses an extended time series of recorded precipitation data as input and generates hydrologic output, such as surface runoff, infiltration, and evapotranspiration, for each model time step.

Continuous hydrologic models are typically run using either 1-hour or 15-minute time steps. Based on a review of available rainfall records in Orange County, the SOCHM will use a 1-hour time step (15-minute time series rainfall data are very limited). Continuous models generate model output for each time step. In this case, hydrologic output is generated for each hour of the continuous model. A continuous simulation model with 35 years of hourly precipitation data will generate 35 years of hourly runoff estimates, which corresponds to runoff estimates for 306,600 time steps over the 35-year simulation period.

Use of the continuous modeling approach allows for the estimation of the frequency and duration by which flows exceed the lower flow threshold (adopted as 10 percent of the 2-year flow for this Plan). The limitations to increases of the frequency and duration of flows within that geomorphically significant flow range represent the key component to the South Orange County approach to hydromodification management.

3.3.1 Continuous Simulation Modeling Software

The following public domain software models may be used to assess hydromodification controls for storm water facilities to meet the hydromodification criteria:

- Hydrologic Simulation Program – FORTRAN (HSPF), distributed by U.S. EPA
- Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS), distributed by the U.S. Army Corps of Engineers Hydrologic Engineering Center
- Storm Water Management Model (SWMM); distributed by U.S. EPA

3.3.2 Parameter Validation for Rainfall Losses

In preparing computer models to assess storm water controls and meet the hydromodification criteria, rainfall loss parameters describing soil characteristics, land cover descriptions, and evapotranspiration data have been validated to prove consistency with the local environment and climatic conditions. The validation process should include documentation of the source of evapotranspiration data and commentary of the effects of varying evapotranspiration patterns between the subject site and parameter data source. To meet the hydromodification criteria, soil and land cover parameter validation are based on the following:

- Calibration to local stream flow data, where applicable. Examples of local calibration studies include, but are not limited to, modeling efforts prepared for the Orange County Retrofit Study. Two watersheds were modeled, including the Anaheim Bay-Huntington Harbor watershed and the Aliso Creek watershed.
- Published parameter values consistent with previous studies for Orange County and Southern California, such as HSPF-related regional calibration studies, research projects, regional soil surveys, etc.
- Recommended parameter value ranges from BASINS (Better Assessment Science Integrating point and Nonpoint Sources) Technical Notice 6, Estimating Hydrology, and Hydraulic Parameters for HSPF, U.S. EPA, July 2000.

Where parameters have been transposed or modified from calibration efforts outside of Southern California, the source was determined and justification provided stating why such data are applicable for Orange County. Details have been provided justifying how parameters from such studies were adjusted to be applicable to Orange County conditions. Storm water flow control devices designed to meet the hydromodification criteria have been analyzed pursuant to the following criteria:

- Infiltration processes have been modeled with sufficient complexity to properly quantify the flow control benefit to the receiving streams.
- Infiltration quantification includes provisions for water head and pore suction effects for multiple layers of varying materials (i.e., ponding areas, amended soil layer, gravel layer, etc.)
- Storage processes associated with each layer of the storm water device are quantified.

- Device outflow curves are considered controls associated with device underdrains.

3.3.3 Peak Flow and Flow Duration Statistics

To assess the effectiveness of storm water flow control devices in mitigating hydromodification effects to meet the hydromodification criteria, peak flow frequency statistics have are required. Peak flow frequency statistics estimate how often flow rates exceed a given threshold. In this case, the key peak flow frequency values are the lower and upper bounds of the geomorphically significant flow range. Peak flow frequency statistics can be developed using either a partial-duration or peak annual series. Partial-duration series frequency calculations consider multiple storm events in a given year while the peak annual series considers just the peak annual storm event.

Flow duration statistics are also summarized to determine how often a particular flow rate is exceeded. To determine if a storm water facility meets the hydromodification criteria, peak flow frequency and flow duration curves are generated for the pre-development condition, or naturally occurring condition, and the post-project condition. Both pre-development and post-project simulation runs are extended for the entire length of the rainfall record.

The need for partial-duration statistics is more pronounced for control standards based on more frequent return intervals (such as the 2-year runoff event), since the peak annual series does not perform as well in the estimation of such events. This phenomenon is especially pronounced in the South Orange County region's semi-arid climate. After a review of supporting literature, the use of a partial-duration series is recommended for semi-arid climates similar to Orange County, where prolonged dry periods can skew peak flow frequency results determined by a peak annual series for more frequent runoff events.

For the statistical analysis of the rainfall record, partial duration series events have been separated into discrete rainfall events assuming the following criteria.

1. To determine a discrete rainfall event, a lower flow limit was set to a very small value, equal to 0.002 cubic feet per second (cfs) per acre of contributing drainage area.
2. A new discrete event is designated when the flow falls below 0.002 cfs per acre for a period of 24 hours.

3.4 Rainfall Data

The SOCHM integrates local rainfall data to design storm water flow control devices. To provide for clear climatic designation between coastal, foothill and mountain areas of the southern part of Orange County, historical records for a series of three rainfall data stations located throughout South Orange County were compiled, formatted and quality controlled for analysis.

Long-term hourly rainfall records have been prepared for these three rainfall stations. Sources of the rainfall data include Orange County Automated Local Evaluation in Real Time (ALERT) telemetry system rain gauges (extending back to 1991), the California Climatic Data Archive, National Oceanic and Atmospheric Administration (NOAA), the National Climatic Data

Center, and the Western Regional Climate Center. In all cases, the length of the overall rainfall station record is a minimum of 20 years.

Gauge selection was further governed by minimum continuous simulation modeling requirements, including the following:

- The selected precipitation gauge data set should be located near the project site to ensure that long-term rainfall records are similar to the anticipated rainfall patterns for the site. Thus, gauges were selected near areas planned for future development and redevelopment.
- Recording frequency for the gauge data set should be at least hourly.
- The gauge rainfall data set should extend for the entire length of the record. Where the gauge record length is less than 20 years, then adjacent gauge data sets were used to extend the rainfall record to at least 20 years.
- Use of the most applicable long-term rainfall gauge data, as opposed to the scaling of rainfall patterns from Laguna Beach, is required to account for the diverse rainfall patterns across South Orange County.

Data gathered from precipitation gauges are summarized in **Table 3-2** below. They all have recording frequencies of one hour and recording data ranges of at least 20 years.

Table 3-2: Summary of Precipitation Gauges

Station	Elevation (feet)	Watershed	Hourly data span
Laguna Beach (CA044647)	35	Laguna Coastal Streams	March 1928 – December 2006
Sulphur Creek Reservoir	200	Aliso Creek	July 1991 – September 2010
Trabuco Canyon (CA048992)	970	San Juan	January 1950 – March 2006

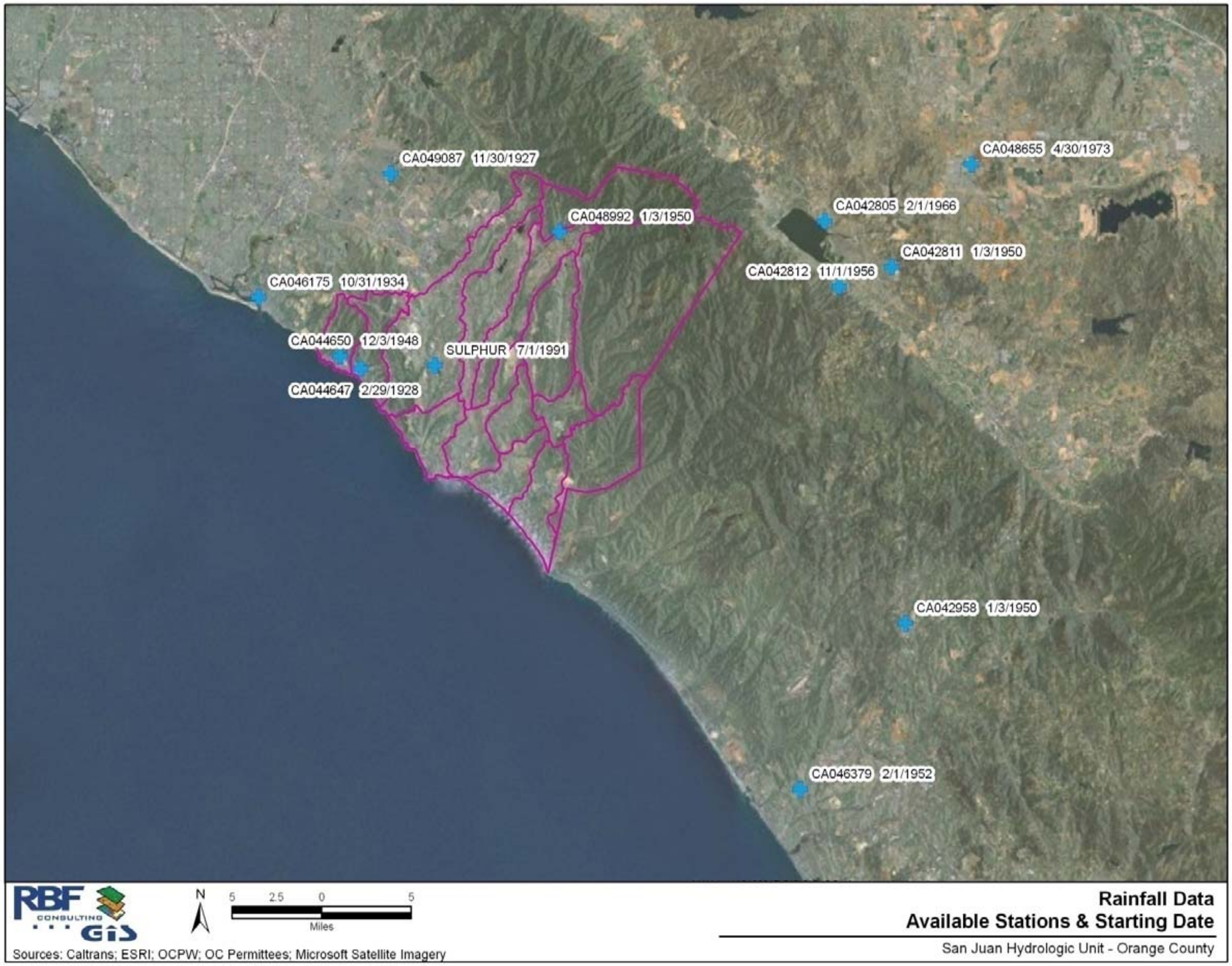
For a given project location, the following factors have been considered in the selection of the appropriate rainfall data set.

In most cases, the rainfall data set nearest the project site is the appropriate choice. A rainfall station map associated with this HMP is presented in **Figure 3-2** for public use.

In some cases, the rainfall data set nearest the project site was a less applicable data set. Such a scenario involved a data set, for instance, with an elevation significantly different from the project site. In addition to a simple elevation comparison, the project proponent may also consult with the Orange County's average annual precipitation isopluvial map, which is provided in the Orange County Technical Guidance Manual, Appendix XVI (2011). Review of this map could provide an initial estimate as to whether the project site is in a similar rainfall zone as compared to the rainfall stations. Generally, precipitation totals in South Orange County increase with increasing elevation.

Where possible, rainfall data sets located in the same topographic zone (coastal, foothill, mountain) as the project should be selected.

Figure 3-2: Rainfall Data – Available Stations and Starting Date



3.5 Rainfall Losses – Infiltration Parameters

Standards developed as part of this HMP to control runoff peak flows and durations are based on a continuous simulation of runoff using locally derived parameters for initial infiltration. A review was conducted of available continuous hydrologic simulation modeling reports in Southern California. These included water quality HSPF models developed for the County of Orange, regional continuous models developed by SCCWRP, and watershed-level continuous models developed for river and large creek systems in San Diego and Los Angeles Counties. Of particular interest and focus in this review was how local and regional continuous hydrologic models simulated the pervious land surface for various combinations of soils and land use types, because this component of hydrologic modeling is typically the most variable and difficult to describe.

The HSPF software package is an industry standard for continuous simulation hydrologic modeling. However, HEC-HMS and SWMM also provide adequate public domain continuous modeling alternatives. The HMP allows the option to use HEC-HMS for a project submittal but only provides infiltration data review for HSPF modeling approaches. Therefore, applicants choosing HEC-HMS should seek prior authorization by the governing municipality.
In preparing computer models to assess storm water controls and meet hydromodification criteria, rainfall loss parameters describing soil characteristics, land cover descriptions, and slope should be validated to prove consistency with the local environment and climatic conditions. The goal, with regard to the South Orange County HMP, is to develop a set of appropriate parameter ranges to account for variations.

In addition to the reports listed in **Table 3-3**, other TMDL reports in Southern California were reviewed. However, only those reports with a substantial description of modeling activities were summarized in the table.

Table 3-3: TMDL Technical Reports

No.	Title	Authors	Date	Summary/Comments
1	Orange County Stormwater Program – Identification of Retrofitting Opportunities – Watershed HSPF Model Development	County of Orange / RBF Consulting	September 12, 2009	Combination of hydrologic and water quality modeling to estimate both pollutant loadings and pollutant removal from retrofitting opportunities. Two watersheds were modeled: Anaheim Bay-Huntington Harbor and Aliso Creek HSPF calibration parameters are specific to each local watershed.
2	TMDL to Reduce Bacterial Indicator Densities at Santa Monica Bay Beaches During Wet Weather (Preliminary Draft)	Los Angeles RWQCB / Tetra Tech	June 21, 2002	Combination of hydrologic and water quality modeling to estimate bacterial loadings to Santa Monica Bay. The HSPF/LSPC model was calibrated and validated using stream flow data collected on Malibu Creek and Ballona Creek. (LSPC stands for Loading Simulation Program in C++, a recoded C++ version of HSPF.) No HSPF model parameters are included.

No.	Title	Authors	Date	Summary/Comments
3	Technical Report – TMDLs for Indicator Bacteria in Baby Beach and Shelter Island Shoreline Park	San Diego RWQCB / Tetra Tech	June 11, 2008	HSPF/LSPC model was calibrated to flow data collected in Aliso Creek and Rose Creek. Calibrated infiltration rates were reported for Natural Resources Conservation Survey (NRCS) Group A, B, C, and D soils. However, it is unclear if these rates correspond to specific HSPF model parameters. The issue of how to apply the calibrated infiltration rates should be addressed through correspondence with study authors.
4	Evaluating HSPF in an Arid, Urbanized Watershed (in Journal of the American Water Resources Association, 2005, p477-486)	Drew Ackerman, Kenneth Schiff, Stephen Weisburg (SCCWRP)	February 2005	HSPF was used to simulate hydrologic processes in arid region, e.g., precipitation on dry soils, effect of irrigation. The model was calibrated to gauge data collected in the lower reaches of Malibu Creek. The calibration set aggregated the soil and land cover variations in the watershed (i.e., spatially “lumped” parameters). Pervious land surface (PWATER) parameters were included.
5	TMDL for Indicator Bacteria Project I – Twenty Beaches and Creeks in the San Diego Region	San Diego RWQCB / Tetra Tech	December 12, 2007	HSPF/LSPC model parameters were selected from regional calibration. Calibration efforts used daily average stream flows as the baseline calibration condition. The Appendices describe the regional calibration process. The modeling files are provided by the San Diego RWQCB.
6	Lake Elsinore and Canyon Lake Nutrient Source Assessment (Final Report) for Santa Ana Watershed Project Authority	Tetra Tech, Inc.	January 2003	The HSPF/LSPC model was calibrated and validated using United States Geological Survey (USGS) gauging site data in the San Jacinto watershed. Model simulated pollutant loading to Lake Elsinore and Canyon Lake. Pervious land surface (PWATER) parameters were not published in the report.

The technical reports listed in **Table 3-3** demonstrate that a variety of detailed HSPF modeling studies have been conducted in the past 10 years in Southern California. The modeling efforts conducted in Orange County, particularly the HSPF model for Aliso Creek watershed, have been adapted for use in the South Orange County HMP (see No. 1 above). The parameters developed for this watershed model were specifically calibrated and validated by using stream flow and water quality data from the Aliso Creek watershed. In addition, the Ackerman study (**Table 3-3**, item No. 3) published a set of generalized parameters that aggregates or “spatially lumps” the contributions of different soil/land use combinations in the upper watershed.

The HSPF model described in the Ackerman paper (**Table 3-3**, item No. 4) simulates all soil and land use combinations using a single composite parameter set. The purpose of the model was to estimate pollutant loadings to area beaches and water bodies. Therefore, the HSPF model was calibrated only to gauge data in the lower Santa Monica Bay watershed. Additionally, the effect of upstream surface water impoundments would have made the development of an accurate, detailed calibration at the sub-catchment scale very difficult to achieve. Unfortunately, this “spatially lumped” parameter set is of limited usefulness for the purpose of the HMP project, given the need to develop parameter sets that describe a variety of common soil and land use combinations.

The following model parameters were incorporated into the Aliso Creek HSPF model. Specific values were associated to each type of land use such that several values are possible for each pervious parameter.

Table 3-4: Model Parameters

Pervious Parameters	Acronym	Value	Unit
Fraction of Remaining Evapotranspiration (E-T) from Active Groundwater Storage	AGEWTP	0.05	-
Basic Groundwater Recession Rate	AGWRC	0.8/0.99	1/day
Fraction of Remaining E-T from baseflow	BASETP	0.2	-
Interception Storage Capacity	CEPSC	0.2	inch
Fraction of Groundwater to Deep Aquifer	DEEPFR	0.05/0.15	-
Forest Fraction	FOREST	0 or 1	-
Infiltration Equation Exponent	INFEXP	2	-
Ratio between the Maximum and Mean Infiltration Capacities	INFILD	2	-
Infiltration Capacity	INFILT	0.1/2	inch/hou r
Interflow Inflow Parameter	INTFW	0.2	-
Interflow Recession Parameter	IRC	0.5	1/day
Groundwater Recession Flow Coefficient	KVARY	5/8	1/inch
Overland Flow Length	LSUR	75 to 190	feet
Lower Zone E-T Parameter	LZETP	0.9	-
Lower Zone Nominal Storage	LZSN	0.8/2.4/3.2	in
Manning's n for Overland Flow	NSUR	0.15/0.25/0.3 5	Comple x
Temperature Maximum for E-T	PETMAX	35	deg F
Temperature that E-T is Zero	PETMIN	30	deg F
Overland Flow Slope	SLSUR	0.2	foot/feet
Upper Zone Nominal Storage	UZSN	0.05/0.07	inch

Additional reference material is contained in the BASINS Technical Notice 6, Estimating Hydrology and Hydraulic Parameters for HSPF, prepared by U.S. EPA (July 2000). This document provides details regarding pervious and impervious land hydrology parameters along with flow routing parameters. Parameter and value range summary tables are included in the document.

3.6 Rainfall Losses - Evapotranspiration Parameters

Standards developed as part of this HMP to control runoff peak flows and durations are based on a continuous simulation of rainfall runoff using locally derived parameters for evaporation and evapotranspiration. Known data sources for potential evapotranspiration data in South Orange County are listed below.

Historical potential evapotranspiration at Laguna Beach station (CA044647) is considered to best represent the coastal evapotranspiration conditions of the San Juan hydrologic unit. Historical potential evapotranspiration at Vista station (CA049378) was found to best correspond to the foothills and mountainous conditions. It is located in San Diego County but remains in the San Juan hydrologic unit.

Other gauging stations that record potential evapotranspiration were not selected because the elevation and land use were not representative of the specific foothill and mountainous conditions present in South Orange County. The potential evapotranspiration will be coupled with historical records of temperature to determine the actual daily evapotranspiration. **Table 3-5** summarizes available sources for potential evapotranspiration in South Orange County.

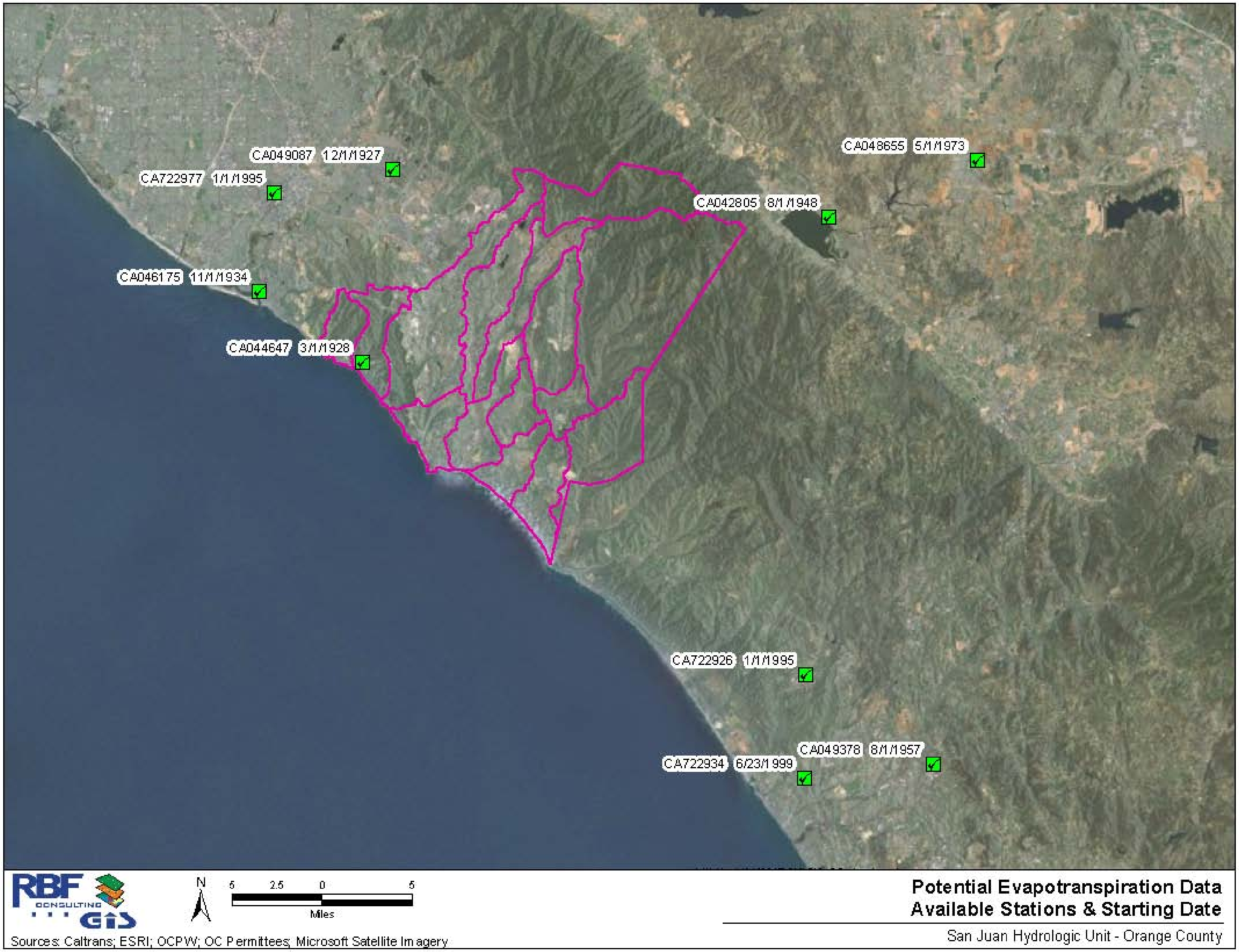
Table 3-5: Available Evapotranspiration Sources

Station Name ID	Data Type	Data Source	Recording Frequency	Hourly data span
Laguna Beach (CA044647)	Potential Evapotranspiration	BASIN	Daily	March 1928 – December 2006
Vista (CA049378)	Potential Evapotranspiration	BASIN	Daily	August 1957 – December 2006

Long-term evaporation / evapotranspiration data sets are being generated to correspond with long-term rainfall records. The final selection of rainfall loss parameters and evaporation data is part of the SOCHM development process.

In summary, the published literature reviewed as part of this study support the methods and approach taken in developing the South Orange County HMP.

Figure 3-3: Potential Evapotranspiration Data – Available Stations and Starting Date



4.0 Requirements and Standards for Projects

Priority Development Projects are required to implement hydrologic control measures and on-site management controls so that post-project runoff flow rates and durations do not exceed pre-development, i.e. naturally occurring conditions, flow rates and durations where they would result in an increased potential for erosion or significant impacts to beneficial uses (Permit Section F.1.h.). The purpose of this chapter is to identify the HMP criteria, detail the HMP applicability requirements, and provide a framework for alternative compliance.

4.1 HMP Criteria

The HMP criteria are designed to manage increases in runoff discharge rates and durations from all Priority Development Projects (PDPs) and they apply to all PDPs. The HMP criteria include the following:

- All PDPs must use continuous simulation to ensure that post-project runoff flow rates and durations for the PDP shall not exceed pre-development, naturally occurring, runoff flow rates and durations by more than 10% for peak flow rates, from 10% of the 2-year runoff event up to the 10-year runoff event.

This HMP includes a tool to provide continuous simulation of peak flow rates, from 10% of the 2-year runoff event up to the 10-year runoff event for PDPs. The tool is the South Orange County Hydrology Model, which is an HSPF model based on the San Diego Hydrology Model and allows PDPs to meet the HMP criteria through interactive graphic user interface. Details about how to use the model are provided in **Appendix C**.

4.2 HMP Applicability Requirements

To determine if a proposed project must implement hydromodification controls, refer to the HMP Decision Matrix in **Figure 4-3**.

The HMP Decision Matrix can be used for all projects. Project tiers are based on the size and type of development or re-development, are identified in **Figure 4-3**, and their associated requirements are defined in **Section 4.5**.

It should be noted that all PDPs are subject to the Permit's LID and water quality treatment requirements even if hydromodification flow controls are not required.

As noted in **Figure 4-3**, projects may be exempt from HMP criteria under the following conditions.

- If the project is not a PDP; or
- If the proposed project discharges storm water runoff directly into underground storm drains discharging directly to bays or the ocean; or
- If the proposed project discharges runoff directly to an exempt receiving water as defined in **Section 4.3.1**; or
- If the project classifies as an infill development projects per the definition provided in **Section 4.3.2**; or
- If the project is an in-stream flood control or restoration project (See **Section 4.3.3**), or,

- If the project discharges to a large river per the definition provided in **Section 4.3.4**

Figure 4-1 through **Figure 4-2** provide an overview of the inventoried south Orange County storm drains, and identify potentially exempt areas per the requirements of the permit and non-exempt areas. **Figure 4-1** through **Figure 4-2** are classified per watershed and geographical localization within the San Juan Hydrologic Unit.

Figure 4-1: South Orange County Storm Drain Inventory 2010

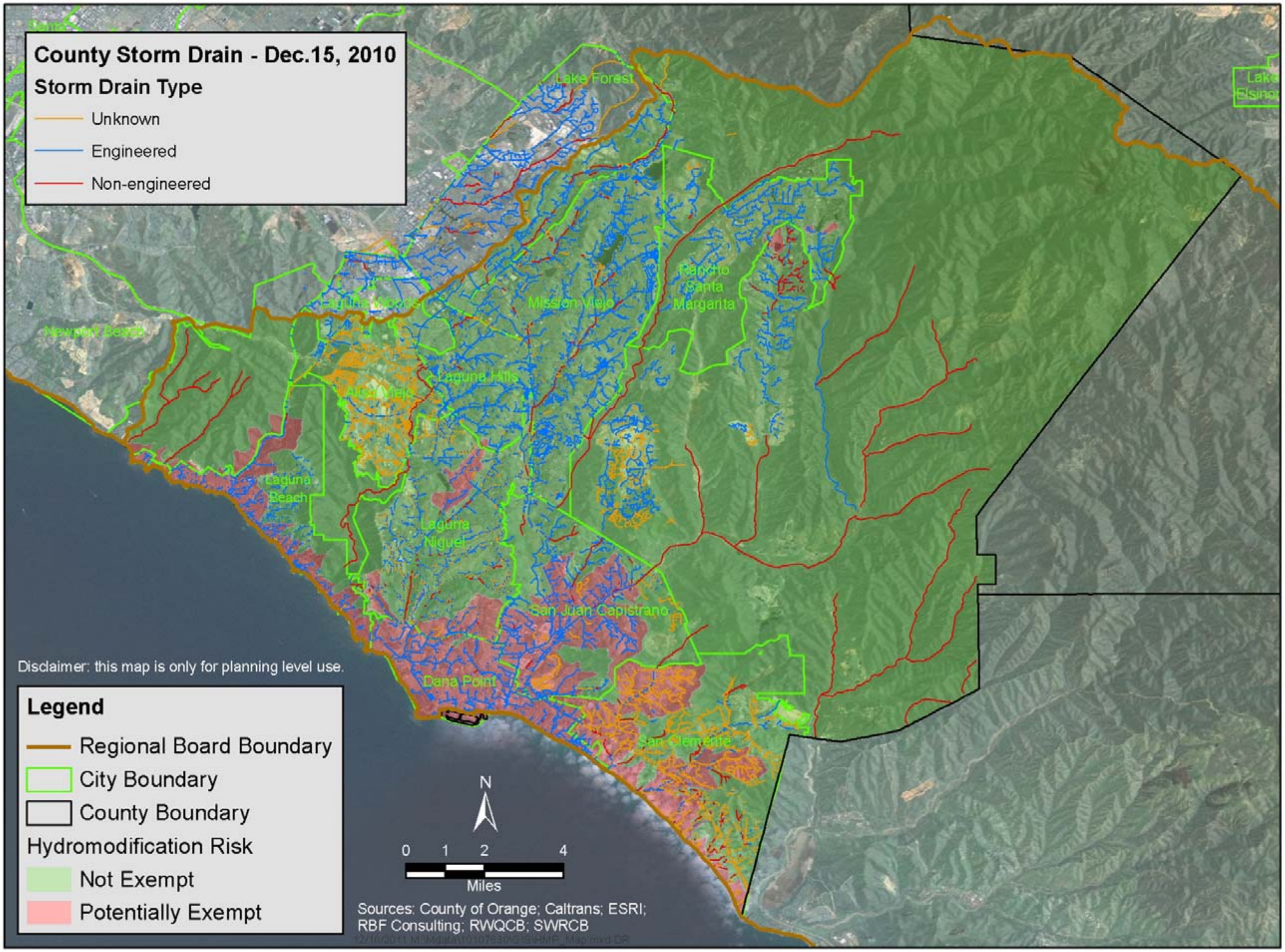


Figure 4-2: Southern Portion South Orange County Storm Drain Inventory 2010

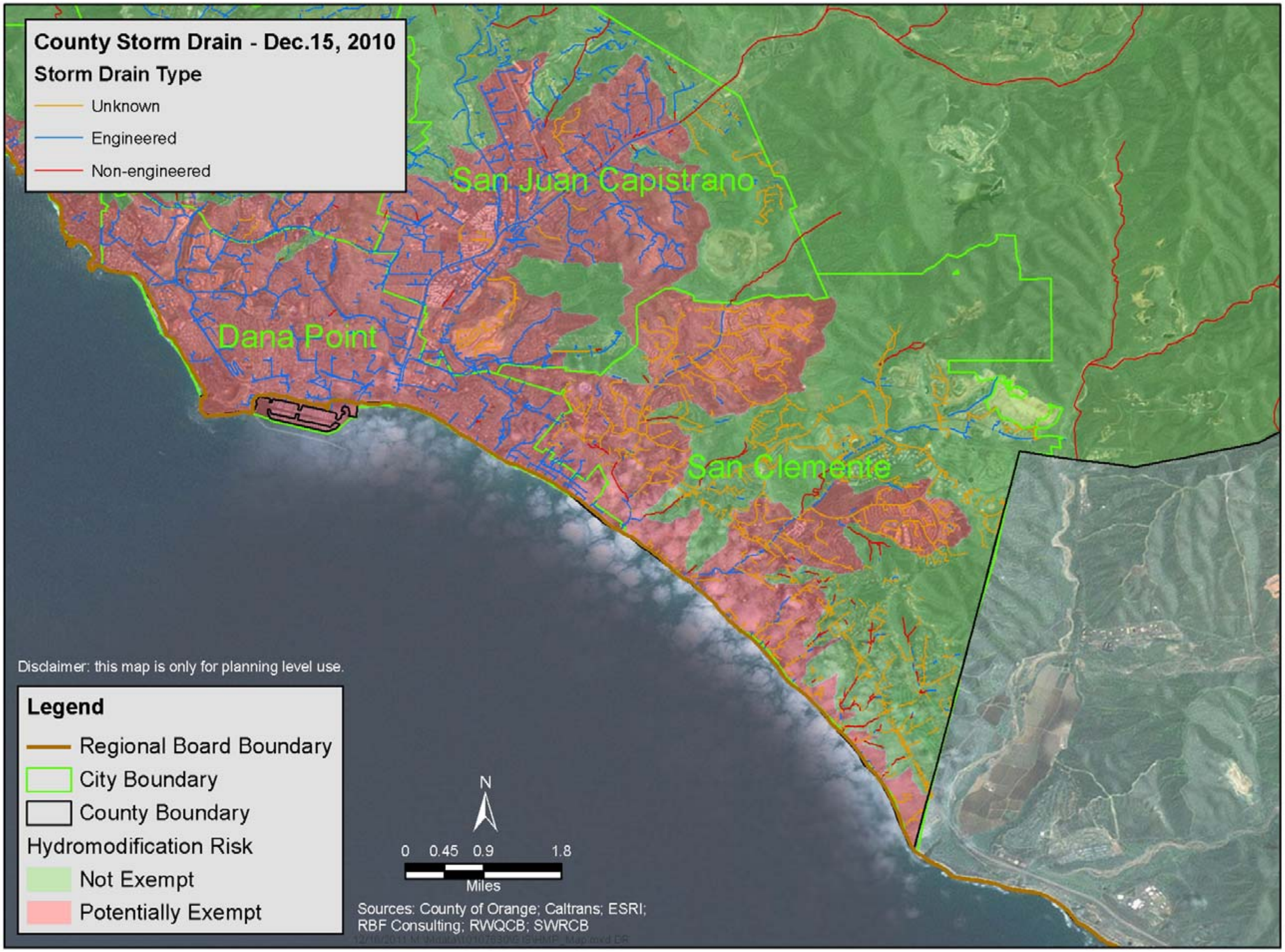
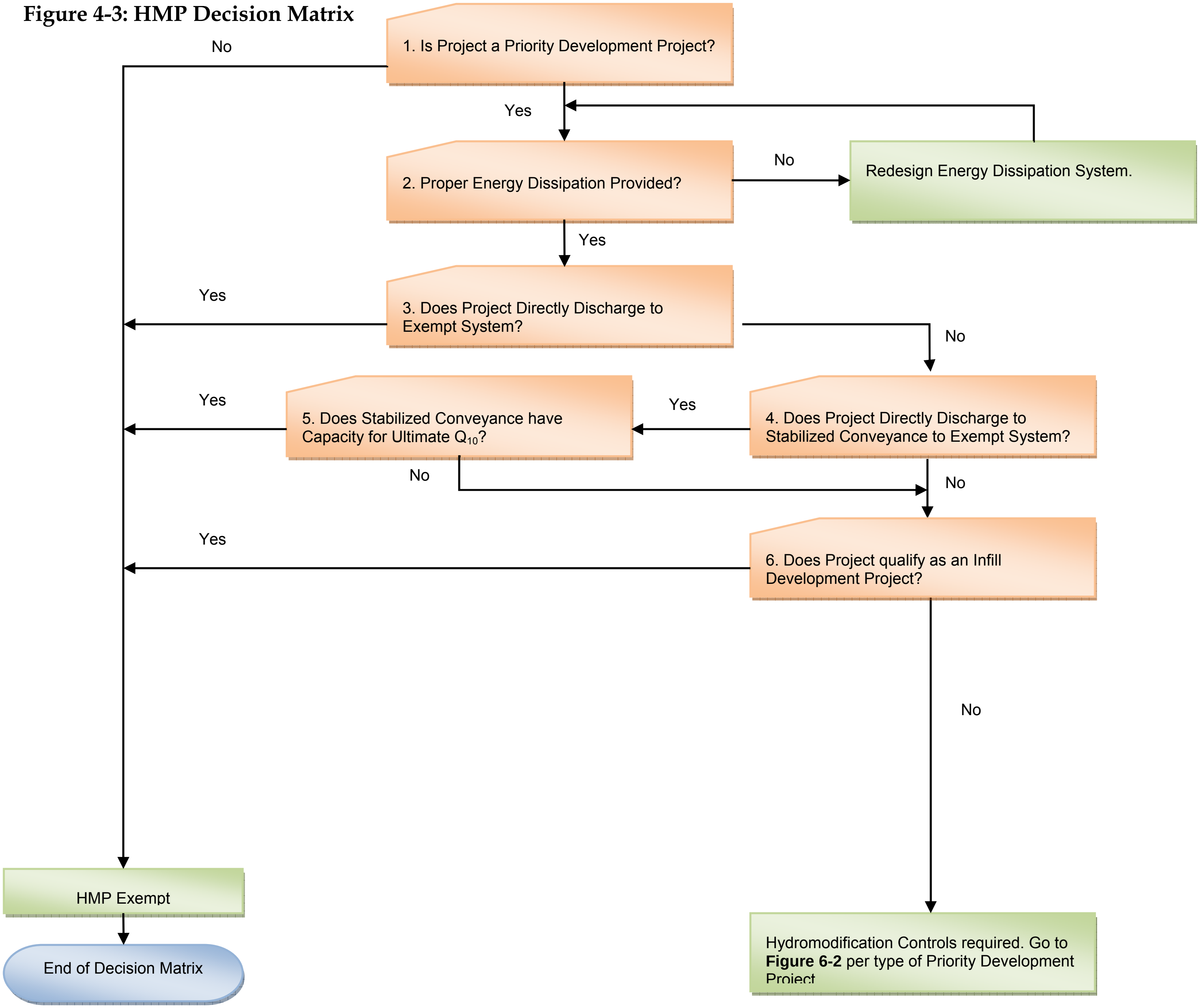


Figure 4-3: HMP Decision Matrix



- **Figure 4-3**, Node 1 – Hydromodification mitigation measures are only required if the proposed project is a PDP, as defined per Permit Item F.1.d.
- **Figure 4-3**, Node 2 – Properly designed energy dissipation systems are required for all project outfalls to unlined channels. Such systems should be designed in accordance with the Orange County Local Drainage Manual to ensure downstream channel protection from concentrated outfalls.
- **Figure 4-3**, Node 3 – Potential exemptions may be granted for projects discharging runoff directly to an exempt receiving water, such as the Pacific Ocean, an exempt river system (identified in **Table 4-1**), an exempt reservoir system (identified in **Table 4-2**), a large river stream (identified in **Section 4.3.4**), but also for in-stream flood control projects (identified in **Section 4.3.3**).
- **Figure 4-3**, Nodes 4 and 5 – For projects discharging runoff directly to an engineered conveyance system that extends to exempt receiving waters detailed in Node 3, potential exemptions from hydromodification criteria may be granted. Such engineered systems could include existing storm drain systems, existing hardened conveyance channels, or stable engineered unlined conveyance channels that are part of the MS4 but that are not receiving waters. To qualify for this exemption, the existing hardened or rehabilitated conveyance system must continue uninterrupted to the exempt system. The engineered conveyance system cannot discharge to an unlined, non-engineered channel segment prior to discharge to the exempt system. Additionally, the project proponent must demonstrate that the engineered conveyance system has the capacity to convey the 10-year ultimate condition flow through the conveyance system. The 10-year flow should be calculated based upon single-event hydrologic criteria as detailed in the Orange County Hydrology Manual.
- **Figure 4-3**, Node 6 – Potential exemption may be granted to a project classified as an infill development project. The criteria that the infill development project must fulfill are listed in **Section 4.3.2**.

4.3 HMP Exemptions

PDPs may be exempt from HMP criteria based on either channel conditions or if the project qualifies as an infill development. These exemptions are detailed in this section.

4.3.1 Engineered Channel Exempt Areas

The channel exempt areas include those areas that discharge to engineered channels sections that have the capacity to convey the 10-year ultimate condition discharge. This includes, as identified in Section F.1.h.3. of the permit,

- PDPs that discharge runoff directly into underground storm drains discharging directly to bays or the ocean; or
- PDPs that discharge runoff into conveyance channels whose bed and bank are concrete lined all the way from the point of discharge to Ocean waters, enclosed bays, estuaries, or water storage reservoirs and lakes.

Only engineered sections (defined as metal, plastic, or concrete closed conduits, and engineered earthen) or concrete channels (concrete or reinforced concrete, riprap and articulated concrete mat) are exempt from the hydromodification requirements. To confirm the exemption, the succession of existing engineered conveyance sections must be continuous from the upstream point to the Pacific Ocean, or to an exempt receiving water, such as a reservoir.

In addition, channel segments that are tidally influenced are exempt from hydromodification requirements. Tidal influence to stream segments may be established for those segments whose invert is below the Mean Higher High Water (MHHW). MHHW is defined by the National Oceanic and Atmospheric Administration (http://tidesandcurrents.noaa.gov/).

The South Orange County Permit area was screened for identification of exempt channels. The screening analysis was conducted using the 2010 Orange County Countywide Storm Drain Inventory. The storm drain inventory defines the type of material and size composing each section of a channel or storm drain. Major storm drains that are exempt from hydromodification requirements are presented in **Table 4-1** for reference only. The PDP may use the exemption map for planning purposes and must determine if the development or redevelopment project discharges runoff into a continuous succession of existing hardened or rehabilitated conveyance sections all the way to the Pacific Ocean or other exempt water body. The table contains the name of the storm drain, as well as the associated downstream and upstream limits. The upstream limit being reported corresponds to the nearest cross street. The resulting map from this effort is presented in **Figure 4-4**. The map shows drainage areas that are exempt from HM criteria. The effect of tidal influence on channel exemption is not reported into these maps.

Table 4-1: Channels Exempt from Hydromodification Requirements in Orange County

Channel	Downstream Limit	Upstream Limit
Laguna Canyon Channel	Pacific Ocean	Philips Street
Sleepy Hollow Storm Drain	Pacific Ocean	Park Avenue
Bluebird Storm Drain	Pacific Ocean	Glenneyre Street
Aliso Creek Channel	Pacific Ocean	Pacific Coast Highway
Salt Creek Channel	Pacific Ocean	300 ft north of Pacific Coast Highway
San Juan Creek Channel	Pacific Ocean	Paseo Michelle
Prima Deshecha Canada Channel	Pacific Ocean	Avenida Vaquero
North Creek	Pacific Ocean	Doheny Park Road
Cacadita Canyon Storm Channel	Prima Deshecha Canada Channel	Via Cascadita
Segunda Deshecha Canada Channel	Pacific Ocean	Calle Frontera
Marquita Storm Channel	Pacific Ocean	Encino Lane
Trafalgar Storm Drain	Pacific Ocean	South Ola Vista

Table 4-2 provides a summary of exempt reservoirs in South Orange County. Large reservoirs or lakes can be exempt systems from a hydromodification standpoint since reservoir and lake storm water inflow velocities are naturally mitigated by the significant tailwater condition in the reservoir. HMP exemptions would only be granted for projects discharging runoff directly to the exempt reservoirs or into conveyance systems designed convey the 10-year ultimate condition discharging into a lake or reservoir. To qualify for the potential exemption, the outlet elevation of the conveyance system must be within (or below) the normal operating water surface elevations of the reservoir and properly designed energy dissipation must be provided.

Table 4-2: Reservoirs in Orange County

Reservoir	Watershed
Sulphur Creek Reservoir	Sulphur Creek
El Toro Reservoir	Oso
Rancho Santa Margarita Lake	Middle Trabuco
Dove Canyon Lake	Upper San Juan

Figure 4-4 below displays the areas of exemption for the entire South Orange County permit area based on the criteria outlined above, where the areas in pink are potentially exempt as they discharge to engineered conveyances all the way to exempt receiving waters (ocean waters, enclosed bays, estuaries, water storage reservoirs, lakes). **Figure 4-5** and **Figure 4-6** show more detailed maps for the exempt areas in the northern coastal part of South Orange County and the southern coastal part of south Orange County, respectively.

Figure 4-4: Exemption Map

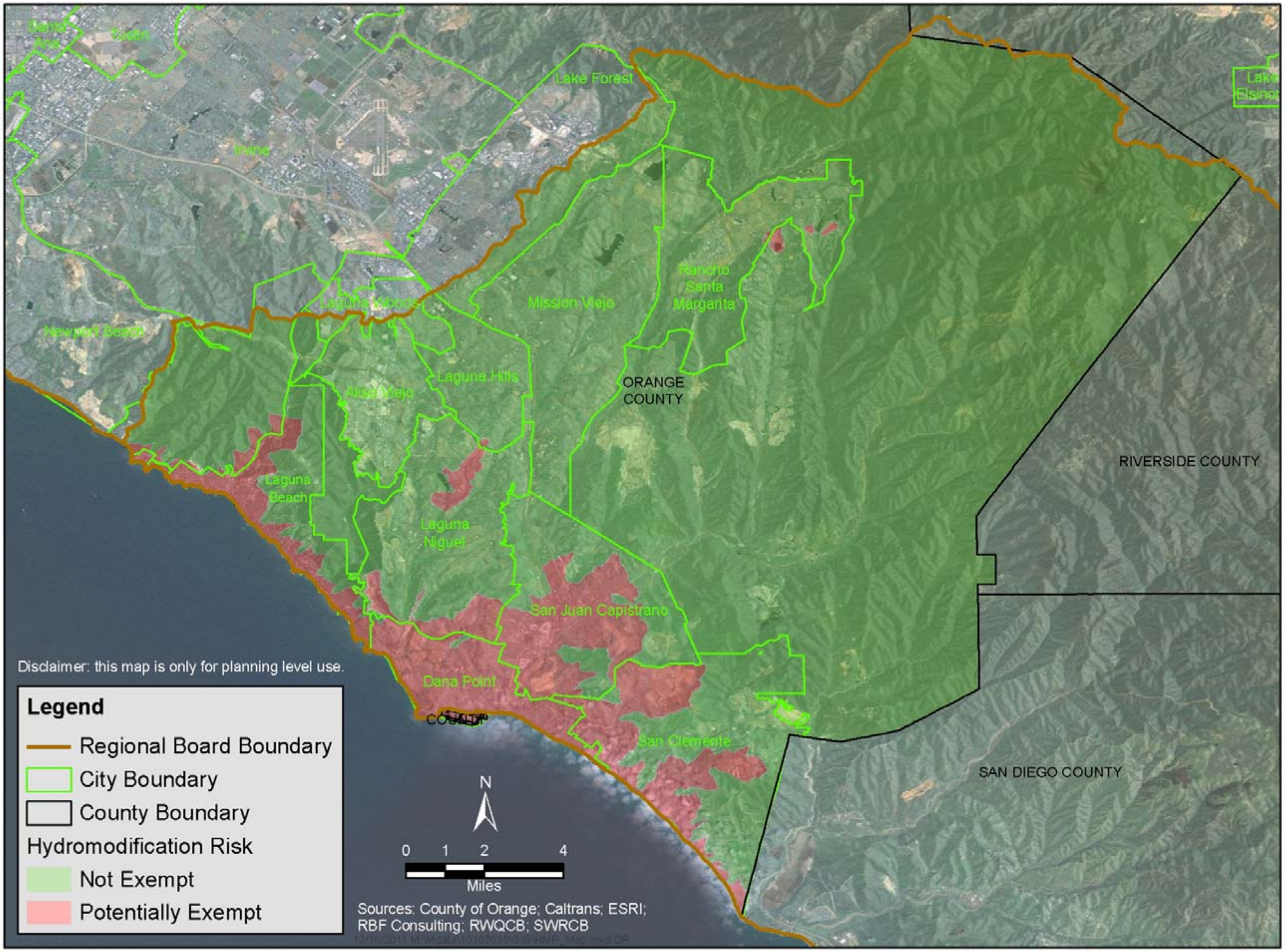


Figure 4-5: Exemption Map Coastal Areas Northern South Orange County

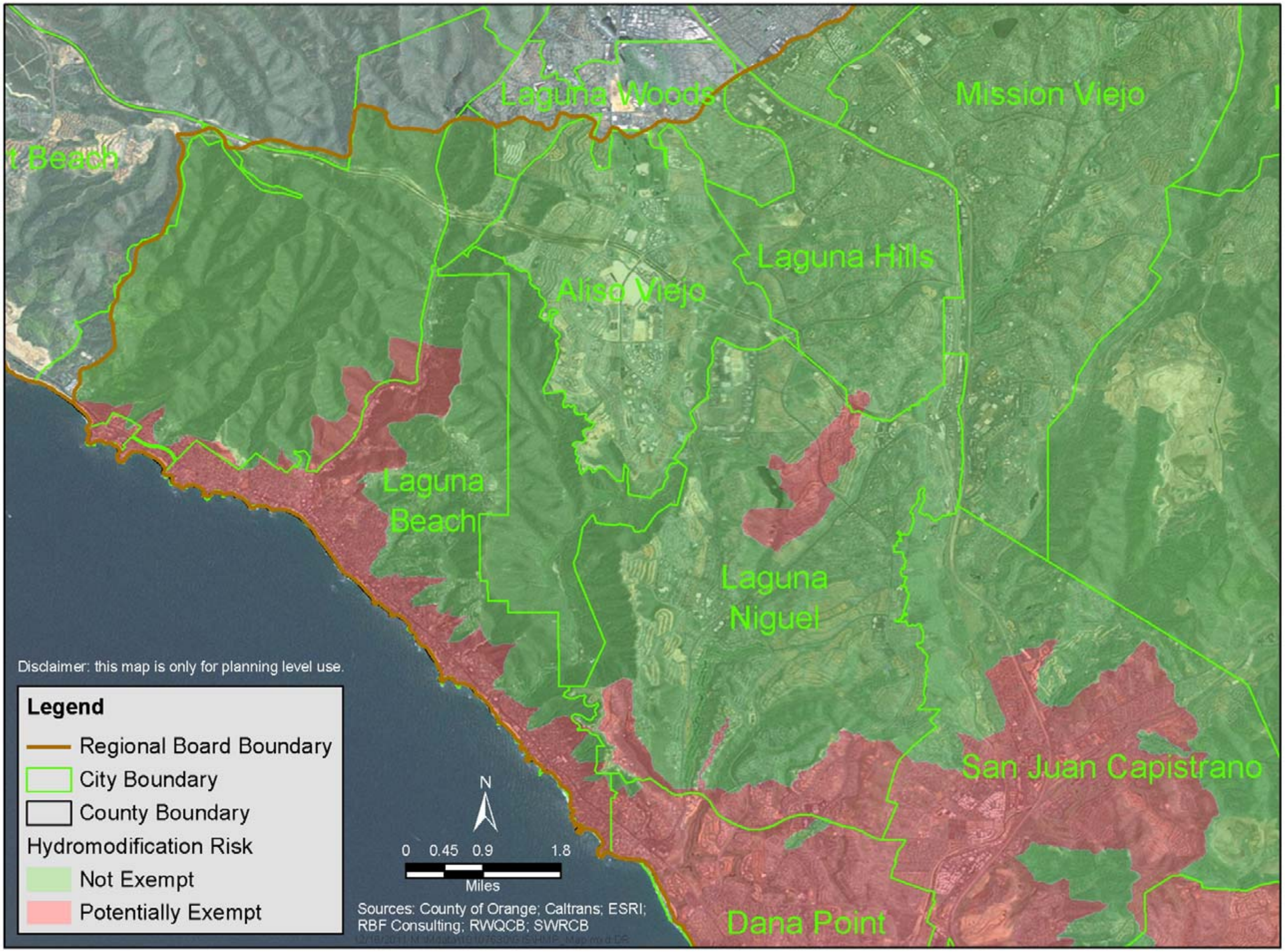
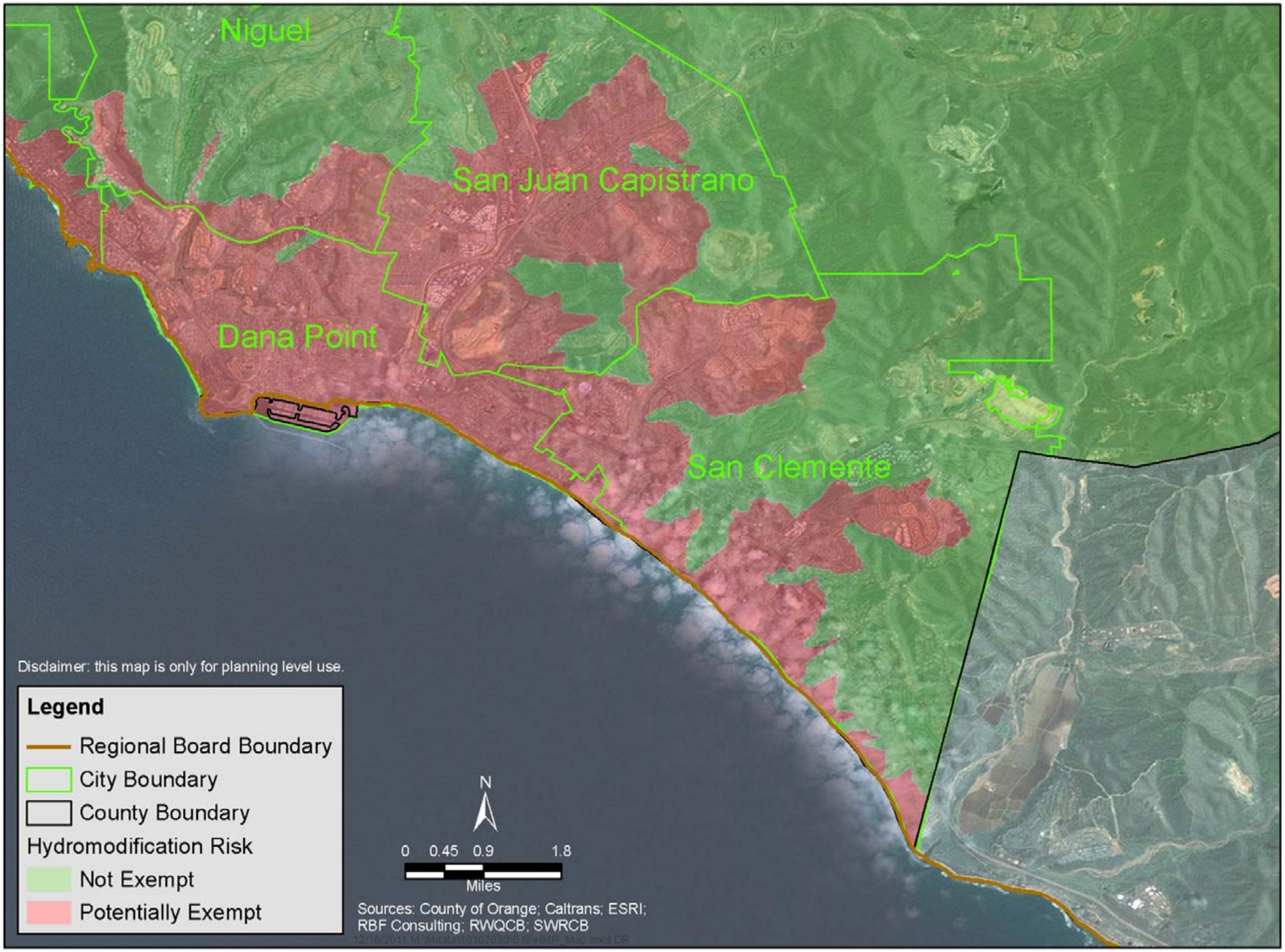


Figure 4-6: Exemption Map Coastal Areas Southern South Orange County



4.3.2 Exemption for Infill Development Projects

Infill development is the development of vacant, underdeveloped or underused sites within an urban area. Section 15332 of the State California Environmental Quality Act (CEQA) Guidelines provide a categorical exemption for infill development projects. Requiring the same hydromodification requirements for infill development as greenfield development will discourage redevelopment and result in lost opportunities to improve water quality through redevelopment projects.

Small urban developments have also been shown to have minor effect on hydromodification in urban watersheds. The effects of cumulative watershed impacts were evaluated through continuous simulation in the San Diego HMP. Findings of the sensitivity analysis include that small urban development or re-development projects have a relatively minor effect on the overall watershed's flow duration curve if the future cumulative additional impacts have the potential to increase the existing watershed impervious area by less than three percent. These findings occurred when the sensitivity analysis was performed on sub-watershed of imperviousness exceeding 40%. For sub-watersheds of imperviousness lesser than 40%, the continuous simulation models indicated a more pronounced response to the flow duration curve when small urban development or re-development projects were added. The effects of hydromodification on the geomorphology of a stream may be assessed across a domain of analysis, which is defined in **Section 3.1** (SCCWRP, 2010). These findings apply to the south Orange County region as the physiographic, geomorphic, and environmental conditions are similar to those encountered in San Diego County.

An exemption to the requirements of the HMP will be provided for redevelopment projects meeting all of the following criteria:

1. The project is consistent with the applicable general plan designation and all applicable general plan policies, as well as with applicable zoning designation and regulations.
2. The proposed development occurs on a project site of no more than eight[1] acres in size and is substantially surrounded by urban uses[2].
3. The project site has no value as habitat for endangered, rare or threatened species.
4. The project site is located within half a mile of an existing – or planned and funded – commuter rail or light rail; or within a quarter mile of one or more stops for two or more public or campus bus lines. The definition corresponds to the LEED Sustainable Sites Credit 4.1 – Alternative Transportation.
5. The urban project is located within a subwatershed whose imperviousness is higher than 40%. The imperviousness is determined from the entire subwatershed, as delineated from the outfall of the urban conveyance system.
6. Planned future developments within the subwatershed would not increase the composite imperviousness by more than three percent when compared to the existing

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[1] Eight-acre thresholds for infill projects criteria based on SB 375, which sets 8 acres as one of the criteria for defining a sustainable communities project.

[2] The term "urban use" includes the following land use categories, as defined in the 2005 Orange County General Plan: Urban Residential (1C), Community Commercial (2A), Regional Commercial (2B), and Public Facilities (4). The existence of surrounding urban uses and the associated density of development are to be determined per the 2008 SCAG land use digital aerial imagery

conditions. The subwatershed boundaries correspond to the entire subwatershed area draining to the outfall of the urban conveyance system. An assessment of the planned future developments may be derived from the 2005, or most current Orange County General Plan.

7. The urban project discharges runoff to an existing engineered conveyance system that extends beyond the domain of analysis defined for the urban project. The domain of analysis is defined per guidelines provided in **Section 3.1**.

4.3.3 Exemption for In-stream Flood Control and Restoration projects

In-stream flood control projects protect citizens and property from injury and damage by flooding. In-stream restoration projects restore beneficial uses of streams and channels, which ultimately provide benefit to benthic communities. Public health and safety, transportation corridors, economic activities, and in-stream aquatic health all benefit from in-stream flood control and restoration projects. For these reasons, in-stream flood control and restoration projects are exempt from the HMP requirements.

4.3.4 Exemption for Large River Reaches

Effects of cumulative watershed impacts are minimal in stream reaches of large depositional rivers. These large rivers typically have very wide floodplain areas when in the natural condition or are stabilized when in the engineered condition, and are of low gradient. The results of a flow duration curve analysis that was performed for the San Diego River are presented in the San Diego HMP.

This analysis demonstrated that the effect of cumulative watershed impacts are minimal in those reaches for which the contributing drainage area exceeds 100 square miles and with a 100-year design flow in excess of 20,000 cfs. Development and re-development projects that discharge either directly or via a conveyance system designed convey the 10-year ultimate condition into such large river streams are hence exempt from the South Orange County HMP requirements, provided that properly sized energy dissipation is implemented at the outfall location. All exempt river reaches, which are presented in **Table 4-3** have a drainage area larger than 100 square miles and a 100-year design flow higher than 20,000 cfs (SDRWQCB, 2002). **Table 4-3** also provides the corresponding upstream and downstream limits to define the exempted reach.

Table 4-3: Exempt River Reaches in South Orange County

River	Downstream Limit	Upstream Limit
San Juan Creek	Outfall to Pacific Ocean	Caper Park Road
San Mateo Creek	Outfall to Pacific Ocean	Nickel & Tenaja Canyons

4.4 HMP Alternative Compliance

For some PDPs, implementation of onsite hydromodification controls consistent with the HMP may not be feasible due to site constraints. These projects require alternatives to onsite hydromodification controls. The LID requirements of the permit require the implementation of LID techniques that effectively result in hydrologic processes that mimic the desired natural watershed conditions. There are two alternative compliance options for PDPs that cannot implement onsite hydromodification controls. One option is for a PDP proponent to identify and construct off-site mitigation to offset the inability to meet the HMP criteria onsite. The other option is for the PDP proponent to pay into an HMP mitigation bank, if an HMP mitigation bank is available to the PDP. The details of these options are provided below.

4.4.1 HMP Alternative Compliance Option 1: Off-site Mitigation

A progression through a defined process is required to document eligibility then implementation of alternative compliance for the HMP. Off-site mitigation is based on a progression of steps to meet compliance that is consistent with Section F.1.h.2 of the MS4 Permit. These steps include the following:

1. Technical feasibility study of onsite hydromodification controls; and
2. Off-site mitigation project within the same hydrologic unit as the PDP or in-stream restoration of the receiving water of the PDP.

Step A: Conduct a technical feasibility study for onsite hydromodification controls

A technical feasibility study is required to identify why onsite hydromodification controls cannot be incorporated into the project. The technical feasibility study must include the project constraints and provide detailed technical justification as to why the project constraints prevent implementation of onsite controls. The technical feasibility study will be submitted to the jurisdiction of the location of the PDP for review as part of the Preliminary WQMP. The jurisdiction must approve the technical feasibility before the PDP moves on to Step B.

Model WQMP Integration

Guidance on the hydromodification technical feasibility study will be incorporated into the Model WQMP and Technical Guidance. The hydromodification technical feasibility study will be integrated with the LID feasibility analysis as part of the Model WQMP; however, it should be noted that the criteria for hydromodification and LID requirements are different. The feasibility analysis for both hydromodification and LID will be integrated into one feasibility study for the project and submitted with the Preliminary WQMP.

Step B: Implement off-site mitigation within the same hydrologic unit as the PDP or in-stream restoration of the PDP receiving water

For those PDPs where the technical feasibility study for onsite controls has been approved by the jurisdiction, step B for the PDP is to either (1) implement an off-site mitigation project within the same hydrologic unit as the PDP, or (2) implement an in-stream restoration project for the receiving water of the PDP. The process for these options under Step B is detailed below:

B(1) Implement off-site mitigation within the same hydrologic unit as the PDP

In choosing this option, the PDP must investigate potential locations for implementation of an off-site mitigation project within the same hydrologic unit as the PDP. The off-site mitigation project must be sized to mitigate the equivalent runoff volume as implementing onsite hydromodification controls for the PDP. The PDP will evaluate and identify potential sites in the same hydrologic unit for implementation of an off-site hydromodification project that has the capacity to mitigate the PDP's hydromodification requirements. If an adequate site is identified by the PDP in the same hydrologic unit, the PDP will submit a report detailing:

- that the off-site mitigation project will be sized to mitigate the equivalent volume as implementing onsite hydromodification controls for the PDP; and
- conceptual plans for the off-site mitigation project as part of an amended WQMP for review and approval.

If no potential off-site mitigation project sites are identified in the same hydrologic unit as the PDP, the PDP must implement Option 2(b), an in-stream restoration project of the PDP receiving water.

B(2) Implement in-stream restoration of the PDP receiving water

In choosing this option, the PDP investigates the potential for implementation of an in-stream restoration project for the receiving water of the project. It must be determined that the receiving water for the project has hydromodification impacts. The in-stream restoration project must be located in the receiving water of the PDP. The PDP must submit a report detailing the condition of the receiving water due to hydromodification, as well as conceptual plans for the in-stream restoration project to the PDP's jurisdiction for review.

Once the project conceptual plans have been approved by the PDP's jurisdiction, the PDP must submit the appropriate permit applications to the appropriate regulatory agencies (e.g., Regional Board, California Department of Fish and Game, U.S. Army Corps of Engineers) for review and approval. If the PDP identifies no opportunities for in-stream restoration in the receiving water that the PDP discharges to, then the PDP must implement Option 2(a), an off-site mitigation project within the same hydrologic unit as the PDP.

4.4.2 HMP Alternative Compliance Option 2: HMP Mitigation Bank

(Note: Option 2 is available only if an HMP mitigation bank has been developed and is available to the PDP.)

The County and the Permittees have the option to develop an HMP mitigation bank or multiple HMP mitigation banks. A mitigation bank will develop regional HMP mitigation projects where PDPs can buy HMP mitigation credits if it is determined that implementing onsite hydromodification controls is infeasible. The development and operation of an HMP mitigation bank will include the identification of potential regional HMP mitigation projects; the planning, design, permitting, construction, and maintenance of regional HMP mitigation projects; the development of a fee structure for PDPs participating in the mitigation bank; and managing the HMP mitigation bank fund. Regional HMP mitigation projects can also serve as projects for an LID waiver program if site conditions allow for implementation of LID-type projects.

If PDPs are unable to meet the HMP criteria by incorporating onsite hydromodification controls, and a HMP mitigation bank is available, the PDP can apply to participate in the bank. The application must include a technical feasibility study to identify why onsite hydromodification controls cannot be incorporated into the project. The technical feasibility study must include the project constraints and detailed technical justification as to why the project constraints prevent implementation of onsite controls. The technical feasibility study will be submitted to the jurisdiction where the PDP is located for review as part of the Preliminary WQMP. The jurisdiction must approve the technical feasibility study for the PDP to participate in a HMP mitigation bank.

4.5 Tiered Requirements

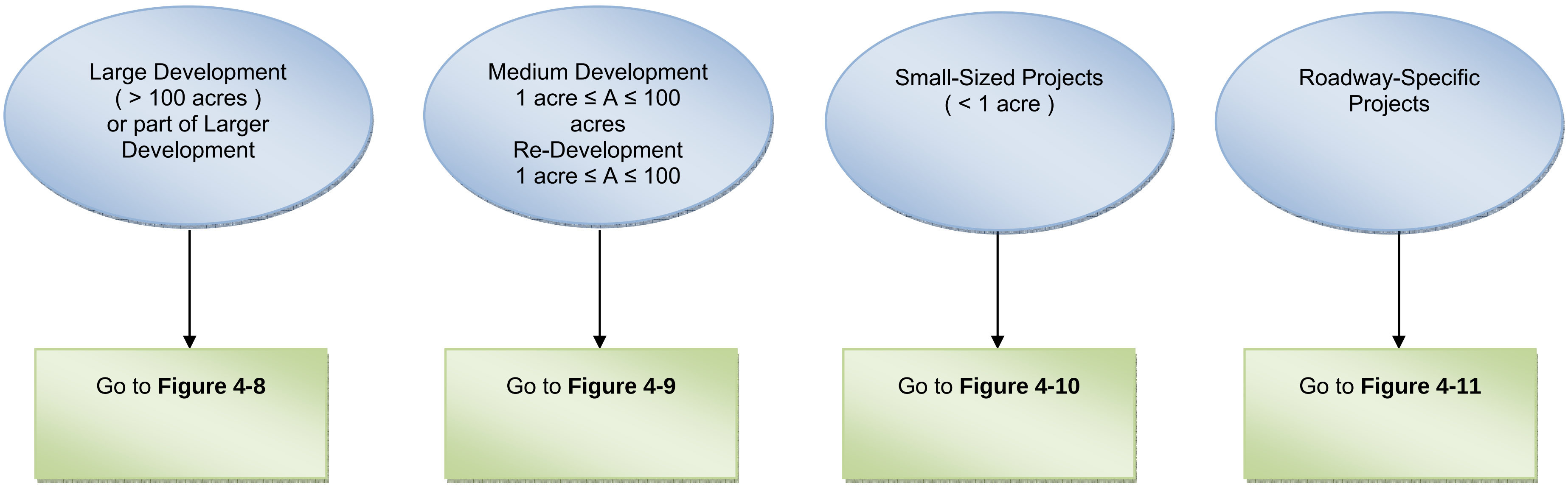
A proposed PDP that is not located in an exemption zone (see **Figures 4-4, 4-5, and 4-6**) must meet the HMP requirements defined in **Section 4.4**. **Figures 4-4, 4-5, and 4-6** are provided for planning purposes; however, the project proponent shall verify the eligibility to exemption criteria as defined in **Section 4.3**. The PDP must be classified by an applicable tier and meet all the requirements outlined for that tier. The project proponent may associate the size and type of the PDP to one of the following four tiers:

- Tier 1 – Large development projects exceeding 100 acres or development projects that are part of a common initial or phased development plan that exceeds 100 acres
- Tier 2 – Medium-sized development projects between one and 100 acres or re-development projects over one acre
- Tier 3 – Small-sized projects less than one acre yet defined as a PDP
- Tier 4 – Roadway-specific projects

Proposed development or re-development projects face different levels of spatial, environmental, financial, technical, and permitting constraints based on their size and type. As such, the permit language was translated into HMP requirements that are specific and adapted to each tier configuration. The definition of the four tiers was principally derived from the elements of the permit, as well as from a review of the other HMPs (Santa Clara, Alameda, Sacramento, and San Diego). The proposed tiers were defined based on the size and type of proposed projects, and include all PDPs as defined in Permit Item F.1.d.(11). Most individual single-family residential projects will be exempt from the HMP requirements.

Figure 4-7 illustrates the four tiers. The following subsections detail the HMP criteria specific to each tier.

Figure 4-7: Hydromodification Controls: PDP Tiers



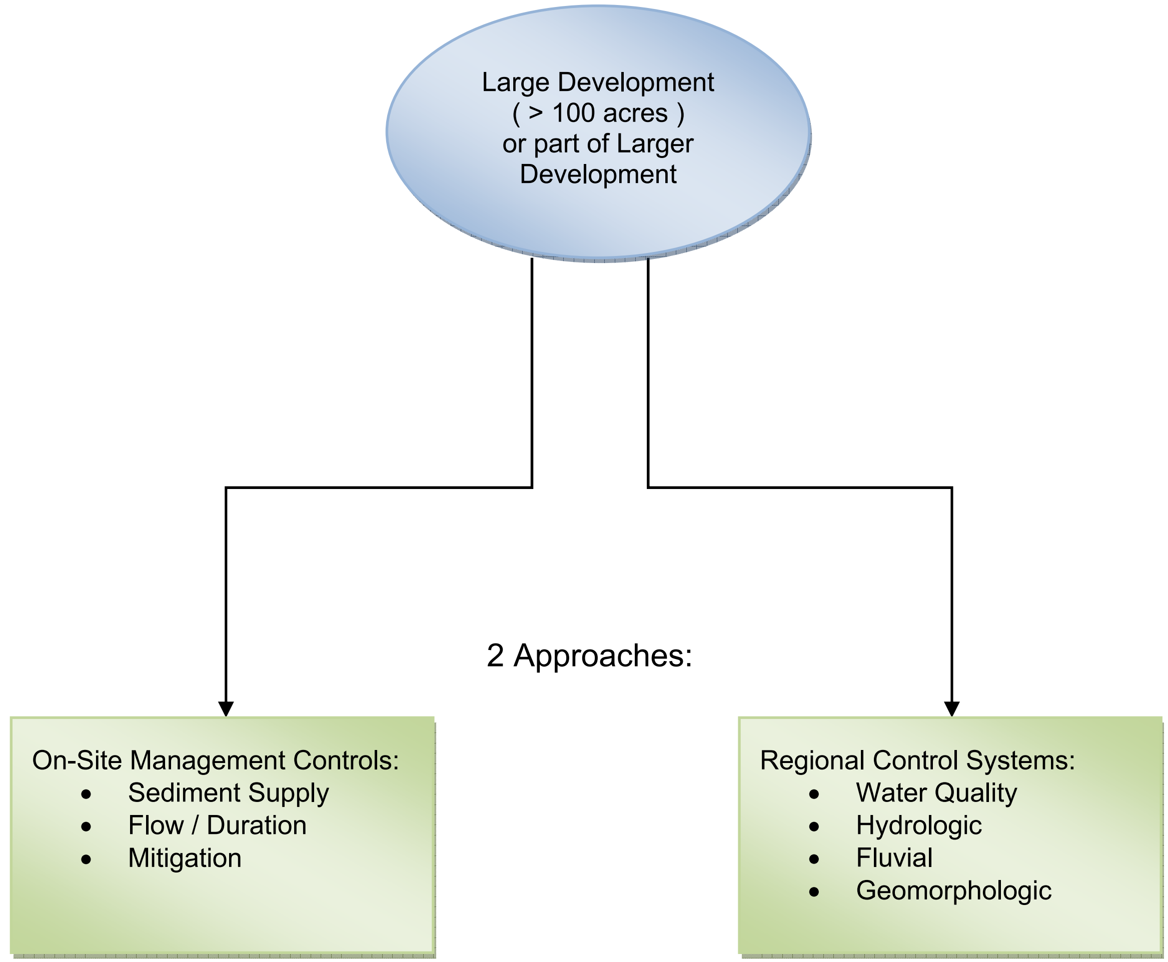
4.5.1 Tier 1 - Large developments (higher than one hundred acres)

Tier 1 includes large development projects greater than 100 acres or development projects in a common development plan that exceeds 100 acres. These developments typically offer a enough space for on-site implementation of flow and sediment management controls. Pursuant to permit item F.1.d.(11), implementation of regional control systems for hydromodification may also be considered. Overall, either of the following approaches may be pursued by the applicant:

- Meet the HMP Criteria identified in **Section 4.1** by mitigating flow and duration through on-site hydrologic control measures and addressing sediment loss through on-site management controls.
- Implement regional control systems in lieu of on-site management controls, consistent with the language in permit item F.1.d.(11). A technical feasibility study must be performed to define regional control systems that fulfill water quality, hydrologic, and fluvial geomorphologic requirements consistent with a study framework. Permit item F.1.d.(11) includes also a clause that allows applicants to implement conventional treatment BMPs, as well as participate in the LID waiver program when the regional LID implementation has been shown to be technically infeasible. This clause would not be translated for hydromodification requirements if such technical infeasibility were demonstrated. The technical feasibility study is Step A in **Section 4.4.1**. If a HMP mitigation bank is available, the PDP can pursue this option. The PDP can also pursue the in-stream restoration option (B2) identified in **Section 4.4.1**.

Figure 4-8 shows the two different approaches in a graphical form.

Figure 4-8: Hydromodification Controls: Large Development



4.5.2 Tier 2 – Medium sized projects (between one acre and one hundred acres)

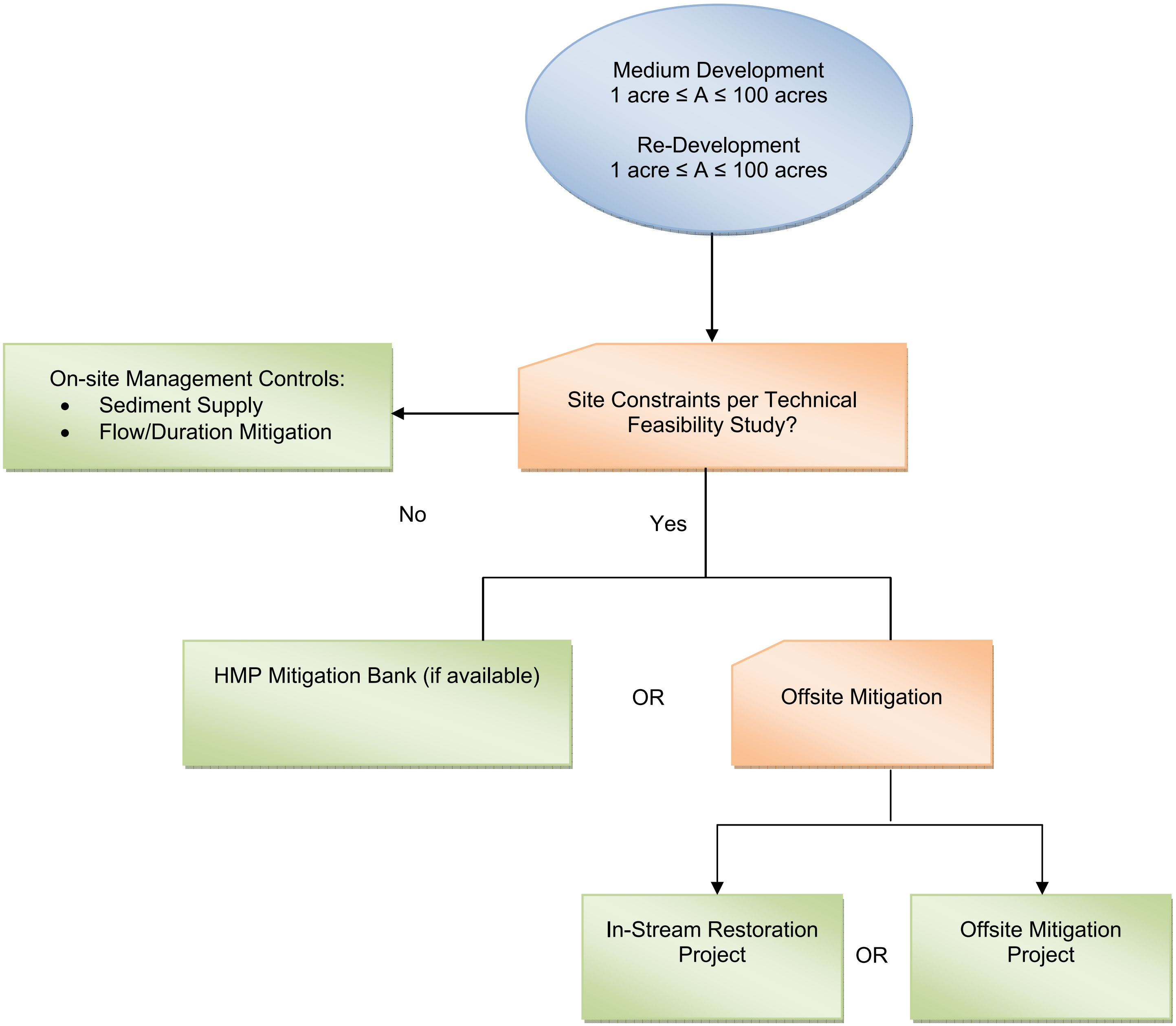
Tier 2 includes medium size development projects of area comprised between one acre and 100 acres, as well as re-development projects of one acre or more. The two boundaries define Tier 2. Tier 2 development or re-development projects will be subject to a large panel of spatial, environmental, financial, technical, and permitting constraints.

Hydrologic control measures and on-site management controls to ensure compliance with the HMP criteria are described in **Section 4.1**. Using this approach, mitigation of both flow and duration is achieved through on-site hydrologic control measures, and sediment loss is addressed through on-site management controls.

Alternatively, if on-site hydrologic control measures and management controls are not technically feasible due to site constraints, a technical study will be developed to demonstrate the infeasibility, per Step A in **Section 4.4.1**. Step B involves implementation of either an off-site mitigation project in the same hydrologic unit as the PDP or implementation of an in-stream restoration project in the receiving water that the PDP discharges to. Details of Step B are provided in **Section 4.4.1**. PDPs can pursue the HMP mitigation bank option, if available.

A flow chart indicating which HM criteria should be pursued and implemented for a Tier 2 project is shown in **Figure 4-9**.

Figure 4-9: Hydromodification Controls: Medium Development



4.5.3 Tier 3 – Smaller-sized projects (less than one acre)

Tier 3 encompasses small-sized projects less than one acre but defined as a PDP. The tier may include the following projects, as characterized by permit Item F.1.d.(1) and Permit item F.1.d.(2):

- New development projects that are smaller than one acre that create 10,000 square feet or more of impervious surfaces (collectively over the entire project site) including commercial, industrial, residential, mixed-use, and public projects. This category includes development projects on public or private land which fall under the planning and building authority of the Permittees.
- Projects on automotive repair shops that are smaller than one acre,. This category is defined as a facility that is categorized in any one of the following Standard Industrial Classification (SIC) codes: 5013, 5014, 5541, 7532-7534, or 7536-7539.
- Restaurants. This category is defined as a facility that sells prepared foods and drinks for consumption, including stationary lunch counters and refreshment stands selling prepared foods and drinks for immediate consumption (SIC code 5812), where the land area for development is greater than 5,000 square feet but lesser than one acre.
- All hillside development greater than 5,000 square feet but lesser than one acre. This category is defined as any development which creates 5,000 square feet of impervious surface which is located in an area with known erosive soil conditions, where the development will grade on any natural slope that is twenty-five percent or greater.
- All development lesser than one acre that are located within or directly adjacent to or discharging directly to an ESA (where discharges from the development or redevelopment will enter receiving waters within the ESA), which either creates 2,500 square feet of impervious surface on a proposed project site or increases the area of imperviousness of a proposed project site to 10 percent or more of its naturally occurring condition. "Directly adjacent" means situated within 200 feet of the ESA. "Discharging directly to" means outflow from a drainage conveyance system that is composed entirely of flows from the subject development or redevelopment site, and not commingled with flows from adjacent lands.
- Parking lots 5,000 square feet or more or with 15 or more parking spaces and potentially exposed to runoff. Only parking lots that are lesser than one acres are included into Tier 3. Parking lot is defined as a land area or facility for the temporary parking or storage of motor vehicles used personally, for business, or for commerce.
- Retail Gasoline Outlets (RGOs) This category includes RGOs that meet the following criteria: (a) 5,000 square feet or more or (b) a projected Average Daily Traffic (ADT) of 100 or more vehicles per day. RGO projects that are lesser than one acre are included into Tier 3.
- Those redevelopment projects lesser than one acre that create, add, or replace at least 5,000 square feet of impervious surfaces on an already developed site and the existing development and/or the redevelopment project falls under the project categories or locations listed in permit section F.1.d.(2). Where redevelopment results in an increase of less than fifty percent of the impervious surfaces of a previously existing development, and the existing development was not subject to Standard Stormwater Mitigation Plan (SSMP) requirements, the numeric sizing criteria discussed in permit section F.1.d.(6) applies only to the addition or replacement, and not to the entire development. Where redevelopment results in an increase of more than fifty percent of the impervious

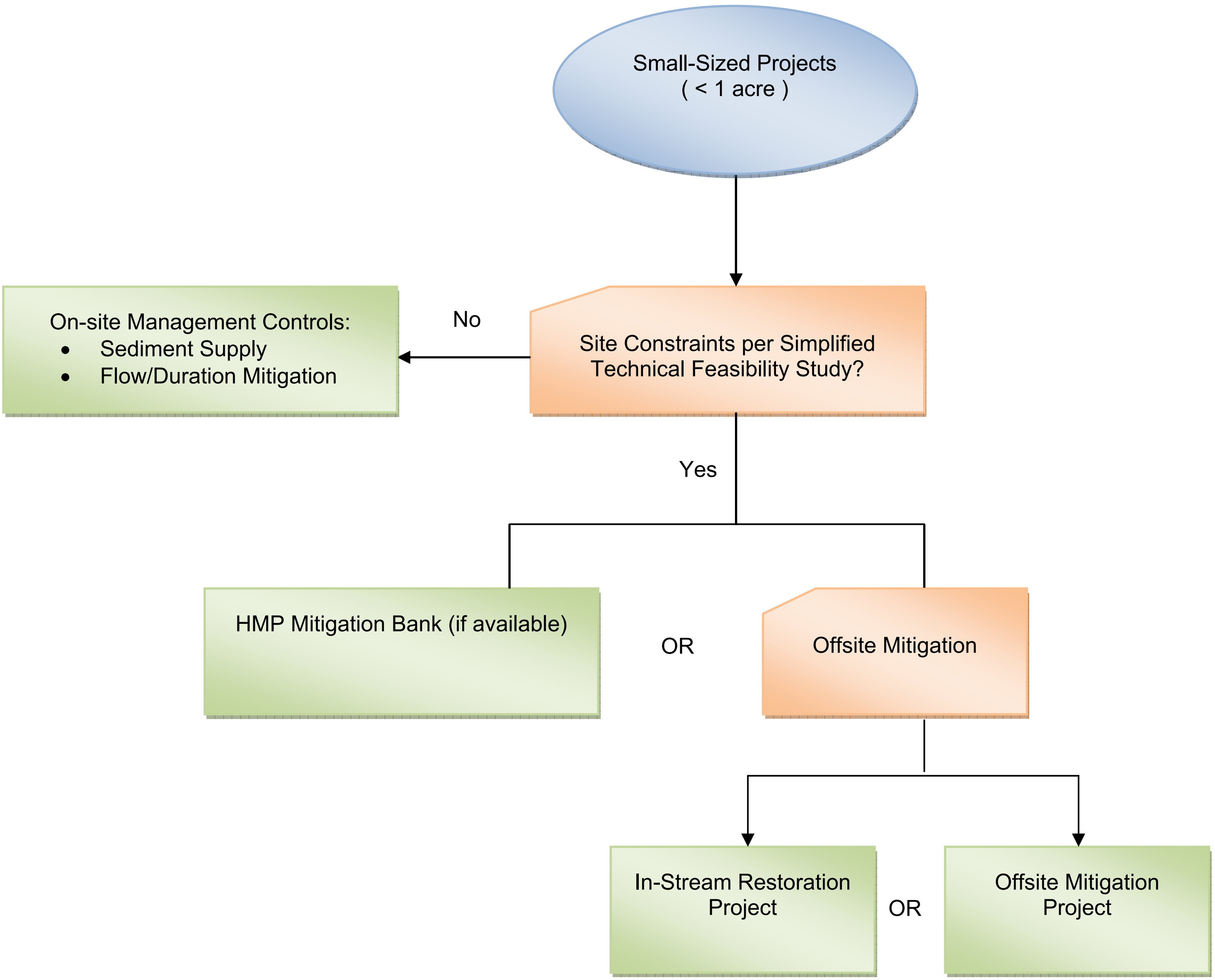
surfaces of a previously existing development, the numeric sizing criteria applies to the entire development.

The majority of Tier 3 projects are completed within a very limited amount of space, making it unlikely the applicant will be able to implement on-site management controls. Two approaches are available.

- Implementing hydrologic control measures and on-site management controls within the project boundaries to ensure compliance with the HMP Criteria identified in **Section 4.1**. Using this approach, mitigation of both flow and duration is achieved through on-site hydrologic control measures, and sediment loss is addressed through on-site management controls.
- If on-site hydrologic control measures and management controls are not technically feasible due to site constraints, a simplified technical feasibility study shall be developed to explain why the HMP criteria cannot be met onsite. The simplified technical feasibility study must include:
  - the soil conditions of the PDP site;
  - a demonstration of the lack of available space for onsite controls; and
  - an explanation of prohibitive costs to implement onsite controls.
  - a written opinion from a California Registered Geotechnical Engineer, who will identify the infeasibility due to geotechnical concerns.
- Once the simplified technical feasibility study is accepted by the jurisdiction of the PDP, the PDP can pursue payment into the HMP mitigation bank, if one exists and is available to the PDP. If not, the PDP must pursue either an off-site mitigation project or an in-stream restoration project detailed in Step B in **Section 4.4.1**.

A flow chart indicating which HMP criteria should be considered for a Tier 3 project is shown in **Figure 4-10**.

Figure 4-10: Hydromodification Controls: Small-Size Projects



4.5.4 Tier 4 – Municipal Roadway Projects

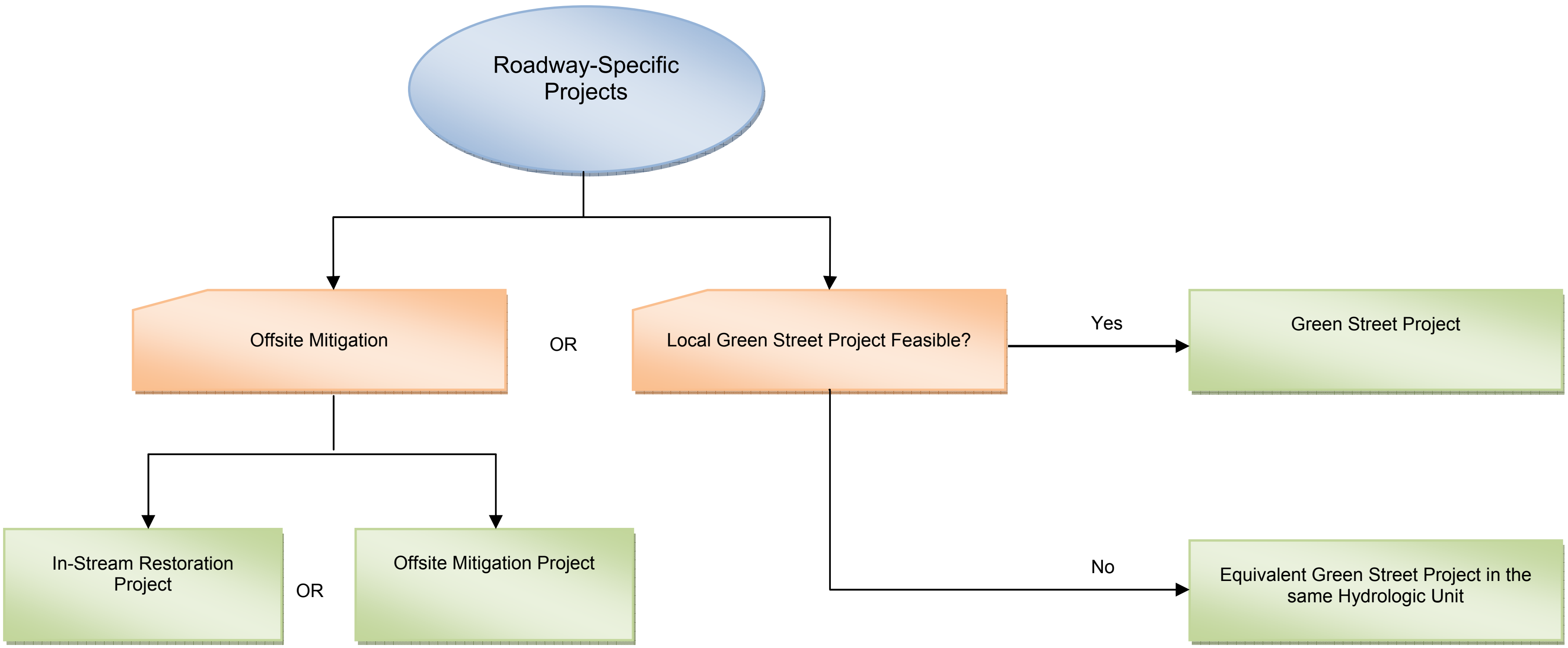
Municipal roadway projects constitute a standalone tier based on their unique characteristics. Roadway projects are linear development or re-development projects to be completed within a limited right-of-way. Tier 4 includes the following roadway projects, as defined per Permit Items F.1.d.(1) and F.1.d.(2):

- Streets, roads, highways, and freeways. This category includes any paved surface that is 5,000 square feet or greater used for the transportation of automobiles, trucks, motorcycles, and other vehicles.
- Roadway redevelopment projects that create, add, or replace at least 5,000 square feet of impervious surfaces. Where a roadway redevelopment project results in an increase of less than 50% of the impervious surface within the limits of the project, and the existing development was not subject to SSMP requirements, the numeric sizing criteria discussed in permit section F.1.d.(6) applies only to the addition or replacement, and not to the entire development. Where the roadway redevelopment project results in an increase of more than 50% of the impervious surface within the limits of the project, the numeric sizing criteria applies to the entire project.

Routine roadway maintenance projects that maintain the original line and grade, hydraulic capacity, original purpose of the facility, or emergency roadway maintenance activities that are required to protect public health and safety are exempt from HMP requirements. The exemption is consistent with the requirements of the 2011 Model WQMP.
Roadway projects have the option to implement a green street approach to meet compliance with the HMP. The opportunity to develop a green street project will depend upon several factors, including but not limited to the ownership of the land adjacent to the right-of-way, the location of existing utilities, the course of the existing storm drain, and potential access opportunities. The PDP will take the following course of action for meeting the HMP Criteria for municipal roadway projects:

- The PDP will evaluate, to the maximum extent practicable (MEP), implementation of a "green streets" approach consistent with the 2008 U.S. EPA Green Streets Manual. If it is determined that due to site constraints implementation of a "green streets" approach for the municipal roadway project is infeasible, the PDP will complete a checklist identifying the constraints of why a "green streets" approach cannot be implemented. If a "green streets" approach is infeasible for the municipal roadway project, the PDP shall implement a "green street" project elsewhere in the same hydrologic unit. This alternative "green street" project shall mitigate an equivalent or greater tributary area than that of the proposed municipal roadway project.
- Alternatively, the PDP may pursue either an off-site mitigation project or an in-stream restoration project detailed in Step B in **Section 4.4.1**.
- The flow chart in **Figure 4-11** shows the four scenarios that shall apply to each proposed roadway project.

Figure 4-11: Hydromodification Controls: Roadway-Specific Projects



4.6 Hydrologic Management Measures

PDPs are encouraged to use the full suite of hydrologic management measures available to meet the HMP criteria identified in **Section 4.1**. The intent of the HMP is not to specify the types of hydrologic control measures that can be used but rather identify the criteria that must be met allowing flexibility for PDPs to use the full suite of management measures to meet the HMP criteria. Section 5 of the Technical Guidance Document provides information on hydromodification control design. Section 5.5 includes Hydromodification Control BMPs, which specifies the type of BMPs that can be used to meet hydromodification standards. The South Orange County Hydrology Model includes BMPs that can be used to meet the HMP criteria and has been developed as the primary tool to select and size the appropriate hydrologic site design and BMP controls to meet the HMP criteria. The model also incorporates buffer zones as a management measure for those PDPs adjacent to stream channels.

4.6.1 Selection and Design of Hydrologic Management Measures

Selection and design of hydrologic management measures is an iterative process that can be facilitated using the South Orange County Hydrology Model (SOCHM). The SOCHM has a comprehensive menu of hydrologic site design measures and hydrologic management measures that can be selected for implementation for PDPs. The design parameters for these hydrologic measures have been incorporated into the model and can be modified to an extent based on site constraints.

4.6.2 Inspection and Maintenance of Hydrologic Management Measures

Maintenance for hydrologic control measures is critical to ensure there optimal operation. PDPs are conditioned to provide verification of inspections and maintenance operations as defined in Section 7.II-4.0 of the approved 2011 Model WQMP. The list of such inspections and maintenance operations shall be included in the WQMP submitted by the applicant. Maintenance activities shall ensure that the systems are properly controlling flow rates and durations to ensure the HMP criteria is being met and inspections shall document the maintenance activities performed and that the hydrologic control measure is functioning properly

5.0 Hydromodification Sediment and Bioassessment Standards

5.1 Sediment Supply Management

Sediment supply plays a role in the stability of alluvial stream channels. A change in coarse (bed material) sediment supply will cause instability in the channel manifested through general scour or aggradation. Lateral bank migration may also result from changes in sediment supply as the channel slope increases or decreases.

The delivery of bed material during construction may increase as land surface is cleared and the potential for erosion is increased. Once the land surface is urbanized, runoff may be discharged through closed conduits and lined channels. The potential for bed material transport may be reduced as compared to the pre-development condition. The purpose of this portion of the HMP is to maintain the pre-development delivery of bed material to receiving streams following urbanization. Bed material is defined as the sediment that comprises the bed and banks of the receiving stream. Bed material load is the material transported by the stream during runoff events. It is comprised partly of the bed load (material that moves along the bed by sliding or saltating) and partly of the suspended load, including particle size fractions in the channel bed sediments. Bed material load is a primary variable controlling stream channel morphology. Wash load is the portion of the total sediment load carried continuously in suspension by the flow, and generally consists of the finest particles. Changes in wash load are not likely to significantly affect the channel stability, and reductions in wash load are generally assumed to improve habitat function.

The resiliency of receiving channels to forestall changes in the watershed due to urbanization varies with the magnitude of the change and characteristics of the channel (bed and bank material, vegetation, channel cross section and slope). It is difficult to quantitatively predict the response in a receiving channel to changes in the fundamental variables described by Lane (1955) of discharge, bed material grain size, channel slope and sediment supply. Accordingly, the most effective approach to ensuring channel stability may be to avoid changes in the fundamental variables (Lane's relationship) during urbanization through the implementation of stream channel management guidelines. In the case of bed material sediment supply, this will be accomplished by avoiding development in areas that are a significant contributor of bed material load to the receiving channel.

The general approach to ensure maintenance of the pre-project sediment supply is a three-step process:

1. Determine whether the site is a significant source of bed material to the receiving stream.
2. Avoid significant bed material supply areas in the site design.
3. Replace significant bed material supply areas that are eliminated through urbanization.

An alternative compliance option allows the project applicant to model the site conditions and the receiving stream and provide additional mitigation in site runoff to compensate for the reduction (or addition) of bed material. This option may only be used if the general approach outlined above is deemed infeasible by the permitting authority, or if the project site design requires significant alteration of on-site streams.

5.1.1 Methodology

The project applicant must determine the location of the downstream alluvial receiving water that may be impacted by the project. Only the first downstream conveyance that is unlined (invert, side slopes or both) will be considered and will serve as the "assessment" or "receiving" stream for the project. The following methodology will be used to ensure that the project does not adversely impact bed material load to the assessment stream.

Step 1

A triad approach will be completed to determine whether the site is a significant source of bed material to the receiving stream and includes the following components:

1. Site soil assessment, including an analysis and comparison of the bed material in the receiving stream and the onsite streams;
2. Determination of the capability of the onsite streams to deliver the site bed material (if present) to the receiving stream; and
3. Present and potential future condition of the receiving stream.

A geotechnical and sieve analysis is the first piece of information to be used in a triad approach to determine of the site is a significant source of bed material load to the assessment stream. An investigation shall be completed of the assessment stream to complete a sieve analysis of the bed material. Two samples shall be taken of the assessment stream using the "reach" approach (TS13A, 2007). Samples in each of the two locations should be taken using the surface and subsurface bulk sample technique (TS13A, 2007) a total of for four samples.

A similar sampling assessment should be conducted on the project site. First-order and greater streams that will be impacted by the project (drainage area changed, stabilized, lined or replaced with underground conduits) will be analyzed in each subwatershed. One stream per subwatershed that will be impacted on the site must be assessed. A subwatershed is defined as tributary to a single discharge point at the project property boundary.

The sieve analysis should report the coarsest 90 percent (by weight) of the material for comparison between the site and the assessment stream. The Geotechnical Engineer shall render an opinion if the material found on the site is of similar gradation to the material found in the receiving stream. The opinion will be based on the following information:

- Sieve analysis results
- Soil erodibility (K) factor
- Topographic relief of the project area
- Lithology of the soils on the project site

The Geotechnical Engineer shall rate the site as having either a high, medium or low probability of supplying bed material load to the receiving stream. This site soil assessment serves as the first piece of information for the triad approach.

The second piece of information is to qualitatively assess the sediment delivery potential of the site streams to deliver the bed material load to the receiving stream, or the bed material sediment delivery potential or ratio. There is no documented procedure to estimate the sediment delivery ratio; it is affected by a number of factors, including the sediment source, proximity to the receiving stream, on-site channel density, project watershed area, slope, length, land use and land cover, and rainfall intensity. The Engineer will qualitatively assess the bed material sediment delivery potential and rate the potential as high, medium or low potential. The final piece of information is the present and potential future condition of the receiving stream. The Engineer shall assess the receiving stream for the following:

- Bank stability. Receiving streams with unstable banks may be more sensitive to changes in bed material load.
- Degree of incision. Receiving streams with moderate to high incision may be more sensitive to changes in bed material load.
- Bed material gradation. Receiving streams with more coarse bed material (such as gravel) are better able to buffer change in bed material load as compared to beds with finer gradation of bed material (sand).
- Transport vs. supply limited streams. Receiving streams that are transport limited may be better able to buffer changes in bed material load as compared to streams that are supply limited.

The Engineer will qualitatively assess the receiving stream using the metrics noted and rate the potential for adverse response based on a change in bed material load as high, medium or low. The Engineer shall use a triad assessment approach, weighting each of the components based on professional judgment to determine if the project site provides a significant source of bed material load to the receiving stream, and the impact the project would have on the receiving stream. The final assessment and recommendation shall be documented in the HMP portion of the WQTR.

The recommendation may be any of the following:

- Site a significant source of sediment bed material – all on-site streams must be preserved.
- Site a source of sediment bed material – some of the on-site streams must be preserved (with identified streams noted).
- Site is not a significant source of sediment bed material.

The final recommendation will be guided by the triad assessment. Projects with predominantly “high” values for each of the three assessment areas would indicate preservation of on-site streams. Sites with predominantly “medium” values may warrant preservation of some of the on-site streams, and sites with generally “low” values would not require site design considerations for bed material.

The Engineer shall also assess if the receiving stream has been altered either for alignment, cross section, or longitudinal grade, or has degraded to the extent that an in-stream restoration project would be required to restore the functions and values of the stream bed. In such cases, the Engineer should discuss options for participating in an in-stream project in lieu of on-site design features to preserve bed material load.

Provision for waiver of sediment assessment. If any of the following are present, the site shall not be required to consider sediment component as a part of the HMP mitigation.

1. The site was previously developed and is being redeveloped.

2. There was no stormwater discharge from the site to a receiving water for the range of flows associated with the HMP.
3. The site discharges directly to a bay, estuary, reservoir, lake or the ocean, or through hardened and maintained channels to any of these receiving waters.

Step 2

If the analysis in Step 1 indicates that some or all of the site stream courses must be preserved as a contributor of bed material load to the receiving stream, the site plan shall be developed to avoid impacting the identified streams. The Engineer will designate streams onsite that should be avoided to preserve the discharge of bed material load from the site. The Engineer may consider the factors discussed above when determining whether a specific on-site stream course is a significant contributor of bed material load and should be preserved.

Step 3

If it is infeasible to avoid on-site streams that contribute significant bed material load in the design of the site plan, the drainage(s) may be moved and replicated elsewhere on the site, provided the Engineer will certify that the relocated drainage course has a similar potential to generate bed material load. The Geotechnical Engineer will also certify that the revised drainage location is in substantially similar material as the natural stream location.

5.1.2 Alternative Compliance Methodology

Applicants may propose an alternative compliance methodology for bed material load mitigation from a project based on numerical modeling. The Engineer may propose adjusting the flow duration curve to maintain pre-project conditions in the receiving channel with the expected change in bed material load discharge from the site. This option may not be practical when the changes in bed material supply from the project are relatively small, due to limitations in the accuracy of modeling. The Engineer shall determine, using best professional judgment, if the alternative modeling approach is applicable.
The alternative modeling approach shall include the following:

1. Continuous hydrologic simulation for the project baseline condition and proposed condition over the range of flow values up to the pre-project 10-year event.
2. Sediment transport model of the receiving stream for the project baseline condition and proposed condition.
3. Analysis of the change in sediment bed material from the project baseline condition to the proposed condition
4. Explanation of method used to control the discharge from the project to account for changes in the delivered sediment bed material.
5. Summary report

Site specific modeling is discussed further in **Appendix D**.

5.2 Bioassessment

5.2.1 Historical hydromodification impacts and IBI scoring

Permit Section F.1.h.(1)(f) requires the identification of areas within the San Juan hydrologic unit where historical hydromodification has resulted in negative impacts to benthic macroinvertebrate communities. This section of the HMP was developed to address permit Section F.1.h.(1)(f). The upper part of the San Juan hydrologic unit (HU 901) is located in Orange County. A Surface Water Ambient Monitoring Program (SWAMP) was prepared in July 2007 for this portion of the hydrologic unit by the Southern California Coastal Water Research Project (SCCWRP, 2007). Findings of the 2007 SWAMP report indirectly identify such areas that are associated with the negative impact to benthic macroinvertebrate and benthic periphyton. These areas are characterized by low (poor) or very low (very poor) Index of Biotic Integrity (IBI) scores. This reporting effort was completed under the supervision of the SDRWQCB. SWAMP monitoring efforts are conducted every five years.

The bioassessment analysis included monitoring data from the following historical monitoring programs:

- California Department of Fish and Game (1998-2000)
- Orange County NPDES (2002-2006)
- Camp Pendleton (2004-2005)

The Southern California IBI is computed as a composite of seven metrics summed and scaled from 0 to 100, as follows:

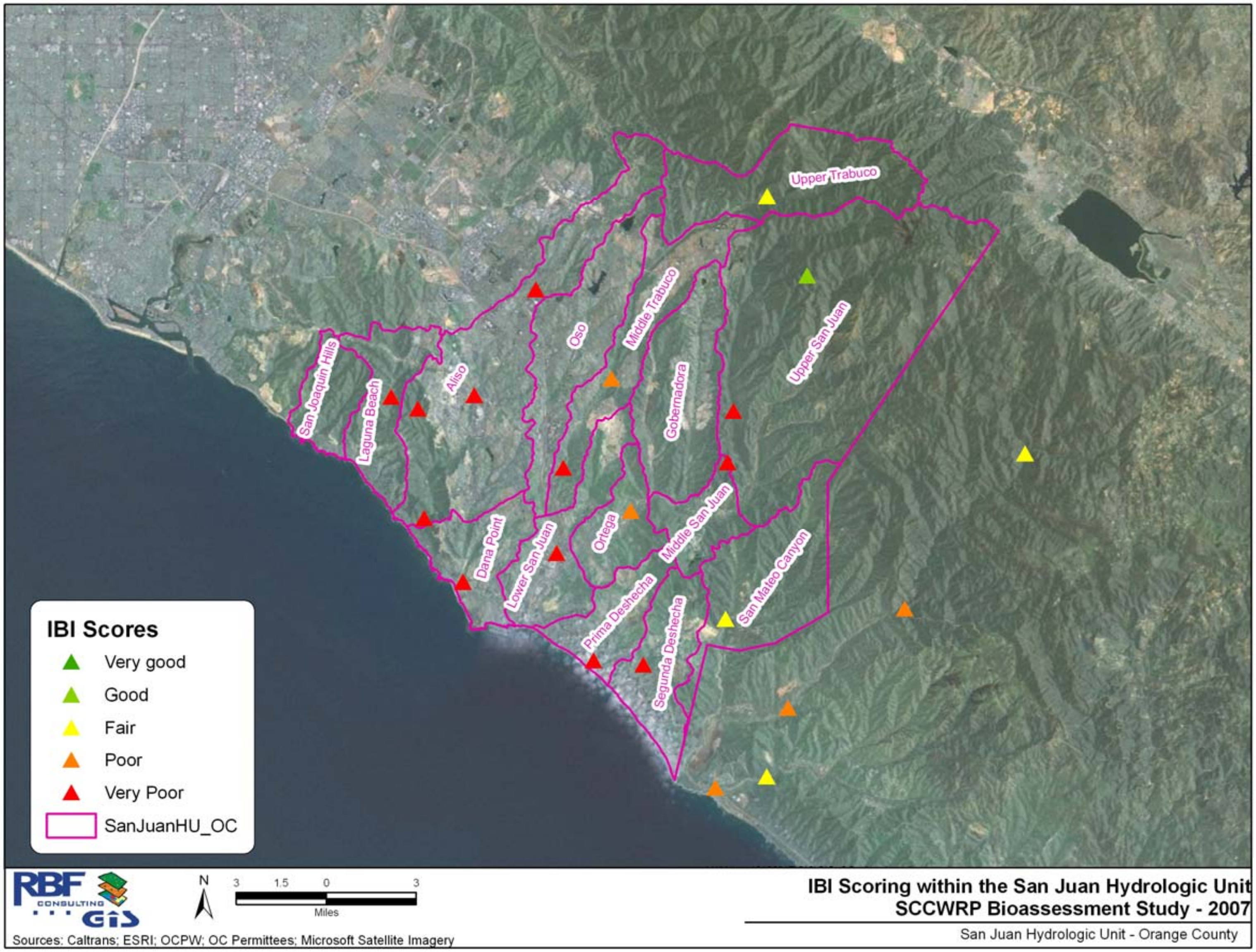
- 0–19 (very poor condition)
- 20–39 (poor condition)
- 40–59 (fair condition)
- 60–79 (good condition)
- 80–100 (very good condition)

Seventeen monitoring stations are located within the Orange County boundaries. **Figure 5-1** shows the location of these stations, as well as their associated IBI scoring category. Associated IBI scores were derived from the statistical analysis of monitoring data that was collected over several seasons (winter, spring, summer, and fall) and different hydrologic conditions.

The SWAMP study considers three monitoring locations as unimpacted by anthropogenic development in the hydrologic unit. They are characterized as reference monitoring locations. The three reference stations and their associated IBI scores are

- Bell Creek (64)
- Cold Spring Creek (34)
- Arroyo Trabuco Creek (68)

Figure 5-1: IBI Scoring within the San Juan Hydrologic Unit



Overall, benthic macroinvertebrate communities may have been impacted by hydromodification in several coastal and foothill subwatersheds that exhibit very poor IBI scores. These include the following subwatersheds: Laguna Beach, Aliso Creek, Dana Point, Lower San Juan, Prima Deshecha, Segunda Deshecha, Middle San Juan subwatersheds, as well as the lower portion of the Middle Trabuco subwatershed. Similarly, benthic macroinvertebrate communities may have been impacted to a lesser level in the Middle Trabuco and Ortega subwatersheds. One of the reference monitoring stations, Cold Creek, exhibits poor IBI scores. Conversely, benthic macroinvertebrate communities of the following subwatersheds may have been not impacted by hydromodification: San Mateo Canyon, Upper Trabuco, and Upper San Juan. Developments in these subwatersheds are limited.

No monitoring stations are available in the Gobernadora, Oso, and San Joaquin Hills subwatersheds. Impacts of hydromodification on IBI scores were not extrapolated to these subwatersheds because of the geographic variability of environmental conditions.

5.2.2 Assessment of watercourses

Hydromodification impacts from development projects and/or maintenance activities may have led to the impairment of state and federal waters and wetlands. U.S. EPA reports three major types of hydromodification activities: channelization and channel modification, dams, and streambank and shoreline erosion (U.S. EPA, 2007). Studies suggest a link between the value of physical habitat/structure and IBI values. Waterbodies that are impacted by hydromodification may have lower IBI scores due to direct and indirect impacts of upstream development.

Accelerated impacts occur to natural or earthen drainages from projects that increase in runoff flow rates and duration. Such impacts to aquatic species may include changes in flow, increased sedimentation, higher water temperatures, lower dissolved oxygen, degradation of biotic structure and decreased water quality (U.S. EPA 2007). Once these environmental stressors are present, subsequent direct and indirect impacts occur, especially to aquatic life. For example, increased sediment loading can decrease fish spawning and reduce macro-invertebrate communities. Hydromodification generally increases the transport of sediment and associated constituents (nitrates, sulfates, metals, turbidity), which impacts water quality to the point where aquatic life thresholds may be exceeded (SCCWRP 2007). Studies suggest a link between the value of physical habitat/structure and IBI values. Waterbodies that are impacted by hydromodification would be expected to have lower IBI scores from direct and indirect impacts of upstream development. It should be noted, however, that low IBI scores may be caused by natural variability.

The second aspect to consider is the reduction of wash load, which is generally viewed as favorable to benthic health. "Natural" discharge of course material (bed material) is beneficial, but colloidal material, clay, and silt are unfavorable. Stabilization of the watershed, particularly of areas generating turbidity in runoff, is the goal. The reduction of wash load during construction activities may be accomplished with the implementation of the requirements of the Construction General Permit.

The impacts of potential hydrograph changes will be assessed through the SWAMP monitoring program, as presented in **Section 6**. In addition, records of channel morphology will be taken at selected monitoring locations.

6.0 HMP and Bioassessment Monitoring & Effectiveness

The following section defines the monitoring approach and the performance protocol that will be implemented to verify the effectiveness of the South Orange County HMP. The section presents technical concepts and defines approaches to monitor the effectiveness of the HMP as required by provisions F.1.h. (1)(g) and F.1.h. (1)(l) of Regional Board Order No. R9-2009-0002. Section F.1.h.(1)(g) requires the definition of a protocol to evaluate the potential hydrograph change impacts to downstream watercourses from PDPs. The protocol must include the use of IBI scores. Section F.1.h.(1)(l) also requires a description of pre- and post- project monitoring and other program evaluation, including IBI score, to assess the effectiveness of the HMP. The defined performance protocol addresses the requirements of provisions F.1.h.(1)(k), including a description of inspections and maintenance of hydrologic controls and sediment supply management measures, as well as a protocol to address potential hydromodification impacts.

6.1 Technical Concepts

6.1.1 HMP Monitoring Measures

Stream Benthic Community

A stream benthic community is a metric for assessing the condition of a stream. Biological communities represent the health of a portion of the benthic stream community. This is explained by the fact that biological organisms, especially benthic macroinvertebrate and periphyton communities, integrate exposure over time and respond to cumulative stressors (SCCWRP, 2011). The IBI integrates several populations of organisms, and as such the combination of organisms offers a differential sensitivity to stressors, allowing for early detection of potential degradation (SCCWRP, 2011). Bioassessment may only be conducted from May to July and only if water is present; however, samples that are collected late spring may provide the most representative results, as vegetation cover and flow conditions are usually optimal. This is particularly true for non-perennial streams of the San Juan Hydrologic Unit. Seasonal variability in benthic communities is typical for non-perennial streams; however, the current IBI has almost exclusively been calibrated for perennial streams (SCCWRP, 2011). SCCWRP is in the process of developing a Benthic Macroinvertebrate Index (BMI) that would account for the typical seasonal variability of non-perennial streams.

Channel incision and widening

The most obvious way to assess changes due to scour or deposition is to physically measure the pre-project and post-project cross sections, and determine if the channel is incising and/or widening over time. This is accomplished by conducting geomorphic assessments and channel surveys downstream of a planned development before and after construction. In addition to physical measurements, comparison of current and historical photos, aerial photography, and site inspection for signs of channel degradation can provide important supporting evidence.

6.1.2 Temporal and Spatial Variability of Monitoring Locations

Temporal variability

The single most important factor affecting the temporal variability inherent to measuring stream degradation is variable inter-annual rainfall frequency and intensity. Droughts in California can last years, with little to no rainfall occurring in Southern California. During El Niño years, anomalously high storm frequencies and intensities can result in sudden geomorphic changes. Rainfall intensity also varies intra-annually. Accordingly, the value of the monitoring program will be derived only over the long-term. Significant trends will likely require many years to identify. IBI scores may be a correlating variable to geomorphic changes in streams.. However, the method used to compute the index is specifically for perennial streams, and does not account for the typical seasonal variability associated with non-perennial streams, as it exists in the San Juan Hydrologic Unit.

Spatial variability

Sampling a representative set of streams is important to capture the range of watershed conditions and biological organisms present in the permit coverage area. Other important factors that affect stream responses to hydromodification include channel grade, watershed area, vegetated cover, and stream sinuosity. In addition to channel and watershed features, location within the watershed is an important consideration. Monitoring stations should be located in the watershed headwaters just downstream of a development project of sufficient size, so that hydromodification effects from the proposed development can be isolated for comparison purposes to the maximum extent practicable. Upper watershed sites provide more definitive measures of HMP effectiveness because they can more directly correlate effects to specific development projects.

Middle watershed and lower watershed sites would be influenced by confounding variables (such as mass wasting and impacts from natural tributary confluences and other existing development projects), including phased developments over many years, in the watershed. Therefore, middle and lower watershed monitoring sites would require much more time to assess overall program effectiveness, if achievable.

The concept of providing hydromodification effectiveness measurements in the watershed headwaters is supported by SCCWRP. Research by SCCWRP has shown that hydromodification effects of a development project become muted with increasing distance from the development site (defined by SCCWRP as the Domain of Effect). To the extent practicable, monitoring locations detailed in this plan will be distributed throughout the San Juan Hydrologic Unit to provide for geographic and climatic variability across south Orange County.

6.2 Approaches Selected to Assess HMP Effectiveness

The HMP Effectiveness Plan extends for a period of five years. However, interim data may be provided to the Regional Board on an annual basis. A period of five years is necessary to implement the monitoring stations, analyze the data, and account for spatial and temporal variability of the conditions in South Orange County.

An examination of benthic macroinvertebrate organisms will be conducted to assess both biological and geomorphologic health of the streams. Additionally, channel assessment cross sections at selected locations, coincident with the IBI sampling locations, will be selected. South Orange County Permittees seek cost-effective methods to implement the HMP Effectiveness Plan. Stream bioassessment for the purpose of HMP effectiveness should be coupled with the Urban Stream Bioassessment and be reported annually in the Orange County Unified Program Effectiveness Assessment (PEA) (OCDP, 2010). Several bioassessment monitoring sites already exist for both the SWAMP, which is developed on a five-year cycle, and the annual PEA. At each of these existing sites, historical bioassessment data is readily available for the establishment of pre-project conditions. Several reference monitoring sites are also readily available including, but not limited to, three urban bioassessment sites. The ultimate selection of bioassessment sites should consider integrating one or several of these existing sites if consistent with the objectives of the HMP Effectiveness Plan.

Considering the constraints and technical approach detailed above, the following approaches are recommended for HMP monitoring.

Evaluate the HMP effectiveness by monitoring benthic macroinvertebrate communities. Biological organisms provide essential information to the overall health of a stream. The evolution of benthic macroinvertebrate communities may be the precursor to an impacted or improved stream. Benthic communities should be monitored once a year, preferably in late spring, at defined monitoring stations. Bioassessment should be done by computing the IBI score and comparing it to historical levels in the same stream. Ultimately, the Benthic Macroinvertebrate Index (BMI) could be used once it has been developed by SCCWRP, however at this time there is no estimated date as far as completion.

Complete a stream channel survey at each of the selected channel sections on an annual basis. The stream channel survey consists of collecting topographic and bathymetric measurements along each cross-section to characterize morphology and longitudinal slope of the stream segment. Four parameters will be surveyed: the floodprone width, the bankfull width, the bankfull depth, and the longitudinal slope. Each surveyed stream segment will be subsequently classified per the simplified Rosgen system of channel classification (Rosgen, 1996). **Figure 6-1** shows the different types of channels per Rosgen channel classification (Rosgen, 1996).

Figure 6-1: Simplified Rosgen Channel Classification

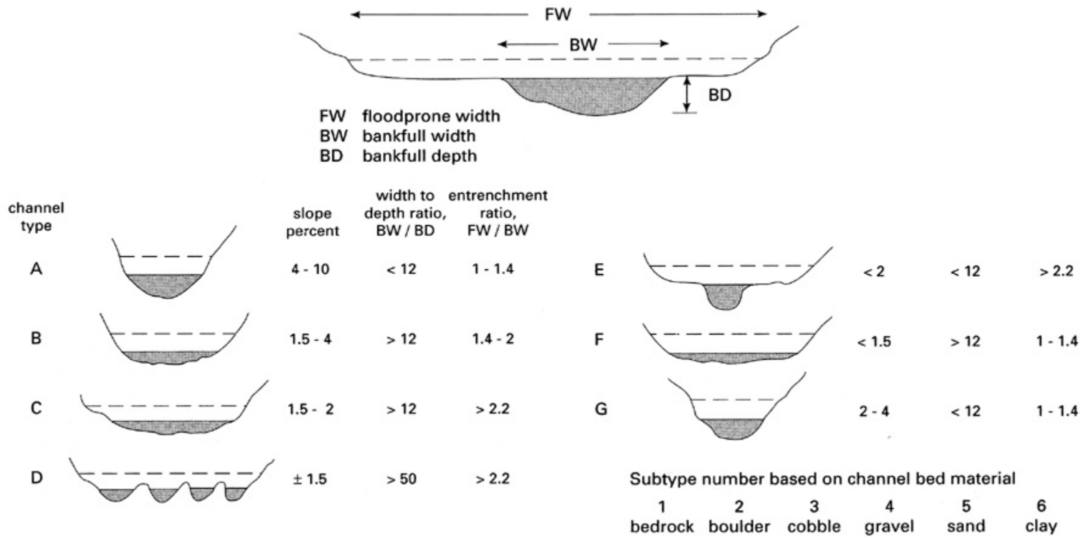
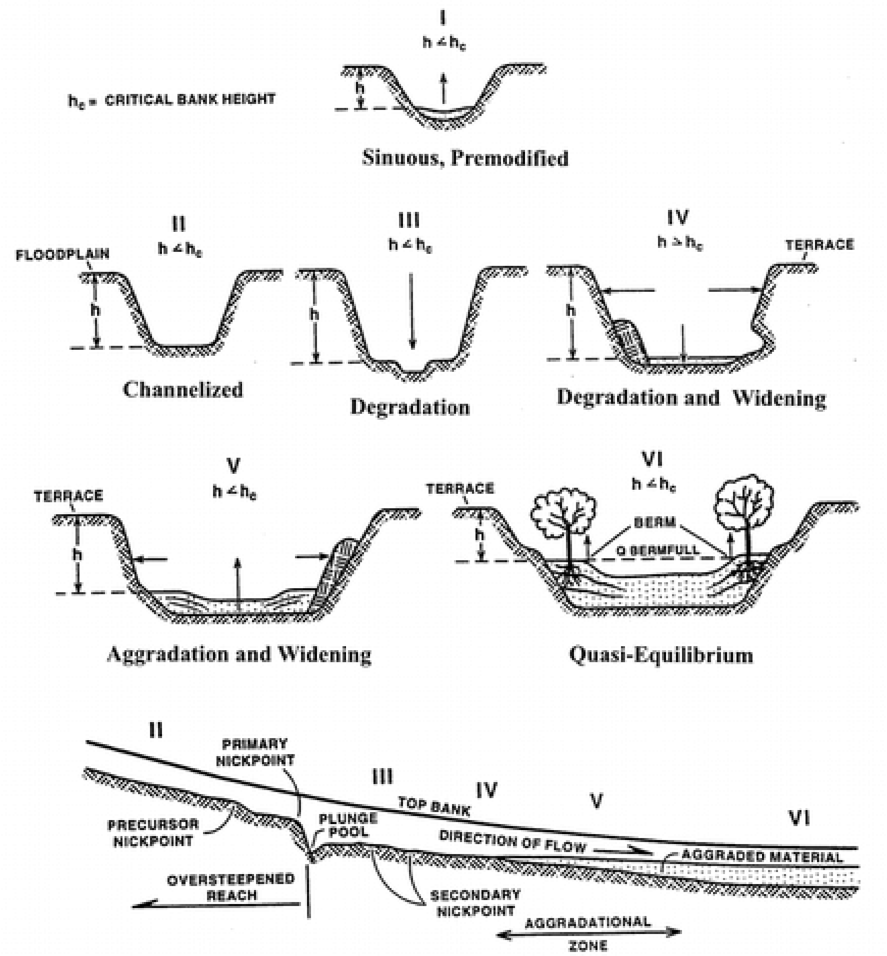


Figure 1.12 The Rosgen system of channel classification.

(Rosgen, 1996)

The temporal evolution in geomorphology, if any, of the surveyed stream segment will be compared to the six-stage Channel Evolution Model defined by Simon, as well as the previous year cross section data, to correlate any potential impacts of urbanization to this change of stream channel geomorphology (Simon et al., 1992). The geomorphologic evolution of a stream segment, if any, will also be compared to the annual bioassessment to determine if the observed aggradation or degradation is associated with changes in the benthic macroinvertebrate communities. **Figure 6-2** illustrates the six-stage sequence of incised channel evolution (Simon et al., 1992). A stream segment will be considered stable over time if features of the stream segment (such as dimension, pattern, and profile) are maintained, and the stream system neither aggrades nor degrades. The channel classification procedure is described in more detail in **Appendix B**.

Figure 6-2: Six-Stage Channel Evolution Model



(Simon et al, 1992)

Monitoring in the upper watershed

Upper watershed monitoring (channel surveys) is recommended to eliminate confounding lower watershed variables that would skew the analysis and minimize the potential for reaching meaningful conclusions.

Monitor three representative locations and one reference station

Providing three geographically representative stations would be sufficient to account for spatial and temporal variability of the conditions present in South Orange County. The reference monitoring station would be located in a watershed for which no upstream development (existing or future) is anticipated, preferably where historical bioassessment has been carried out. Data from the reference stations can be used to supplement pre-project condition data obtained at the representative monitoring sites, since the amount of pre-project condition data that can be obtained at such sites is dependent on the land development process. Providing three representative stations balances the need to characterize spatial variability against the cost of monitoring.

6.3 HMP Effectiveness Evaluation

The effectiveness of the HMP is to be evaluated into two main axes:

- BMP inspections and maintenance
- Performance protocol

6.3.1 BMP Inspections and Maintenance

One key component of the implementation of the HMP is to ensure hydrologic controls and sediment supply management measures perform effectively. PDPs are conditioned to verify inspections and maintenance operations as defined in Section 7.II-4.0 of the approved 2011 Model WQMP. The list of such inspections and maintenance operations shall be included in the WQMP submitted by the applicant. Maintenance activities shall ensure that the systems are properly controlling flow rates and durations to meet the requirements defined in the permit Item F.1.h.(1)(k).

6.3.2 Performance Protocol

As defined in **Section 6.2**, channel section surveys and IBI scores are to be monitored on a regular basis at representative locations in the San Juan Hydrologic Unit. If a significant degradation of a stream segment has been detected, a hydrologic analysis shall be performed. A significant degradation of the stream segment will be subjectively interpreted by the analyst as a sudden decline in the IBI, or a rapid change of the morphology of the channel (cross-section). A drastic change in IBI scores may indicate that flow conditions have consequently changed. A significant improvement of the IBI scores may validate the approach taken in this HMP.

The hydrologic analysis, if required, shall determine if the significant degradation of the stream segment is associated to geomorphically significant flows (10% of the 2-year storm event to the 10-year storm event). A significant difference between the expected and the observed flow duration curves for the identified flow range would automatically trigger a performance protocol. The objective of the performance protocol is to correct any performance deficiencies in the existing hydrologic controls and sediment supply management measures. If the stream degradation was caused by flows outside the critical range (a relatively rare storm event), the extensive hydrologic analysis may terminate and no further investigation is needed.

The performance protocol consists of investigating the tributary area of the impacted stream segment to identify the potential source(s). Hydrologic controls and sediment supply management measures of one or several PDPs will be examined to determine if they are under-performing due to a lack of maintenance or poor design. In this case, the lack of performance may appear to be directly responsible for the drastic change in stream conditions (IBI score, morphology). Rehabilitation of the stream segment may be required. It is expected that initial conclusions regarding the effectiveness of the HMP will be drawn after a minimum of five years of observations.

6.4 Summary and Conclusions

The HMP Effectiveness Plan, scheduled for initial implementation over a five-year period, will include the following specific activities:

Baseline Monitoring Plan Requirements:

- Development of QAPP (to be provided to Regional Board staff for review and comment)
- Bioassessment monitoring station analysis and installation
- Annual data analysis (2013–2017)
- Mid-term evaluation of the HMP Effectiveness after review of initial findings (interim report to be submitted in 2015)
- Report preparation (final report to be prepared in 2017)

Monitoring stations:

- Four monitoring locations – three representative stations monitoring exclusively areas in development located in the upper part of the San Juan Hydrologic Unit, and one reference station.
- Bioassessment conducted once a year

Bioassessment

- Annual sampling, preferably during spring season – similar to annual PEA and SWAMP (2012–2017)

Channel Assessments:

- Initial geomorphic assessment at each monitoring location (2012-2013)
- Baseline cross section surveys at each monitoring location (2012-2013)
- Annual geomorphic assessments and cross-section survey at each monitoring location to assess channel condition and response (2013–2017)

7.0 HMP and Model WQMP Integration

Within 90 days after a finding of adequacy from the San Diego Regional Water Quality Control Board Executive Officer the Final South Orange County HMP requirements will be incorporated into the Model Water Quality Management Plan (Model WQMP) and the Technical Guidance Document (TGD). The HMP requirements including the HMP criteria, alternative compliance options and steps, tiered requirements, and the sediment supply management methodology and steps will be incorporated into the Section 7II-2.4.2.2 Determine Hydromodification Performance Criteria under the South County Requirements. The HMP alternative compliance and the alternative compliance for sediment supply management will also be integrated into the Section 7.II-3.0 Alternative Compliance Approaches.

Guidance regarding the hydromodification technical feasibility study will be integrated with the LID feasibility analysis as part of the TGD. This guidance will identify that the criteria for hydromodification and LID requirements are different, however the feasibility analysis for both hydromodification and LID are to be integrated into one feasibility study for the project and submitted with the Preliminary WQMP. Section 5.4, "System Design to Address HCOCs" in South Orange County of the TGD will be updated to include the requirements of the HMP. The Permittees will use the revised Model WQMP and TGD with the HMP requirements to incorporate requirements into the local approval processes via their local WQMPs and municipal ordinances. This will also be completed within 90 days after receiving a finding of adequacy from the San Diego Regional Water Quality Control Board Executive Officer.

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APPENDIX A
HSPF Pervious Land Parameters

Pervious Land Hydrology (PWATER) Parameters

The HSPF hydrology parameters of PWATER are divided into four sections, titled PARM1-4. PARM1 is a series of checks to outline any monthly variability versus constant parameter values within the simulated algorithm; whereas, PARM2 and 3 are a series of climate, geology, topography, and vegetation parameters that require numerical values to be input.

PARM2 involves the basic geometry of the overland flow, the impact of groundwater recession, potential snow impact due to forest cover and the expected infiltration and soil moisture storage. The main parameters of groundwater recession are KVARY and AGWRC. The infiltration and soil moisture storage parameters are INFILT and LZSN.

PARM3 involves the impact of climate temperature during active snow conditions, a wide range of evaporation parameters due to the variability of the onsite soil and existing vegetation and subsurface losses due to groundwater recharge or the existing geology. The main evaporation parameters are INFEXP, INFILD, BASETP, and AGWETP. The parameter for subsurface loss is DEEPFR, which accounts for one of only three major losses from the PWATER water balance (i.e., in addition to evaporation, and lateral and stream outflows).

PARM4 involves the flow and hydrograph characteristics, the expectation of rain interception due to the inherent moisture storage capacity from existing vegetation, land use and/or near surface soil conditions and evaporation due to the root zone of the soil profile. The main interception parameters are CEPSC and UZSN. The parameter for evaporation as a primary function of vegetation is LZETP.

PARM2

KVARY. Groundwater recession flow parameter used to describe non-linear groundwater recession rate (/inches) (initialize with reported values, then calibrate as needed).
KVARY is usually one of the last PWATER parameters to be adjusted; it is used when the observed groundwater recession demonstrates a seasonal variability with a faster recession (i.e., higher slope and lower AGWRC values) during wet periods, and the opposite during dry periods. Value ranges are shown in Table A-4. Values that are representative of the conditions in south Orange County have been selected for the SOCHM. Plotting daily flows with a logarithmic scale helps to elucidate the slope of the flow recession.

AGWRC. Groundwater recession rate, or ratio of current groundwater discharge to that from 24 hours earlier (when KVARY is zero) (/day) (estimate, then calibrate).

The overall watershed recession rate is a complex function of watershed conditions, including climate, topography, soils, and land use. Hydrograph separation techniques can be used to estimate the recession rate from observed daily flow data (such as plotting on a logarithmic scale).

INFILT. Index to mean soil infiltration rate (in/hr); (estimate, then calibrate).
In HSPF, INFILT is the parameter that effectively controls the overall division of the available moisture from precipitation (after interception) into surface runoff. Since INFILT is not a maximum rate nor an infiltration capacity term, its values are normally much less than published infiltration rates, percolation rates (from soil percolation tests), or permeability rates from the literature.

INFILT is primarily a function of soil characteristics, and value ranges have been related to SCS hydrologic soil groups (Donigian and Davis, 1978, p.61, variable INFIL) as follows (Table A-1):

Table A-1: SCS Hydrologic Soil Group Characteristics

SCS Hydrologic Soil Group	INFILT Estimate		Runoff Potential
	(in/hr)	(mm/hr)	
A	0.4 – 1.0	10.0 – 25.0	Low
B	0.1 – 0.4	2.5 – 10.0	Moderate
C	0.05 – 0.1	1.25 – 2.5	Moderate to High
D	0.01 – 0.05	0.25 – 1.25	High

An alternate estimation method that has not been validated is derived from the premise that the combination of infiltration and interflow in HSPF represents the infiltration commonly modeled in the literature (e.g., Viessman et al., 1989, Chapter 4). With this assumption, the value of 2.0*INFILT*INTFW should approximate the average measured soil infiltration rate at saturation, or mean permeability.

LZSN. Lower zone nominal soil moisture storage (inches).

LZSN is related to both precipitation patterns and soil characteristics in the region. Viessman, et al, 1989, provide initial estimates for LZSN in the Stanford Watershed Model (SWM-IV, predecessor model to HSPF) as one-quarter of the mean annual rainfall plus four inches for arid and semiarid regions, or one-eighth annual mean rainfall plus 4 inches for coastal, humid, or subhumid climates.

PARM3

INFEXP. Exponent that determines how much a deviation from nominal lower zone storage affects the infiltration rate (HSPF Manual, p. 60).

Variations of the Stanford approach have used a POWER variable for this parameter; various values of POWER are included in Donigian and Davis (1978, p. 58). However, the vast majority of HSPF applications have used the default value of 2.0 for this exponent.

INFILD. Ratio of maximum and mean soil infiltration capacities.

In the Stanford approach, this parameter has always been set to 2.0, so that the maximum infiltration rate is twice the mean (i.e., input) value; when HSPF was developed, the INFILD parameter was included to allow investigation of this assumption. However, there has been very little research to support using a value other than 2.0.

DEEPFR. The fraction of infiltrating water which is lost to deep aquifers (i.e., inactive groundwater), with the remaining fraction (i.e., 1-DEEPFR) assigned to active groundwater storage that contributes baseflow to the stream.

It is also used to represent any other losses that may not be measured at the flow gauge used for calibration, such as flow around or under the gauge site. Watershed areas at high elevations, or in the upland portion of the watershed, are likely to lose more water to deep groundwater (i.e., groundwater that does not discharge within the area of the watershed), than areas at lower elevations or closer to the gauge.

BASETP. ET by riparian vegetation as active groundwater enters streambed; specified as a fraction of potential ET, which is fulfilled only as outflow exists.

If significant riparian vegetation is present in the watershed then non-zero values of BASETP are typically applied. If riparian vegetation is significant, a generic BASETP value of 0.2 is typically representative of the evapotranspiration conditions in the San Juan Hydrologic Unit. This value was established in conjunction with a satisfactory annual water balance.
AGWETP. Fraction of model segment (i.e., pervious land segment) that is subject to direct evaporation from groundwater storage, e.g., wetlands or marsh areas, where the groundwater surface is at or near the land surface, or in areas with phreatophytic vegetation drawing directly from groundwater. This is represented in the model as the fraction of remaining potential ET (i.e., after base ET, interception ET, and upper zone ET are satisfied), that can be met from active groundwater storage.

A value of 0.05 has been selected for inclusion into the SOCHM. This value was adjusted and calibrated in the Aliso Creek watershed HSPF model based on adjustment of the low-flow simulation, and ultimately the annual water balance.

PARM4

CEPSC. Amount of rainfall, in inches, which is retained by vegetation, that never reaches the land surface, and is eventually evaporated (estimate, then calibrate). Typical guidance for CEPSC for selected land surfaces is provided in Donigian and Davis (1978, p. 54, variable EPXM) (**Table A-2**).

Table A-2: CEPSC for Selected Land Surfaces

Land Cover	Maximum Interception (in)
Grassland	0.10
Cropland	0.10 – 0.25
Forest Cover, light	0.15
Forest Cover, heavy	0.20

LZETP. Index to lower zone evapotranspiration (unitless).

LZETP is a coefficient to define the ET opportunity; it affects evapotranspiration from the lower zone, which represents the primary soil moisture storage and root zone of the soil profile. LZETP behaves much like a “crop coefficient” with values mostly in the range of 0.2 to 0.7; as such, it is primarily a function of vegetation. Typical and possible value ranges are shown in **Figure 4-3**, and the following ranges for different vegetation are expected for the "maximum" value during the year (**Table A-3**):

Table A-3: LZETP Value Ranges

Land Cover Type	Input Coefficient
Forest	0.6 – 0.8
Grassland 0.4	0.4 - 0.6
Row Crops 0.5	0.5 – 0.7
Barren 0.1	0.1 – 0.4
Wetlands 0.6	0.6 – 0.9

Table A-4: Typical permanent channel cross-section with benchmark locations and points of measurement – Rosgen (1996)

HSPF HYDROLOGY PARAMETERS AND VALUE RANGES

NAME	DEFINITION	UNITS	RANGE OF VALUES: TYPICAL MIN	TYPICAL MAX	POSSIBLE MIN	POSSIBLE MAX	FUNCTION OF ...	COMMENT
PWAT - PARM2								
FOREST	Fraction forest cover	none	0.0	0.50	0.0	0.95	Forest cover	Only impact when SNOW is active
LZSN	Lower Zone Nominal Soil Moisture Storage	inches	3.0	8.0	2.0	15.0	Soils, climate	**Calibration**
INFILT	Index to Infiltration Capacity	in/hr	0.01	0.25	0.001	0.50	Soils, land use	**Calibration**, divides surface and subsurface flow
LSUR	Length of overland flow	feet	200	500	100	700	Topography	Estimate from high resolution topo maps or GIS
SLSUR	Slope of overland flow plane	ft/ft	0.01	0.15	0.001	0.30	Topography	Estimate from high resolution topo maps or GIS
KVARY	Variable groundwater recession	1/inches	0.0	3.0	0.0	5.0	Baseflow recession variation	Used when recession rate varies with GW levels
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	Baseflow recession	**Calibration**
PWAT - PARM3								
PETMAX	Temp below which ET is reduced	deg. F	35.0	45.0	32.0	48.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
PETMIN	Temp below which ET is set to zero	deg. F	30.0	35.0	30.0	40.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
INFEXP	Exponent in infiltration equation	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
INFILD	Ratio of max/mean infiltration capacities	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
DEEPFR	Fraction of GW inflow to deep recharge	none	0.0	0.20	0.0	0.50	Geology, GW recharge	Accounts for subsurface losses
BASETP	Fraction of remaining ET from baseflow	none	0.0	0.05	0.0	0.20	Riparian vegetation	Direct ET from riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0.0	0.05	0.0	0.20	Marsh/wetlands extent	Direct ET from shallow GW
PWAT - PARM4								
CEPSC	Interception storage capacity	inches	0.03	0.20	0.01	0.40	Vegetation type/density, land use	Monthly values usually used
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1.0	0.05	2.0	Surface soil conditions, land use	Accounts for near surface retention
NSUR	Manning's n (roughness) for overland flow	none	0.15	0.35	0.05	0.50	Surface conditions, residue, etc.	Monthly values often used for croplands
INTFW	Interflow inflow parameter	none	1.0	3.0	1.0	10.0	Soils, topography, land use	**Calibration**, based on hydrograph separation
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	Soils, topography, land use	Often start with a value of 0.7, and then adjust
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	Vegetation type/density, root depth	**Calibration**

Source: U.S. EPA BASINS Technical Note 6

Model assumptions for stream reach infiltration rates were derived through calibration based on data collected within the reaches of Aliso Creek (11 stations) and Rose Creek (6 stations). In the model, infiltration rates vary by soil type. Stream infiltration was calibrated by adjusting a single infiltration value, which was varied for each soil type by factors established from literature ranges (U.S. EPA 2000) of infiltration rates specific to each soil type. The final resulting infiltration rates were 1.368 in/hr (Soil Group A), 0.698 in/hr (Soil Group B), 0.209 in/hr (Soil Group C) and 0.084 in/hr (Soil Group D). The infiltration rates for Soil Groups B, C, and D are within the infiltration range given in literature (Wanielisata et al. 1997). The result for Soil Group A is below the range given in Wanielisata et al. (1997); however, this result only represented one watershed in this TMDL study.

APPENDIX B
Stream Classification Procedure

The procedure derives from the "Stream Stability Validation" approach that is described by Rosgen (1996). Stream stability over time may be assessed by monitoring the stream channel for five factors: (1) aggradation (2) degradation (3) shifting of particle sizes of stream bed materials (4) changing the rate of lateral extension through accelerated bank erosion (5) morphological changes following the CEM (Simon et al., 1992). If any hydrological changes or disturbance occurs in the watershed, the five elements defined above are critical to analyze the channel response to the implementation of HMP mitigation measures.

One reference stream station will be used for comparison purposes and should coincide with the station selected for the bioassessment. The reference station should be located in a stream that shows the same lithology, sediment regime, and morphometric parameters as the study stream stations. Annual comparisons of channel stability will be carried out at the same time of the year, at the end of the spring season, thus maximizing the chances to monitor similar weather patterns.

Channel stability will be evaluated, on an annual basis, at selected cross-sections in the San Juan hydrologic unit. Evaluation of the vertical or bed stability will serve as the reference method to understand the geomorphological changes of a channel stream over time. Vertical or bed stability will be evaluated at each of the identified cross-sections: this field method will identify a potential aggradation or degradation, if any, of the stream. Rate, magnitude, and direction of vertical change, if any, will be quantified.

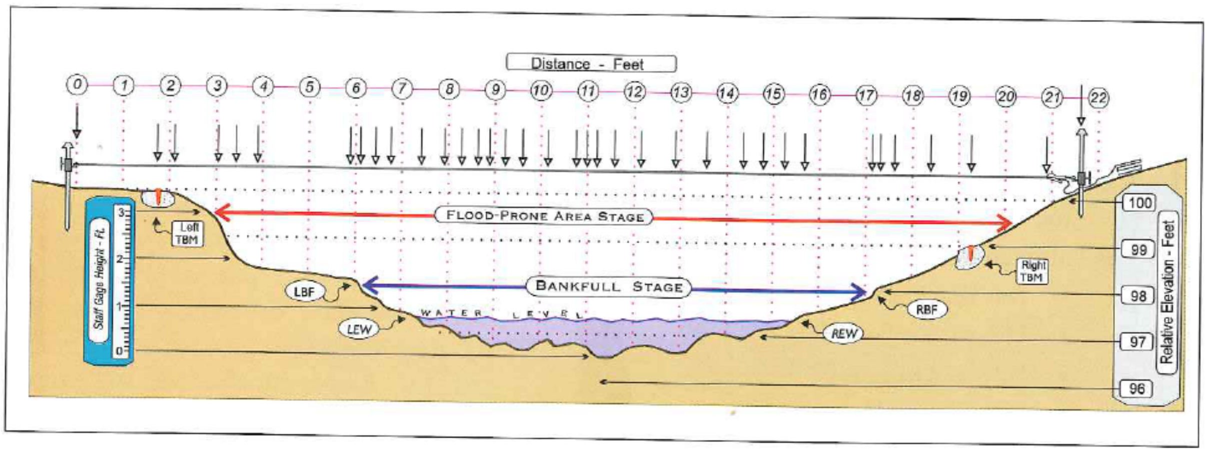
Vertical or bed stability:

Rosgen (1996) has documented a couple methods including one, known as the "Monumented cross-sections method". At each selected site, the method consists of setting permanently monumented cross-sections that are located on a riffle and pool segment (or step/pool segment), i.e., two monumented cross-sections per site. Annual measurements at the two monumented cross-sections per site will be compared to the reference elevations taken during the initial survey.

Initially, one permanent bench mark should be installed on each bank of the stream: a left temporary bench mark and a right temporary bench mark. These should be made permanent by digging a hole in which a 10-inch stove bolt will be set up by a pad of concrete. The intent is to avoid vandalism damage. These two bench marks will be located at the cross-section on a stable site above and away from the bankfull channel. Additionally, an elevation cross-section is often needed if the left or right side of the cross-section is located on an unstable slope. An elevation bench mark is established and often does not represent a true representation, but rather a relative elevation set at 100 feet.

During each cross-section survey, a leveled tape line is set above the stream channel. Measurements originate from the intercept of the rod with the leveled tape line (**Figure A-1**).

Figure A-1: Typical permanent channel cross-section with benchmark locations and points of measurement – Rosgen (1996)



Simple measurements are made with the measuring tape and elevation rod method as described by Rosgen (1996):

- Locate the permanent bench mark on both sides of the stream (or, if on one side, a bearing for the transect is needed)
- Stretch the tape very tight with spring clamp and tape level
- Locate tape at same elevation as reference bolt on bench mark
- Read distance and elevation reading of rod intercept with tape
- Measure major features, such as:
  - Left bench mark (LBM)
  - Left terrace/floodplain (LT, LFP)
  - Left bankfull (LBF)
  - Left bank (LB)
  - Left edge of water (LEW)
  - Various bed features, bars, etc.
  - Thalweg (TW)
  - Inner berm features (IB)
  - Right edge of water (REW)
  - Right bank (RB)
  - Right bankfull (RBF)
  - Right terrace/floodplain (RT, RFP)
  - Right benchmark (RBM)

Measurements must include the floodplain, terraces, and stream adjacent slopes. Other surveying procedures such as auto or laser levels and total station surveys may be adapted from the described “measuring tape and elevation rod” method. If technically feasible, any exceptional event associated with level higher than the bankfull level needs to be marked and indicated on the cross-section. The cross-section needs to be plotted for each measurement and compared to previous cross-sections to evaluate bed stability.

Finally, the longitudinal slope will be assessed based on measurements taken at two consecutive cross-sections. Rosgen (1996) also recommends developing a vicinity map and detailed site map indicating the locations of monumented cross-sections, as well as upstream and downstream photographs for site documentation. Channel dimensions for stream classification need to be correlated in order to document morphological comparisons for extrapolation.

Each stream segment being surveyed will be classified on an annual basis per the simplified Rosgen system of channel classification (Rosgen, 1996). Classification will be possible upon identification of the following parameters: floodprone width, bankfull width, bankfull depth, and longitudinal slope. **Figure A-2** shows the different types of channels per Rosgen channel classification (Rosgen, 1996).

Figure A-2: Simplified Rosgen Channel Classification (Rosgen, 1996)

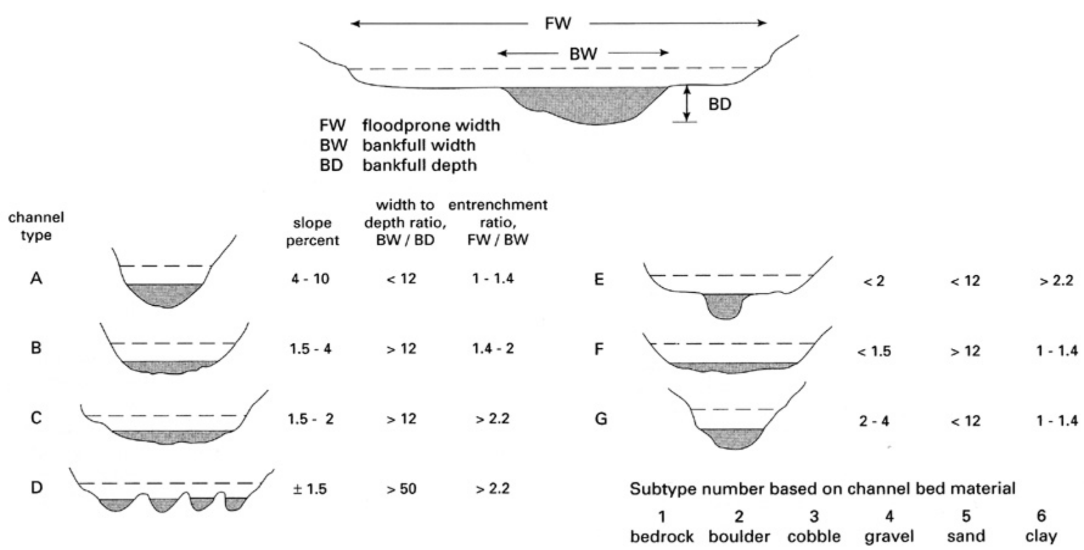


Figure 1.12 The Rosgen system of channel classification.

APPENDIX C
South Orange County Hydrology Model Instructions

To be developed upon completion of the model.

APPENDIX D
Conducting a Site-Specific Hydromodification Analysis

A project proponent may choose to develop a site specific hydromodification mitigation analysis in lieu of using the continuous simulation tool provided by the south Orange County Hydromodification Management Plan (HMP). The site specific analysis must be developed to demonstrate that the project will not adversely impact the receiving stream through either changes in the receiving stream hydrograph, or changes in bed material load supply to the stream.

The following items are not intended to be an approach to complete the analysis, rather, they are provided for information as suggestions for the engineering analysis. Each project will have unique conditions and will require a customized approach for analysis. A site specific analysis may or may not be ultimately approved by the reviewing agency. It is the responsibility of the engineer to assess the potential for an analysis to successfully demonstrate that the project is consistent with the guidelines of this HMP.

1. It is recommended that the applicant develop a study approach and outline, and review it with the local agency prior to beginning the full study.
2. The study must demonstrate that the project is consistent with the requirements of the south Orange County NPDES Permit and this HMP.
3. Site specific information to characterize bed sediment gradation, flow and rainfall data, and watershed hydrologic parameters will be required. Continuous simulation is required.
4. An objective of the study may be to determine if the loss of bed material load from the project site to the receiving stream can be partially or fully mitigated by additional mitigation of the runoff discharge from the project site.
5. Sediment transport modeling has inherent uncertainty. The agency may not approve a site specific analysis if it is apparent that the change in conditions that will be modeled are about the same magnitude as the model uncertainty.

The method of analysis, including the specific modeling program, the sediment transport function, the reach of the receiving water to be modeled, the method of determining bed material discharge in the receiving stream, the method of determining bed material discharge from the project site, the period of record for continuous simulation and other parameters are left to the discretion of the engineer. The study report should document and justify the approach, selected models and methods, data requirements, analysis method and results for review.

APPENDIX E
Practitioner Quick Start Sheet

The quick start summary lists the chronological steps that a practitioner should follow for their development project or re-development project to meet the requirements of this South Orange County Hydromodification Plan. The chronological steps are, as follows:

1. The first step consists of verifying if the project is exempt from hydromodification requirements. Exemption occurs:
   - If the project is not classified as Priority Development Project per permit item F.1.d., or,
   - If the proposed project discharges runoff directly to an exempt receiving water such as the Pacific Ocean, an exempt river reach, an exempt reservoir, or a tidally-influenced area. Or, if the proposed project discharges to an engineered conveyance system with the capacity to convey the 10-year ultimate condition that extends to the Pacific Ocean, a tidally-influenced area, an exempt river reach or reservoir (See **Section 4.3.1**), or,
   - If the project classifies as an infill development projects per the definition provided **in Section 4.3.2**, or,
   - If the project is an in-stream flood control or restoration project (See **Section 4.3.3**), or,
   - If the project discharges to a large river per the definition provided in **Section 4.3.4**

2. If the project is non-exempt, the practitioner should identify the tier requirements that apply to the proposed project. For specific tier requirements, the practitioner may refer to **Section 4.5**. These include hydrologic management controls and sediment supply management:
   a. Hydrologic management controls

The following table summarizes the different options that a practitioner may pursue to achieve hydrologic management controls. Prioritization of hydrologic controls, as well as the applicability of each type of hydrologic control are defined in this table. Onsite hydrologic controls are to be designed based on the South Orange County Hydrology Model. Alternatively, the practitioner may develop its own numerical criteria but should support his findings with continuous simulation models. Technical infeasibility of a type of hydrologic control should be documented. Specifics are provided in **Section 4.5**.

Type of hydrologic control	**Onsite**	**Regional**	**Offsite (mitigation or instream restoration)**	**Mitigation bank (if available)**	**Green Street Project or equivalent**
Large (>100 ac)	Yes	Yes	n/a	n/a	n/a
Medium (1 ac ≤A≤100 ac)	Yes - #1	n/a	Yes - #2a	Yes - #2b	n/a
Small (<1 ac)	Yes - #1	n/a	Yes - #2a	Yes - #2b	n/a

Type of hydrologic control	Onsite	Regional	Offsite (mitigation or instream restoration)	Mitigation bank (if available)	Green Street Project or equivalent
Public roadway	n/a	n/a	Yes	n/a	Yes

b. Sediment supply management

The practitioner may follow a three-step process to ensure maintenance of the pre-project sediment supply to the stream:

1. Determine whether the site is a significant source of bed material to the receiving stream.
2. Avoid significant bed material supply areas in the site design.
3. Replace significant bed material supply areas that are eliminated through urbanization.

If the three-step process is deemed infeasible, an alternative compliance option allows the project applicant to model the site conditions and the receiving stream and provide additional mitigation in site runoff to compensate for the reduction (or addition) of bed material. Specifics are detailed in **Section 5.1**.

3. The practitioner shall integrate hydrologic management controls and sediment supply management into the project site design, and define the design specifics in the preliminary WQMP that should be submitted to the jurisdiction. The jurisdiction may approve the proposed design upon identification of compliance with the requirements of this HMP.